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RE: IN THE MATTER OF THE COMMISSION'S OWN GENERIC INVESTIGATION OF THE ENERGY POLICY ACT OF 1992
Docket No. E-00000C-11-0328

Pursuant to the Notice issued by the Arizona Corporation Commission ("Commission") in the above docket on May 23, 2013, Arizona Public Service Company ("APS" or "Company") is providing the attached materials concerning the alleged health effects of Advanced Metering Infrastructure ("AMI"), sometimes referred to as "smart" meters.[1] These attachments consist of five studies or other official pronouncements by or on behalf of regulatory agencies as well as other government organizations. Also included are documents from such diverse sources as the Electric Power Research Institute in Palo Alto, California (the research arm for the electric utility industry for over 40 years) and the American Cancer Society. Finally, APS has attached the relevant portions of state regulatory orders addressing the health concerns raised by some consumers relative to AMI.[2]

APS would especially like to highlight the very comprehensive studies and analyses conducted by the California Council on Science and Technology ("Science Council"), the Texas Public Utilities Commission ("TPUC"), and the Maine Center for Disease Control ("Maine"). These studies, issued in 2011, 2012 and 2010, respectfully, are directly on point and served as the basis for actions by the California, Texas and Maine regulators to continue deployment of AMI with (California and Maine) or without (Texas) an opt-out program in place.

[1] APS would remind the Commission that the Company has already provided expert testimony to the Commission in the form of a presentation made by Dr. Leeka Kheifets, a world-renowned epidemiologist from UCLA, at the Commission's Workshop of September 8, 2011. The opponents of AMI have yet to provide any live witness on the subject, let alone an expert with credentials comparable to those of Dr. Kheifets.

[2] It appears that the vast majority of states have not been called upon to issue any pronouncements on this subject despite the fact that AMI has been deployed in all 50 states.

Health Impacts of Radio Frequency Exposure from Smart Meters
California Council on Science and Technology ("Science Council")
August 2011

This study was in response to a request from California Assembly Member Jared Huffman that the Science Council perform an independent, science-based study that would help policy makers and the general public resolve the debate over whether smart meters present a significant risk of adverse health effects. The Science Council is a non-profit research organization created by the State of California in the 1980s and involves a collaboration of all major California universities as well as leading private researchers. The Science Council specifically addressed: (1) whether FCC standards for smart meters are sufficiently protective of public health, taking into account current exposure levels to radiofrequency and electromagnetic fields; and (2) whether additional technology-specific standards are needed for smart meters and other devices that are commonly found in and around homes, to ensure adequate protection from adverse health effects. The findings of the study were that: (1) FCC standard does provide an adequate margin of safety against known RF induced health impacts of smart meters and other electronic devices in the same range of RF emissions; and (2) there is no compelling evidence that additional standards are needed to protect the public from smart meters or other common household electronic devices.

Health and RF EMF from Advanced Meters
Public Utility Commission of Texas ("TPUC"),
Infrastructure & Reliability Division, Staff Report
December 2012

This study was conducted in response to citizen concern in Texas over potential health effects from exposure to radiofrequency emissions from wireless technology of advanced metering. The study is a survey of existing scientific research and analyses that have been performed to investigate the potential health effects of exposure to low-level radio frequency electromagnetic fields emitted by wireless communication devices including smart meters. The study concludes that the body of scientific research does not reveal any proven biological effect from exposure to low-level RF signals. Further, it finds no credible evidence to suggest that advanced meters emit harmful amounts of EMF.

Maine CDC Executive Summary of Review of Health Issues Related to Smart Meters
Maine CDC
November 2010

This study was in response to a complaint filed with the Maine Public Utilities Commission focusing on concerns related to health, safety, and security of smart meters. Maine concluded that there is no indication of any convincing evidence to support any concern over health effects related to the use of radiofrequency in the rate of frequencies

and power used by smart meters. It further concluded that there is also no indication of an association of EMF exposure with the symptoms that have been described as electromagnetic sensitivity.

But these three states are far from alone. Others, although not perhaps conducting independent studies of their own, did evaluate the factual assertions of those opposed to AMI on the basis of health concerns.

The Maryland Public Service Commission has "not found convincing evidence that smart meters pose any health risks to the public at large." *In re Potomac Elec. Power Co.*, Consolidated Case Nos. 9207, 9208, 9294, Order No. 85294 at 7 (Md. Pub. Serv. Comm'n Jan. 7, 2013).

Similarly, the Idaho Public Utilities Commission, in dismissing two customer complaints about smart meters, found that "complainants have not provided sufficient demonstrable, credible factual evidence to support a finding that the [smart] meters present legitimate safety or potentially inappropriate communication concerns." *Menth v. Idaho Power Co.*, Case No. IPC-E-12-04, Order No. 32500 at 3 (Idaho Pub. Utils. Comm'n Mar. 27, 2012).

The Michigan Public Service Commission accepted a comprehensive staff report about AMI meters that concluded, among other things, that "'after careful review of the available literature and studies, the Staff has determined that the health risk from the installation and operation of metering systems using radio transmitters is insignificant. In addition, the appropriate federal health and safety regulations provide assurance that smart meters represent a safe technology.'" *In re Issues Bearing on the Deployment of Smart Meters by Regulated Elec. Utils. in Michigan*, Case No. U-17000 at 3 (Mich. Pub. Serv. Comm'n, Sept. 11, 2012) (quoting Staff Report).

The New Hampshire Public Utilities Commission declined to consider a state standard for RF emissions because it found that the utility's meters complied with relevant the Federal Communication Commission's standards and those standards would "pre-empt a separate and potentially conflicting state standard." *In re Wirth Request for Hearing on Installation of Smart Meters*, Case No. DE 12-245, Order No. 25,409 at 8 (NH Pub. Utils. Comm'n Sept. 6, 2012).

The Nevada Public Utilities Commission has likewise declined to regulate RF emissions from smart meters. The Nevada PUC adopted the report of a Hearing Officer, which concluded that claimed "health concern issues [regarding smart meters] are beyond the regulatory authority of this Commission [and t] he FCC, not this Commission, establishes standards for the exposure of humans to RF fields." *In re NV Energy's Advanced Serv. Delivery Meter Program a/k/a Smart Meter and its Implementation*, Docket No. 11-10007, Order at 8 (Nev. Pub. Utils. Comm'n March 2, 2012).

These are just a sampling of regulatory decisions supporting the continued deployment and use of AMI. The most important take away one can draw from the work of these various regulatory jurisdictions is that NO state or federal regulatory agency in the United States (or overseas, for that matter) has concluded that AMI represents a credible threat to human health or that mere concerns over the possibility of such a threat is a reasonable basis to warrant systemic restrictions on AMI use.[3] After an examination of the attached materials, as well as the materials presented by the Company at the original September 2011 Workshop, APS is confident that the Commission will draw similar conclusions.

Sincerely,

Thomas L. Mumaw

Thomas L. Mumaw
Attorney for Arizona Public Service Company

TLM/jlj

cc: Parties of Record
Chairman Bob Stump
Commissioner Gary Pierce
Commissioner Brenda Burns
Commissioner Robert L. Burns
Commissioner Susan Bitter Smith

[3] This does not mean that these or other states have not authorized AMI opt-out programs under specified conditions. Indeed, APS supports providing this optional service to residential customers and has submitted an opt-out proposal to the Commission in a separate docket.

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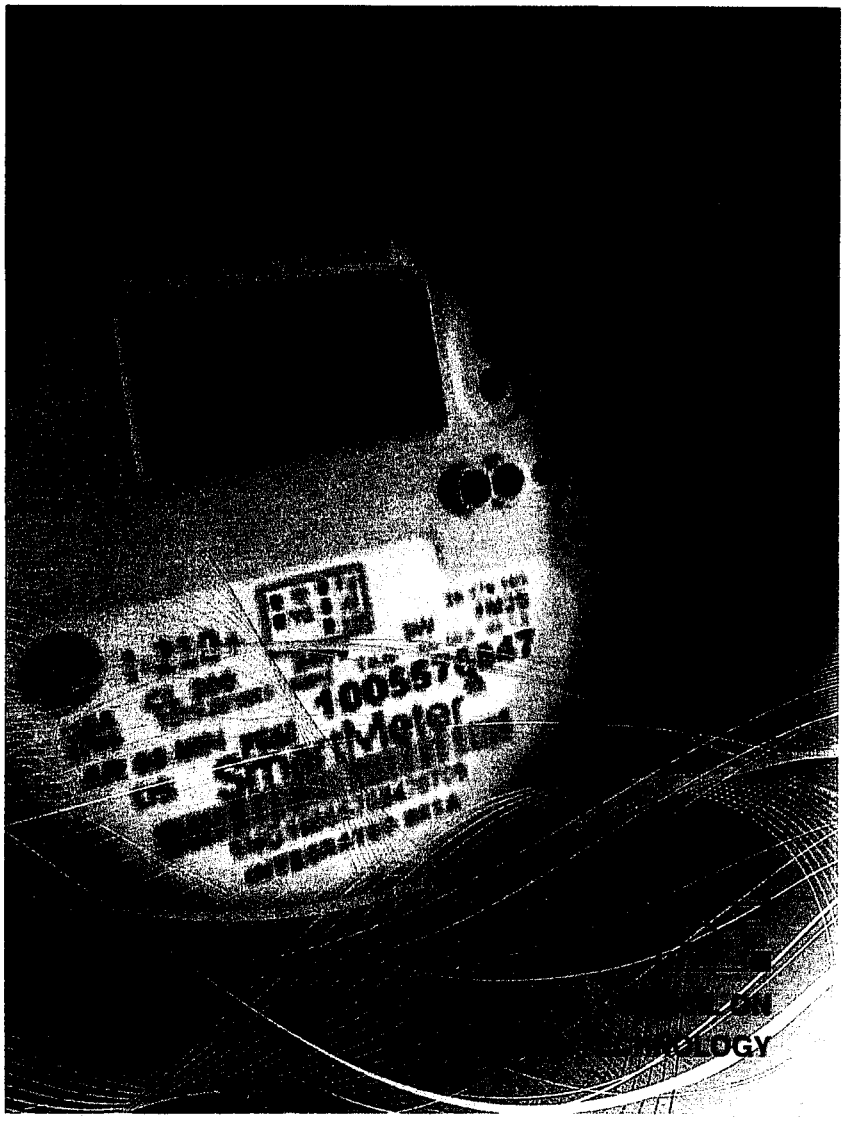
ATTACHMENT A -
CALIFORNIA COUNCIL
ON SCIENCE AND TECHNOLOGY

HEALTH IMPACTS OF RADIO FREQUENCY EXPOSURE FROM SMART METERS

APRIL 2011 - FINAL REPORT



ACKNOWLEDGMENTS

We would like to thank the many people who provided input and feedback towards the completion of this report. Without the insightful feedback that these individuals generously provided, this report could not have been completed. We would like to give special thanks to the California Smart Grid Center, College of Engineering and Computer Science at the California State University, Sacramento and to the University of California's Center for Information Technology Research in the Interest of Society (CITRIS).

This report was conducted with the oversight of a CCST Smart Meter Project Team, whose members include: Rollin Richmond (Chair), Emir Macari, Patrick Mantey, Paul Wright, Ryan McCarthy, Jane Long, David Winickoff, and Larry Papay. We also thank J.D. Stack for his technical contributions and Lora Lee Martin for the overall coordination of this report response. We express gratitude to CCST's members and colleagues for their many contributions to the report. Comments on the January 2011 draft of this report were solicited from the public. Many very thoughtful and informed comments were received. All public comments were reviewed and taken into consideration as this final report was completed.

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CCST is a non-profit organization established in 1988 at the request of the California State Government and sponsored by the major public and private postsecondary institutions of California and affiliate federal laboratories in conjunction with leading private-sector firms. CCST's mission is to improve science and technology policy and application in California by proposing programs, conducting analyses, and recommending public policies and initiatives that will maintain California's technological leadership and a vigorous economy.

Note: The California Council on Science and Technology (CCST) has made every reasonable effort to assure the accuracy of the information in this publication. However, the contents of this publication are subject to changes, omissions, and errors, and CCST does not accept responsibility for any inaccuracies that may occur.

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Letter from CCST

With rapidly emerging and evolving technologies, lawmakers at times find themselves pressed to make policy decisions on complex technologies. Smart meters are one such technology.

Smart meters are being deployed in many places in the world in an effort to create a new generation of utility service based on the concepts of a smart grid, one that is agile, efficient and cost effective.

The electricity crisis of 2000 and 2001 helped force the issue here in California, lending significant urgency to the need for better management of power generation and distribution. In 2006, the California Public Utilities Commission authorized the Pacific Gas and Electric Company to implement a relatively new technology, smart meters, to gather much more precise information about power usage throughout the state. The process of installing the meters throughout the state is still underway.

As with any new technology, there are unknowns involved. Smart meters generally work by transmitting information wirelessly. Some people have expressed concerns about the health effects of wireless signals, particularly as they become virtually ubiquitous. These concerns have recently been brought to the attention of state legislators, with some local municipalities opting to ban further installation of the meters in their communities.

We are pleased that Assembly Members Huffman and Monning have turned to CCST for input on this issue. It is CCST's charge to offer independent expert advice to the state government and to recommend solutions to science and technology-related policy issues. In this case, we have assembled a succinct but comprehensive overview of what is known about human exposure to wireless signals and the efficacy of the FCC safety standards for these signals. To do so, we assembled a project team that consulted with over two dozen experts and sifted through over a hundred articles and reports, providing a thorough, unbiased overview in a relatively rapid manner.

In situations where public sentiment urges policy makers to make policy decisions with potentially long-term consequences, access to the best information possible is critical. This is the role that CCST was created to fulfill.

Susan Hackwood
Executive Director, CCST

Rollin Richmond
Project Team Chair, CCST

Health Impacts of Radio Frequency from Smart Meters
Response to Assembly Members Huffman and Monning

California Council on Science and Technology
April 2011

KEY REPORT FINDINGS

1. Wireless smart meters, when installed and properly maintained, result in much smaller levels of radio frequency (RF) exposure than many existing common household electronic devices, particularly cell phones and microwave ovens.
2. The current FCC standard provides an adequate factor of safety against *known thermally* induced health impacts of existing common household electronic devices and smart meters.
3. To date, scientific studies have not identified or confirmed negative health effects from *potential non-thermal* impacts of RF emissions such as those produced by existing common household electronic devices and smart meters.
4. Not enough is currently known about potential non-thermal impacts of radio frequency emissions to identify or recommend additional standards for such impacts

OTHER CONSIDERATIONS

Smart electricity meters are a key enabling technology for a "smart grid" that is expected to become increasingly clean, efficient, reliable, and safe at a potentially lower cost to the consumer. The CCST Smart Meter Project Team offers the following for further consideration by policy makers, regulators and the utilities. We appreciate that each of these considerations would likely require a cost/benefit analysis. However, we feel they should be considered as the overall cumulative exposure to RF emissions in our environment continues to expand.

1. As wireless technologies of all types increase in usage, it will be important to: (a) continue to quantitatively assess the levels of RF emissions from common household devices and smart meters to which the public may be exposed; and (b) continue to investigate potential thermal and non-thermal impacts of such RF emissions on human health.
2. Consumers should be provided with clearly understood information about the radiofrequency emissions of all devices that emit RF including smart meters. Such information should include intensity of output, duration and frequency of output, and, in the cases of the smart meter, pattern of sending and receiving transmissions to and from all sources.
3. The California Public Utilities Commission should consider doing an independent review of the deployment of smart meters to determine if they are installed and operating consistent with the information provided to the consumer.
4. Consideration could be given to alternative smart meter configurations (such as wired) in those cases where wireless meters continue to be concern to consumers.

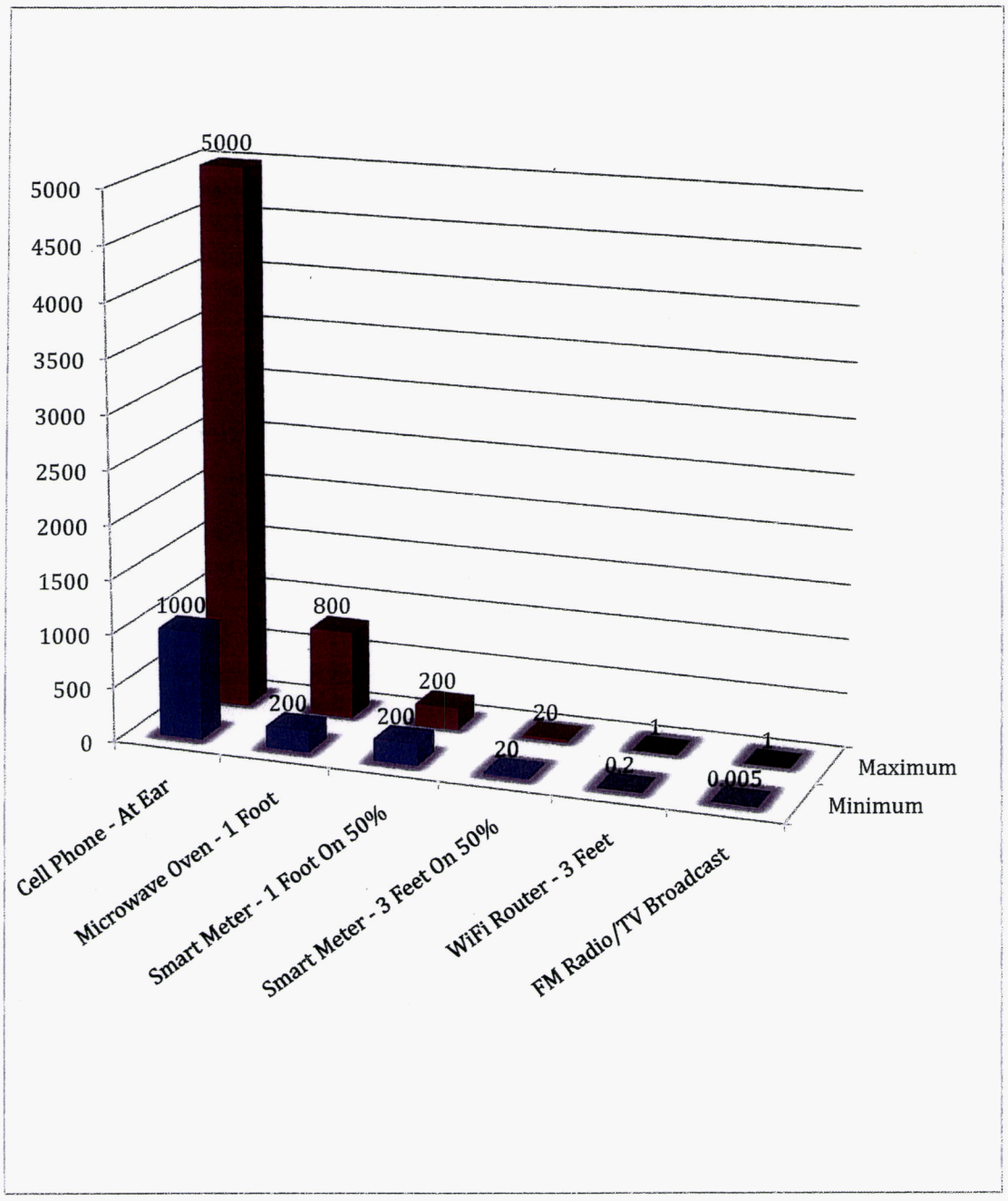

Figure 1. Instantaneous Radio Frequency Power Density Levels of Common Devices (in microWatts/cm^2)
About this figure: This figure was developed by the CCST project team. Quantities for different distances calculated using Inverse Square Law. Assumes distances in far-field, where power density reduces as the square of the distance from the source. Smart meter power scaled to obtain output for 50% duty cycle. The source for the various starting measurements came from Electric Power Research Institute (EPRI), Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model (February 2011)

Legislative Request

On July 30, 2010, California Assembly Member Jared Huffman wrote to the California Council on Science and Technology (CCST) to request that the Council perform an "independent, science-based study...[that] would help policy makers and the general public resolve the debate over whether smart meters present a significant risk of adverse health effects." California Assembly Member Bill Monning signed onto the request with his own letter to CCST on September 15, 2010. The City of Mill Valley also sent a letter on September 20th supporting Assembly Member Huffman's request for the study.

Approach

Reflecting the requests of the Assembly Members, CCST agreed to compile and assess the evidence available to address:

> **1. Whether Federal Communications Commission (FCC) standards for smart meters are sufficiently protective of public health, taking into account current exposure levels to radiofrequency and electromagnetic fields.**
>
> **2. Whether additional technology-specific standards are needed for smart meters and other devices that are commonly found in and around homes, to ensure adequate protection from adverse health effects.**

CCST convened a Smart Meter Project Team composed of CCST Council and Board members supplemented with additional experts in relevant fields (see Appendix A for Project Team members). The Project Team identified and reviewed over 100 publications and postings about smart meters and other devices in the same range of emissions, including research related to cell phone RF emissions, and contacted over two dozen experts in radio and electromagnetic emissions and related fields to seek their opinion on the two identified issues.

It is important to note that CCST has not undertaken primary research of its own to address these issues. This response is limited to soliciting input from technical experts and to reviewing and evaluating available information from past and current research about health impacts of RF emitted from electric appliances generally, and smart meters specifically. This report has been extensively reviewed by the Project Team, experts in related fields, and has been subject to the CCST peer review process (see Appendix B). It has also been made available to the public for comment.

Two Types of Radio Frequency Effects: Thermal and Non-thermal

Household electronic devices, such as cellular and cordless telephones, microwave ovens, wireless routers, and wireless smart meters produce RF emissions. Exposure to RF emissions may lead to thermal and non-thermal effects. Thermal effects on humans have been extensively studied and appear to be well understood. The Federal Communications Commission (FCC) has established guidelines to protect public health from known hazards associated with the thermal impacts of RF: tissue heating from absorbing energy associated with radiofrequency emissions. Non-thermal effects, however, including cumulative or prolonged exposure to lower levels of RF emissions, are not well understood. Some studies have suggested non-thermal effects may include fatigue, headache, irritability, or even cancer. *But these findings have not been scientifically established, and the mechanisms that might lead to non-thermal effects remain uncertain.* Additional research and monitoring is needed to better identify and understand potential non-thermal effects.

Findings

Given the body of existing, *generally accepted scientific knowledge* regarding smart meters and similar electronic devices, CCST finds that:

1. **The FCC standard provides an adequate factor of safety against known RF induced health impacts of smart meters and other electronic devices in the same range of RF emissions.**
   The potential for behavioral disruption from increased body tissue temperatures is the only biological health impact that has been consistently demonstrated and scientifically proven to result from absorbing RF within the band of the electromagnetic spectrum (EMF) that smart meters use. The Federal Communications Commission (FCC) has set a limit on the Standard Absorption Rate (SAR) from electronic devices, which is well below the level that has been demonstrated to affect behavior in laboratory animals. Smart meters, including those being installed by Pacific Gas and Electric Company (PG&E) in the Assembly Members' districts, if installed according to the manufacturers instructions and consistent with the FCC certification, emit RF that is a very small fraction of the exposure level established as safe by the FCC guidelines.

   FCC staff has recently confirmed that it "relied on the expert opinions of EPA, NCRP, and others to conclude that the RF exposure limits it adopted were adequately protective of human health from all known adverse effects, regardless of whether these effects were thermal or athermal in origin".[1]

   The FCC guidelines provide a significant factor of safety against known RF impacts that occur at the power levels and within the RF band used by smart meters. Given current

[1] Statement provide by Robert Weller regarding FCC regulations on February 3, 2011. Robert Weller, Chief, Technical Analysis Branch, Office of Engineering and Technology, Federal Communications Commission.

scientific knowledge, the FCC guideline provides a more than adequate margin of safety against known RF effects.

2. **At this time there is no clear evidence that additional standards are needed to protect the public from smart meters or other common household electronic devices.** Neither the relevant scientific literature nor our expert consultations support that there is a causal relationship between RF emissions and non-thermal human health impacts. Nor does the relevant evidence convincingly describe mechanisms for such impacts, although more research is needed to better understand and verify these potential mechanisms. Given the absence of evidence supporting a real hazard, the benefits of elevating existing standards are highly speculative. Further, there is not an existing basis from which to understand what types of standards could be helpful or appropriate. Without a clearer understanding of the biological mechanisms involved identifying additional standards or evaluating the relative costs and benefits of those standards cannot be determined at this time.

   Given the existing significant scientific uncertainty around non-thermal effects, there is currently no generally accepted definitive, evidence-based indication that additional standards are needed. Because of the lack of generally accepted evidence, there is also not an existing basis from which to understand what types of standards could be helpful or appropriate. Without a clearer understanding of the biological mechanisms involved identifying additional standards or evaluating the relative costs and benefits of those standards cannot be determined at this time.

   CCST notes that in some of the studies reviewed, contributors have raised emerging questions from some in the medical and biological fields about the potential for biological impacts other than the thermal impact that the FCC guidelines address. A report of the National Academies identifies research needs and gaps and recommended areas of research to be undertaken to further understanding of long-term exposure to RF emissions from communication devices, particularly from non-thermal mechanisms.[2] In our increasingly wireless society, smart meters account for a very small portion of RF emissions to which we are exposed. Concerns about human health impacts of RF emissions from smart meters should be considered in this broader context.

[2] National Research Council (2008) *Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communication,* The National Academies Press, Washington, D.C.

THE SCIENTIFIC METHOD

"Scientifically established", "generally accepted scientific knowledge" and other such references throughout this document are referencing information obtained through the scientific method. A scientific method consists of the collection of data through observation and experimentation, and the formulation and testing of hypotheses. These steps must be repeatable in order to predict future results. Scientific inquiry is generally intended to be as objective as possible, to reduce biased interpretations of results. Another basic expectation is to document, archive and share all data and methodology so they are available for careful scrutiny by other scientists, giving them the opportunity to verify results by attempting to reproduce them. This practice, called full disclosure, also allows statistical measures of the reliability of these data to be established.

INTERPRETING THE SCIENTIFIC LITERATURE

In our review of the relevant scientific evidence, we privileged those studies that had as many of the following indicia of scientific reliability as possible: (1) Empirical testing; (2) Peer review and publication; (3) The use of accepted standards and controls; (4) Degree to which the finding is generally accepted by a relevant scientific community. These criteria of scientific reliability are broadly based on the standards of expert testimony and evidence in the US Federal Courts.

Health concerns surrounding RF from smart meters are similar to those from many other devices that we use in our daily lives, including cordless and cellular telephones, microwave ovens, wireless routers, hair dryers, and wireless-enabled laptop computers. As detailed in the report, a comparison of electromagnetic frequencies from smart meters and other devices shows that the exposure level is very low.

Standards of Proof or Certainty in Public Health

In this report, scientific evidence is the primary consideration. Upon consulting with the California Department of Public Health, it is noted that using scientific evidence to shape public policy is always challenging. The standards for declaring certainty within a scientific discipline, which are based on the results of statistical testing, may be unrealistic or inappropriate for making public policy decisions, particularly those with potential impacts on population health. Statistical tests usually rely on the convention of whether the results of a given study are sufficient to reject the null hypothesis of no effect (i.e., of a given exposure). This is effectively a standard of 95% certainty, analogous to the legal standard of proof "beyond a reasonable doubt."

In public health, five factors are generally considered when reviewing scientific evidence for policy decisions related to specified exposures:

1. Severity of potential effect(s): e.g., cancer or serious birth defects would be considered more severe than skin irritation;
2. Number of people with potential exposure;
3. Levels of likely and possible exposures;
4. Degree of certainty of the specific effect(s) at different exposure levels; certainty just above 50% might be characterized as "more likely than not."
5. Cost to mitigate potential effect(s), typically considered in light of the other factors.

Policy makers constantly weigh these factors consciously or unconsciously as they interact with stakeholders to craft good public policy. In one situation, they might consider high-cost mitigations for high-severity effects with high-certainty evidence. In another situation with high-severity effects and "more likely than not" certainty of those effects, they might choose low-cost mitigations. This report did not extend beyond the scientific evidence realm with which we were charged leaving those issues to the policy makers to whom this report has been delivered.

What are Smart Meters?

Smart meters measure attributes of electricity, natural gas, or water as delivered to consumers and transmit that information (e.g., usage) digitally to utility companies. Some smart meters are also designed to transmit real-time information to the consumer. These smart meters replace traditional, analog meters and meter readers with an automated process that is expected to reduce operating costs for utilities, and potentially, costs for customers (see Figure 2). Each of California's major electricity utilities has begun deploying smart meter infrastructure.

a. Analog Meter b. Digital Meter

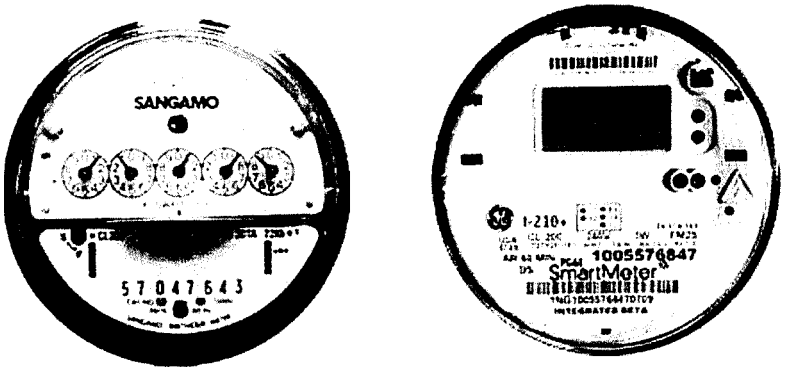

Figure 2. a) An analog, conventional meter and a (b) digital smart meter (Source: PG&E)

There are many kinds of smart meters manufactured by a variety of companies. The meter, including sensors and the housing or casing, may be manufactured by one company while the communications device (installed within the meter) is manufactured by another. Depending upon the internal communications device employed, meters are configured to operate in a wired or in wireless environment. The smart meters used by PG&E are made by General Electric and Landis + Gyr and use a wireless communications technology from Silver Spring Networks. Each of these PG&E meters has two transmitters to provide two different communications of data from these meters.[3] The first provides for the "automatic meter reading" (AMR) function

[3] Tell, R. (2008) "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System," Prepared for Pacific Gas & Electric Company, Richard Tell Associates, Inc., October 27.

of the meter (and for more detailed and real time monitoring of the characteristics of the electrical energy delivered to the consumer) and sends this data to an access point, where it is collected along with data from many other customers and transmitted to PG&E using a wireless area network (WAN) (similar to the way cell phone communication works).

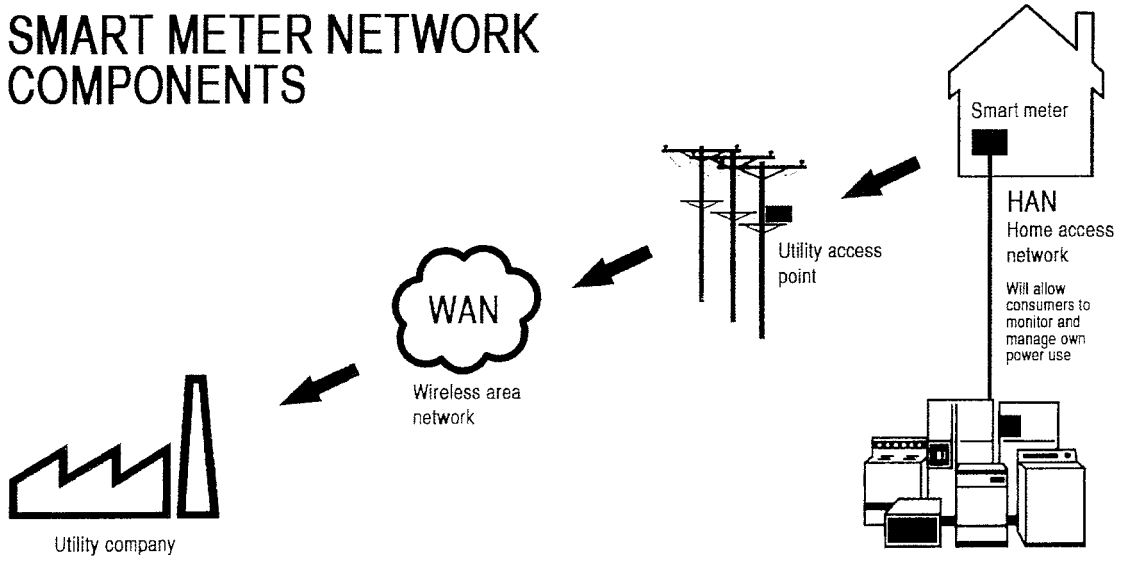

Figure 3. Simplified depiction of Smart Meter system network. Arrows show the use of radiofrequency (RF) signals for automated meter reading, communications among electric power meters, relays, access points, the company's enterprise management systems. The future home access network will operate within the house.

Smart meters have evolved from automatic meter reading (AMR; i.e., replacing meter readers) to a real time monitoring of power as delivered to the consumer by the utility company. CCST obtained from PG&E the Richard Tell Associates report, which describes the operation of the smart meter from the 2008 perspective of AMR, not a fully deployed real time smart grid. The Richard Tell Associates reports describe the use of the smart meter radios being deployed by PG&E as licensed by the FCC for a maximum power output of 1 W (watt) and within the 902-928 MHz (mega-hertz) frequency band. In its initial deployment, PG&E reports that it will configure the radios to transmit data from the meter to the access point once every four hours, for about 50 milliseconds at a time.[4] Accounting for this, the current duty cycles of the smart meter transmitter (that is, the percent of time that the meter operates) would then typically be 1 percent, or in some cases where the meter is frequently used as a relay, as much as 2-4 percent. *This means that the typical smart meter in this initial (AMR) use would not transmit any RF signal at least 96-98 percent of the time.*

[4] Tell, R. (2008) "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System," Prepared for Pacific Gas & Electric Company, Richard Tell Associates, Inc., October 27. http://www.pge.com/includes/docs/pdfs/shared/edusafety/systemworks/rfsafety/rf_fields_supplemental_report_2008.pdf)

It is important to note that any one smart meter is part of a broader "mesh" network and may act as a relay among other smart meters and utility access points. In addition, when the smart grid is fully functional the smart meters would be expected to be transmitting much more than once every four hours, providing data in near real-time, which will result in a much higher duty cycle. For purposes of this report we include a hypothetical scenario where the smart meter is transmitting 50 percent of the time (i.e., transmitting half the time and receiving half the time). Even in this 50% duty cycle situation the power output would be well below the FCC limits.

Smart meters are designed to transmit data to a utility access point that is usually 25 feet above ground, on utility or light poles. These access points are designed to transmit data from up to 5,000 smart meters to the utility company. Access points have a similar AMR transmitter as smart meters, as well as an additional *AirCard,* which communicates with utilities and is similar to wireless cards used in laptop computers. *AirCard*s typically operate at 0.25-1 W, in the 800-900 MHz or 1.9 GHz range.

In some cases, data is moved through the mesh network, relaying the data through other meters to the utility access point. This may occur when the topography or built environment interferes with the transmission of data from a smart meter to the access point. In these cases, the relaying of data may occur between one smart meter and another before the signal is sent to the utility access point (e.g., hops along a set of meters). Additionally, some non-meter data relays will also exist in the system to connect some smart meters to utility access points.

Many smart meters, including those from PG&E, also have a second transmitter that, at some future point in time, will allow customers to enable a home access network (HAN). The HAN will allow increased consumer monitoring of electricity use and communication among appliances and the future smart grid. This functionality is important to achieve the full potential of the smart grid. This second internal transmitter, for delivery of smart meter data to the consumer, reportedly will operate at a rated power of 0.223W, at frequency of about 2.4 GHz (again, similar to that of cell phones and wireless phones). The actual duty cycle of this transmitter will depend on the design and operation of the home area network.

Why are Smart Meters Being Installed Throughout California?

It is anticipated, when fully operational, that smart electricity meters are a key enabling technology for a "smart grid" that is expected to become increasingly clean, efficient, reliable, and safe (see Figure 3) at a potential lower cost to the consumer. (Digital meters are also being used for reading of natural gas and water consumption). Smart electrical meters allow direct two-way communication between utilities and customers, which is expected to help end users adjust their demand to price changes that reflect the condition of the electricity grid. These end user adjustments can help to protect the overall reliability of the electricity grid, cut costs for utility customers, and improve the operation and efficiency of the electricity grid. The smart grid will enable grid operators to better balance electricity supply and demand in real-time,

which becomes increasingly important as more intermittent wind and solar generation resources are added to the grid.

Figure 4 depicts the potential operation of a smart grid.

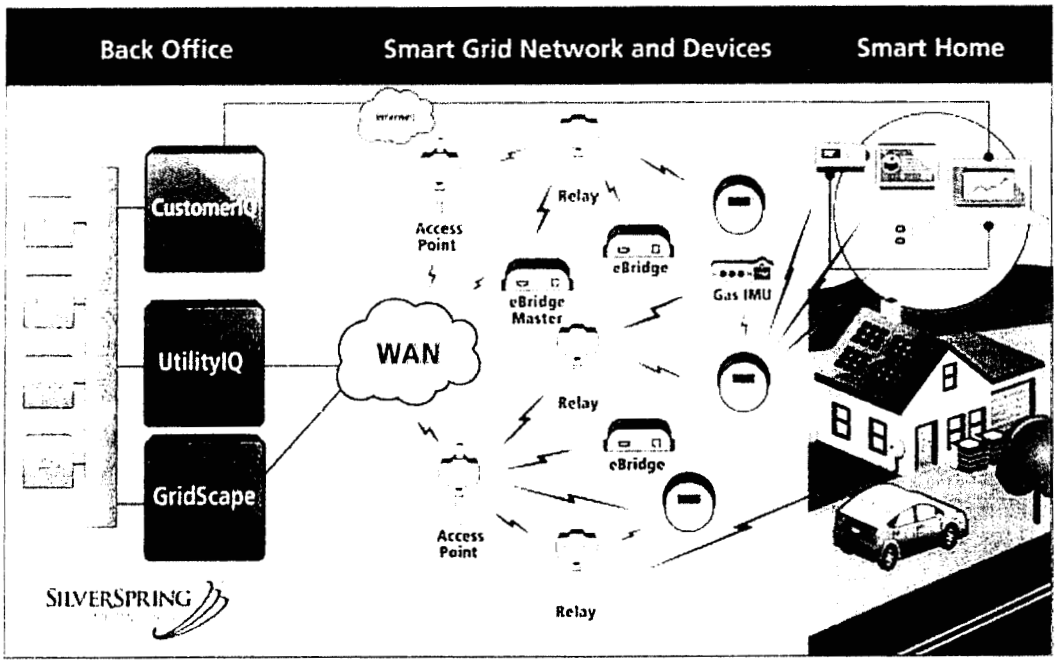

Figure 4. Illustration of components of the PG&E Smart Meter Program Upgrade showing the use of radiofrequency (RF) signals for communications among electric power meters, relays, access points and, ultimately, the company's enterprise management systems. (Source Silver Spring Network[5])

Smart meters will also allow utilities to communicate grid conditions to customers through price signals, so that consumers, via their HAN, can delay non-time sensitive demands (such as clothes drying) to a time when electricity is cheapest or has the most benefit to the reliability of the system. In some cases wireless signals interior to the structure will also be able to automatically adjust the heating and ventilation systems and to adjust heat or air conditioning units. This adaptation to price or reliability signals could reduce overall electricity costs for customers, improve the utilization of renewable and non-renewable power plants, and cut costs associated with adding intermittent wind and solar resources to the grid.

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[5] See http://www.silverspringnet.com/products/index.html for component descriptions. Network infrastructure includes the Silver Spring Access Points (APs) and Relays that forward data from endpoints across the utility's backhaul or WAN infrastructure into the back office.
The UtilityIQ application suite incorporates both utility applications such as Advanced Metering and Outage Detection as well as administrative programs for managing and upgrading the network. GridScape provides management for DA communications networks.
The CustomerIQ web portal enables utilities to directly communicate usage, pricing, and recommendations to consumers. Silver Spring works with each utility to customize the information portrayed and to import utility-specific information such as rate schedules.

While such long-term value of smart meters will take years to fully realize, they are sufficiently promising that the federal government has required utilities to take steps to implement smart grid networks, including the use of smart meters.[6] After review and authorization from the California Public Utilities Commission,[7] utilities in California have begun to install smart meters throughout the state. Some California utilities (such as Sacramento Municipal Utility District) have received significant federal funding for smart meter deployment from the American Recovery and Reinvestment Act (federal stimulus package). Many countries around the world are actively deploying smart meters as well. Digital smart meters are generally considered to be the fundamental technology required to enable widespread integration of information technology (IT) into the power grid (i.e., the smart grid). The following table (table 1) summarizes some potential societal benefits expected to result from the smart grid.

Table 1: Smart Grid Benefits

Consumers	**Environment**
1. Cost Savings Resulting from Energy Efficiency 2. Increased Consumer Choice and Convenience 3. More Transparent, Real-Time Information and Control for Consumers	1. Widespread Deployment of Renewable Energy (Solar, Wind, Biofuels) and Electric Vehicles (EVs) 2. Reduced Need to Build More Fossil Fueled Power plants 3. Reduced Carbon Footprint and Other Pollutants (via Renewables, Energy Efficiency, Electric Vehicles)
Utilities	**Economy**
1. Reduced Cost Due to Increased Efficiencies in Delivering Electricity and Reduction in Manpower to Read Meters. 2. Improved Reliability and More Timely Outage Response 3. Increased Customer Satisfaction Due to Cost Savings and Self-Control *Source: California Smart Grid Center*	1. Creates New Market for Goods and Services (i.e., New Companies, New Jobs) 2. Up-skilling Workforce to be Prepared for New Jobs 3. Reduced Dependence on Foreign Oil, Keeps Dollars at Home

[6] The federal Energy Independence and Security Act of 2007 directs states to encourage utilities to initiate smart grid programs, allows recovery of smart grid investments through utility rates, and reimburses 20% of qualifying smart grid investments. The American Recovery and Reinvestment Act of 2009 provided $4.5 billion to develop smart grid infrastructure in the U.S. For more information, see: Congressional Research Service (2007) "Energy Independence and Security Act of 2007: A Summary of Major Provisions," CRS Report for Congress, Order Code RL34l294, December 21. (http://energy.senate.gov/public/_files/RL342941.pdf)

[7] California Public Utilities Commission decision on Application 07-12-009 (March 12, 2009). Decision on Pacific Gas and Electric Company's Proposed Upgrade to the Smartmeter Program.

What Health Concerns are Associated with Smart Meters?

Human health impacts from exposure to electromagnetic frequency (EMF) emissions vary depending on the frequency and power of the fields. Smart meters operate at low power and in the RF portion of the electromagnetic spectrum. At these levels, RF emissions from smart meters are unlikely to produce *thermal effects; however it is not scientifically confirmed whether or what the non-thermal effects* on living organisms, and potentially, human health might be. These same concerns over potential impacts should apply to all other electronic devices that operate with similar frequency and power levels, including cell phones, computers, cordless phones, televisions, and wireless routers. Any difference in health impacts from these devices is likely to be a result of differences in usage patterns among them.

Thermal Effects

Electromagnetic waves carry energy, and EMF absorbed by the body can increase the temperature of human tissue. The scientific consensus is that body temperatures must increase at least 1°C to lead to potential biological impacts from the heat. The only scientifically verified effect that has been shown to occur in the power and frequency range that smart meters are designed to occupy is a disruption in animal feeding behavior at energy exposure levels of 4 W/kg and with an accompanying increase in body temperature of 1°C or more.[8] The exposure levels from smart meters even at close range are far below this threshold. The FCC has set limits on power densities from electronic devices that are well below the level where demonstrated biological impacts occur, and the limits are tens or hundreds of times higher than likely exposure from smart meters.[9]

Non-thermal Effects

There are emerging questions in the medical and biological fields about potential harmful effects caused by non-thermal mechanisms of absorbed RF emissions. Complaints of health impacts from "electromagnetic stress" have been reported, with symptoms including fatigue, headache, and irritability. Some studies have suggested that RF absorption from mobile phones may disrupt communication between human cells, which may lead to other negatives impacts on human biology.[10,11] While concerns of brain cancer associated with mobile phone usage persist, there is currently no definitive evidence linking cell phone usage with increased

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[8] D'Andrea, J.A., Adair, E.R., and J.O. de Lorge (2003) Behavioral and cognitive effects of microwave exposure, *Bioelectromagnetics* Suppl 6, S39-62 (2003).

[9] Tell, R. (2008) "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System," Prepared for Pacific Gas & Electric Company, Richard Tell Associates, Inc., October 27. (http://www.pge.com/includes/docs/pdfs/shared/edusafety/systemworks/rfsafety/rf_fields_supplemental_report_2008.pdf)

[10] Markova, E., Malmgren, L., and I.Y. Belyaev (2009) Microwaves from mobile phones inhibit 53PB1 focus formation in human stem cells stronger than in differentiated cells: Possible mechanistic link to cancer risk. Environmental Health Perspectives, doi:10.1289/ehp.0900781.

[11] Nittby, H., Grafstrom, G., Eberhardt, J.L., Malmgren, L., Brun, A., Persson B.R.R., and L.G. Salford (2008) Radiofrequency and Extremely Low-Frequency Electromagnetic Field Effects on the Blood-Brain Barrier Electromagnetic Biology and Medicine, 27: 103–126, 2008.

incidence of cancer.[12] But due to the recent nature of the technology, impacts of long-term exposure are not known. Ongoing scientific study is being conducted to understand non-thermal effects from long-term exposure to mobile phones and smart meters, etc., especially the cumulative impact from all RF emitting devices including that of a network of smart meters operating throughout a community.[13]

There currently is no conclusive scientific evidence pointing to a non-thermal cause-and-effect between human exposure to RF emissions and negative health impacts. For this reason, regulators and policy makers may be prudent to call for more research while continuing to base acceptable human RF exposure limits on currently proven scientific and engineering findings on known thermal effects, rather than on general concerns or speculation about possible unknown and as yet unproven non-thermal effects. Such questions will likely take considerable time to resolve. The data that are available strongly suggest that if there are non-thermal effects of RF absorption on human health, such effects are not so profound as to be easily discernable.

FCC Guidelines

In 1985, the FCC first established guidelines to limit human exposure and protect against thermal effects of absorbed RF emissions. The guidelines were based on those from the American National Standards Institute (ANSI) that were issued in 1982.[14] In 1996, the FCC modified its guidelines,[15] based on a rulemaking process that began in 1993 in response to a 1992 revision of the ANSI guidelines[16, 17] and findings by the National Council on Radiation Protection and Measurements (NCRP).[18] The 1996 guidelines are still in place today.

> In its rulemaking process to set SAR and MPE limits, the FCC relied on many federal health and safety agencies, including the U.S. Environmental Protection Agency and the Food and Drug Administration.

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[12] Ahlbom, A., Feychting, M., Green, A., Kheifets, L., Savitz, D. A., and A. J. Swerdlow (2009) Epidemiologic evidence on mobile phones and tumor risk: a review. *Epidemiology* 20, 639-52 (2009).

[13] National Research Council (2008) *Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communication,* The National Academies Press, Washington, D.C. (http://www.nap.edu/catalog/12036.html)

[14] American National Standards Institute (1982) "American National Standard Radio Frequency Radiation Hazard Warning Symbol," ANSI C95.2-1982, Institute of Electrical and Electronics Engineers, Inc.

[15] FCC (1997) "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," OET Bulletin 65 (Edition 97-01), Federal Communications Commission, August. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf)

[16] American National Standards Institute (1992) "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992 (previously issued as IEEE C95.1-1991), Institute of Electrical and Electronics Engineers, Inc.

[17] American National Standards Institute (1992) "Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields – RF and Microwave," ANSI/IEEE C95.3-1992, Institute of Electrical and Electronics Engineers, Inc.

[18] NCRP (1986) "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86 (1986), National Council on Radiation Protection Measurements.

While the FCC guidelines appear to provide a large factor of safety against known thermal effects of exposure to radiofrequency, they do not necessarily protect against potential non-thermal effects, nor do they claim to.[19] Without additional understanding of these effects, there is inadequate basis to develop additional guidelines at this time.

The FCC guidelines measure exposure to RF emissions in two ways. Specific absorption rate (SAR) measures the rate of energy absorption and is measured in units of watts-per-kilogram of body weight (W/kg). It accounts for the thermal effects on human health associated with heating body tissue and is used as a limiting measurement for wireless devices, such as mobile phones, that are used in close proximity to human tissue.[20] The FCC limits, as well as the underlying ANSI and NCRP limits, are based on a SAR threshold of 4 W/kg. At the time of the FCC rulemaking, and still today, behavioral disruption in laboratory animals (including non-human primates) at this absorption rate is the only adverse health impact that has been clearly linked to RF at levels similar to those emitted by smart meters. This finding is supported in scientific literature[21, 22] and by the World Health Organization and many health agencies in Europe.[23, 24] The FCC limit of 1.6 W/kg provides a significant factor of safety against this threshold.

Limits on SAR provide the basis for another measurement of exposure, maximum permissible exposure (MPE). MPE limits average exposure over a given time period (usually 30 minutes for general exposure) from a device and is often used for exposure to stationary devices and where human exposure is likely to occur at a distance of more than 20 cm. It is measured in micro (10^{-6}) watts-per-square-centimeter ($\mu W/cm^2$), and accounts for the fact that the human body absorbs energy more efficiently at some radiofrequencies than others. The human body absorbs energy most efficiently in the range of 30-300 MHz, and the corresponding MPE limits for RF emissions in this range are consequently the most stringent. In the frequency bands where smart meters operate, including PG&E's, namely the 902-928 MHz band and 2.4 GHz range, the human body absorbs energy less efficiently, and the MPE limits are less restrictive.

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[19] The U.S. EPA confirmed this in a letter to The Electromagnetic Radiation Policy Institute, dated March 8, 2002. (http://www.emrpolicy.org/litigation/case_law/docs/noi_epa_response.pdf)

[20] FCC (2001) "Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions," Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01), Federal Communications Commission, June. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65c.pdf)

[21] D'Andrea, J.A., Adair, E.R., and J.O. de Lorge (2003) Behavioral and cognitive effects of microwave exposure, *Bioelectromagnetics* Suppl 6, S39-62 (2003).

[22] Sheppard, A.R, Swicord, M. L., and Q. Balzano (2008) Quantitative evaluations of mechanisms of radiofrequency interactions with biological molecules and processes, *Health Phys* 95, 365-96 (2008).

[23] The World Health Organization has reviewed international guidelines for limiting radiofrequency exposure and scientific studies related to human health impacts and concludes that exposure below guideline limits don't appear to have health consequences. (http://www.who.int/peh-emf/standards/en/)

[24] Committee on Man and Radiation (COMAR) (2009) "Technical Information Statement: Expert reviews on potential health effects of radiofrequency electromagnetic fields and comments on The Bioinitiative Report," Health Physics 97(4):348-356 (2009).

The FCC limits on MPE are summarized in Figure 5.[25, 26] At 902 MHz, appropriate for operation of the AMR transmitter of the smart meter; the FCC limit is 601 $\mu W/cm^2$. At higher frequencies, the human body absorbs even less energy, and the threshold for the 2.4 GHz transmitter for home area network communications is consequently higher, 1000 $\mu W/cm^2$.

PG&E commissioned a 2008 study by Richard Tell Associates, "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System." In this study of PG&E's proposed smart meter network it is noted that the FCC limits on MPE include a factor of safety, and the perceived hazardous exposure level is 50 times higher than the FCC limits.[27] The study estimates that the highest exposure from smart meters, if an individual were standing directly in front of and next to the meter, would be 8.8 $\mu W/cm^2$ transmitting at 2 to 4% of the time. The study notes that this is almost 70 times less than the FCC limit and 3,500 times less than the demonstrated hazard level. In all likelihood, individuals will be much farther away from smart meters and likely behind them, (within a structure) where power density will be much lower. The highest exposure from the entire smart meter system would occur immediately adjacent to an access point. It is very unlikely that an individual would be immediately adjacent to an access point, as they are normally located 25 feet above the ground on a telephone or electrical pole or other structure. The peak power density from an access point is estimated to be 24.4 $\mu W/cm^2$, or about 25 times less than the FCC limit. From the ground, exposure to power density from access points is estimated to be 15,000 times less than the FCC limit in great part due to the distance from the device.

The PG&E commissioned report by Richard Tell Associates is based only on an AMR duty cycle of transmitting data once every four hours which results in this very low estimated peak power. However, we are not aware of the justification for using averaging over a four-hour period. We do know the FCC[28] allows averaging of exposure over a designated period (30 minutes). To truly be a smart grid the data will be transmitted at a much more frequent rate than this. In this report we look at the worst-case scenario, a meter that is stuck in the "on" position, constantly relaying, at a 100% duty cycle. Even in this 100% scenario the RF emissions would be measurably below the FCC limits for thermal effects.

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[25] FCC (1997) "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," OET Bulletin 65 (Edition 97-01), Federal Communications Commission, August. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf)

[26] FCC (1999) "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields," OET Bulletin 56 (Fourth Edition), Federal Communications Commission, August. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf)

[27] Tell, R. (2008) "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System," Prepared for Pacific Gas & Electric Company, Richard Tell Associates, Inc., October 27. (http://www.pge.com/includes/docs/pdfs/shared/edusafety/systemworks/rfsafety/rf_fields_supplemental_report_2008.pdf)

[28] http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf

Power Density (and Exposure Level) Declines Rapidly with Distance

The power density from smart meters, or other devices that emit RF, falls off dramatically with distance. Figure 6 illustrates this affect for an example smart meter. While the estimated maximum exposure level at 1 foot from the meter with a duty cycle of 50% is 180 $\mu W/cm^2$ (far below the FCC guidelines), at a distance of about 10 feet, the power-density exposure approaches zero.

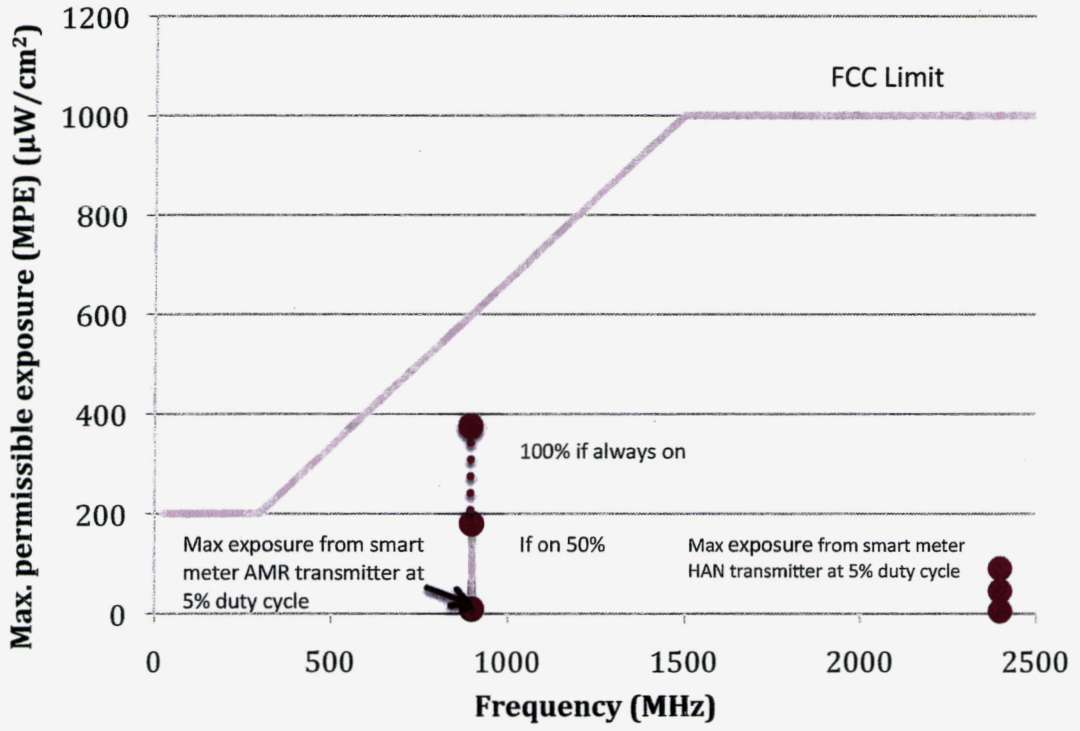

Figure 5. FCC maximum permissible exposure limits on power density rise with frequency because the human body can safely absorb more energy at higher frequencies. The estimated maximum exposure from a 1-Watt AMR transmitter at 5% duty cycle (i.e., 72 minutes/day) and one-foot distance is 18 $\mu W/cm^2$, or 3% of the FCC limit. Even if a meter malfunctioned and was stuck in the always-on transmit mode (i.e., 100% duty cycle), exposure levels would be 60% of the FCC limit for an AMR transmitter. For a 250mW HAN transmitter at a 5% duty cycle, the level would be .45% of the FCC limit and 9% of the FCC limit if the transmitter were on 100%. Exposure figures derived from February 2011 Electric Power Research Institute (EPRI) field measurement study entitled "Radio Frequency Exposure Levels from Smart Meters: A Case Study of One Model".[29]

[29] EPRI (2011) "Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model," Electric Power Research Institute, February 2011.

Figure 6. Power density from a sample smart meter versus distance;[30] 1-Watt emitter at 50% duty cycle. Typical smart meter AMR transmitter power density declines rapidly with distance. The rapid drop of power density with distance (inverse-square law) is similar for various duty cycles and different sets of source data.

Comparison of Electromagnetic Frequencies from Smart Meters and Other Devices

Health concerns surrounding RF from smart meters are similar to those from many other devices that we use in our daily lives, including cordless and mobile telephones, microwave ovens, wireless routers, hair dryers, and wireless-enabled laptop computers.

In addition to slight differences in frequency and power levels, which affect human absorption of RF from these devices, the primary difference among them is how they are used. Cell phones, for example, are often used for many minutes at a time, several times over the course of a day, and held directly next to one's head.

For perspective, microwave ovens operate at a similar frequency as the HAN transmitter of smart meters (2.45 GHz), and the U.S. Food and Drug Administration has set limits on leakage levels that are five times higher (5,000 µW /cm^2) than the FCC limit for smart meters and other

[30] EPRI (20110) "Radio- Frequency Exposure Levels from Smart Meters; A Case Study of One Model, "" Electric Power Research Institute, February 2011.

devices operating at 2.4 GHz.[31] Wireless routers and Wi-Fi equipment produce radiofrequency fields of about 0.2 – 1.0 μW /cm^2.[32, 33, 34] People in metropolitan areas are exposed to radiofrequency from radio and television antennas, as well, although for most of the population, exposure is quite low, around 0.005 μW /cm^2.[35]

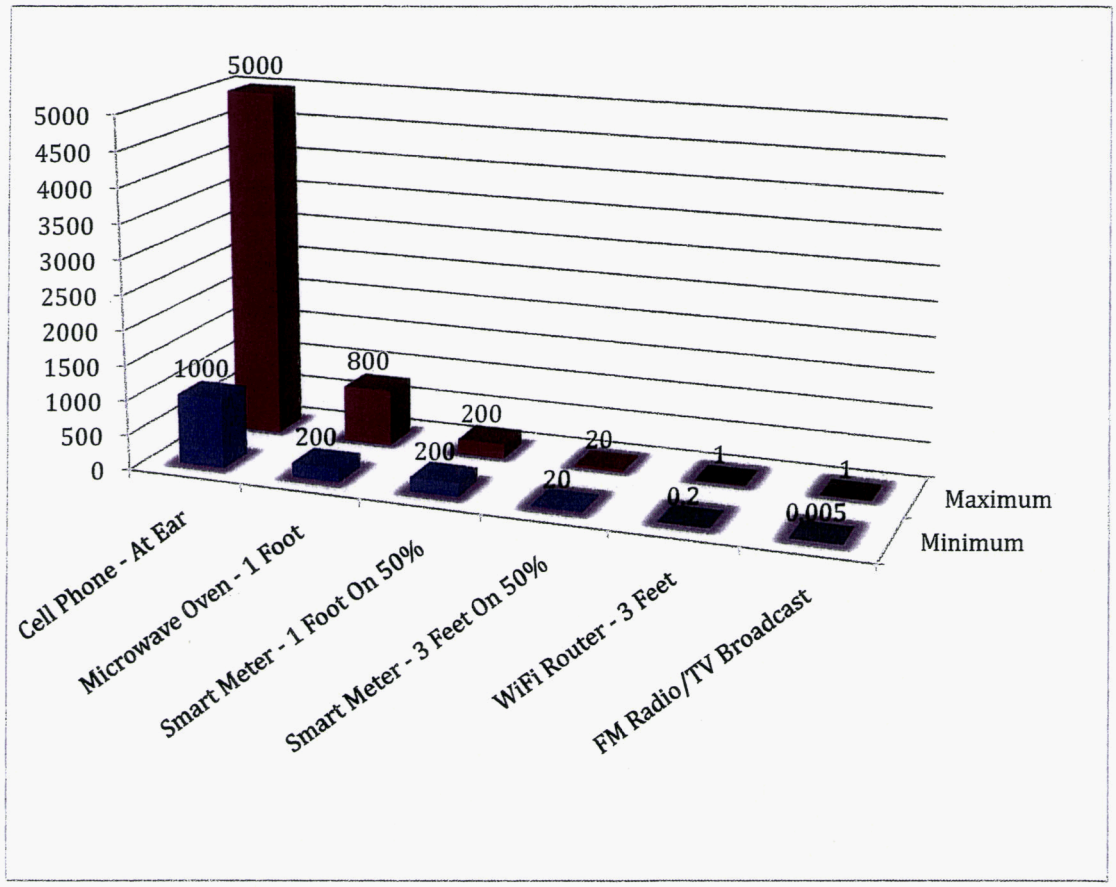

Figure 7. Instantaneous Radio Frequency Power Density Levels of Common Devices (in microWatts/cm^2)
About this figure: This figure was developed by the CCST project team. Quantities for different distances calculated using Inverse Square Law. Assumes distances in far-field, where power density reduces as the square of the distance from the source. Smart meter power scaled to obtain output for 50% duty cycle. The source for the various starting measurements came from Electric Power Research Institute (EPRI), Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model (February 2011)

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[31] FDA, "Summary of the Electronic Product Radiation Control Provisions of the Federal Food, Drug, and Cosmetic Act," U.S. Food and Drug Administration. (http://www.fda.gov/Radiation-EmittingProducts/ElectronicProductRadiationControlProgram/LawsandRegulations/ucm118156.htm)

[32] EPRI (2011) "Radio-Frequency Exposure Levels from Smart Meters; A Case Study of One Model, "Electric Power Research Institute, February 2011.

[33] Foster, K.R. (2007) Radiofrequency exposure from wireless LANS utilizing WI-FFI technology. *Health Physics*, Vol. 92, No. 3, March, pp. 280-282.

[34] Schmidt, G. et al. (2007) Exposure of the general public due to wireless LAN applications in public Places, *Radiation Protection Dosimetry*, Vol. 123, No. 1, Epub June 11, pp. 48-52.

[35] EPA (1986) The Radiofrequency Radiation Environment: Environmental Exposure Levels and RF Radiation Emitting Sources, EPA 520/1-85-014, U.S. Environmental Protection Agency, July.

Table 2: Radio-Frequency Levels from Various Sources

Source	Frequency	Exposure Level (mW/cm^2)	Distance	Time	Spatial Characteristic
Mobile phone	900 MHz, 1800 MHz	1—5	At ear	During call	Highly localized
Mobile phone base station	900 MHz, 1800 MHz	0.000005—0.002	10s to a few thousand feet	Constant	Relatively uniform
Microwave oven	2450 MHz	~50.05-0.2	2 inches2 feet	During use	Localized, non-uniform
Local area networks	2.4—5 GHz	0.0002—0.001 0.000005—0.0002	3 feet	Constant when nearby	Localized, non-uniform
Radio/TV broadcast	Wide spectrum	0.001 (highest 1% of population) 0.000005 (50% of population)	Far from source (in most cases)	Constant	Relatively uniform
Smart meter	900 MHz, 2400 MHz	0.0001 (250 mW, 1% duty cycle) 0.002 (1 W, 5% duty cycle) 0.000009 (250 mW, 1% duty cycle) 0.0002 (1 W, 5% duty cycle)	3 feet 10 feet	When in proximity during transmission	Localized, non-uniform

Source: Electric Power Research Institute (EPRI), Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model (February 2011)

What is Duty Cycle and How Does it Relate to RF Exposure?

Duty cycle refers to the fraction of time a device is transmitting. For instance, a duty cycle of 1% means the device transmits RF energy 1% of a given time period. One percent of the time in a day is equivalent to 14.4 minutes per day. *The duty cycle, or signal duration is an often-overlooked factor when comparing exposures from different kinds of devices (e.g., mobile phones, Wi-Fi routers, smart meters, microwave ovens, FM radio/TV broadcast signals).*

Duty cycles of various devices vary considerably. The duty cycle of AM/FM radio/TV broadcasts, are 100%; in other words, they are transmitting continuously. Mobile phones usage varies widely from user to user, of course. However, the national average use is about 450 minutes per month. This usage equates to a 1% duty cycle for the "average" user.

From information that CCST was able to obtain we understand that the smart meter transmitter being used by PG&E operates with a maximum power output of 1 W (watt) and within the 902-928 MHz (mega-hertz) frequency band. Each smart meter is part of a broader "mesh" network and may act as a relay between other smart meters and utility access points. The transmitter at each smart meter will be idle some of the time, with the percent of time idle (not transmitting) depending on the amount and schedule of data transmissions made from each meter, the relaying of data from other meters that an individual meter does, and the networking protocol (algorithm) that manages control and use of the communications paths in the mesh network.

Theoretically the transmit time could increase substantially beyond today's actual operation level if new applications and functionality are added to the meter's communication module in the future. For a hypothetical illustration (i.e., the meter transmits half the time and receives half the time), an upper end duty cycle would be 50%,. The table below compares the effect of different duty cycles against the FCC guidelines for human exposure limits.

Typical Smart Meter Operation With Repeater Activity	**Scaled Hypothetical Maximum Use Case (i.e., always on)**
5% Duty Cycle	50% Duty Cycle
72 minutes/day	12 hours/day
3% of FCC limit	30% of FCC limit

Source data on operating duty cycles (i.e., first column) from Electric Power Research Institute (EPRI) actual field testing of smart meters, as reported in *Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model*, February 2011. Second column hypothetical maximum case derived through extrapolation of first column data. Both exposure levels at 1-foot distance.

In summary, the duty cycles of smart meters in typical meter-read operation and added maximum-case repeater operation result in exposures that are 3% of the FCC exposure guidelines. Even in a hypothetical extreme and unusual case of half-transmit and half-receive scenario the maximum exposure would be about 30% of the FCC limit, which provides a wide safety margin from known thermal effects of RF emissions.

What About Exposure Levels from a Bank of Meters and from Just Behind the Wall of a Single Meter?

In a February 2011 study Electric Power Research Institute (EPRI)[36] field tested exposure levels from a bank of 10 meters of 250 mW power level at one foot distance in order to simulate a bank of smart meters located at a multifamily building, such as an apartment house. The exposure level was equivalent to 8% of the FCC standard.

In the same study EPRI measured exposure of one meter from eight inches *behind* the meter panel box in order to simulate proximity on the opposite site of the meter wall. At 5% duty cycle it yielded an exposure of only 0.03% of the FCC standard. Even at 100% duty cycle (i.e., always transmitting), exposure at eight inches behind the meter was 0.6% of the FCC limit.

Is the FCC Standard Sufficient to Protect Public Health?

The FCC guidelines do provide a significant factor of safety against thermal impacts the only currently understood human health impact that occurs at the power level and within the frequency band that smart meters use. In addition to the factor of safety built into the guidelines, at worst, human exposure to RF from smart meter infrastructure operating at even 50% duty cycle will be significantly lower than the guidelines. While additional study is needed to understand potential non-thermal effects of exposure to RF and effects of cumulative and prolonged exposure to several devices emitting RF, given current scientific knowledge the FCC guideline provides an adequate margin of safety against known RF effects.

Are Additional Technology-specific Standards Needed?

FCC guidelines protect against thermal effects of RF exposure. Many non-thermal effects have been suggested, and additional research is needed to better understand and scientifically validate them.

Given the scientific uncertainty around non-thermal effects of all RF emitting equipment, at this time there is no clear indication of what, if any, additional standards might be needed. Neither is there a basis from which to understand what types of standards could be helpful or appropriate. Without a clear understanding of the biological mechanisms at play, the costs and benefits of additional standards for RF emitting devices including smart meters, cannot be determined at this time.

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[36] EPRI (2010) "A perspective on radio-frequency exposure associated with residential automatic meter reading technology," Electric Power Research Institute, February, 2011.

Public Information and Education

It is important that consumers have clear and easily understood information about smart meter emissions as well as readily available access to clear, factual information and education on known effects of RF emissions at various field strengths and distances from an array of devices commonly found in our world.

Equipped with this information, people can make knowledgeable judgments about how to prudently minimize possible risks to themselves and their families by utilizing standards-compliant devices at known safe distances. Also, people will be better able to gauge relative field strengths of various RF sources in our everyday environment (e.g., mobile phones, electric blankets, clock radios, TV and radio, computers, smart meters, power lines, microwave ovens, etc.). An ongoing regularly updated source of unbiased information on the state of scientific research, both proven and as-yet-unproven causal effects being studied, if presented by an independent entity, would provide consumers a credible and transparent source from which to obtain facts about RF in our environment.

CCST is not currently aware of a single website with up-to-date consumer information which we are able to endorse as impartial.

Alternatives to Wireless?

Assembly Member Huffman has inquired about potential alternatives to wireless communication with smart meters. There are currently several other methods of transmitting data from some smart meters to the utility company. These methods include transmitting over a power line or wired through phone lines, fiber-optic or coaxial cable. Each method has tradeoffs among cost and performance (e.g., how much data can be carried, how far, how fast). The ability to have a transmission protocol alternative to wireless depends upon the type and configuration of the meter used. Some existing smart meters can be hard-wired, while others would have to be modified or replaced. The communications board plugs into a digital meter. The current PG&E meters use a SilverSpring communications board that only supports wireless protocol. SilverSpring or another vendor could provide an alternative communications means if such were warranted and cost effective. The related costs of an alternative approach would need to be factored into the decision making process related to different options.

If future research were to establish a causal relationship between RF emissions and negative human health impacts, industries and governments worldwide may be faced with difficult choices about practical alternatives to avoid and mitigate such effects. This would greatly affect the widespread use of mobile phones, cordless phones, Wi-Fi devices, smart meters, walkie-talkies, microwave ovens, and many other everyday appliances and devices emitting RF. If such a hypothetical scenario were to occur, smart meters could conceivably be adapted to non-wireless transmission of data. However, retrofitting millions of smart meters with hard-wired technology could be difficult and costly. Perhaps more importantly, retrofitting smart

meters would not address the significantly greater challenge presented by the billions of mobile phones in use globally.

Key Factors to Consider When Evaluating Exposure to Radiofrequency from Smart Meters

1. Signal Frequency	Compare to devices in the 900 MHz band and 2.4 GHz band	Frequency similar to mobile phones, Wi-Fi, laptop computers, walkie-talkies, baby monitors, microwave ovens
2. Signal Strength (or Power Density)	Microwatts/square centimeter ($\mu W/cm^2$)	Meter signal strength very small compared to other devices listed above
3. Distance from Signal	Signal strength drops rapidly (doubling distance cuts power density by four)	Example: 1 ft. – 8.8 $\mu W/cm^2$ 3 ft. – 1.0 $\mu W/cm^2$ 10 ft. – 0.1 $\mu W/cm^2$
4. Signal Duration	- Extremely short amount of time (2.0-5.0%, max.) - No RF signal 95-98% of the time (over 23 hours/day)	- Often overlooked factor when comparing devices. - Short duration combined with weak signal strength yields tiny exposures
5. Thermal Effects	- Scientific consensus on proven effects from heat at high RF levels	- FCC "margin-of-safety" limits 50 times lower than hazardous exposure level - Typical meter operates at 70 times less than FCC limit and 3,500 times less than the demonstrated hazard level
6. Non-thermal Effects	- Inconclusive research to date - No established cause-and-effect pointing to negative health impacts	Continuing research needed

Conclusion

The CCST Project Team, after carefully reviewing the available literature on the current state of science on health impacts of radiofrequency from smart meters and input from a wide array of subject matter experts, concludes that:

1. **The FCC standard provides a currently accepted factor of safety against known thermally induced health impacts of smart meters and other electronic devices in the same range of RF emissions. Exposure levels from smart meters are well below the thresholds for such effects.**

2. **There is no evidence that additional standards are needed to protect the public from smart meters.**

The topic of potential health impacts from RF exposure in general, including the small RF exposure levels of smart meters, continues to be of concern. This report has been developed to provide readers and consumers with factual, relevant information about the:

- Scientific basis underpinning current RF limits
- Need for further research into RF effects
- Relative nature of RF emissions from a wide array of devices commonly used throughout world (e.g., cellular and cordless phones, Wi-Fi devices, laptop computers, baby monitors, microwave ovens).

CCST encourages the ongoing development of unbiased sources of readily available and clear facts for public information and education. A web-based repository of written reports, frequently asked questions and answers, graphics, and video demonstrations would provide consumers with factual, relevant information with which to better understand RF effects in our environment.

Appendix A – Letters Requesting CCST

STATE CAPITOL
P.O. BOX 942849
SACRAMENTO, CA 94249-0006
(916) 319-2006
FAX (916) 319-2106

DISTRICT OFFICE
3501 CIVIC CENTER DRIVE, SUITE 412
SAN RAFAEL, CA 94903
(415) 479-4920
FAX (415) 479-2123

Assembly
California Legislature

JARED HUFFMAN
ASSEMBLYMEMBER, SIXTH DISTRICT

COMMITTEES
CHAIR, WATER, PARKS AND WILDLIFE
NATURAL RESOURCES
UTILITIES AND COMMERCE

SUBCOMMITTEE NO.3
ON RESOURCES

July 30, 2010

Karl Pister, Chair
Susan Hackwood, Executive Director
California Council on Science and Technology
1130 K Street, Suite 280
Sacramento, CA 95814-3965

Dear Chair Pister and Ms. Hackwood:

I am writing to request a study by the California Council on Science and Technology in response to the many concerns and questions that have been raised by constituents in my Assembly District including the Marin County Board of Supervisors, City of Sebastopol, City of Fairfax, and Marin Association of Realtors relating to potential negative health effects from SmartMeters, the electronic monitoring devices that Pacific Gas and Electric Company (PG&E) is installing statewide to continuously measure the electricity output from each household and business.

SmartMeters are currently being installed throughout the state under the authority of the California Public Utilities Commission (CPUC) pursuant to a series of decisions that span from 2006 through 2009. The authority for PG&E to deploy SmartMeters in its territory is embodied in two decisions: D.06-07-027 (the initial deployment) and D.09-03-026 (the upgrade). On the question of health effects of radiation from the devises, PG&E and CPUC maintain that electromagnetic fields emitted from these SmartMeters and the radio frequency power associated with the wireless radios fall within the Federal Communications Commission's (FCC) regulations, pointing out that SmartMeters emit fewer radio frequencies than the amount allowable for cellular telephones, microwave ovens, and wireless Internet Services.

Critics claim, among other things, that FCC standards are not sufficiently protective of public health and do not take into account the cumulative effect of radiation exposure from a growing number of sources and devices, including continuous exposure from some sources. For example, they cite a letter from the Radiation Protection Division of the Environmental Protection Agency (attached), they argue, ..."these standards were thermally based and do not apply to chronic, nonthermal exposure situations, ... and that ... the current exposure guidelines are based on the effects resulting from whole-body heating, not exposure of and effect on critical organs including the brain and the eyes." Therefore, they argue the "safety" standards were not designed to protect the public from health problems under the circumstances which the meters are being used.

Printed on Recycled Paper

An independent, science-based study by the California Council on Science and Technology would help policy makers and the general public resolve the debate over whether SmartMeters present a significant risk of adverse health effects. Toward that end, I request that the Council specifically determine whether FCC standards for SmartMeters are sufficiently protective of public health taking into account current exposure levels to radiofrequency and electromagnetic fields, and further to assess whether additional technology specific standards are needed for SmartMeters and other devises that are commonly found in and around homes, to ensure adequate protection from adverse health effects.

Thank you for your serious consideration of this important and time-sensitive request. Please do not hesitate to contact me if I can be of assistance going forward

Sincerely,

JARED HUFFMAN
Assemblymember, 6th District

COMMITTEES
CHAIR, HEALTH
ARTS, ENTERTAINMENT, SPORTS, TOURISM & INTERNET MEDIA
ENVIRONMENTAL SAFETY & TOXIC MATERIALS
JOINT LEGISLATIVE AUDIT COMMITTEE
JUDICIARY
LABOR AND EMPLOYMENT
WEBSITE: www.assembly.ca.gov/monning

Assembly
California Legislature

WILLIAM W. MONNING
ASSEMBLYMEMBER, TWENTY SEVENTH DISTRICT

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FAX (831) 425-3570

99 PACIFIC STREET, SUITE 555-D
MONTEREY, CA 93940
(831) 649-2832
(831) 649-2836

SANTA CLARA COUNTY DISTRICT LINE
(408) 782-4647

September 15, 2010

Karl Pister, Chair
California Council on Science and Technology
1130 K Street, Suite 280
Sacramento, CA 95814-3965

Dear Chair Pister:

This letter is to formally request that I be included in the response from the California Council on Science and Technology (CCST) regarding the health safety evaluation of the new electronic metering devices, otherwise known as Smart Meters, currently being installed by Pacific Gas and Electric Company (PG&E) which will be available by October 15, 2010.

Numerous concerns and questions have been raised by PG&E customers throughout the state, as well as local government entities such as the County of Santa Cruz, the City of Capitola, City of Santa Cruz, City of Scotts Valley, and the City of Watsonville, relating to potential health effects of the radio frequency (RF) emitted from Smart Meters.

As you know, the federal Energy Independence and Security Act of 2007 required each state to initiate a smart grid system. In response to this federal mandate, the State of California enacted Senate Bill 17, Chapter 327, Statutes of 2009, granting the California Public Utilities Commission (CPUC) smart grid oversight authority. While the CPUC has authorized PG&E to install their current Smart Meter system, CPUC has not addressed the question of whether the RF emissions from Smart Meter devices have potential health impacts.

While PG&E maintains that Smart Meters comply with the Federal Communications Commission (FCC) safety standards, there is still public concern that the FCC standards do not sufficiently protect the public's health and do not take into account the cumulative effect of radiation exposure from the growing number of sources and devices emitting RF.

The scientific evaluation by the California Council on Science and Technology will help to inform both elected officials and the public about the safety of PG&E's Smart Meters and I appreciate the Council taking the time to assess this very important issue.

Thank you for your time and assistance on this issue.

Sincerely,

WILLIAM W. MONNING
Assemblymember, 27th District

WWM:rog

Stephanie Moulton-Peters
Mayor
Ken Wachtel
Vice-Mayor
Garry Lion
Councilmember

MILL VALLEY

Shawn Marshall
Councilmember
Andrew Berman
Councilmember
James C. McCann
City Manager

September 20, 2010

Karl Pister, Chair
Susan Hackwood, Executive Director
California Council on Science and Technology
1130 K Street, Suite 280
Sacramento, CA 95814-3965

Dear Chair Pistel and Ms. Hackwood:

On behalf of the Mill Valley City Council, I am writing to support Assemblymember Jared Huffman's request for a study by the California Council on Science and Technology (CCST) to specifically determine whether Federal Communications Commission (FCC) standards for Pacific Gas and Electric (PG&E) SmartMeters are sufficiently protective of public health.

This request is in response to the many concerns and questions that have been raised by Mill Valley residents relating to potential negative health effects from SmartMeters. Mill Valley residents have expressed their concerns that these devices, which are regulated by the California Public Utilities Commission (CPUC), emit levels of radiation that may be harmful to public health, especially with consideration to the long-term and cumulative impacts of the devices. The CPUC maintains that SmartMeters emit radiation well below the FCC-established safety standards, and have therefore not ordered PG&E to halt the installation of the advanced metering devices.

Critics argue that the safety standards determined by the FCC are not sufficient and specifically not designed to protect the public from health problems under the circumstances which the meters will be used. The FCC standards, they claim, do not take into consideration long-term and cumulative exposures to these devices.

The City of Mill Valley City Council therefore join Assemblymember Huffman in requesting the CCST undertake a study to specifically determine whether FCC standards for SmartMeters are sufficiently protective of public health, taking into account current exposure levels to radiofrequency and electromagnetic fields, and further to assess whether additional technology

City of Mill Valley, 26 Corte Madera Avenue, Mill Valley, California 94941 • 415-388-4033

specific standards are needed for SmartMeters and other devices that are commonly found in and around homes, to ensure adequate protection from adverse health effects.

Thank you for your consideration.

Sincerely,

Stephanie Moulton Peters

Stephanie Moulton-Peters, Mayor
City of Mill Valley

Cc: Mill Valley City Council
Assemblymember Jared Huffman
Joshua Townsend, PG&E Public Affairs Manager
Marzia Zafar, CPUC Business and Community Outreach Division Manager

Appendix B – Project Process

CCST Smart Meter Project Approach

Assembly Member Huffman (Marin) (July 30, 2010 letter) and Assembly Member Monning (Santa Cruz) (September 17, 2010 letter) requested CCST's assistance in determining if there are health safety issues regarding the new SMART meters being installed by the utilities. In addition, the City of Mill Valley sent a letter to CCST (September, 2010) in support of Mr. Huffman's request. (Appendix A - letters)

The CCST Executive Committee appointed a Smart Meter Project Team that oversaw the development of a response on the issue (Appendix C):

- Rollin Richmond (Chair), President Humboldt State University, CSU
- Jane Long, Associate Director at Large, Global Security Directorate Fellow, Center for Global Security Research Lawrence Livermore National Laboratory
- Emir Macari, Dean of Engineering and Computer Science, California State University, Sacramento and Director of the California Smart Grid Center
- Patrick Mantey, Director, CITRIS @ Santa Cruz
- Ryan McCarthy, 2009 CCST Science and Technology Policy Fellow
- Larry Papay, CEO, PQR, LLC, mgmt consulting firm
- David Winickoff, Assistant Professor of Bioethics and Society, Department of Environmental Science, Policy and Management, UC Berkeley
- Paul Wright, Director, UC Center for Information Technology Research in the Interest of Society (CITRIS)

In addition to those on the project team, CCST approached over two dozen technical experts to contribute their opinion to inform CCST's response. The experts were referred from a variety of sources and were vetted by the Smart Meter Project Team. Efforts were made to include both biological and physical scientists and engineers to help provide broad context and perspective to the response. Many of the experts approached indicated they did not time to provide a written response however they provided references to additional experts and/or literature for review. A few experts identified were not asked to contribute due to affiliations that were felt to be a conflict of interest. Experts were asked to provide written comment on two issues, to provide referral to other experts, and to suggest literature that should be reviewed. Appendix D provides a list of those experts who provided written comment.

Smart Meter Project Team members and the experts providing written technical input completed a conflict of interest disclosure form to reveal any activities that could create the potential perception of a conflict.

In addition to written and oral input from technical experts, CCST identified relevant reports and other sources of information to inform the final report. This material can be found listed in Appendix E and on a CCST website: http://ccst.us/projects/smart/.

Peer Review: After the draft report was vetted in great detail by the Smart Meter Project Team, it was forwarded to the CCST Board and Council for peer review.

Public Comment: Comments on the January 2011 draft of this report were solicited from the public. The report was posted to the CCST website to allow the general public to easily comment. Many very thoughtful and informed comments were received. All public comments were reviewed and taken into consideration as this final report was completed.

Appendix C – Project Team

The California Council on Science and Technology adheres to the highest standards to provide independent, objective, and respected work. Board and Council Members review all work that bears CCST's name. In addition, CCST seeks peer review from external technical experts. The request for rigorous peer review results in a protocol that ensures the specific issue being addressed is done so in a targeted way with results that are clear and sound.

In all, this report reflects the input and expertise of nearly 30 people in addition to the project team. Reviewers include experts from academia, industry, national laboratories, and non-profit organizations.

We wish to extend our sincere appreciation to the project team members who have helped produce this report. Their expertise and diligence has been invaluable, both in rigorously honing the accuracy and focus of the work and in ensuring that the perspectives of their respective areas of expertise and institutions were taken into account. Without the insightful feedback that these experts generously provided, this report could not have been completed.

Rollin Richmond, Smart Meter Project Chair, CCST Board Member
President Humboldt State University, CSU

Prior to Richmond's appointment at Humboldt State University in 2002, he had a distinguished career as a faculty member, researcher in evolutionary biology and academic administrator. Richmond received a Ph.D. in genetics from the Rockefeller University and a bachelor's degree in zoology from San Diego State University. Dr. Richmond's career has included: Chairperson of biology at Indiana University, founding Dean of the College of Arts and Sciences at the University of South Florida, Provost at the State University of New York at Stony Brook, and Provost and Professor of Zoology and Genetics at Iowa State University. He was named the sixth President of Humboldt State University in July of 2002. Dr. Richmond is a fellow of the American Association for the Advancement of Science and a member of Phi Beta Kappa. His research interests are in evolutionary genetics.

Jane Long, CCST's California's Energy Future Project Co-Chair and CCST Sr. Fellow
Associate Director at Large, Global Security Directorate Fellow, Center for Global Security Research Lawrence Livermore National Laboratory

Dr. Long is the Principal Associate Director at Large for Lawrence Livermore National Laboratory working on energy and climate. She is also a Fellow in the LLNL Center for Global Strategic Research. Her current interests are in reinvention of the energy system in light of climate change, national security issues, economic stress, and ecological breakdown. She holds a bachelor's degree in engineering from Brown University and Masters and Ph.D. from UC Berkeley.

Patrick Mantey

Director, UC Center for Information Technology Research in the Interest of Society (CITRIS) @ Santa Cruz, University of California, Santa Cruz

Mantey holds the Jack Baskin Chair in Computer Engineering and was the founding Dean of the Jack Baskin School of Engineering. He is now the director of CITRIS at UC Santa Cruz and of ITI, the Information Technologies Institute in the Baskin School of Engineering. In 1984, he joined the UCSC faculty to start the engineering programs, coming from IBM where he was a senior manager at IBM Almaden Research. His research interests include system architecture, design, and performance, simulation and modeling of complex systems, computer networks and multimedia, real-time data acquisition, and control systems. Mantey is a Fellow of the Institute of Electrical and Electronics Engineers. His current projects at CITRIS include the Residential Load Monitoring Project and work on power distribution system monitoring and reliability. Mantey received his B.S. (magna cum laude) from the University of Notre Dame, his M.S. from the University of Wisconsin-Madison, and his Ph.D. from Stanford University, all in electrical engineering. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE).

Emir José Macari

Dean of Engineering and Computer Science, California State University, Sacramento and Director of the California Smart Grid Center

Prior to his appointment as dean at CSU Sacramento, Macari was dean of the College of Science, Mathematics and Technology at the University of Texas at Brownsville. Prior to that, he served as the program director for the Centers of Research Excellence in Science and Technology at the National Science Foundation. He spent five years as the Chair and Bingham C. Stewart Distinguished Professor in the Department of Civil and Environmental Engineering at Louisiana State University. At the Georgia Institute of Technology he taught both engineering and public policy and at the University of Puerto Rico he was a professor and director of Civil Infrastructure Research Center. He has also worked as a civil engineer in private industry and has been a fellow at NASA. Macari holds both a doctorate and a master's degree in civil engineering geomechanics from the University of Colorado. He has a bachelor's degree in civil engineering geomechanics from Virginia Tech University.

Larry Papay CCST Board Member

CEO, PQR, LLC, mgmt consulting firm

Papay is currently CEO and Principal of PQR, LLC, a management consulting firm specializing in managerial, financial, and technical strategies for a variety of clients in electric power and other energy areas. His previous positions include Sector Vice President for the Integrated Solutions Sector, SAIC; Senior Vice President and General Manager of Bechtel Technology & Consulting; and Senior

Vice President at Southern California Edison. Papay received a B.S. in Physics from Fordham University, a M.S. in Nuclear Engineering from MIT, and a Sc.D. in Nuclear Engineering from MIT. He is a member of the National Academy of Engineering and served on its Board of Councilors from 2004-2010. He served as CCST Council Chair from 2005 through 2008, after which he was appointed to the Board.

David E Winickoff

Associate Professor of Bioethics and Society, Department of Environmental Science, Policy and Management, UC Berkeley

David Winickoff (JD, MA) is Associate Professor of Bioethics and Society at UC Berkeley, where he co-directs the UC Berkeley Science, Technology and Society Center. Trained at Yale, Harvard Law School, and Cambridge University, he has published over 30 articles in leading bioethics, biomedical, legal and science studies journals such as The New England Journal of Medicine, the Yale Journal of International Law, and Science, Technology & Human Values. His academic and policy work spans topics of biotechnology, intellectual property, geo-engineering, risk-based regulation, and human subjects research.

Paul Wright

Director, UC Center for Information Technology Research in the Interest of Society (CITRIS)

As Director of CITRIS Wright oversees projects on large societal problems such as energy and the environment; IT for healthcare; and intelligent infrastructures such as: public safety, water management and sustainability. Wright is a professor in the mechanical engineering department, and holds the A. Martin Berlin Chair. He is also a co-director of the Berkeley Manufacturing Institute (BMI) and co-director of the Berkeley Wireless Research Center (BWRC). Born in London, he obtained his degrees from the University of Birmingham, England and came to the United States in 1979 following appointments at the University of Auckland, New Zealand and Cambridge University England. He is also a member of the National Academy of Engineering.

Ryan McCarthy

Science and Technology Policy Fellow, California Council on Science and Technology

McCarthy recently completed the CCST Science and Technology Policy Fellowship in the office of California Assembly Member Wilmer Amina Carter, where he advised on issues associated with energy, utilities, and the environment, among others. McCarthy holds a master and doctorate degree in civil and environmental engineering from UC Davis, and a bachelor's degree in structural engineering from UC San Diego. His expertise lies in transportation and energy systems analysis, specifically regarding the electricity grid in California and impacts of electric vehicles on energy use and emissions in the state.

Appendix D – Written Submission Authors

Written Input Received from:

Physical Sciences/Engineers

Kenneth Foster, Professor, Department of Bioengineering, University of Pennsylvania
Rob Kavet, Physiologist/Engineer, Electric Power Research Institute (EPRI)

Biologists/medical

De-Kun Li, MD, Ph.D., Senior Reproductive and Perinatal Epidemiologist, Division of Research, Kaiser Foundation Research Institute, Kaiser Permanente
Asher Sheppard, Ph.D., Asher Sheppard Consulting, trained in physics, environmental medicine, and neuroscience
Magda Havas, B.Sc., Ph.D., Environmental & Resource Studies, Trent University, Peterborough, Canada
Cindy Sage, MA, Department of Oncology, University Hospital, Orebro, Sweden and Co-Editor, BioInitiative Report

Appendix E – Additional Materials Consulted

All sources can be accessed through the CCST website at http://www.ccst.us

American Academy of Pediatrics

- The Sensitivity of Children to Electromagnetic Fields American Academy of Pediatrics (August 3, 2005)

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

- www.arpansa.gov.au Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
- Radiation Protection - Committee on Electromagnetic Energy Public Health Issues (Fact Sheet)
  Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (May 2010)
- Radiation Protection - Mobile Telephones and Health Effects
  Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (June 25, 2010)

Bushberg, Jerrold – Written Submission

- Background on the Thermal vs. Non-thermal Exposure and Health Issue
  Jerrold Bushberg

Documents From the California Department of Public Health (CDPH)

- Correspondence Provided by Rick Kreutzer, California Department of Health
  Rick Kreutzer, California Department of Public Health (March 10, 2011)
- Mixed Signals About Cellphones' Health Risks Hang Up Research
  The Chronicle (September 26, 2010)
- Summary of the Literature: What do we Know About Cell Phones and Health? (July 20, 2010)
- Brain Tumor Risk in Relation to Mobile Telephone Use: Results of the INTERPHONE International Case - Control Study
  Oxford University Press (March 8, 2010)
- Mobile Phones and Health
  U.K. Department of Health
- Late Lessons from Early Warnings: Towards Realism and Precaution with EMF?
  David Gee, European Environment Agency, (January 30, 2009)
- Statement of Finnish Radiation and Nuclear Safety Authority (STUK) Concerning Mobile Phones and Health
  Radiation and Nuclear Safety Authority - STUK (January 7, 2009)
- Fact Sheet: Children and Safe Cell Phone Use
  Toronto Public Health (July 2008)
- Children and Mobile phones: The Health of the Following Generations in Danger
  Russian National Committee on Non-Ionizing Radiation Protection (April 14, 2008)
- AFSSE Statement on Mobile Phones and Health
  French Environmental Health and Safety Agency - AFSSE (April 16, 2003)

Committee on Man and Radiation (COMAR)

- IEEE Engineering in Medicine and Biology Society Committee on Man and Radiation (COMAR)
- COMAR Technical Information Statement the IEEE Exposure Limits for Radiofrequency and Microwave Energy
  IEEE Engineering in Medicine and Biology Magazine (April 2005)

Commonwealth Club of California

- Commonwealth Club of California - The Health Effects of Electromagnetic Fields (Video) (November 18, 2010)

Electric Power Research Institute (EPRI)

- emf.epri.com EMF/RF Program at EPRI
- Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model
  Electric Power Research Institute (EPRI) (February 2011) Final Report
- Radio-Frequency Exposure Levels from SmartMeters Draft
  Electric Power Research Institute (November 2010) Draft Report - accessed via the Internet December 2010
- Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading Technology
  Electric Power Research Institute (EPRI) (February 22, 2010)
- Testing and Performance Assessment for Field Applications of Advanced Meters
  Electric Power Research Institute (EPRI) (December 4, 2009)
- Overview of Personal Radio Frequency Communication Technologies
  Electric Power Research Institute (EPRI) (September 9, 2008)
- Characterizing and Quantifying the Societal Benefits Attributable to Smart Metering Investments
  Electric Power Research Institute (EPRI) (July 2008)
- Metering Technology
  Electric Power Research Institute (June 20, 2008)
- The BioInitiative Working Group Report
  Electric Power Research Institute (EPRI) (November 23, 2007)
- An Overview of Common Sources of Environmental Levels of Radio Frequency Fields
  Electric Power Research Institute (EPRI) (September 2002)

Environmental Protection Agency

- United States Environmental Protection Agency's Response to Janet Newton (March 8, 2002)
- United States Environmental Protection Agency's Response to Jo-Anne Basile (September 16, 2002)

Epidemiology

- Prenatal and Postnatal Exposure to Cell Phone Use and Behavioral Problems in Children
  Epidemiology July 2008 - Volume 19 - Issue 4 - pp 523-529

European Journal of Oncology - Ramazzini Institute

- Non-Thermal Effects and Mechanisms of Interaction between Electromagnetic Fields and Living Matter
  (2010)

Federal Communications Commission

- Radio Frequency Safety FAQ's
- RF Safety Page
- Statement Provided by Robert Weller Regarding FCC Regulations
  Robert D. Weller, Chief, Technical Analysis Branch, Office of Engineering and Technology, Federal Communications Commission (February 3, 2011)
- Federal Communications Commission Response to Cindy Sage
  (August 6, 2010)
- FCC Certifications
  - FCC Certification for the Silver Spring Networks Devices - September 28, 2009
  - FCC Certification for the Silver Spring Networks Devices - September 28, 2009
  - FCC Certification for the Silver Spring Networks Devices - September 4, 2007
  - FCC Certification for the Silver Spring Networks Devices - July 6, 2007
- Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields
  Federal Communications Commission Office of Engineering & Technology (August 1999)
- Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
  Federal Communications Commission Office of Engineering & Technology (August 1997)

Food and Drug Administration

- No Evidence Linking Cell Phone Use to Risk of Brain Tumors
  U.S. Food and Drug Administration (May 2010)

Health Protection Agency

- Wi-Fi
  Health Protection Agency (Last reviewed: October 26, 2009)
- Cordless Telephones - Digital Enhanced Cordless Telecommunications (DECT) and other Cordless Phones
  Health Protection Agency (Last reviewed: September 4, 2008)

International Commission on Non-Ionizing Radiation Protection (ICNIRP)

- www.icnirp.de International Commission on Non-Ionizing Radiation Protection (ICNIRP)
- International Commission on Non-Ionizing Radiation Protection (ICNIRP) on the Interphone Publication

International Commission on Non-Ionizing Radiation Protection (May 18, 2010)

- ICNIRP Statement on the "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)"
  International Commission on Non-Ionizing Radiation Protection (September 2009)
- Epidemiologic Evidence on Mobile Phones and Tumor Risk
  International Commission on Non-Ionizing Radiation Protection (September 2009)
- Exposure to High Frequency Electromagnetic Fields, Biological Effects and Health Consequences (100 kHz - 300 GHz)
  International Commission on Non-Ionizing Radiation Protection (2009)

National Academies Press

- Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communication
  National Academies Press (2008)
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- Smart Grid Information Clearinghouse (SGIC)
- stopsmartmeters.org

Appendix F – Glossary

Access point - A term typically used to describe an electronic device that provides for wireless connectivity via a WAN to the Internet or a particular computer facility.

Duty cycle – A measure of the percentage or fraction of time that an RF device is in operation. A duty cycle of 100% corresponds to continuous operation (e.g., 24 hours/day). A duty cycle of 1% corresponds to a transmitter operating on average 1% of the time (e.g., 14.4 minutes/day).

Electromagnetic field (EMF) - A composition of both an electric field and a magnetic field that are related in a fixed way that can convey electromagnetic energy. Antennas produce electromagnetic fields when they are used to transmit signals.

Far-field - A distance which extends from about two wavelengths distance from the antenna to infinity, is the region in which the field acts as "normal" electromagnetic radiation. The power of this radiation decreases as the square of distance from the antenna. By contrast, the **near-field**, which is inside about one wavelength distance from the antenna, is a region in which there are effects from the currents and charges in the antenna, which do not behave like far-field radiation. These effects decrease in power far more quickly with distance, than does the far-field radiation power.

Federal Communications Commission (FCC) - The Federal Communications Commission (FCC) is an independent agency of the US Federal Government and is directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. The FCC also allocates bands of frequencies for non-government communications services (the NTIA allocates government frequencies). The guidelines for human exposure to radio frequency electromagnetic fields as set by the FCC are contained in the Office of Engineering and Technology (OET) Bulletin 65, Edition 97-01 (August 1997). Additional information is contained in OET Bulletin 65 Supplement A (radio and television broadcast stations), Supplement B (amateur radio stations), and Supplement C (mobile and portable devices).

Gigahertz (GHz) - One billion Hertz, or one billion cycles per second, a measure of frequency.

Hertz - The unit for expressing frequency, one Hertz (Hz) equals one cycle per second.

Maximum permissible exposure (MPE) limit. An exposure limit or guideline for RF energy exposure published by a recognized consensus standards organization.

Megahertz (MHz) - One million Hertz, or one million cycles per second, a unit for expressing frequency.

Mesh network - A network providing a means for routing data, voice and instructions between nodes. A mesh network allows for continuous connections and reconfiguration around broken or blocked data paths by "hopping" from node to node until the destination is reached.

Milliwatt per square centimeter (mW/cm^2) - A measure of the power density flowing through an area of space, one thousandth (10^{-3}) of a watt passing through a square centimeter.

Microwatt per square centimeter ($\mu W/cm^2$) - A measure of the power density flowing through an area of space, one millionth (10^{-6}) of a watt passing through a square centimeter.

Radiofrequency (RF) - The RF spectrum is formally defined in terms of frequency as extending from 0 to 3000 GHz, the frequency range of interest is 3 kHz to 300 GHz.

Repeater unit - A device that can simultaneously receive a radio signal and retransmit the signal. Repeater units are used to extend the range of low power transmitters in a geographical area.

Router - An electronic computer device that is used to route and forward information, typically between various computers within a local area network or between different local area networks.

Smart meter - A digital device for measuring consumption, such as for electricity and natural gas, and sending the measurement to a utility company. Automated meter reading (AMR) meters send information one-way only. Automated meter infrastructure (AMI) meters are capable of two-way communications.

Specific absorption rate (SAR) - The incremental energy absorbed by a mass of a given density. SAR is expressed in units of watts per kilogram (or milliwatts per gram, mW/g).

Transmitter - An electronic device that produces RF energy that can be transmitted by an antenna. The transmitted energy is typically referred to a radio signal or RF field.

Wide area network (WAN) - A computer network that covers a broad area such as a whole community, town, or city. Commonly, WANs are implemented via a wireless connection using radio signals. High-speed Internet connections can be provided to customers by wireless WANs.

Wi-Fi - An name given to the wireless technology used in home networks, mobile phones, and other wireless electronic devices that employ the IEEE 802.11 technologies (a standard that defines specific characteristics of wireless local area networks).

Appendix G – CCST 2011 BOARD MEMBERS

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Donna King, Executive Assistant and Accountant
Sandra Vargas-De La Torre, Program Coordinator, Layout and Design

ATTACHMENT B -

HEALTH AND RF EMF FROM ADVANCED METERS

PUBLIC UTILITY COMMISSION

OF TEXAS

Donna L. Nelson
Chairman

Kenneth W. Anderson, Jr.
Commissioner

Rolando Pablos
Commissioner

Brian H. Lloyd
Executive Director

Rick Perry
Governor

Public Utility Commission of Texas

Date: December 17, 2012

To: Chairman Donna L. Nelson
Commissioner Kenneth W. Anderson, Jr.
Commissioner Rolando Pablos

From: Alan Rivaldo
Infrastructure & Reliability Division

Subject: Project No. 40190, Project Relating to Advanced Metering Issues
Report on Health and Radiofrequency Electromagnetic Fields from Advanced Meters

---

Recently, some citizens of Texas have expressed concern over the potential health effects of exposure to the radiofrequency emissions from the wireless technology of advanced metering. Some of these individuals have appeared before or submitted comments to the Commission (under Project 40190, *Project Relating to Advanced Metering Issues*) and the Texas Senate Committee on Business and Commerce (at http://www.senate.state.tx.us/75r/senate/commit/c510/c510.htm).

Some have relied on social media as a source of information because it disseminates ideas rapidly and widely, but it also can be inaccurate and lack objectivity. Therefore, Staff decided to investigate the health concerns expressed by citizens and other interested parties. The product of this investigation is the attached document intended to objectively address the issue and help inform decision makers. Staff reviewed recent research on the potential health effects of radio frequency electromagnetic field (RF EMF), reported on the findings, and assessed disputes regarding the findings.

Staff found many scientific research papers published on the effects of EMF on health over a period of nearly 90 years; they number in the thousands. Despite this extensive body of work, scientific research continues, and dozens of papers are published each year.

Staff has determined that the large body of scientific research reveals no definite or proven biological effects from exposure to low-level RF signals. Further, Staff found no credible evidence to suggest that advanced meters emit harmful amounts of EMF.

While many different organizations have performed primary research on health and RF EMF, Staff relied heavily on the following sources:

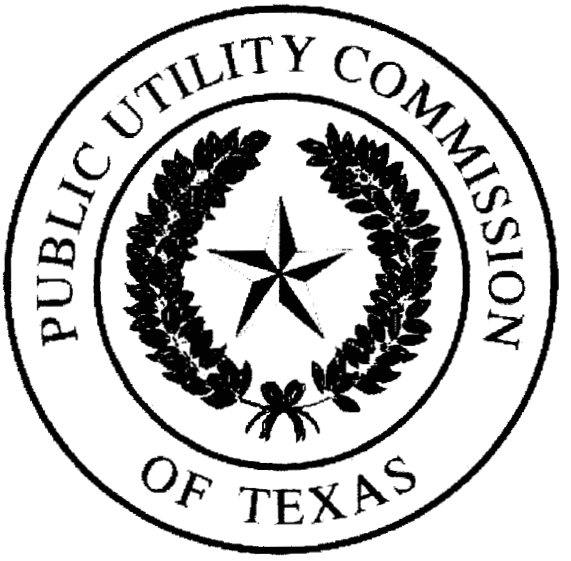
1. The California Council on Science and Technology (CCST), an independent state agency, assessed the available evidence of whether FCC standards provide sufficient protection of public health. Its report also questioned whether additional standards are needed to ensure adequate protection from adverse health effects of wireless communication technology.
2. The Michigan Public Service Commission requested help from Lawrence Berkeley National Laboratory (LBNL) in assessing claims made by some individuals who refuted the findings of the CCST report. The PUCT report summarizes the LBNL work.
3. The measurements and assessments performed by the Electrical Power Research Institute (EPRI), an organization that performs research and provides technical expertise to the electrical utility industry.

Staff found the CCST conclusions, LBNL's work, and the investigations by EPRI to be highly credible and based on sound scientific principles.

Other material Staff reviewed, found valuable, and used to inform the report came from:

- The federal government (FCC, NIH, and other agencies);
- The Canadian government and its provincial health authorities;
- Countries in Western Europe;
- Several municipalities deploying advanced meters;
- Various governmental entities in Australia;
- Academia;
- The United Nations' World Health Organization;
- Utility industry organizations; and
- International standards-settings organizations.

Alan Rivaldo is available to answer any questions you may have.



Health and RF EMF from Advanced Meters

An Overview of Recent Investigations and Analyses

Public Utility Commission of Texas
Infrastructure & Reliability Division
Staff Report

Prepared by Alan Rivaldo
Project No. 40190

December 2012

This document is work supported by the Department of Energy under award numbers DE-OE0000092 and DE-OE0000180.

Any views presented in this paper do not necessarily represent a Commission decision.

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Executive Summary

This paper is a survey of existing scientific research and analyses that have been performed to investigate the potential health effects of exposure to low-level radio frequency electromagnetic fields emitted by wireless communication devices including smart meters. No independent empirical research has been performed by Public Utility Commission of Texas (PUCT) staff, but the results of several studies are summarized in this report.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. Further, Staff reviewed all available material and found no credible evidence to suggest that smart meters emit harmful amounts of Electromagnetic Field (EMF) radiation.

Radiation comes in two forms: ionizing and non-ionizing. The methods of data transmittal by smart meters most common in Texas (which communicate wirelessly) and other forms of telecommunications (television, radio, cell phones, satellite) utilize non-ionizing EMF radiation in the Radio Frequency (RF) band, commonly known as RF EMF.

In contrast, ionizing radiation carries an inherently greater amount of energy; it may come from the decay of fissionable material like uranium or from EMF at significantly higher frequencies, such as X-rays or cosmic rays. Because of its inherent high energy, ionizing radiation is known to cause cellular disruption which may lead to various acute or chronic medical problems, including the induction of cancer.

Smart meters do not emit or utilize ionizing radiation.

RF EMF can cause the heating of living tissue (thermal effect) when the tissue is exposed to a certain level of intensity, which is the only known risk of exposure to such emissions. The Federal Communications Commission (FCC) has therefore established two tiers of Maximum Permissible Exposure (MPE) - one tier applies if exposure occurs in an occupational or "controlled" situation, and the other tier applies if the general population is exposed or exposure results from an "uncontrolled" situation. The FCC uses a safety factor for the general population tier that sets the MPE at 1/50th of the level of known thermal effects while the occupational MPE is set at 1/10th of the level. Because smart meters are devices deployed among the general population, the more restrictive of the two safety factors is applied; the MPE for the general population is 80% lower than the occupational MPE.

Many governmental health agencies from around the world, including those at the state, provincial, county, and city levels, in addition to academic institutions and other researchers have stated that there are no known non-thermal effects from exposure to RF EMF. This lack of non-thermal effect includes the effects which manifest from exposure to ionizing radiation. Nonetheless, substantial medical research on any potential non-thermal effects of non-ionizing radiation has been conducted and is ongoing. It is anticipated that medical researchers will continue to perform investigations of both the potential thermal and non-thermal health effects of RF for the foreseeable future.

It is important to note that one must use caution when relying solely on the results of individual research studies because conflicts or inconsistencies may exist among the results of other individual studies. Laymen often may not recognize poorly executed studies, or they can misinterpret the results of properly conducted scientific research. Either circumstance may lead a casual observer to draw errant conclusions. Furthermore, it is impossible to scientifically prove absolute safety (the null hypothesis).

The Electric Power Research Institute (EPRI) has undertaken several substantial investigations of smart meter RF EMF, and found that smart meters comply with the FCC MPE requirements. Furthermore, it found that in-residence exposure to the emissions from a smart meter is greatly mitigated by several factors:

- The intensity of RF EMF is reduced *exponentially* with greater distance from the emitting device;
- The shielding provided by the meter enclosure;
- The home's building materials further weaken the field strength;
- The meter antenna orientation inhibits the inward direction of the field pattern; and
- RF EMF emissions are only intermittent; a smart meter typically transmits 1 - 5% of the time.

Several governmental entities such as the City of Naperville in Illinois, the Vermont Department of Health, the Victorian State Government of Australia, and the City of Richmond in British Columbia, Canada have performed their own tests on RF EMF from smart meters. These tests corroborated the results of EPRI's investigations.

Some smart meter opponents have raised the concern that the meters may interfere with other electronic devices. Smart meters typically communicate using the 902-928 MHz frequency band which is unlicensed spectrum and falls in the vicinity of where some cordless telephones operate. The FCC's technical rules mitigate the potential for the meters to interfere with other electronic devices by requiring them to be tested and certified as compliant with these rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure.

Despite a lack of credible evidence, opponents have challenged the use of common devices that emit RF EMF on the basis of health and environmental concerns. Some of these concerns involved cell phones and towers, some focused on the use of Wi-Fi[1] in schools, and a few were specifically related to smart meter deployments. As a result of concerns about the wireless technology employed by smart meters, the California state legislature commissioned the California Council on Science and Technology (CCST) to perform a study. The CCST, an independent, non-profit organization, solicited input from technical experts and reviewed and evaluated available research information about health impacts of RF emitted by electric appliances and smart meters. The CCST report concluded that:

- The exposure to RF from smart meters was lower than that from many household devices;
- The FCC standard provides adequate protection from known thermal effects;
- There were no identified non-thermal health effects from existing common household devices, including smart meters; and
- There was no call at this time for devising standards to govern the non-thermal effects of RF exposure.

In response to these findings, various parties opposed to smart meters filed comments with the California Public Utilities Commission which questioned or conflicted with the conclusions of the CCST report. As a result, the Michigan Public Service Commission asked Lawrence Berkeley National Laboratory (LBNL) to review the assertions made in those comments. EPRI also provided its opinions on the submitted comments separately. EPRI found that the submitted comments ignored a substantial amount of existing evidence and that the content indicated a general misunderstanding of concepts and basic principles about smart meters. LBNL was far more critical of the meter opponents' comments in its response and provided greatly detailed assessments of what it viewed as shortcomings of the submittals.

[1] Wi-Fi is a popular technology that allows an electronic device to exchange data wirelessly using radio waves over a computer network, including high-speed Internet connections. Wi-Fi products are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards.

Some opponents of smart meters have raised the idea of the existence of Electromagnetic Hypersensitivity (EHS), a condition in which certain people seem to be especially susceptible to EMF, exhibiting a wide range of physical afflictions. The World Health Organization (WHO) has issued documents on the topic, including recitations of a number of studies which had been conducted on individuals claiming to suffer from EHS. The studies typically attempted to elicit symptoms under controlled laboratory conditions. The WHO concluded that the symptoms experienced by those who have been described as being hypersensitive were not correlated with EMF exposure, and therefore there was no scientific basis to link EHS symptoms to EMF exposure. It suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF or that the symptoms may be due to pre-existing psychiatric conditions or stress reactions resulting from worrying about EMF health effects, rather than the EMF exposure itself. Further, scientific studies show that people who are ill are highly receptive to negative suggestion and may demonstrate a "nocebo response" as a result of these suggestions.

A few people opposed to the use of wireless technologies have made claims that EMF can be used as a weapon to cause pain, disrupt thought, or alter or control human behavior. Smart meters do not have the capabilities to do these things.

Smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. A meter may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

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Introduction

Some members of the public have expressed concerns over the possible health effects from exposure to electromagnetic fields (EMF) emitted by advanced meters that transmit data wirelessly (smart meters). People have stated their concerns in public forums hosted by the Public Utility Commission of Texas (PUCT) or submitted written comments to the agency. The comments are available on the PUC's website under project 40190.[2] Citizens have also appeared before the Texas Senate Committee on Business and Commerce[3] to make statements. This report is intended to inform decision makers and other parties interested in the topic.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. In reviewing all available material, Staff found no credible evidence to suggest that smart meters emit harmful amounts of EMF.

This paper begins by explaining radiation which is a word that has several meanings. This document explains the distinction between ionizing and non-ionizing radiation. Also discussed are some fundamental characteristics of radio-frequency EMF (RF EMF) which is the non-ionizing form of radiation utilized by almost all wireless forms of telecommunication and by smart meters that send data through the air.

Because properly understanding radiation and health depends upon understanding the foundations of science, this paper explains the scientific method and outlines what constitutes valid science. Some people have claimed that they can make scientific arguments against the use of wireless communications technology, or describe what they view as its egregious hazards, or produce evidence of harm. This document provides guidance when considering such assertions.

As new technologies continue to pervade our lives, matters of science are addressed more often by our legal system. Public policy must also address technology, and those who craft laws and regulations often rely on external sources to provide subject matter expertise in matters of science, including medicine. This was true for the California Public Utilities Commission (CPUC). CPUC asked the California Council on Science and Technology (CCST) to analyze submittals made by various experts in science and medicine regarding RF EMF.

CPUC received comments that were critical of the CCST report. Various parties responded in defense of the conclusions of the CCST report. This paper summarizes the CCST report, some of the reply comments, and responses to those comments. Staff found the CCST conclusions to be based on sound scientific principles.

Several entities, such as the Electric Power Research Institute (EPRI), have measured the level of RF EMF exposure one would receive from smart meters. This report summarizes the findings of the EPRI investigations as well as those performed by other organizations.

This paper discusses standards for human exposure to EMF and regulations that govern devices which emit EMF. This report provides statements from health agencies of several countries and those made by academia regarding human exposure to RF EMF. This document concludes with a discussion about a purported medical condition called electromagnetic hypersensitivity and the notion of using EMF as a weapon. A chart of acronyms and abbreviations follows, along with an alphabetized list of references and resources.

---

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[3] <http://bandc.posterous.com/updated-october-9-2012-agenda-with-links-57790>.

The Science

Background – Radiation, Science

The fear of things that cannot be seen is innate to human beings. Imagine being dropped off alone in a forest in the middle of the night, with no moon to light the way. Are there venomous snakes or scorpions underfoot? Are there other unseen threats nearby? RF EMF is also invisible, so some people may be predisposed to feeling anxious about it.

Fear of the unknown is also common, and to some people, the notion of wireless communications technology is new, or something with which they have no experience. To make matters worse, wireless technology is a form of electromagnetic radiation (EMR), and the term "radiation" is rather ambiguous and commonly misunderstood. Exposure to radiation has been traditionally associated with chronic illnesses (specifically cancer) and death. Lastly, microwave ovens use EMR to cook food and boil water; knowing this, some people may imagine themselves being cooked or boiled alive if exposed to EMR.

Radiation

Radiation can be characterized as energetic particles or waves traveling through matter or space. Radiation can come from natural or man-made sources. For this report, it is important to first know that there are two types of radiation: ionizing and non-ionizing. Making the distinction is crucial because the word "radiation" on its own can evoke images of the victims of the atom bomb or the outcomes of the Chernobyl and Fukushima Daiichi disasters, when in fact the many forms of radiation we encounter in our daily lives are inert.

Ionizing Radiation

Ionizing radiation can come in one of two forms: particulate (e.g. neutron, alpha, or beta particles) or electromagnetic (e.g. gamma, cosmic, or X- rays). Ionizing radiation has such a high energy level that when it hits an atom, typically an electron is stripped away or dislodged from the shell of the atom. This changes the properties of the atom – leaving it with a net positive charge. Note that the high energy level of ionizing radiation is basic to its nature, and distinct from what its *intensity* may be in any given instance.

Ionizing radiation is generally harmful and potentially lethal because it can alter the molecules in living organisms, such as the genetic material of cells. If the genetic material of a cell is altered, it may lead to death of the cell or to cell mutation.

Ionizing radiation can come from outer space or from naturally occurring materials in the terrestrial environment, such as uranium or radon gas. Ionizing radiation can also be introduced into the environment from human activities like nuclear power production, medical and industrial uses, the transportation of radioactive material, mining, and by drilling for oil and gas. *Note that smart meters do not produce or use ionizing radiation.*

Non-Ionizing Radiation

In contrast, the waves of non-ionizing radiation inherently do not possess enough energy to displace electrons from the shell of an electron. Non-ionizing radiation may cause excitation of an electron, moving it to a higher energy state, but not stripping it away.

Electromagnetic radiation whose frequency is between that of extremely low frequency radiation and ultraviolet light is considered non-ionizing radiation. The radio emissions from cell phones, smart meters, and other forms of wireless communication lie between these two extremes. Therefore, radio communication from a smart meter is a form of non-ionizing radiation.

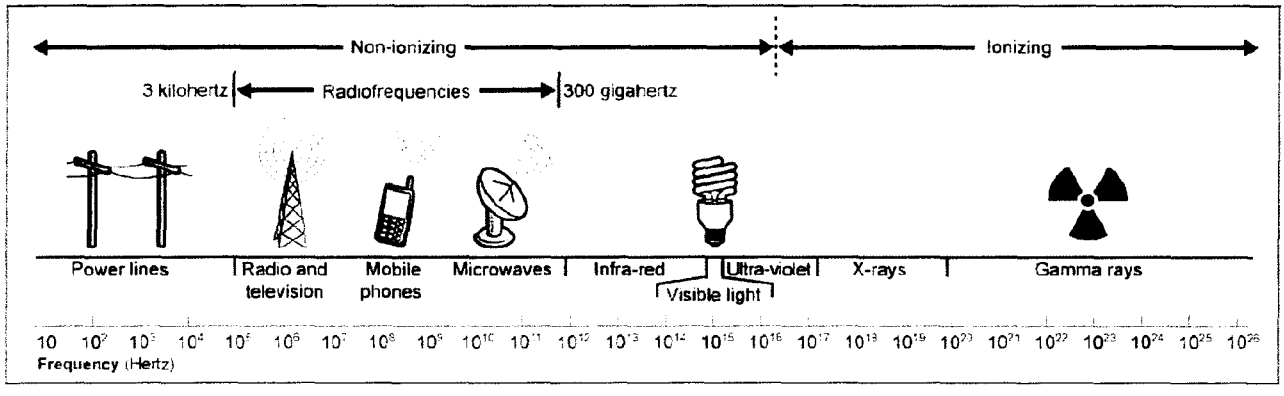
Electromagnetic Spectrum

The various forms of radiation, whether ionizing or non-ionizing, lie on a continuum called the electromagnetic spectrum, as seen in Figure 1. Smart meters that communicate wirelessly use frequencies that are between the frequencies of UHF television channels and those of mobile phones (somewhere between 900 MHz and 2.4 GHz), depending on the wireless technology (or technologies) the meters employ.

Figure 2 shows some of the chart's information in a tabular format. The frequency range in which wireless smart meters transmit data has been emphasized in that figure.

Note that the Public Utility Commission of Texas addressed potential health effects of extremely low frequency (60 Hz) electric power at very high voltages and currents, as is conducted in transmission lines. That report, issued in 1992, was entitled "Executive Summary: Health Effects of Exposure to Powerline-Frequency Electric and Magnetic Fields." The considerations being addressed in this *Health and RF EMF from Smart Meters* report are substantially different from those contemplated in 1992.

Figure 1: Chart of the Electromagnetic Spectrum[4]



[4] Not shown in the chart is the fact that as the frequency (Hz) of radiation increases, the "electron volt" (eV) value increases in a linear fashion. In this context, electron volts serve as a measure of how much energy the radiation carries and therefore the potential it has to excite an electron (or, if it has enough energy, dislodge it from an atom).

Figure 2: Types of Radiation and Their Frequency Ranges

Frequency Range	Top End of Frequency Range (in Hz)	Designation or Abbreviation	Primary Use
Radio. Non-ionizing radiation.			
3 – 30 Hz	30	ELF	Submarine communications
30 – 300 Hz	300	SLF	Not commonly used; electrical power is in this range
300 – 3000 Hz	3,000	ULF	Military communications
3 – 30 kHz	30,000	VLF	Submarine communication
30 – 300 kHz	300,000	LF	Military, AM radio
300 kHz – 3 MHz	3 million	MF	AM radio, shortwave radio
3 – 30 MHz	30 million	HF	Amateur radio, CB radio, aviation radio
30 – 300 MHz	300 million	VHF	VHF TV, FM radio, amateur radio
300 MHz – 3 GHz	***3 billion***	***UHF "microwave"***	***UHF TV, land-based mobile radio, cell phones, smart meters***
3 – 30 GHz	30 billion	SHF "microwave"	WLAN, radars, industrial devices
30 – 300 GHz	300 billion	EHF "microwave"	Short range data transmission
Light. Non-ionizing radiation.			
300 GHz – 400 THz	400 trillion	Infrared (IR)	TV remote controls, heat lamps
400 THz – 770 THz	770 trillion	Visible ("light")	Illumination
Ionizing radiation.			
750 THz – 30 PHz	30 quadrillion	Ultraviolet (UV)	Tanning beds, medical, industrial applications
30 PHz – 30 EHz	30 quintillion	X-Ray	Medicine, scientific, and industrial uses
more than 15 EHz	> 15 quintillion	Gamma ray	Medicine, scientific, and industrial uses

Electromagnetic Fields

An electromagnetic field is the result of the mutual interaction of electric and magnetic fields.[5] An electric field can be most simply described as being produced by stationary charges. A higher voltage yields a stronger electric field. In contrast, a magnetic field is produced by moving charges (typically electrons, i.e., an electric current). A greater current flow yields a stronger magnetic field.

An RF electromagnetic field is an electromagnetic field that is produced by electrical current that is oscillating at a radio frequency, which is defined as a frequency between 3 cycles per second and 300 billion cycles per second. Smart meters typically communicate with one another (or to their data concentrator) in a frequency band that is near 900 MHz.

Electromagnetic (EM) field intensity decreases greatly with distance. There are many variables involved in precisely calculating the anticipated intensity of an EM field from a given distance. To simplify the mathematics involved, it can be reasonably stated that the intensity of an EM wave, which is three-

[5] <http://www.britannica.com/EBchecked/topic/183201/electromagnetic-field>.

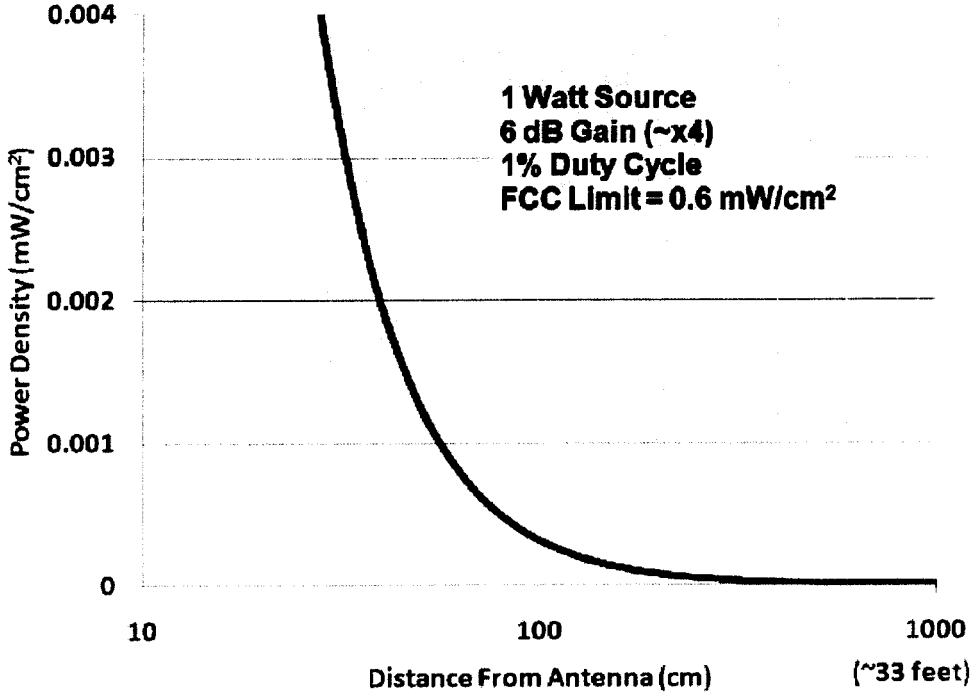
dimensional, decreases exponentially at a rate of approximately the square of the distance from its source. This is known as the inverse-square law,[6] expressed as a mathematical formula by:

$$Y = \frac{1}{X^2} \text{ (where } Y \text{ is the intensity and } X \text{ is relative distance).}$$

For example, if the EM intensity from a smart meter is measured to be Y_0 at an initial distance of 1 foot away, then Y_1, the field intensity from two feet away, would be $(\frac{1}{2^2})Y_0$, or $\frac{1}{4}Y_0$. From a three-foot distance, the intensity Y_2 will be $(\frac{1}{3^2})Y_0$, or $\frac{1}{9}Y_0$. From ten feet away, the field intensity will only be $(\frac{1}{10^2})Y_0$, or 1/100th of what it was at one foot away. Figure 3 shows how the average power density of EMF from a typical smart meter varies with distance.

Upon inspecting the graph, the power density value may appear to become zero, but in actuality it does not; the resolution of the image belies the asymptotic nature of the curve. While the power density may seem to become infinitesimal at the greater distances shown, the radio circuitry of smart meters is sensitive enough to receive and process the signal.

Figure 3: Calculated Average Power Density vs. Distance for a Typical Smart Meter[7]



[6] <http://www.osha.gov/SLTC/radiofrequencyradiation/electromagnetic_fieldmemo/electromagnetic.html#appendix_b>.

[7] Notes: The graph shows expected (calculated) values. The power density is average power density, not instantaneous; measured values will vary around a nominal value. This graph does not account for possible ground reflections, but ground reflections would not change the basic shape of the curve. Graph source: EPRI.

EMF and RF EMF in our Environment

Almost all household devices powered by electricity emit RF EMF in some amount. The FCC has classified devices in three categories – intentional radiators, unintentional radiators, and incidental radiators.

- Intentional radiators deliberately generate and emit RF energy. Typical intentional radiators include cordless telephones, remote control toys, garage door openers, mobile data devices such as iPads, and other low power transmitters.

- Unintentional radiators are devices that generate and use RF energy within the device but are not intended to emit RF energy. Typical unintentional radiators include devices such as personal computers, printers, automobile dashboard electronics, and other digital devices that have internal "clocks" or circuitry used for timing within the device. Radio receivers, such as television receivers and AM/FM radios, are also unintentional radiators.

- Incidental radiators are devices that generate RF energy during the course of their operation but are not intentionally designed to generate or emit that energy. Typical incidental radiators include automobile ignition systems, ceiling fans, vacuum cleaners, electric shavers, and mechanical light switches.

RF EMF also comes from natural sources, such as the sun, the Earth, and the outer layer of the Earth's atmosphere (the ionosphere).

The environment in which we live includes numerous other sources of RF EMF sourced from outside the home. These sources are intentionally transmitted and beyond an individual's control. The transmitting sources emit RF at a much greater intensity than smart meters do, and the signals permeate homes and other buildings. This RF EMF has had a ubiquitous presence both indoors and outdoors since the 1920s when AM radio broadcasts (centered near the 1 MHz frequency) were introduced. In the 1930s, FM radio (around 100 MHz) was introduced, and then in the 1940s and 1950s, the broadcasting of VHF television (50 to 200 MHz) and UHF television (400 to 900 MHz) expanded. Satellite communication started in the 1960s and is now commonplace, including for consumer use. Cellular telephone towers (base stations) have been deployed in increasing numbers since at least the 1990s; they are now considered ubiquitous.

Other sources of RF EMF one may encounter in public and private places are wireless routers, cordless telephones, cellular phones, RF remote control devices, and baby monitors. The intensity of EMF emitted by each of these devices is documented to be well below the threshold that requires any type of notification signage.[8]

The Role of RF EMF in our Country's Infrastructure

The United States of America (U.S.) has had a wireless communications infrastructure in place for nearly a hundred years. For example, radio and television stations have continually broadcasted their programming in all directions for public consumption since the early part of last century. Emergency services like police, fire, and ambulance services have their own dedicated radio spectrum. Municipal governments and the military also transmit data on various frequency bands assigned to them. Citizen's Band and short wave radio are used by individuals and hobbyists, but one could argue that it is also a part of our nation's communications infrastructure that benefits all, especially in times of emergency.

[8] <http://standards.ieee.org/findstds/standard/C95.2-1999.html>.

Satellite transmissions blanket our country from above, using various frequencies in the RF band. Downlinks from satellites are used by the television and radio industries for delivery of syndicated programming to local stations. Satellites also provide Internet access to users in remote areas and television programming for those without access to cable television or who seek an alternative. They also provide subscription-based programming for SiriusXM radio, and to fulfill government functions such as transmitting climate and mapping data and Global Positioning System (GPS) locational and timing information (which is used by utilities). The military also uses satellites for communications and surveillance.

Cell phones and their associated base stations are also a common source of EMF, having become ubiquitous worldwide; the International Telecommunication Union reported that there were six billion mobile phone subscriptions by the end of 2011, nearly one for every human being on the planet.[9]

Some people object to the installation of wireless smart meters on the grounds that they fear exposure to RF and because they do not anticipate benefitting from the devices' advanced capabilities. What they may not realize or acknowledge is that every individual is continuously exposed to RF emitted by a multitude of local television (TV) and radio stations, irrespective of whether one ever chooses to tune into any of them.

When a new radio or TV station begins broadcasting in a community, it introduces a new source of RF to a wide area. While the *exposure* to RF emissions is the primary consideration for the topic of this paper, some opponents of smart meters have called attention to their power output. It is therefore worth noting that the permitted maximum effective radiated power (ERP, which includes antenna gain[10]) of an FM radio station transmitter in the U.S., depending upon its FCC classification, can be as high as 100,000 watts.[11] In contrast, the radio module in a wireless smart meter is only capable of a maximum power output of one watt, and in some implementations, it is even less than that. The ERP of a stationary cell phone base station is limited to either 500 or 1000 watts, depending on its location.[12] The maximum peak ERP of a cell phone in the U.S., for example one operating in the GSM-1900 band and at GSM Power Class Number 30, is two watts.[13]

Despite the fact that radio stations broadcast at power levels that are tens of thousands times higher than those of smart meters, Staff could not find any references to reported health complaints or individuals attributing their health issues to new radio or TV transmissions. Similarly, while a limited number of people may still have some trepidation regarding cellphone towers, their ubiquity and the continued popularity of cell phones and other wireless communication devices seems to have quelled the number of concerns being expressed.

Advanced Metering Infrastructure

Making prudent investments in RF communications technologies has become essential to maintaining our quality of life, and many aspects of the world's infrastructure depend upon it. Many industries, including electrical utilities, use radio communication as an essential tool. Until recently, utilities have traditionally limited their use of radio to telemetry, transmitting system data from distant points along the transmission portion of the electric grid.

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[9] <http://www.itu.int/net/pressoffice/press_releases/2012/70.aspx>.

[10] In this context, this is defined by how well a transmitting antenna converts input power into radio waves headed in a specified direction.

[11] <http://www.fcc.gov/encyclopedia/fm-broadcast-station-classes-and-service-contours>.

[12] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol2/xml/CFR-2011-title47-vol2-sec22-913.xml>.

[13] <http://www.radio-electronics.com/info/cellulartelecomms/gsm_technical/power-control-classes-amplifier.php>.

Now many of the electric utilities in the U.S. are enhancing the distribution portion of the electrical infrastructure by modernizing its technology. One of the ways electrical utilities are upgrading distribution grid technology is by replacing existing electric meters with Advanced Metering Infrastructure (AMI). The meters being replaced typically have an analog display[14] in the form of a series of dials that indicate accumulated usage and a large spinning aluminum disk that protrudes through the face of the meter. This electromechanical technology is over a century old and has shortcomings.

The most important feature of the meters used in AMI ("smart meters") is that they measure and record usage data in regular intervals[15] and allow for two-way communications between the utility and the customer. These smart meters and their associated communication components form an infrastructure that allow utilities to overcome the old technology's limitations and is now crucial to the utility and to the energy market's proper functioning.

Almost all smart meters used in the U.S. communicate by means of wireless technology. Each utility proposes the technology it will deploy and determines how it is to be configured in order to best suit the needs of its service area. The most common method of communication chosen by Texas utilities has been in the form of a wireless mesh network.

A wireless mesh network topology allows "mesh-enabled" meters to securely route data via other nearby meters and relay devices. These meters and relay devices are connected to several other mesh-enabled devices. All these devices function as signal repeaters and relay the data to an access point. The access point device aggregates, encrypts, and conveys the data to and from the utility (this is known as the backhaul portion of the network). The access point typically uses cellular phone technology to transport this data.[16]

Wireless Technology Standards and Regulation

Intentional radiator devices such as cordless telephones, cellular phone handsets, and smart meters operate in unlicensed spectrum. Unlicensed spectrum is simply a band that has pre-defined rules for both the hardware and the deployment methods of the transmitting radio; they are required to be tested and certified as compliant with these rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate Federal Communications Commission (FCC) equipment authorization procedure.[17] The mitigation of potential interference within the bands is addressed by the FCC definition of technical rules rather than the agency restricting the bands by issuing an exclusive license to use the spectrum.[18,19]

Any person or entity that complies with the rules for the equipment (which are pre-certified by the manufacturer) and its use can establish a license-free network at any time for either private or public purposes. This is why a person can set up a wireless network at home and a utility can set up its smart meter mesh network without having to obtain a license from the FCC. The radio(s) in the smart meter is pre-certified, just as a home user's wireless router is.

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[14] Note that not all meters being replaced have the same appearance. A few of the old meters may have digital displays and solid state circuitry, but are not considered to be AMI.

[15] Due to the limited scope of this paper, the specific market and regulatory aspects of Texas and the ERCOT market and the infrastructure design choices of each of the utilities will not be discussed.

[16] There are several possible variations to the mesh design described above. Take what is outlined here as an example.

[17] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet63/oet63rev.pdf>.

[18] <http://www.wimax.com/wimax-regulatory/what-is-unlicensed-spectrum-what-frequencies-are-they-in>.

[19] U.S. frequency allocations: <http://www.ntia.doc.gov/files/ntia/publications/spectrum_wall_chart_aug2011.pdf>.

The FCC is required by the National Environmental Policy Act of 1969 to evaluate the effect of emissions from FCC-regulated transmitters on the quality of the human environment. At the present time there is no federally-mandated RF exposure standard. However, several non-government organizations, such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE), and the National Council on Radiation Protection and Measurements (NCRP) have issued recommendations for human exposure to RF electromagnetic fields.[20] The potential hazards associated with RF electromagnetic fields are discussed in the FCC's Office of Engineering and Technologies (OET) Bulletin No. 56, "Questions and Answers About Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields."[21]

On August 1, 1996, the FCC adopted the NCRP's recommended MPE limits for field strength and power density for the transmitters operating at frequencies of 300 kHz to 100 GHz. In addition, the FCC adopted the Specific Absorption Rate (SAR) limits for devices operating within close proximity to the body as specified within the ANSI/IEEE C95.1-1992 guidelines.[22] The FCC's requirements are detailed in Parts 1 and 2 of the FCC's Rules and Regulations [47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093].[23,24,25,26]

Studies by EPRI and others have found that the exposure an individual would receive from a smart meter that is 10 feet away is not much different from the range of exposure levels received from TV and radio broadcasts.

The Effects of RF EMF on Living Tissue

There are three scientifically established mechanisms where EMF is known to cause health effects:[27,28]

- Induced voltage gradients and/or electric currents in the body;
- Thermal effects (dielectric heating); and
- Ionizing radiation effects.

The relative importance of these mechanisms depends on the EMF frequency and field strength. Decades of research into EMF and health has produced a large body of scientific literature which national and international standards organizations have reviewed to establish their safe exposure limits. For example, the WHO has formally recognized the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to develop its international EMF exposure guidelines.

At frequencies in the range of 0-3 kHz, induced voltage gradients and/or electric currents in the body are the only known health effects in the presence of strong electric and magnetic fields. Because the purpose of this report is to address smart meters that communicate using RF, induced voltages and currents will not be discussed. Smart meters do not emit ionizing radiation, so that topic will also not be covered in this document. If one would like to know more about the health effects of induced voltages or ionizing radiation, credible resources are freely available elsewhere.

[20] <http://transition.fcc.gov/oet/rfsafety/background.html>.
[21] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.
[22] <http://standards.ieee.org/findstds/standard/C95.1-2005.html>.
[23] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1307.xml>.
[24] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1310.xml>.
[25] <http://www.gpo.gov/fdsys/pkg/CFR-2009-title47-vol1/xml/CFR-2009-title47-vol1-sec2-1091.xml>.
[26] <http://www.gpo.gov/fdsys/pkg/CFR-2009-title47-vol1/xml/CFR-2009-title47-vol1-sec2-1093.xml>.
[27] <http://www.emfandhealth.com/EMFExplained.html>.
[28] <http://standards.ieee.org/findstds/standard/C95.6-2002.html>.

Thermal effects are the primary health impact when living tissue absorbs enough EMF power to cause heating. This effect is the primary concern in the RF frequency range of 30 MHz to 300 GHz. In theory, the total EMF power absorbed by tissue is determined by the photon energy multiplied by the number of photons per second being absorbed. The practical method used to measure this energy is based on the SAR. For portable devices, the FCC specifies that SAR safety limits are to be used.[29] These safety limits are specified in units of watts per kilogram (W/kg) of body tissue.

Note that the energy from devices that are not intended for use within 20 centimeters of a user, such as smart meters, is measured using a different methodology. The FCC safety limits for these devices, known as Maximum Permissible Exposure (MPE), are specified in units of microwatts per square centimeter ($\mu W/cm^2$).

Existing regulations from the FCC set the SAR and MPE safety limits in the U.S. Other countries such as the United Kingdom (UK), Canada, and Australia have similar standards. International standards regarding safety for commercial products also exist from entities such as the WHO and the ICNIRP and are also similar to the U.S. standards.

The Scientific Method, the Value of Meta-analysis, Laymen Difficulties, and other Cautions

The investigation of RF EMF and its potential effects on health requires an understanding of several fields of science. While the intent of this report is not to impart a deep understanding of all the relevant scientific fields of study, it is still important to have a basic grasp on the concepts and what science itself entails. The latter is referred to as the scientific method.

Meta-analysis is an important tool in science because in some areas of study there are a large number of studies which are similar, and researchers want to have a method of combining them to help facilitate drawing satisfactory conclusions.

People generally have an interest in maintaining their health, so any given research study that shows a positive correlation between a disease and an environmental factor will naturally have the tendency to pique the interest of the public more than one that does not show any correlation. While journalists and news editors have codes of ethics and guidelines for professional conduct,[30,31,32,33] there is a risk that the mass media may sensationalize an individual study which shows such a correlation and be less inclined to report research studies that refute the findings, because documenting something which may be interpreted by an audience as uneventful is not as captivating or lucrative. Studies have revealed that the publishing of misconceptions about alleged effects of exposure to electric or magnetic fields in the popular press is not uncommon.[34,35,36,37] Some less reputable media outlets may be motivated by viewership ratings, subscription renewals, or webpage hits, rather than reporting the news properly. Integrity in the media plays a role in maintaining the integrity of scientific research.

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[29] The FCC defines portable devices as transmitters whose radiating structures are designed to be used within 20 centimeters (approximately eight inches) of the body of the user.

[30] <http://www.rtdna.org/pages/media_items/code-of-ethics-and-professional-conduct48.php?g=36?id=48>.

[31] <http://www.apme.com/?page=EthicsStatement>.

[32] <http://asne.org/content.asp?pl=24&sl=171&contentid=171>.

[33] <http://www.spj.org/ethicscode.asp>.

[34] <http://www.dtic.mil/dtic/tr/fulltext/u2/a275434.pdf>.

[35] <http://www.jmpee.org/JMPEE_PDFs/26-4_bl/JMPEE-Vol26-Pg189-Jauchem.pdf>.

[36] <http://www.jmpee.org/JMPEE_PDFs/28-3_bl/JMPEE-Vol28-3-Pg140-Jauchem.pdf>.

[37] <http://www.jmpee.org/JMPEE_PDFs/30-3_bl/JMPEE-Vol30-Pg165-Jauchem.pdf>.

Understanding the concepts behind science is important because opponents of wireless data transmission technologies have attempted to use science (typically by quoting research studies) as support for their arguments. At the same time, one must remain mindful of the relationships among science, modern media, and the public.

Scientific Method

The modern use of the word "science" is defined both as a reliable body of knowledge that can be logically and rationally explained and also by the method of pursuing that knowledge, namely, the scientific method. Scientific method requires inquiry to be based on evidence that is empirical and measurable and is subject to specific principles of reasoning. More specifically, the scientific method consists of systematic observation, measurement, and experiment, as well as the formulation, testing, and modification of hypotheses.[38]

The following process steps[39] are considered the basic elements of scientific method:

- Formulate a question - to summon an explanation of a specific observation, or it can be open-ended;
- Hypothesis - a conjecture that may explain the observed behavior;
- Prediction - made by determining the logical consequences of the hypothesis;
- Test - investigate (via experiment) whether the real world behaves as predicted by the hypothesis; and
- Analysis - determine what the experimental results demonstrate and decide the next actions to take.

Other components are necessary to the scientific process, even when all the iterations of the steps above have been completed:

- Replication - if an experiment is repeated and does not produce the same results, this implies that the original results were in error. As a result, it is common for a single experiment to be performed multiple times, especially when there are uncontrolled variables or other indications of experimental error. Surprising or significant results may motivate other scientists to also investigate, especially if the results would be important to their own work;
- External review - experts perform a peer review, which is an evaluation of the experiment. These experts give their opinions anonymously to foster unbiased criticism. The peer review does not certify correctness of the results, only that the experiments themselves were sound. Note that the evaluation of the experiment depends on its description being supplied by the experimenter. If the work passes peer review (which may require new experiments requested by the reviewers), it will be published in a peer-reviewed scientific journal. The journal that publishes the results indicates the perceived quality of the work; and
- Data recording and sharing - scientists must record all data very precisely to reduce their own bias and aid in replication by others. This data must be supplied to other scientists who wish to replicate any results. Experimental samples that may be difficult to obtain must also be shared.

Scientific studies are intended to be as objective as possible to reduce any bias in how the results are interpreted. All data and the methodologies employed are to be documented, archived, and shared so that they are available for close scrutiny by other researchers. This gives scientists the opportunity to verify results by attempting to reproduce them and establish statistical measures of the reliability of the experimental data.

[38] <http://oxforddictionaries.com/definition/english/scientific%2Bmethod>.
[39] <http://en.wikipedia.org/wiki/Scientific_method>.

Meta-analysis

The study of EMF has been going on for decades resulting in a multitude of research studies, many of which possess similar elements. The existence of such large bodies of work makes researchers want to integrate similar studies and attempt to synthesize more definitive conclusions. The traditional method of integration calls for a reviewer to provide a narrative, namely a chronological discourse on previous findings.[40] Gene V. Glass, the statistician and researcher who coined the term meta-analysis, considered the traditional method to be flawed and inexact because reviewers:

- Are unable to deal with the large number of studies on a topic and focus on a small subset of studies, often without describing how the subset was selected;
- Often cite the conclusions of previous reviews without examining those reviews critically; and
- Are usually active and prominent in the field under review. Therefore, they might not be inclined to give full weight to evidence that is contrary to their own positions.

In a meta-analysis, research studies are collected, coded, and interpreted using statistical methods similar to those used in primary data analysis. The result is an integrated review of findings that is more objective and exact than a narrative review.

Inherent Problems and Laymen Difficulties with Scientific Research; Non-traditional Medicine

Science is by no means a discipline of perfection; it depends upon human thought and activity, and is thereby subject to human failings, including the introduction of bias into the process steps outlined above. Most failures can be attributed to inadvertent errors, while some failures can be pinned on researchers that have taken shortcuts through the scientific process. Only rarely have researchers who had been generally considered to be legitimate been found attempting to subvert science for personal benefit, to perhaps gain notoriety, or to secure future research grants.[41]

Findings of scientific misconduct occasionally come to light. In the course of gathering material for this paper, Staff discovered several studies of RF EMF and health that were found to be fraudulent. For example, the U.S. Department of Health and Human Services' (HHS) Office of Research Integrity found that Robert P. Liburdy, Ph.D. engaged in scientific misconduct in biomedical research by intentionally falsifying and fabricating data and claims about the purported cellular effects of EMF that were reported in two of his scientific papers.[42] Another example of misconduct was exposed through an investigation performed by an independent review body at the Medical University of Vienna. The investigation revealed that data was fabricated in two papers authored by lab chief Hugo Rüdiger and his colleagues in 2005 and 2008 which reported DNA breakage in cells exposed to electromagnetic fields. The papers were part of a European Union-funded project called REFLEX.[43]

Some people have made assertions that research studies that had depended upon funding or other support from industry should be considered as unreliable and having tainted results. What is far more important than the sources of funding for research is strict adherence to the scientific process. Rigorous peer reviews, combined with attempts by others to replicate results, tend to remove from consideration studies whose results rely on questionable research practices. Opponents of wireless technology may not understand this, and have expressed dismay when content from studies they favor does not appear in other documents such as

[40] <http://echo.edres.org:8080/meta>.
[41] <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0005738>.
[42] <http://grants.nih.gov/grants/guide/notice-files/not99-111.html>.
[43] <http://www.emfandhealth.com/sciencerudigerfraud.pdf>.

the report by the California Council on Science and Technology.[44] There is a risk that opponents may attribute the exclusion of favored material to attempts by government agencies or industry to suppress the truth rather than accepting the idea that the opponents' favored studies were errant or lacked scientific rigor.

Nonetheless, some research studies can receive undeserved notoriety despite shortcomings such as:

- Experiments that are poorly designed or lack sufficient controls;
- Studies that are inadequately peer-reviewed;
- Public revelation of findings that are only preliminary;
- Reports that are unpublished but appear in the popular press;
- Reports published in scientific journals of lesser esteem;
- Conclusions that are drawn to satisfy a political agenda rather than advance human knowledge; and
- Cited primary research studies are old and out of date.

The "BioInitiative Report"[45] is an example of a report that received notoriety despite being viewed negatively by the research community. Its contributors are described as a group of 14 scientists, researchers, and public health policy professionals. The stated purpose of the report was to document "bioeffects, adverse health effects and public health conclusions about impacts of non-ionizing radiation." The document was edited by Cindy Sage, an environmental consultant, and Dr. David O. Carpenter, director of the Institute for Health and the Environment at the State University at Albany (New York).

The report is often cited by opponents of wireless technology, but it was widely criticized by government research agencies and subject matter experts in Australia,[46] Belgium,[47] the European Commission (EC),[48] France,[49] Germany,[50] and the Netherlands.[51] It was also criticized by EPRI[52] and the IEEE.[53] The overall opinion of these institutions was that the report had many shortcomings. Some of the stated criticisms were that the report:

- Provided views that were not consistent with the consensus of science;
- Recommended safety limits that were not supported by the weight of scientific evidence;
- Included selection bias in several research areas;
- Lacked objectivity and balance; and
- Suffered from uneven editing quality.

Some researchers have developed a level of notoriety for their assertions regarding the purported dangers of EMF exposure. Opponents of wireless technology have naturally called upon these people to testify as expert witnesses and this tends to raise their profiles to an even greater degree. These efforts have not always been successful. For example, Carpenter attempted to rely on his work on the BioInitiative Report as one of the qualifications to testify as an expert for intervenors opposed to plans by Hydro Québec, a utility in Canada, to

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[44] <http://www.ccst.us/publications/2011/2011smart-final.pdf>.
[45] <http://www.bioinitiative.org/freeaccess/report/docs/report.pdf>.
[46] <http://www.acrbr.org.au/FAQ/ACRBR%20Bioinitiative%20Report%2018%20Dec%202008.pdf>.
[47] <http://mmfai.info/public/docs/eng/MMF_Viewpoint_BioInitiativeReport.pdf>.
[48] <http://ihcp.jrc.ec.europa.eu/our_activities/public-health/exposure_health_impact_met/emf-net/docs/efrtdocuments/EMF-NET%20Comments%20on%20the%20BioInitiative%20Report%2030OCT2007.pdf>.
[49] <http://www.afsset.fr/upload/bibliotheque/964737982279214719846901993881/Rapport_RF_20_151009_l.pdf>.
[50] <http://www.emf-forschungsprogramm.de/int_forschung/wirk_mensch_tier/Synopse_EMFStudien_2008.pdf>.
[51] <http://www.gezondheidsraad.nl/sites/default/files/200817E_0.pdf>.
[52] <http://emf.epri.com/BioInitiative_Working_Group_Report_Updated_7-09.pdf>.
[53] <http://www.emfandhealth.com/12265_COMAR_2009.pdf>.

install wireless smart meters on homes and businesses. The regulatory authority for the province, The Québec Energy Board (The Board), stated (translated from French):[54]

> "The Board has refused to grant the requested expert status on the grounds that David Carpenter is not a doctor, never had clinical experience with patients and has never personally done any research on the effects of RF health.[55] The Board does not, however, reject his testimony in the case because of his knowledge on the research done by others in this field. It therefore accepted this testimony, subject to establishing the probative value to be accorded."

The Board also did not view Carpenter as independent and unbiased, as required by its rules governing the expectations of expert witnesses. The Board stated (translated from French):[56]

> "Clearly, the witness Carpenter, expert or not, does not meet the criteria of objectivity which the Board is entitled to expect."

Another individual who has been described as an expert by opponents of wireless technology is Magda Havas, a professor at Trent University, a liberal arts institution located in Peterborough, Ontario, Canada. Havas is not a medical doctor; she has a B.S. degree in biology and a Ph.D. in botany (the study of plant life).[57]

While not naming Havas directly, in response to her assertions against the proposed installation of Wi-Fi in several schools in Canada and the U.S., her colleagues at Trent University published a brief statement[58] in the *Peterborough Examiner* newspaper:

> On the issue of health effects of radio frequency waves, a large body of evidence now exists, and the international consensus is described in the references listed at www.trentu.ca/physics/emfrefs.pdf. Based on these considerations, we do not believe that electromagnetic waves associated with Wi-Fi in schools pose a health risk to children or teachers.
>
> Profs Bill Atkinson, Peter Dawson, David Patton, Ralph Shiell, Alan Slavin and Rachel Wortis
> Members of the Department of Physics, Trent University

Havas' critics are not limited to her colleagues at Trent. There are a few websites whose stated goals are to enhance the public's familiarity with sound scientific concepts. These sites state that their contributors seek to promote a better understanding of science and to help others distinguish between evidence-based science and poor science. Some contributors have responded to Havas' activities by creating pages that are dedicated to exposing and explaining what they claim to be significant flaws in her studies, contradictory statements she has made, comments which were not consistent with established facts, and instances where they claim she had misled the public.[59,60,61,62,63,64,65]

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[54] <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0163-DEC-DEC-2012_10_05.pdf>.
[55] David O. Carpenter holds a medical degree (M.D.) from Harvard but is not accredited to practice medicine.
[56] <http://www.regie-energie.qc.ca/regie/DirectivesInstructions/Regie_RoleExperts_18juillet2011.pdf>.
[57] <http://www.magdahavas.org/dr-magda-havas-bio/>.
[58] <http://www.thepeterboroughexaminer.com/2010/10/15/physicists-see-no-danger-from-wifi-in-schools>.
[59] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%201.html>.
[60] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%202.html>.
[61] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%203.html>.
[62] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%204.html>.
[63] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%205.html>.
[64] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%206.html>.

Note that some of the work that Havas performs involves the study of Electromagnetic Hypersensitivity (EHS), which has not been recognized by the medical or scientific communities as a valid diagnosis.

Some scientists and medical practitioners may be valued as experts by a small segment of the population because their ideas have been proclaimed as novel or superior because they do not conform to the prevailing conclusions of the scientific or medical communities. These researchers and medical professionals may be characterized as fighting the medical or scientific establishments for the benefit of their supporters. The problem is if these maverick researchers become imbued with noble stature because of these impressions, it may put the integrity of true science and medicine at risk.

Scientists prefer to maintain cordial relationships with one another and therefore avoid using the terms "junk science" and "pseudoscience" when referring to research or unconventional medical treatments they find questionable, because these terms are considered pejorative.

While skepticism of research is central to ensuring its quality, it is important to avoid being drawn to the allure of ideas that conflict with the body of scientific evidence. Without an appreciation for the meaning and value of scientific consensus, one risks being distracted by notions that have been discounted by numerous studies conducted in adherence to the scientific method.

Scientific consensus can be described as the collective judgment, position, and opinion of the community of scientists in a particular field of study.[66] In the context of scientific research, consensus is general agreement and not unanimity, which has a stricter meaning. This collective judgment of scientists cannot be used as a valid scientific argument on its own, and that it is not part of the scientific method; it is more the *result* of it.

A consensus can be developed by scientists through replication of experimental results, peer review, and publication of results – key components of the scientific method. When this process is followed iteratively and agreement exists, those within the discipline recognize they have reached a consensus. As scientific research continues and new data is produced by experiment, models are refined. This change may bring about shifts in scientific consensus. How consensus within the scientific community develops over time is a study in its own right.[67]

The challenge for researchers becomes communicating to outsiders (especially laymen) that scientific consensus has been reached. This is because to the uninitiated, the debates through which science progresses may seem to be contestation. Laypeople and others outside the particular field of study who misinterpret these scientific debates as adversarial may reach erroneous conclusions about the science. When scientific debate is misinterpreted in this manner, effective government also may be subject to risk. The risk is that members of the public that have misconceptions about the existence of scientific consensus may exert pressure on their elected leaders to devise public policy that is based on faulty assumptions.

In medicine, one result of misinterpreting scientific debate can be a mistaken belief in a medical diagnosis that the scientific community does not recognize as valid, such as EHS. If the true cause of an affliction is not diagnosed, it can lead to negative consequences for an individual. Medical professionals and others may offer treatments that are not efficacious or have not been properly vetted for safety. The pursuit of these treatments can delay receiving effective medical care.

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[65] <http://www.sciencebasedmedicine.org/index.php/cfls-dirty-electricity-and-bad-science/>.
[66] <http://en.wikipedia.org/wiki/Scientific_consensus>.
[67] <http://asr.sagepub.com/content/75/6/817.full.pdf+html>.

The Internet offers amulets made of crystal or stone, typically worn as a pendant around the neck, that are purported to help an individual overcome EHS or to mitigate the claimed negative health effects of exposure to EMF. No valid scientific explanations are offered to explain the mechanisms by which these items may operate. Dietary supplements are promoted with claims they provide a "strong protective effect" against EMF but have not been assessed by the U.S. Food and Drug Administration (FDA) for safety or effectiveness.

Some physicians offer treatments for EHS and other purported "environmental sensitivities." One such doctor is Dr. William J. Rea of Dallas, Texas. An example treatment by Rea is that he will administer injections of a highly diluted solution of automobile exhaust to provide an "electromagnetic imprint" of the environmental pollutant. Rea claims that a patient's immune system will interact with the injections and desensitize the patient to the substance.

Staff has not been able to locate any other references to the term "electromagnetic imprint" in a medical context.

Rea's treatments had met with controversy, leading the Texas Medical Board to file a complaint against him[68,69,70] that resulted in a Mediated Agreed Order issued in 2010, requiring his consent form to state:

- The injections given are not FDA-approved;
- The patient will be receiving non-traditional medicine (must be in bold and oversized print);
- The effectiveness of the injections is disputed;
- There has been no testing of the contents of the injection or any proven medical effectiveness;
- The therapeutic value of the injections is not established or proven;
- There is no active agent in the therapy being provided; and
- The injections are not endorsed, sanctioned, or approved by the Texas Medical Board.

Rea's controversial treatments were also featured on a segment of ABC News' *Nightline* television program in 2008.[71,72]

Rea appeared before the Texas Senate Committee on Business and Commerce on October 9, 2012 to speak as a medical expert in opposition to wireless smart meters.

Cautions about Anecdotes, Attempts at "Do-it-Yourself" Science, and Reliance on Social Media and Blogs

Opponents of smart meters have provided accounts of ill health or have cited anecdotal reports of health problems that have been attributed by laypeople to the installation of smart meters. Caution must be used when considering anecdotal reports, because they:

- Are prone to human cognitive biases such as confirmation bias;[73]
- Use nonprobability sampling and therefore suffer from self-selection bias;[74]

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[68] <http://www.casewatch.org/board/med/rea/order.shtml>.
[69] <http://www.med.ohio.gov/pdf/Minutes/2011/08-11minutes.pdf>.
[70] <http://www.tmb.state.tx.us/news/press/2010/090210.php>.
[71] <http://abcnews.go.com/Nightline/video?id=5881281>.
[72] <http://www.youtube.com/watch?v=-gx4zxxi0xQ>.
[73] In psychology and cognitive science, confirmation bias is a tendency to search for or interpret information in a way that confirms one's preconceptions, leading to statistical errors. Source: <http://www.sciencedaily.com/articles/c/confirmation_bias.htm>.

- Do not supply a sufficiently large sample size;
- Prevent a rigorous statistical analysis of subject sample data;
- Do not account for a myriad of variables present in the environment (lack of controls); and
- Do not provide evidence that other aspects of the scientific method were followed.

In summary, conclusions drawn primarily from anecdotal reports do not possess scientific merit.

A common tendency for laypeople is to "cherry pick" scientific literature. Cherry picking is the act of pointing to data or individual cases that seem to confirm a particular position, while ignoring a significant portion of data or cases that may contradict the position. Selectively referencing only the studies that support a view is a common example of confirmation bias. Cherry picking may be committed unintentionally. Scientists are not immune to the behavior.

When raising concerns about wireless technology, some opponents have acquired RF EMF measurement equipment and posted online videos[75] showing readings being taken from smart meter installations. These videos have been presented as evidence that the smart meters were emitting RF EMF at levels higher than those claimed by utilities or meter manufacturers. More discerning viewers may question the validity of these videos for the following reasons:

- The videos tend to be brief, relying on fleeting numbers displayed on a readout;
- The data do not appear to be recorded for later study or shared with others;
- No evidence is provided that the operator is certified to use the measuring equipment;
- It is not noted whether the operator received any formal training to avoid, for example, using improper techniques when setting up or handling the equipment;
- Little explanation is offered to help the viewer determine if the appropriate settings were used (such as unit scaling) or whether instantaneous peak or average values were being measured;
- No evidence is given that the equipment was properly calibrated; and
- There may be other tools available which are better suited to the intended use.

One video[76] on YouTube that provides an example of an EMF measurement device being used purports to show the deleterious effects of a smart meter on a shrub situated directly in front of the meter in Stratford, Ontario, Canada. On the afflicted plant, the leaves have curled up and are losing color. There are two shrubs of identical breed on either side of it which do not seem to be as adversely affected. While a shrub is clearly not a human being, some smart meter opponents refer to the video as evidence of its apparent danger to all living things.

The person who recorded the video enabled the "audio analysis" mode on the measurement device, which creates a shrill sound reminiscent of a police siren but with varying pitch. The sound is intended to represent a characteristic signal pattern of the EMF being detected, which helps the device's user to identify the source of emissions. To an individual who has not experienced the operation of this device, the sound it makes in the presence of EMF may seem disturbing and evoke an unpleasant emotional response in the uninitiated.

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[74] Self-selection bias is a specific form of selection bias. Selection bias leads to distortions, because certain characteristics are over-represented in a sample. Self-selection bias introduces other errors. For example, sample populations that are the result of self-selection suffer from a correlation with willingness to be included. There may be a purposeful intent on the part of respondents.

[75] Go to YouTube: <http://www.youtube.com> and search for "smart meter emissions" or other similar phrases.

[76] <http://www.youtube.com/watch?v=lsuP_WBBr2c>.

An interesting observation about this video which some viewers may not notice is that as the camera focuses closely on the vegetation, it is readily apparent that the shrub is infested by what appears to be a large number whiteflies or aphids. These kinds of insects suck juices from the leaves of host plants, and can lead to serious injury, causing wilting, yellowing, leaf drop, and possibly death. As the video camera pans back and forth, one can see that the insects are also on the leaves of the adjacent shrubs, but are not yet as prevalent. The ability for viewers to provide comment is disabled for this particular video, so no one can call attention to the insect infestation or challenge the claims made by the person who posted the video.

The Texas A&M Forest Service estimated that 301 million trees had died across Texas forestlands as a result of the 2011 drought,[77] but to date there have been no known credible reports of dying vegetation attributed to smart meters or other wireless equipment despite the fact that millions of the devices have been deployed in the state.

Many smart meter opponents who have made assertions about the purported detrimental health effects of wireless technology have cited material obtained from blogs,[78] Internet videos, and other forms of social media as sources of information. Blogs may contain items that are topical but they are not to be confused with news sites; contributors to blogs are not held to standards for journalistic integrity. Most of the cited blogs are run by self-described activists who overtly state their opposition to smart meters and for various reasons. While blogs and social media sites have democratized the Internet, enabling almost anyone to widely publish his points of view, caution must be used when considering material obtained from such sources. These sites have many shortcomings, including the following:

- Site content is not vetted for objectivity or a diversity of opinions;
- Inaccurate reporting is common, and errors are rarely corrected;
- Many comments are written in an authoritative manner, promoting speculative statements as factual;
- Provocative language and hyperbole are often used to elicit emotional responses;
- Individuals promoted as experts tend to lack substantial academic credentials or possess credentials that are not associated with the field of study under consideration; and
- There is no assurance that authors resist the influence of advertisers or special interests.

The people who run blogs typically are not scientists and do not realize that an individual study is not to be considered definitive. Much of the research that Staff found cited on blogs was old and may have been out of date, or had been considered unreliable by the scientific community.

Case Law and Matters of Science

The Supreme Court cases *Daubert v. Merrell Dow Pharmaceuticals,*[79] *General Electric Co. v. Joiner,*[80] and *Kumho Tire Co. v. Carmichael*[81] articulated what is known as the "Daubert standard." The standard addressed Rule 702 of the Federal Rules of Evidence,[82,83] and clearly defined a judge's role in playing "gatekeeper," determining whether expert testimony is based on sound scientific reasoning and methodology.

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[77] <http://texasforestservice.tamu.edu/main/popup.aspx?id=16509>.

[78] A blog is a website that typically contains an online personal journal and that sometimes allows users to post their own opinions and commentary or other information.

[79] 509 U.S. 579 (1993).

[80] 522 U.S. 136 (1997).

[81] 526 U.S. 137 (1999).

[82] Pub. L. 93–595, §1, Jan. 2, 1975, 88 Stat. 1937; Apr. 17, 2000, eff. Dec. 1, 2000; Apr. 26, 2011, eff. Dec. 1, 2011.

[83] <http://www.law.cornell.edu/rules/fre/rule_702>.

According to Rule 702, *Testimony by Expert Witnesses*, a witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

a. The expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
b. The testimony is based on sufficient facts or data;
c. The testimony is the product of reliable principles and methods; and
d. The expert has reliably applied the principles and methods to the facts of the case.

In 2011, the National Academies published[84] the third edition of its *Reference Manual on Scientific Evidence*,[85] which was developed to guide judges as they encounter scientific evidence at trials. The cases are taken into consideration when government uses the "weight of evidence" to create public health policy and law.[86]

In a matter that is germane to the topic of this report, the Daubert case and the reference manual were both cited in a recent court decision in which the plaintiff claimed his exposure to low-level RF EMF emitted by electronics within his neighbor's house were triggering adverse health effects.[87] The court excluded the plaintiff's evidence because it was not scientifically reliable and consequently granted the defendant's motion for summary judgment for failing to demonstrate causation.[88]

Public Policy

The WHO published "Establishing a Dialogue on Risks from Electromagnetic Fields,"[89] a handbook intended as a guide for decision makers and those who craft policy to help reduce misunderstandings and improve trust through better dialogue when faced with a combination of public controversy, scientific uncertainty, and the need to operate or establish infrastructure facilities that emit EMF. The guide discusses risk assessment, risk perception by the public, and risk management. The document also calls out the need for involvement by individuals or organizations with the right set of competencies. It states that a combination of relevant scientific expertise, strong communication skills, and good judgment are required by those in the areas of management and regulation to properly respond to challenges presented by the topic. The handbook also provides references and suggested reading material for those who seek more information.

[84] <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=13163>.
[85] <http://www.nap.edu/catalog.php?record_id=13163>.
[86] <http://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.2004.044727>.
[87] Firstenberg v. Monribot and Leith, No. D-101-CV-2010-00029, New Mexico 1st Dist, Santa Fe County, Sept 18, 2012.
[88] <http://www.casewatch.org/civil/firstenburg/dismissal_order.pdf>.
[89] <http://www.who.int/peh-emf/publications/EMF_Risk_ALL.pdf>.

Recent Studies and Expert Opinions

California Council on Science and Technology Report and Responses

In 2010, the CPUC initiated an investigation of smart meters. Several members of the California State Assembly asked the California Council on Science and Technology to provide assistance to the CPUC.

CCST is an independent, not-for-profit 501(c)(3) corporation established in 1988 by the California legislature. It is designed to offer expert advice to the state government and to recommend solutions to science- and technology-related policy issues. CCST's Board of Directors is composed of representatives from its sponsoring academic institutions, as well as the business and philanthropic communities.[90]

The Assembly's request to provide assistance was motivated by concerns expressed by the public about the possibility of health effects from exposure to RF EMF emitted by smart meters. In January 2011, CCST issued "Health Impacts of Radio Frequency from Smart Meters." The document was authored by a project team that consulted with over two dozen experts and sifted through more than one hundred articles and reports which CCST considered as providing a thorough, unbiased overview in a relatively rapid manner. The report identified four key findings: [91]

1. Wireless smart meters, when installed and properly maintained, result in much lower levels of RF exposure than many existing common household electronic devices, particularly cell phones and microwave ovens;
2. The current FCC standard[92,93,94] provides an adequate safety factor against known thermally induced health impacts of existing common household electronic devices and smart meters;
3. To date, scientific studies have not identified or confirmed negative health effects from potential non-thermal impacts of RF emissions such as those produced by existing common household electronic devices and smart meters; and
4. Not enough is currently known about potential non-thermal impacts of radio frequency emissions to identify or recommend additional standards for such impacts.

CCST did not undertake primary research of its own to address issues. Its response was limited to soliciting input from technical experts and to reviewing and evaluating available information from past and current research about health impacts of RF emitted by electric appliances in general, and more specifically by smart meters.

Response to CCST Report: County of Santa Cruz Health Services Agency

Following the release of the CCST report, Poki Stewart Namkung, Health Officer of the County of Santa Cruz Health Services Agency (Santa Cruz), issued a memorandum. The memo was published on January 13, 2012 and is entitled "Health Risks Associated with Smart Meters."[95] The document has gained notoriety for two reasons. The first reason is because it made assertions that were in direct opposition to the CCST report's key

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[90] <http://www.ccst.us/about.php>.
[91] <http://www.ccst.us/publications/2011/2011smart-final.pdf>.
[92] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf>.
[93] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.
[94] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1310.xml>.
[95] <http://www.santacruzhealth.org/pdf/2012%20Report%20on%20SmartMeters.pdf>.

findings. The second reason is because the assertions made in the Santa Cruz memo have been used by some smart meter detractors to justify calls for a moratorium on installation of the devices.

The Santa Cruz memo stated that CCST's report did not account for the frequency of transmissions, any reflections of the emissions, banks of smart meters firing simultaneously, or distances closer than three feet. The memo also asserted that smart meters would emit RF EMF almost continuously and that it would not be possible to program them to not operate at 100% of a duty cycle (on continuously). It stated that because of these factors, one could not claim that Smart Meters do not exceed the time-averaged MPE limit adopted by the FCC.

The Santa Cruz memo also stated that RF EMF exposure is additive[96] and consumers may have already increased their exposures to RF EMF emissions in the home through the voluntary use of RF emitting devices.

Michigan Public Service Commission: SGTAP Assessment of Santa Cruz Memo

On March 20, 2012, the Michigan Public Service Commission (MPSC) asked the Smart Grid Technical Advisory Project (SGTAP) to review the Santa Cruz memorandum. SGTAP is located at the Lawrence Berkeley National Laboratory (LBNL) and provides technical assistance and training to state regulatory commissions on topics related to smart grid. Primary SGTAP contributors are Roger Levy, a Research Specialist and owner of Levy Associates, and Janie Page, a Science/Engineering Associate at LBNL and the former Managing Editor at Bioelectromagnetics Society. SGTAP's response provided an analysis[97] of the Santa Cruz memo and called its accuracy and substance into question.

SGTAP noted the following:

1. The Santa Cruz memo made statements that were technically and scientifically incorrect and not supported by any research;
2. The memo did not appear to provide a balanced representation of the research, the risks, or the mitigation options;
3. The memo was instead largely focused on scientifically unsupported claims related to EHS;
4. Only half of the memo's citations met the peer review criteria that Santa Cruz itself had identified as necessary to be considered as a valid source; and
5. Out of the remaining references, half came from a single issue of the journal Pathophysiology,[98] which would only provide a limited acknowledgement to other relevant health, scientific, or industry sources. By relying so much on the journal, Santa Cruz denied exposing itself to a diversity of sources.

Finally, SGTAP noted that science can work toward understanding the causes of any health effects if and when they are observed, but it has never been able to categorically declare *anything* as being completely safe.

SGTAP Comments on Hirsch Document

SGTAP pointed out that the Santa Cruz memo had referred to a five-page document authored by Daniel Hirsch, a lecturer on Nuclear Policy at the University of California, Santa Cruz. This is notable because Hirsch had critiqued the CCST report and opponents of smart meters have cited Hirsch's document as support for their argument.

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[96] Note that the letter stated *additive* not *cumulative*.
[97] <http://eetd.lbl.gov/ea/ems/reports/schsa-042012.pdf>.
[98] <http://www.sciencedirect.com/science/journal/09284680/16/2-3>.

SGTAP concluded that:

1. The Hirsch document was not a formal report. It was a private submittal to the CPUC that did not meet Santa Cruz's own standards for consideration;
2. The educational and professional credentials of neither Hirsch nor his assistants could be identified which may have qualified them to profess expertise on EMF radiation, health, or smart meter operations;
3. The Hirsch document was severely flawed in several respects:
    a. It made arbitrary assumptions;
    b. It changed results that had been independently measured for some RF EMF emitting devices to levels that are not physically possible; and
    c. It further inflated figures that already had been overstated in the CCST report.

EPRI also published a paper critical of the Santa Cruz memo. EPRI's comments will be discussed later in this report.

Michigan Public Service Commission: SGTAP Assessment of AAEM Submittal

On April 12, 2012, the American Academy of Environmental Medicine (AAEM)[99] submitted a letter[100] to the MPSC in opposition to the installation of smart meters in homes and schools. According to AAEM's website, it is an international association of physicians and other professionals interested in the clinical aspects of humans and their environment. AAEM states on its site that it is interested in expanding the knowledge of interactions between human individuals and their environment, as these may be demonstrated to be reflected in their total health.

The AAEM site states that it provides research and education in the recognition, treatment and prevention of illnesses induced by exposures to biological and chemical agents encountered in air, food, and water. The certifying board for AAEM is the American Board of Environmental Medicine (ABEM), founded in 1988.[101] It is worth noting that neither AAEM nor ABEM is recognized by the American Board of Medical Specialties (ABMS).[102,103] Furthermore, the certification criteria required by ABEM are relatively sparse compared to those of ABMS. ABEM requires that an applicant have three years' experience practicing environmental medicine, take the AAEM medical instructional courses, and pass a written and an oral exam.

In contrast, the ABMS certification process involves 3-7 years of residency in the specialty, testing in the specific area of practice, a fellowship program of 1-3 years' duration and an optional subspecialty certification. In order to maintain certification the doctor is subjected to an *ongoing* peer evaluation and improvement process designed and administered by specialists in the specific area of medicine.

As a result of AAEM's letter, MPSC asked SGTAP to review the submittal. SGTAP provided a report[104] on April 18, 2012, which focused on the logical foundation of the AAEM statements and the relevance of its citations to

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[99] <http://www.aaemonline.org/>.
[100] <http://efile.mpsc.state.mi.us/efile/docs/17000/0391.pdf>.
[101] <http://www.americanboardofenvironmentalmedicine.org>.
[102] <http://www.abms.org/Who_We_Help/Physicians/specialties.aspx>.
[103] The ABMS was established in 1933, and is composed of approved medical boards which represent 24 broad areas of specialty medicine. ABMS is the largest physician-led specialty certification organization in the U.S. The American Medical Association's Council on Medical Education plays a significant role in ABMS.
[104] <http://eetd.lbl.gov/ea/emp/reports/aaem-042012.pdf>.

the smart meter issues. SGTAP did not comment on the technical merits of the individual research citations in the AAEM letter.

The SGTAP assessment found the following four aspects of the AAEM submittal to be problematic:

1. AAEM's assertion that research established causality of non-thermal effects;
2. The AAEM research citations and references were unrelated to smart meters;
3. AAEM's claims of electromagnetic hypersensitivity; and
4. AAEM's statements about the RF environment.

The following items provide detail on SGTAP's findings.

Aspect 1: SGTAP's Findings on AAEM's Assertion of Non-thermal Effects Causality

When considering the purported causality of non-thermal effects, recall that RF represents an extremely wide range of radio waves from 3 kHz to 300 GHz that spans eight orders of magnitude.[105] SGTAP stated that the RF EMF range cannot be generalized down to a single signal and that RF EMF is distinguished by a variety of independent characteristics, including frequency and intensity.

SGTAP pointed out that existing research has emphasized the unique characteristics and potential differences in effects from various RF EMF signals and sources. Thus, SGTAP concluded, an RF EMF effect reported at one frequency from one source cannot be presumed to imply an effect at another frequency from a completely different source.

The thermal effects observed as a result of exposure to RF EMF emissions at lower intensities are due to known mechanisms and could imply larger effects at a higher intensity.

Non-thermal effects are different because they appear to be related to distinct characteristics of the biological system being exposed and that symptoms or effects appear at specific frequencies or at distinct combinations of fields but not at others. Because there are no identified clear mechanisms for non-thermal RF EMF effects, there is no basis for someone to extrapolate observed non-thermal effects from one RF EMF source to another.

The AAEM submittal referred to the nine "Hill Criteria"[106] and the results of research studies which AAEM had extended to smart meters. Note that the criteria are most often used for assessing evidence of causation in epidemiological studies to test whether a particular agent is the cause of a selected effect. The criteria are typically employed when it is difficult to establish controls for all experimental variables. Using the criteria in research requires one to infer the causative agents from observational data.

SGTAP pointed out that inference is not proof and stated that the criteria cannot be applied when there are no research-related observational results. SGTAP concluded that it is not appropriate to presume an effect when the RF EMF sources differed in frequency, intensity, and proximity to critical biological tissues. Table 1 was included in the SGTAP report and addresses each criterion in relation to cell phones and smart meters. Reviewing the assessment of these criteria, it appears that the criteria have not been satisfied for cell phones, but it is quite obvious that the Hill criteria have not been satisfied for smart meters. No matter how well the criteria may or may not have been satisfied for cell phones, the significant differences between the two

[105] An order of magnitude is a Power of Ten, so eight orders of magnitude would be 10^8, or a 1 followed by eight zeroes (100,000,000).
[106] <http://www.edwardtufte.com/tufte/hill>.

technologies and the absence of research that specifically addresses smart meter operating characteristics make any attempt to assess smart meters using Hill's criteria moot.

Table 1: SGTAP Assessment Using Hill Criteria

Hill Criteria	Cell phones	Smart Meters
Strength: How large is the effect?	No widespread disease has yet been reported.	No published, peer-reviewed, scientific research at this time.
Consistency: Has the same association been observed by others, in different populations, using a different method?	Limited evidence from INTERPHONE study,[107] interpreted differently by different researchers. Opponents of smart meters focus strictly on Hardell's positive results without acknowledging the other results in the INTERPHONE study.	No published, peer-reviewed, scientific research at this time.[108]
Specificity: Does altering only the cause alter the effect?	A variety of studies has looked at changes in experimental setup to alter the source or size of the exposure with compelling results, most of which are related to distinct endpoints (e.g. oxidative stress markers and pathological changes in brain tissue in AAEM citation 16)	No published, peer-reviewed, scientific research at this time.
Temporality: Does the cause precede the effect?	Hard to discern in some epidemiology studies because hard to know state of individuals prior to study. Generally well controlled in lab studies.	No published, peer-reviewed, scientific research at this time, although some people claim a particular set of symptoms arise shortly after meters are installed.
Biological gradient: Is there a dose response?	Intensity of fields is often assumed as dose in a thermal model. For non-thermal effects, these criteria may not apply until we have a better understanding of dose.	No published, peer-reviewed, scientific research at this time.
Plausibility: Does it make sense? (Hill noted that knowledge of the mechanism is limited by current knowledge).	Mechanisms have not been well developed other than heating processes, where it is assumed that energy accumulates until dissipated.	No published, peer-reviewed, scientific research at this time.

[107] <http://ije.oxfordjournals.org/content/39/3/675.full.pdf>.

[108] For the purposes of the Hill criteria, reported symptoms need to be derived from well-structured research, not self-reported anecdotal reports (e.g. Internet blogs, newspaper articles, complaints/statements to regulatory commissions, etc.).

Coherence: Does the evidence fit with what is known regarding the natural history and biology of the outcome?	Limited coherence – many of the reported effects have unknown etiologies.	No published, peer-reviewed, scientific research at this time.
Experiment: Are there any clinical studies supporting the association?	There are some studies suggesting effects under certain circumstances.	No published, peer-reviewed, scientific research at this time.
Analogy: Is the observed association supported by similar associations?	Presumed to be supported by earlier (generally higher power) microwave studies.	Presumed to be supported by cell phone studies.

Aspect 2: SGTAP's Findings on AAEM's Research Citations and References

SGTAP stated that the citations and references in AAEM's letter were unrelated to smart meters. Smart meters operate in the frequency range of 902 - 928 MHz, and at an intensity of less than 1 watt, but the AAEM submittal cited references in which the frequencies and exposures measured appear to be substantively different from the fields that have been measured from smart meters.

In the one study cited by AAEM that did use a frequency in proximity of the range used by smart meters, the reported Specific Absorption Rate was at much greater field strength than that of a smart meter. Also, the test subject animals' proximity to the RF EMF source most likely would have been impossible to duplicate with a normal wall-mounted smart meter.

Aspect 3: SGTAP's Findings on AAEM's Claims of Electromagnetic Hypersensitivity

SGTAP found two problems with AAEM's claim that EHS had been documented in controlled and double-blind[109] placebo controlled conditions and in which 100% of subjects showed reproducible reactions to a frequency to which they were supposedly most sensitive. SGTAP pointed out that disagreements to the purported reproducibility of these reactions have been documented.

SGTAP also stated that the researcher AAEM had cited claimed that the frequencies involved in living systems are so precise that even the *phase* of a frequency was significant in research results. SGTAP concluded that while AAEM may have considered its cited researcher as credible, that finding would be in direct opposition to AAEM's attempt to extrapolate results from studies that used another frequency.

SGTAP also performed a detailed meta-analysis[110] of available literature and found that there was no evidence that study participants previously described as being "hypersensitive" had an improved ability to detect RF EMF. This was further reinforced by the conclusions drawn by the World Health Organization's (WHO) examination of EHS. The organization found that well-controlled double-blind studies showed no correlation between symptoms and RF EMF exposure.

[109] In a double-blind experiment, neither the test subjects nor the researchers know who belongs to the control group and who belongs to the experimental group. This is done to lessen the influence of any prejudices and unintentional physical cues on the results.

[110] A meta-analysis is a "study of studies," i.e. a systematic method of evaluating statistical data based on results of several independent studies of the same problem.

SGTAP made special note of the fact that the references cited by AAEM to describe claimed sensitivities among self-identified EHS individuals were at very specific frequencies, none of which were associated with the operation of smart meters.

Aspect 4: SGTAP's Findings on AAEM's Statements about the RF Environment

SGTAP stated that recent measurements revealed that smart meters contribute only a small fraction of the total RF EMF emissions in a typical environment to which the general population is routinely exposed. SGTAP concluded that only a negligible reduction in total existing RF EMF exposures would result if smart meters were eliminated entirely.

Electric Power Research Institute

EPRI[111] is an independent, nonprofit organization that conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. EPRI provides technology, policy, and economic analyses to promote long-range research and development planning and supports research in emerging technologies. Scientists and engineers from EPRI, along with experts from academia and industry, address the challenges of electricity including reliability, efficiency, health, safety, and the environment.

For more than 30 years, EPRI has taken an active role in characterizing electromagnetic environments associated with power frequency transmission and distribution systems. More recently, the organization has done the same with RF EMF from smart meters. In February 2010, EPRI released a brief overview on RF EMF exposure associated with smart meters entitled "A Perspective on Radio-Frequency Exposure Associated with Residential Automatic Meter Reading Technology."[112] Since that time, EPRI has performed multiple investigations on RF EMF, and the results have been shared with regulators and industry as well as with the general public in an effort to foster a common understanding of RF EMF environments.

EPRI Technical Report on RF Emissions from Two Models of Smart Meters

EPRI has published several documents related to the RF EMF emitted by smart meters. In a December 2011 document[113], EPRI presented the results of a study by Richard Tell Associates[114] which EPRI had sponsored. Richard Tell Associates is a scientific consulting business focused on electromagnetic field exposure assessment, compliance with applicable standards and regulations on RF and power frequency fields and training related to the measurement, analysis and interpretation of electromagnetic fields.

The EPRI study was performed over a period of approximately six months during 2011 and analyzed two different wireless smart meters, a General Electric-I210 and a Landis+Gyr Focus AXR-SD, that Pacific Gas & Electric (PG&E) was in the process of deploying in its service territory. The meters contained two low power transmitters. One transmitter was 1W, to be used for communication in a mesh network, while the other was 0.1W, intended for a potential future Home Area Network (HAN). Each meter was also equipped with one of two different wireless communication packages developed by Silver Spring Networks.

The study found that the RF EMF field levels from the smart meters were below the exposure limits specified by the FCC. Furthermore, calculations determined that as the system was operating, nearly 99.9% of the

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[111] <http://www.epri.com/>.
[112] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001020798>.
[113] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001021829>.
[114] <http://www.radhaz.com/>.

meters transmitted 1% or less of the time, and 99% of the meters transmitted less than 0.4% of the time. FCC exposure limits for the general public take these duty cycles[115] into account when estimating potential exposures and are based on a 30-minute average of power density across the body.

Preliminary measurements on the meters were conducted to:

- Determine the magnitude of the RF fields generated by the 1W mesh transmitter;
- Examine the meter's directional characteristics;
- Observe any unusual low frequency emissions in the 5 Hz to 100 kHz band that might be produced by the electronic circuits within the meters; and
- Measure the attenuation by a simulated stucco wall, common in many California homes.

In the next phase of the study, on-site measurements at six residential locations were conducted. This was done to determine typical indoor values of the RF EMF produced by the smart meter installed on a home. In addition, measurements were taken of the composite RF EMF environment where collections of smart meters were aggregated in a small space. This procedure was performed at three different apartment complexes, including one where 112 smart meters were collocated. Short-term duty cycles for several smart meters were also measured. Finally, the investigators took field measurements at a single data collector which gathers meter data from potentially thousands of residences.

Calculating Smart Meter RF EMF Emission Duty Cycles

The study collected and analyzed data transmissions from 88,296 smart meters through the utility's data management system. This large sample revealed the statistical distribution of meter duty cycles and enabled the calculation of the value for time-averaged potential exposure.

The EPRI report stated that the analysis identified one meter in 88,296 that exhibited a maximum duty cycle of 13.9%. It also found that half of the meters exhibited duty cycles not exceeding 0.0465%, 99% of meters had duty cycles not exceeding 0.355%, 99.9% had duty cycles at or below 1.12%, and 99.99% of meters had maximum duty cycles of 4.53% or less. The data confirmed that smart meters, while transmitting intermittently throughout the day, create RF fields for only very small fractions of the day. For example, half of all meters would be expected to actually transmit no more than 40 seconds per 24 hour day.

Considering the Directionality of RF EMF

The study also investigated the directional emission patterns of the meters. It found that the forward direction was strongest; rearward-directed fields were reduced by a factor of ten, and in some cases reductions of a factor of 100 were measured.[116]

Considering Groups of Meters

EPRI's report demonstrated that groups of smart meters mounted on apartment buildings at three different locations did not result in greater peak values of RF EMF fields than those produced by an individual meter. The study did find that average field magnitudes were higher due to the operation of multiple meter

[115] Duty cycle is the time that the radio module in a smart meter is emitting as a fraction of the total time period being considered.

[116] To be more precise, the reductions were 10 and 20 decibels respectively.

transmitters but that higher average composite duty cycles did not change the conclusion that such exposures are compliant with the established FCC limits.

Considering the HAN Transmitter

The HAN radio inside a smart meter is not currently implemented in PG&E's deployment, but the study found that when it was activated, the resulting EMF RF fields were substantially weaker due to their lower effective isotropic[117] radiated power (EIRP).[118] These radios also complied with the FCC exposure limits.

Report Conclusions on RF EMF Exposure

The EPRI report concluded that individuals in smart meter-equipped homes are commonly exposed to RF EMF emissions that are orders of magnitude less than what would occur for an individual standing immediately adjacent to and in front of the meter. It stated that the measurements performed in the six subject California residences found that 99% of the measured peak values were less than 0.8% of the MPE for the general public tier, and 90% of the measured values were less than 0.1% of the MPE.

The report stated that RF EMF emissions from smart meters that transmit data wirelessly are constrained by the low power of the transmitter's power and by the antenna's gain. Estimating smart meter fields is a straightforward calculation based on the EIRP of the meter. Locations where the greatest exposure can occur warrant no special consideration of reflections.

In summary, the EPRI report stated that the smart meter emissions are minute compared to the applicable FCC exposure limits. It also concluded that the smart meters comply with the FCC MPEs whether:

- The peak measured fields are corrected for meter duty cycles;
- Spatial averaging or any other factor that reduces RF fields, such as the construction materials of homes is considered;
- The meters exist in a large group or individually; or
- Individuals are outside near the smart meter or inside their residence.

As expected, the EPRI study found that the strongest fields occurred at the closest distance that measurements were performed (one foot). Typical peak fields at this distance were found to be about 10-15% of the MPE. The study also found that time-averaged and spatially-averaged values, at this point of maximum peak field, were estimated to be at most 0.14% of the FCC MPE, depending on the activity of the meter.

EPRI Comments on the Santa Cruz and AAEM Memoranda

EPRI also provided commentary[119] on the documents that the County of Santa Cruz Health Services Agency and AAEM had issued in response to the report from the CCST. EPRI stated that neither the Santa Cruz memo nor the AAEM document accounted for the large body of research on RF EMF that has been conducted over the past 50 years or the "weight-of-evidence" approach utilized by a large number of expert groups and panels that have convened over the years to assess the literature on RF health science.

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[117] Isotropic means "uniform in all orientations."

[118] EIRP is the amount of power that a theoretical antenna that evenly distributes power in all directions would emit to produce the peak power density observed in the direction of maximum antenna gain.

[119] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001024952>.

EPRI concluded:

> "The transmittal from the Santa Cruz County health officer reflected a misunderstanding of several terms and concepts, including some of the basic principles of how smart meters work."

FCC RF EMF Exposure Guidelines

The 1997 FCC rule on RF EMF exposure was crafted from two earlier guidelines. The first guideline was published by the NCRP in 1986.[120] The second guideline was issued by the IEEE in 1991 and revised in 2005.[121] Before the FCC published its rule, it received endorsements from the U.S. Environmental Protection Agency (EPA), the FDA, and the U.S. Occupational Safety and Health Administration (OSHA). The EPA reaffirmed its opinion in 1999 and 2002.

Both sets of guidelines originated from an extensive review of the literature published in the fields of biology and health, regardless of whether the research had been conducted at non-thermal levels of exposure. NCRP and IEEE both concluded that the only established health effects of RF EMF were associated with tissue heating and that there were no confirmed adverse effects from RF exposure levels below an exposure threshold associated with an elevation in body temperature of about 1.8° F (1° C).

EPRI stated that since the FCC rulemaking, experts have revisited the expanding body of scientific evidence concerning potential health effects from RF EMF exposure. The conclusions were consistent with the position taken by the FCC in 1997.

Furthermore, following a comprehensive review of the scientific literature, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published exposure limits in 1998 and reaffirmed them in 2009, while the IEEE issued its exposure limits in 2005. EPRI stated that both organizations' numbers were very similar to those of the FCC.

EPRI Addresses the WHO Classification of EMF as a 2B Carcinogen

In the spring of 2011, concerns about RF EMF exposures received significant visibility when the International Agency for Research on Cancer (IARC), a division of the WHO, published the results of its evaluation of potential cancer risks from RF exposures. The "IARC Monographs" identify environmental factors which can increase the risk of cancer in humans. These factors include chemicals, complex mixtures, occupational exposures, physical agents, biological agents, and lifestyle factors. National health agencies can use this information as scientific support for their actions to prevent exposure to potential carcinogens.[122]
According to EPRI, based on what can be considered as limited epidemiologic evidence in studies of cell phones and also limited evidence from a small fraction of all reported animal experiments, IARC classified radiofrequency electromagnetic fields as a "possible" or a Group 2B carcinogen.

To help put things into perspective, one must first understand the hierarchy of IARC categories. The categories, also known as Monograph Groups, consist of the following:

[120] "NCRP Report No. 86 - Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields".
[121] <http://standards.ieee.org/findstds/standard/C95.1-2005.html>.
[122] <http://monographs.iarc.fr/>.

- Group 1: Carcinogenic to Humans (i.e., sufficient evidence);
- Group 2A: Probably Carcinogenic (less than sufficient evidence);
- Group 2B: Possibly Carcinogenic (limited evidence, less supportive evidence than 2A);
- Group 3: Not Classifiable (inadequate and/or insufficient evidence for classification).[123]

With reference to Monograph Groups 2A and 2B, IARC stated:

> "The terms probably carcinogenic and possibly carcinogenic have no quantitative significance and are used simply as descriptors of different levels of evidence of human carcinogenicity, with probably carcinogenic signifying a higher level of evidence than possibly carcinogenic."[124]

EPRI stated that the IARC 2B classification of RF EMF provides for a range of qualitative interpretations concerning its potential carcinogenicity. This IARC 2B classification indicates that more research information would be required for a more definitive statement in either direction.

EPRI continued, saying that the weight of current evidence still does not provide a basis to conclude that RF EMF can be considered as being "probably" carcinogenic. EPRI also indicated that IARC has near-term plans to evaluate the potential effects of RF EMF on all health outcomes, including cancer.

PUCT Staff's Observations on IARC 2B Carcinogens

There are over 200 substances in the IARC's 2B category, many of which have lengthy chemical names. Casual observers of such a list may become alarmed when they recognize a familiar item on it.[125]

Opponents of smart meters have noted the pending inclusion of RF EMF into the IARC 2B classification, and typically mention the pesticide DDT (dichlorodiphenyltrichloroethane) and elemental lead as also having been placed into the same classification (DDT was added in 1991, lead was added in 1987).

All this must be examined objectively and in the proper context.

Decades ago, DDT was found to have a demonstrable negative environmental impact widely viewed as outweighing its perceived benefits and found to accumulate in living tissue, leading to obvious health issues. For those reasons, it was removed from the market. Note that the potential for cancer is not why the substance was withdrawn.

Lead is also a bioaccumulative substance and has known toxic effects, such as interfering with a variety of body processes including those of the nervous system. As a result, its use has been continually reduced over the past few decades. Again, the potential for lead to cause cancer is generally not why the use of the substance has fallen out of favor.

To date, there is insufficient evidence to declare with confidence that either one of these substances is cancer-causing. Otherwise by now, one or both substances most likely would have been placed under a different IARC classification, namely one that required a higher level of evidence.

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[123] <http://monographs.iarc.fr/ENG/Preamble/CurrentPreamble.pdf>.
[124] <http://monographs.iarc.fr/ENG/Preamble/currentb6evalrationale0706.php>.
[125] See the References and Resources page for the entry under "Way, Tom."

In exploring comments made by some smart meter opponents filed with the Commission or found while researching the issue on the Internet, elemental lead and DDT have been mentioned in conjunction with RF EMF, but there has been no mention of the following well-known, common substances that are also included in the 2B Classification by the IARC:

- Coffee (added 1991);
- Pickled vegetables (added 1993); and
- Talc body powder (added 2010).

Lead and DDT are two substances that are widely known to cause health effects other than cancer and therefore carry with them a stigma. To mention them while excluding other substances which are both commonly used and generally considered benign, such as the ones listed above, and without the proper context, imparts a negative bias. This negative bias may prejudice the observer and alarm and confuse those who may have valid concerns about health and are attempting to understand rather complex concepts.

EPRI Workshops on RF Emissions and Health

In 2011, EPRI hosted two workshops to discuss the IARC classification. A report on the proceedings is available to the public in a document entitled "Program on Technology Innovation: Environmental and Health Issues Related to Radiofrequency Emissions from Smart Grid Technologies - Summary of Two Workshops."[126]

The purpose of the first workshop was to more specifically identify emerging technologies within the electric utility industry whose operation would result in EMF emissions. Such emissions may be produced for purposeful reasons, namely for communications, or might be a byproduct of a technology, such as emissions from appliances powered with variable speed drives.

The second workshop was a gathering of international scientists who shared their expertise to review the most important health issues associated with RF exposure and to identify priorities for further research. This workshop covered all aspects of RF science including exposure assessment, epidemiology, laboratory studies on both animals and humans, and biophysical mechanisms.

As a result of the workshops, EPRI issued a report that functions as a backdrop for potential future research to address environmental and health issues regarding smart grid technologies. It concluded:

- Current research regarding the health implications associated with RF emissions of new technologies has focused primarily on the nearly universal use of cell phones;
- Little information concerning characterization of exposure from projected smart grid and associated technologies is currently available;
- Though no adverse effects of "non-thermal" exposures have been identified, various unresolved questions remain, including a consistent observation of slightly altered brain wave activity in human subjects exposed to radio-frequency fields under laboratory conditions; and
- That the organization was well positioned to inform and educate all stakeholders about environmental risks and risk management options associated with technology deployment and operation.

[126] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001024737>.

EPRI Investigations of RF EMF from Smart Meter Technology and Smart Grid Components

In 2010, EPRI published a 222-page technical report on its investigation of a particular smart meter entitled "An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter."[127] The results indicated that RF EMF from the smart meter was well below the MPE established by the FCC.

For instance, at a distance of one foot, the RF EMF from a meter was not expected to exceed 0.8% of the MPE established by the FCC. For the cell relay, the study found that the RF field would not exceed 0.2% of the MPE. Even at very close distances, such as one foot directly in front of the meter and making the highly unrealistic assumption that the transmitters operate at 100% duty cycle, the resulting exposure was still found to be less than the FCC MPE.

When viewed in the context of a realistic and typical exposure distance of ten feet, the RF fields were much smaller: about 0.008% for the meter and about 0.002% of MPE for the cell relay.

EPRI's study stated that for occupants of a home equipped with a smart meter, interior RF fields were expected to be less than one-tenth as intense simply due to the directional properties of the meter. The investigation found that when a stucco[128] home's construction was included, the realistic value of the interior RF field would be attenuated to about 0.023% of the MPE for a meter and about 0.065% for a cell relay.

The investigators stated that regardless of duty cycle values for meter and cell relay meters, typical exposures that resulted from the operation of smart meters were very low and complied with scientifically-based human exposure limits by a wide margin.

EPRI also produced a brief case study in February 2011 on another smart meter with similar results under the title "Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model."[129] In the interest of brevity and to avoid repetition, the findings of that EPRI publication are summarized in Table 2 below. The entire referenced document is publicly available from EPRI.

[127] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001021126>.
[128] Stucco is a common home construction material in California, where this analysis was performed.
[129] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001022270>.

Table 2: EPRI Findings – Radio Frequency Levels from Various Sources[130]

Source	Frequency	Exposure Level (mW/cm^2)	Distance	Time	Spatial Characteristic
Cell phone[131]	900 MHz and 1800 MHz	1-5	At ear	During call	Highly localized
Cell phone base station	900 MHz and 1800 MHz	0.000005-0.002	Tens to a few thousand feet	Constant	Relatively uniform
Microwave oven	2450 MHz	~5 0.05-0.2	2 inches 2 feet	During use	Localized, non-uniform
Local area networks[132]	2400 MHz or 5000 MHz	0.0002-0.001 (wireless router) 0.000005-0.0002 (client card)	3 feet	Constant when nearby	Localized, non-uniform
Radio/TV broadcast	Wide spectrum	0.001 (highest 1% of population) 0.000005 (50% of population)	Far from source (in most cases)	Constant	Relatively uniform
Smart meter[133]	900MHz and 2400 MHz	0.0001 (250mW, 1% duty cycle) 0.002 (1 W, 5% duty cycle) 0.000009 (250 mW, 1% duty cycle) 0.0002 (1 W, 5% duty cycle)	3 feet 10 feet	When in proximity during transmission	Localized, non-uniform

EPRI has also published a document that outlines eight projects involving the study of EMF and RF health and safety which the organization plans to perform in 2013. Most of these projects have multiple parts, several of which are expected to continue into subsequent years. The organization refers to this series of investigations and their resulting products as Program 60.[134] Its estimated funding for the program in 2013 is $5 million. Among the products to be completed in 2013 are:

- A peer review of literature regarding investigations of potential EMF/RF interference with implanted medical devices (e.g. pacemakers);
- A technical report to address emerging concerns about potential EMF effects on behavior and health of honeybees and cattle; and
- A technical update on RF exposure from wireless sources.

[130] FCC rule: From 300 MHz to 1500 MHz, MPE = 0.2 x f/300 mW/cm^2 (f is frequency in MHz); for 1500 MHz and greater, MPE = 1 mW/cm^2. For example, at 900 MHz MPE = 0.2 x (900/300) mW/cm^2 = 0.6 mW/cm^2. Note: Compliance for cell phones is provided by manufacturers, and expressed in terms of SAR, which cannot exceed 1.6 W/kg for any single gram of tissue.

[131] Based on a 3-inch, 250 mW antenna emitting in a cylindrical wave front.

[132] Wireless router based on a 30-100 mW isotropic emitter. Client card based on: Foster KR. 2007.

[133] Based on spatial peak power density with 6 dB (x4) antenna gain. For instantaneous power density during transmission, multiply the value for 1% duty cycle by 100, and the value for 5% duty cycle by 20.

[134] <http://mydocs.epri.com/docs/Portfolio/PDF/2013_P060.pdf>.

EPRI Comments on Sage Report

In January 2010, Sage Associates,[135] an environmental consulting firm whose principal is Cindy Sage,[136] issued a report entitled "Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters."[137] The report compared RF field levels of smart meters to the FCC's exposure limits and concluded that smart meters and collector meters installed in California were likely to violate the FCC limits, even under normal conditions of installation and operation. The report also compared field levels from smart meters to those from studies that reported biological and health effects.

In February 2010, EPRI addressed the research findings cited in the Sage report in a document titled "EPRI Comment: Sage Report on Radio-Frequency (RF) Exposures from Smart Meters."[138] EPRI found that:

- The Sage report misapplied the specifications in the FCC rule;
- The report findings had not been replicated or were inconsistent with the results of other studies; and
- Virtually every recent mainstream expert scientific review of the RF health literature conducted in North America and Europe either had not confirmed the effects cited in the report or found them indefinite.

Joint White Paper of EEI, UTC, and AEIC

In March 2011, Edison Electric Institute (EEI), Utilities Telecom Council (UTC), and Association of Edison Illuminating Companies (AEIC) jointly issued a white paper[139] entitled "A Discussion of Smart Meters and RF Exposure Issues."

The paper discusses how the location, distance from the transmitter, shielding by meter enclosures, attenuation of building materials, direction of RF emissions, and transmit duty cycle have a significant effect on RF EMF exposure levels. It also reviews the conclusions of several Smart Meter RF studies and actual measurements of Smart Meter RF emissions. Other observations made in the paper include:

- All smart meter radio devices must be certified to the FCC's rules;
- Tests simulating multi-family metering locations containing several meters in close proximity have shown RF exposure levels dramatically less than the FCC limits;
- The FCC limits on MPE for application to the general public were set using safety factors one-fiftieth (1/50th) of the levels of known effects;
- Exposure levels drop significantly:
    - with the distance from the transmitter;
    - with spatial averaging; and
    - in living spaces due to the attenuation effects of building materials.
- Due to shielding of the meter enclosure and signal patterns, RF exposure from the rear of a metering location is nominally one-tenth of that in front of the meter and dramatically below FCC limits, not including the spatial averaging and building material attenuation reductions;

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[135] <http://www.silcom.com/~sage/emf/index.html>.

[136] The Sage website states that Mrs. Sage has been involved in EMF issues as an environmental consultant and public policy researcher since 1982. She holds an M.A. degree in Geology and a B.A. in Biology.

[137] <http://sagereports.com/smart-meter-rf/>.

[138] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001022639>.

[139] <http://www.aeic.org/meter_service/smartmetersandrf031511.pdf>.

- For measurement and calculation purposes, some studies use a 100% duty cycle. However, the maximum operational duty cycle for smart meter systems is less than 50% to prevent message traffic congestion and data packet collisions. The typical duty cycle for smart meter systems is between 1% and 5%;
- An RF exposure comparison of a person talking on a cell phone and a person three and ten feet from a continuously operating smart meter would result in smart meter RF exposure that is 0.08% - 0.8% of a cell phone; and
- In test environments simulating operational conditions, for power (0.250 - 2 watts), duty cycle (2% – 5%) at close distance (one foot) from in front of the transmitter, smart meters produce very low RF exposure to the consumer. They are typically well under 10% of the FCC exposure regulations.

The paper stated that before utilities accept and deploy smart meters, the devices must meet a number of national standards and comply with state and local codes designed to ensure proper operation, functionality, and safety. Specifically, smart meters and smart meter installations are typically designed to conform with and certified to comply with:

- ANSI C12.1, 12.10, and 12.20 standards for accuracy and performance;
- National Electrical Manufacturers Association (NEMA) SG-AMI 1-2009 "Requirements for Smart Meter Upgradeability";
- FCC standards for intentional and unintentional radio emissions and safety related to RF exposure, Parts 1 and 2 of the FCC's Rules and Regulations [47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093];
- Local technical codes and requirements; and
- Utility-specific and customer beneficial business and technical requirements.

The paper also discusses how manufacturers conduct performance and life cycle testing for meters and for major design changes to existing meters, including hardware and firmware. Once the testing is successfully completed, components of the smart meter system are certified by a utility or a third party for production and purchase. Finally, the paper outlines the process utilities use to accept materials and to evaluate each shipment of equipment for quality and compliance to specification after certification and purchasing.

Government and Academia

National Cancer Institute at the National Institutes of Health

The National Cancer Institute (NCI)[140] was established by Congress in 1937 and is one of 27 Institutes and Centers that form the National Institutes of Health (NIH). The NIH is one of the world's foremost medical research centers and is a part of HHS. NIH officials reported that the agency has provided about $35 million for research on health effects of RF energy from mobile phone use from 2001 to 2011.[141]

NCI's main responsibilities include coordinating the National Cancer Program, conducting and supporting cancer research, training physicians and scientists, and disseminating information about cancer detection, diagnosis, treatment, prevention, control, palliative care, and survivorship. Most of NCI's budget is used to fund grants and contracts to universities, medical schools, cancer centers, research laboratories, and private firms in the U.S. and about 60 other countries around the world.

One result of NCI's responsibilities to collect, analyze, and disseminate the results of cancer research conducted in the U.S. and in other countries is its webpage "Cell Phones and Cancer Risk,"[142] that concisely provides information in a Question and Answer format. While the webpage does not explicitly address the wireless communications technologies used by smart meters, if one accepts the notion that these technologies are similar to cell phones, the page offers useful information.

Key points made by NCI:

- Cell phones emit RF energy, a form of non-ionizing EM radiation which can be absorbed by tissues closest to where the phone is held;
- The amount of RF energy to which a cell phone user is exposed depends on the technology of the phone, the distance between the phone's antenna and the user, the extent and type of use, and the user's distance from cell phone towers; and
- Studies thus far have not shown a consistent link between cell phone use and cancers of the brain, nerves, or other tissues of the head or neck. More research is needed because cell phone technology and how people use cell phones have been changing rapidly.

These conclusions were mainly based on the results of some recently published studies including one from early 2012. NCI had reported on the results[143] indicating that while cell phone use in the U.S. had increased substantially over the period from 1992 to 2008 (from nearly zero to almost 100 percent of the population), the country's trends in glioma, the main type of brain cancer hypothesized to be related to cell phone use, did not mirror that increase. Results of this study were published online March 8, 2012 in the British Medical Journal.[144]

The NCI statement generally agreed with its comments[145] regarding the Interphone study[146] released nearly two years prior. The study was an international collaboration and the largest of its kind at the time which had

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[140] <http://www.cancer.gov/cancertopics/factsheet/NCI/NCI>.
[141] <http://www.gao.gov/assets/600/592901.pdf>.
[142] <http://www.cancer.gov/cancertopics/factsheet/Risk/cellphones>.
[143] <http://www.cancer.gov/newscenter/pressreleases/2012/GliomaCellPhoneUse>.
[144] <http://www.bmj.com/content/344/bmj.e1147>.
[145] <http://www.cancer.gov/newscenter/pressreleases/2010/Interphone2010Results>.
[146] <http://ije.oxfordjournals.org/content/39/3/675.full.pdf>.

looked at both glioma and meningioma, another form of brain cancer. It was published online in the International Journal of Epidemiology on May 17, 2010.

FCC Letter: Equipment Authorization, Exposure Limits, and Interference

The FCC is an independent U.S. government agency.[147] The agency was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. Only three commissioners may be members of the same political party. None of them can have a financial interest in any Commission-related business. The commissioners supervise all FCC activities, delegating responsibilities to staff units and Bureaus.

The FCC's OET laboratory oversees the Equipment Authorization program. This program provides guidelines for the sale and use of equipment using the radio frequency spectrum. The devices subject to these rules must comply with the regulations in order to be considered as operating properly and to not create harmful interference. Subject RF devices may not be imported and/or marketed until they have demonstrated compliance with the technical standards specified by the FCC. These standards may be found in the rule section that governs the service wherein the equipment is to be operated. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure. The Equipment Authorization procedures are publicly available for review.[148]

In March 2010, Cindy Sage sent a letter to the FCC with questions on several topics such as the agency's RF exposure limits, adjacent smart meter installations, and the potential for interference with other devices, especially medical devices. In August 2010, Julius Knapp, Chief of the FCC's Office of Engineering and Technology, responded.[149] The FCC letter explained that SAR evaluations were unnecessary with devices not held against the body and that power density (field strength) measurements were a sufficient and appropriate measure of exposure. The letter explained that FCC field strength limits and SAR limits are both time-averaged figures.

The FCC response pointed out that when the agency grants equipment authorizations (EA), it takes into account the peak power of the device because it is relevant to interference concerns. In contrast, exposure evaluations utilize maximum time-averaged power because that measurement takes into account how often a device will transmit. The purpose of a smart meter is to provide very infrequent information, so it transmits only in occasional bursts.

The FCC letter also addressed multiple adjacent smart meter installations. Since each smart meter has its own antenna, the separation distance of a person from most of the antennas is relatively large so that the potential exposure is quite small. Only one transmitter at a time can communicate with the collector to avoid the packets of data colliding with one another. Therefore, exposure from multiple signals at once does not occur. Signal strength decreases exponentially with distance, and there are additional losses of signal due to not being in the line of sight. In order for a device to be granted an EA, even banks of collocated meters must be compliant to the FCC's public exposure limits. Finally, the letter explained that auditing and review of EA grants is a routine function of the OET laboratory.

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[147] <http://transition.fcc.gov/aboutus.html>.

[148] <http://transition.fcc.gov/oet/ea/procedures.html>.

[149] <http://www.ccst.us/projects/smart/documents/Sage_Letter_from_%20Knapp_FCC.pdf>.

The FCC letter also addressed interference with medical devices, explaining that smart meters operate under Part 15 of the FCC Rules,[150] which specify power limitations to avoid interference. It stated that certain medical devices may need special precautions in many other environments, and that these are generally considered during FDA approval of the individual medical device.

GAO Report: Exposure and Testing Requirements for Mobile Phones Should Be Reassessed

In July 2012, the U.S. Government Accountability Office (GAO) issued a report[151] that recommended the FCC formally reassess and, if appropriate, change its current RF energy exposure limit and mobile phone testing requirements. It suggested that consideration be given to likely usage configurations, particularly when phones are held against the body. The FCC noted that it is currently considering a draft document which has the potential to address the GAO's recommendations.

The GAO also noted that international organizations have updated their exposure limit recommendation in recent years, based on new research whereas the FCC's current standards were based on research prior to 1996. The new international limit had been widely adopted by other countries, including countries in the European Union.

It is important to note that the GAO stated *"the new recommended limit could allow for more RF energy exposure* (emphasis added), but actual exposure depends on a number of factors including how the phone is held during use." Whereas one may argue that new RF exposure limits could be considered germane to smart meters (although RF emissions from smart meters are several orders of magnitude less than the exposure limit), smart meters are not in direct contact with the body.

According to the GAO report, the National Institute of Environmental Health Sciences (NIEHS), a part of the NIH, has a study underway described as "examining the toxicology and carcinogenic effects of RF energy in laboratory animals as part of the National Toxicology Program." The National Toxicology Program is an interagency program whose three core federal agencies are NIEHS, the Centers for Disease Control and Prevention's (CDC)[152] National Institute for Occupational Safety and Health (NIOSH),[153] and the FDA's National Center for Toxicological Research. Total NIH funding for the study was reported to be $25.6 million, and its estimated year of completion is 2015.

According to the GAO report, CDC officials reported that a staff member is collaborating with researchers in seven countries to conduct additional analyses on data collected through the INTERPHONE study to determine whether occupational exposure to RF energy and chemicals was a risk factor for brain cancer.[154]

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[150] <http://www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol1/xml/CFR-2010-title47-vol1-part15.xml>.

[151] <http://www.gao.gov/assets/600/592901.pdf>.

[152] The CDC states that its mission is to collaborate to create the expertise, information, and tools that people and communities need to protect their health – through health promotion, prevention of disease, injury and disability, and preparedness for new health threats.

[153] NIOSH states that its mission is to generate new knowledge in the field of occupational safety and health and to transfer that knowledge into practice for the betterment of workers.

[154] Ibid.

Other Governmental Jurisdictions and Agencies

City of Naperville, Illinois

In early 2011, some utility customers of Naperville, Illinois expressed concerns regarding the RF EMF emissions from the smart grid equipment that was being deployed for the Naperville Smart Grid Initiative (NSGI). To address the concerns, detailed RF measurements were taken from the smart grid equipment, common household devices, and the ambient Naperville RF EMF environment. Engineers from the Naperville Department of Public Utilities performed the RF testing and compared it to permissible FCC power density specifications.

This emissions testing report issued on November 10, 2011 contains the test scope, overall approach, detailed test procedures, the complete set of test data, explanations, illustrations, and conclusions.[155,156] The comprehensive testing resulted in the following key findings:

- The NSGI smart grid equipment emitted RF power densities that are well below the FCC guidelines;
- Measurements of the smart meter equipment's instantaneous or peak RF power densities ranged between 1% and 3.2% of FCC limits at 20 cm in front of the meter. Note that the measurements observed were from a specially programmed continuously transmitting meter, which would yield inflated results when compared with real world situations;
- Measurements of the smart meter equipment average RF power densities ranged between 0.002% and 0.003% of FCC limits at 20 cm in front of the meter over a 30-minute period.
- The maximum backhaul equipment measured instantaneous or peak RF power density observed was 0.0277% of the FCC limit (measured 20 cm directly in front of the antenna); and
- The smart grid equipment average RF power densities were lower than typical household devices such as microwaves, cell phones, and Wi-Fi routers.

NSGI also issued a brochure[157] to put the RF EMF emissions from its smart meters into perspective:

> "...a person sitting 10 feet in front of their smart meter would have to be there for more than 100 years[158] to receive the same RF energy that they would receive from a 3-minute cell phone[159] call. If a person were sitting inside their home 3 feet from the back of a smart meter, they would have to be there for more than 200 years[158] to receive the same RF energy as they would from a 3-minute cell phone[159] call."

[155] <http://www.naperville.il.us/emplibrary/Smart_Grid/Pilot2-RFEmissionsTesting-SummaryReport.pdf>.
[156] <http://www.naperville.il.us/emplibrary/Smart_Grid/Pilot2RFEmissionsTesting-Final.pdf>.
[157] <http://www.naperville.il.us/emplibrary/Smart_Grid/SmartMeterandRFCommunications.pdf>.
[158] Meter Specifications: Front of meter - Duty Cycle: 0.1%, AMI radio power: 250 mW EIRP, Distance: 10 ft. (305 cm); Behind Meter - Duty Cycle: 0.1%, Distance 3 ft. (91 cm).
[159] Cell Phone Specifications: Duty Cycle 45%, Peak Transmitter Power after antenna: 600 mW EIRP, Distance: 1 cm.

Maine Center for Disease Control & Prevention

On October 25th, 2010 a complaint was filed with the Maine Public Utilities Commission (MPUC) focusing on concerns related to the health, safety, and security of smart meters.[160] The Maine Office of the Public Advocate (OPA) called upon the Maine Center for Disease Control & Prevention (Maine CDC) to comment on health concerns related to the wireless communication technology used in the smart meters being installed by Central Maine Power. The Maine CDC received numerous emails and other communications on the issue, and its Public Health Director, Dr. Dora Anne Mills, reviewed the materials sent to her by both opponents and proponents of smart meters. Dr. Mills assembled several Maine CDC staff for further review of the material.

A report was issued[161] by the Maine CDC on November 8, 2010 to the MPUC and OPA. The Maine CDC reported that its review of national and international government or government-affiliated assessments[162] indicated a broad consensus that studies at the time gave no consistent or convincing evidence of a causal relation between RF exposure in the range of frequencies and power used by smart meters and adverse health effects.

According to the Maine CDC's report, they discovered little information in the assessments that spoke directly about the safety of RF exposure from smart meters. There was, however, much discussion about the safety of mobile phones. Mobile phone use represents an RF EMF exposure qualitatively similar to smart meters in range of frequency, but because the power of mobile phones is higher and typical use entails exposure closer to the body, the resulting exposure to RF EMF appeared to be quantitatively much greater than that from smart meters.

Thus, the report stated, it appeared that the lack of any consistent and convincing evidence of a causal relation between RF EMF exposure from mobile phones and adverse health effects would indicate even less concern for potential health effects from use of smart meters.

Subsequent to the investigation, the Maine CDC and others received several letters from people expressing concerns about the review. In order to ensure that OPA, MPUC, and the correspondents had concise responses, Maine CDC grouped the concerns into eight topic areas and compiled a "Frequently Asked Questions" (FAQ) document[163] published on November 29, 2010, which addressed the concerns.

Vermont Department of Health

In January 2012, the Vermont Department of Health measured the RF EMF emissions at active smart meters that had been installed in the town of Colchester by Green Mountain Power. The resulting report[164] stated that readings from the meters verified that the devices emitted only a small fraction of the RF EMF emitted from a typical cell phone, even at very close proximity to the meter. The readings were well below regulatory limits set by the FCC.

The report stated that the measurements taken directly in contact with a smart meter mounted on the exterior wall of a residence ranged from 50 to 140 microwatts per square centimeter (abbreviated $\mu W/cm^2$),

[160] <https://www.maine.gov/dhhs/boh/smart_meters.shtml>.
[161] <https://www.maine.gov/dhhs/boh/documents/Smart_Meters_Maine_CDC_Executive_Summary_11_08_10.pdf>.
[162] <https://www.maine.gov/dhhs/boh/documents/Smart_Meters_Review_of_Government_Resources_11_08_10.pdf>.
[163] <https://www.maine.gov/dhhs/boh/documents/smart-meters-faq.pdf>.
[164] <http://healthvermont.gov/pubs/ph_assessments/radio_frequency_radiation_and_health_smart_meters.pdf>.

compared to the FCC's 610 $\mu W/cm^2$ MPE limit for the general population.[165] Measurements taken at distances of three feet or more away from the smart meter were at or near background levels of RF EMF.

Monterey County, California

In late 2010, members of the public that had concerns about potential adverse health effects of smart meters asked the Monterey County Board of Supervisors (the Board) to ban the use of smart meters in Monterey County. On January 11, 2011, the Board requested that the Monterey County Health Department review the literature and produce a report that summarized scientific findings related to smart meters and any potential adverse health effects. In March, 2011 the Health Department issued its report, entitled "Review of Health Issues Related to Smart Meters."[166]

The report's conclusions were as follows:

- Currently available literature indicates that exposure to RF energy from smart meters should be less than that experienced by routine mobile phone use;
- Based on the data available at the time of this review, the current FCC standard provides an adequate factor of safety against known thermally induced health impacts of existing common household electronic devices and smart meters;
- Despite extensive studies, there is no consistency of findings across studies regarding an association between non-thermal adverse health effects and exposure to EMFs from mobile phones;
- Due to various factors, further study is warranted to understand the potential for long-term adverse non-thermal health effects of RF energy from sources such as mobile phones;
- The lower exposure levels likely to be experienced from the deployment of smart meters compared to mobile phones should provide consumers some reassurance that there is a lower potential for adverse non-thermal health effects from the operation of smart meters; and
- Some countries have adopted different exposure limits for EMF or placement of EMF arrays and towers in relation to certain populations based on the Precautionary Principle rather than on scientific certainty.

Australia: Smart Meter Installations in the State of Victoria

In Australia, smart meters and other wireless devices used for communication having frequencies similar to mobile and cordless phones, are regulated by the Australian Communications and Media Authority (ACMA). Emissions from these wireless devices must comply with the ACMA Radiocommunications (Electromagnetic Radiation - Human Exposure) Standard 2003 as amended in 2011.[167] This standard mandates the exposure limits set by Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) which were designed to protect against all known adverse health effects. These exposure limits are described in the document "Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz."[168]

In 2011, the Victorian state government commissioned an independent study by testing laboratory EMC Technologies to determine the actual levels of RF EMF exposures from smart meters, and make sure that the meters complied with the exposure levels set by ARPANSA.

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[165] The micron symbol, μ, is a prefix that represents 10^{-6}, or one-millionth. 1 μW = one-thousandth of one milliwatt (mW).
[166] <http://publicagendas.co.monterey.ca.us/MG97205/AS97224/AS97230/AI99413/DO99416/DO_99416.pdf>.
[167] <http://www.comlaw.gov.au/Details/F2011C00165>.
[168] <http://www.arpansa.gov.au/pubs/rps/rps3.pdf>.

EMF measurement site surveys were conducted on a range of smart meters installed in various types of houses. The EMF measurements were performed on AMI meters installed by the five major utilities in the state of Victoria. The five utilities have joint programs in place to manage these installations, with the end result being three combined deployments. Most measurements were conducted on single AMI installations but also included a group meter installation (with 9 to 12 meters) from each of the three deployments. In these group meter installations, up to six meters were interrogated simultaneously to measure the maximum combined EMF from multiple transmissions.

EMC Technologies tested both types of electromagnetic exposures produced from smart meters - the EMF generated by the operation of a smart meter and RF emissions related to the built-in two-way communications. EMC Technologies found[169] that the maximum RF EMF power density levels were well below the ARPANSA General Public Limit specified by ARPANSA Radiation Protection Standards, even when the meter was forced to transmit continuously (100% duty cycle). More specifically, exposure levels from smart meters inside dwellings ranged from 0.000001% to 0.0113% of ARPANSA's General Public Limit of 450 $\mu W/cm^2$.

The test results also showed that in measurements made at sites with grouped meters, even with a number of meters being requested for meter data upload, the EMF peak field measured did not increase above the level of a single meter transmission. No two meters were transmitting simultaneously. The report concluded that the maximum RF EMF power density from a group meter installation is expected to not be higher than that of a single meter installation.

RF EMF tests were also conducted on various household appliances that emit RF fields – a wireless modem, microwave oven, baby monitor, mobile phone and cordless phone. The RF EMF levels from the meters, even when measured from a foot away, were lower than the levels from these other common household items. The actual EMF levels from a meter, when measured inside the house, were very low compared to the levels from the abovementioned items.

Smart Meters Have Lower ELF EMF Levels than Electromechanical Meters

Extremely Low Frequency electromagnetic fields (ELF EMF) occur at 50Hz in Australia and at 60Hz in the U.S. and are predominantly found in electric energy generation, transmission, and distribution. Unlike the testing performed by the other organizations in this report, the scope of work in the Australian investigation included the measurement of ELF EMF. Tests were conducted on smart meters and on an electromechanical (i.e., rotating disc) electricity meter, as well as an electric blanket, vacuum cleaner, microwave oven, and CRT (Cathode Ray Tube) television.

In the tests, the 50 Hz fields around the smart meter were lower than those from some other common appliances such as vacuum cleaners and microwave ovens. The levels from other appliances such as hairdryers, power tools, induction cookers, fans, and air conditioners would also be much higher.

Finally, the test results showed that ***the fields from the smart meter are slightly lower than the fields from the analog (electromechanical) meter***. The report concluded that the smart meters themselves do not cause any increase in the power line-related EMF levels and that replacement of the older analog meters with AMI meters would reduce ELF EMF exposure.

[169] <http://www.dpi.vic.gov.au/smart-meters/publications/reports-and-consultations/ami-meter-em-field-survey-repor>.

United Kingdom: Health Protection Agency

In April 2012, the Advisory Group on Non-ionising Radiation (AGNIR), an independent advisor to the Health Protection Agency of the UK, produced a document entitled "Health Effects from Radiofrequency Electromagnetic Fields."[170] The Health Protection Agency is an independent organization that was formed by the UK government in 2003 to protect the public from threats to their health from infectious diseases and environmental hazards. According to its website, it does this by providing advice and information to the general public, to health professionals such as doctors and nurses, and to national and local government.[171]

The report starts out by saying that the quantity and quality of research published on the potential health effects of RF field exposure has increased substantially since AGNIR had last reviewed the subject in 2003. While the publication admitted that limitations to the published research still exist and therefore preclude a definitive judgment, the evidence considered did not demonstrate any adverse health effects of RF EMF exposure at levels below the internationally accepted guideline.

The paper stated that while there were possible effects on Electroencephalography (EEG) patterns, they were not conclusively established and that it was unclear whether such effects would have any health consequences.

The AGNIR document also stated that, in regard to RF EMF exposure that was below guideline levels:

- The evidence indicated that it does not cause symptoms;
- RF cannot be detected by people, even by those who considered themselves sensitive to RF fields;
- The evidence pointed toward no material exposure to the risk of cancer although there is little data on risks beyond 15 years from first exposure;
- RF showed no effect on health not related to cancer; and
- There was a lack of convincing evidence that it caused health effects in adults or children.

Health Canada: Safety Code 6

Health Canada[172] is the Canadian federal department responsible for helping its country's people maintain and improve their health, while respecting individual choices and circumstances. Health Canada's document titled "Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3 kHz to 300 GHz"[173,174] is a code that specifies Canada's radiofrequency exposure guidelines, commonly known as "Safety Code 6 (2009)." The guidelines provide recommended best practices for ensuring compliance with the maximum exposure levels for controlled and uncontrolled environments. The Safety Code 6 (2009) standards are similar to the U.S. FCC standards established in 1997.

Regarding MPE, Safety Code 6 states the following:

> "For frequencies from 100 kHz to 300 GHz, tissue heating is the predominant health effect to be avoided. Other proposed non-thermal effects have not been conclusively documented to occur at levels below the threshold where thermal effects arise."

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[170] <http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317133827077>.
[171] <http://www.hpa.org.uk/AboutTheHPA/>.
[172] <http://www.hc-sc.gc.ca/ahc-asc/index-eng.php>.
[173] <http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct-eng.php>.
[174] <http://www.scribd.com/doc/36604752/Safety-Code-6>.

British Columbia Provincial Health

On December 23, 2011 a statement[175] was prepared at the request of the British Columbia (BC) Provincial Health Officer by Mary McBride, a Distinguished Scientist at the Department of Cancer Control of the BC Cancer Agency (BCCA) in Vancouver, BC. The letter had been approved by Dr. David McLean, Head of Cancer Prevention at the BCCA.

The statement indicated that research evidence does not support a conclusion that RF EMF, whether from cell phones or smart meters, can cause brain tumors in adults. With more than 20 years' cell phone use and limited information on a risk of other cancers, the information that BCCA officials possess generally does not support the notion of cancer. The statement admits that while there is no direct information on children, more studies are underway to address gaps in their understanding of RF EMF and cancer risk. The statement concluded by saying that extensive laboratory research to date has not identified any mechanisms that could function in either adults or children which would lead to an excess risk of tumors in general.

Ontario Province: Ontario Agency for Health Protection and Promotion

On September 16, 2010, the Ontario Province of Canada's Agency for Health Protection and Promotion (Ontario Health Agency) issued a brief paper that cautioned against relying on the results of individual research studies regarding the potential health effects from exposure to RF EMF because inconsistencies or conflicts may exist among the results of other individual studies.

The Ontario Health Agency stated that performing reviews of literature that followed an approach of weighing evidence would be far more useful to inform debate and make sound policy than it would be to merely rely on individual studies.

The Ontario Health Agency pointed to the Royal Society of Canada's (RSC) highly credible review from 1999[176] with updates to the review published as recently as 2009.[177,178] The RSC review called for additional research to follow up on new findings from an additional decade of research and noted that there was still no conclusive evidence of adverse health effects at exposure levels that are below the current Canadian guidelines.

The Ontario Health Agency stated that recently published research demonstrated that Wi-Fi exposure is well within recommended limits and is also only a small fraction (less than 1%) of exposure during the typical use of a cell phone. Because of this, much of the research on possible effects of RF EMF has been focused on exposures from cell phones rather than the lower exposures associated with RF uses such as Wi-Fi, and the focus will continue to be on cell phones. The Ontario Health Agency also stated that public exposure, including school children, to Wi-Fi is far lower than what occurs with cell phone use, and that there is no plausible evidence to date that would indicate that current public exposure to Wi-Fi is causing any adverse health effects.

[175] <http://www.health.gov.bc.ca/pho/issues.html>.
[176] <http://www.rsc.ca/documents/RFreport-en.pdf>.
[177] <http://www.rsc.ca/documents/expert_panel_radiofrequency_update2.pdf>.
[178] <http://www.ncbi.nlm.nih.gov/pubmed/20183523>.

City of Richmond, British Columbia and Vancouver Coastal Health

The BC Hydro and Power Authority is an electric utility in British Columbia. The company serves 1.8 million customers in most areas of the province and is deploying smart meters. On November 14, 2011, the City of Richmond in British Columbia passed a resolution requesting its Medical Health Officer to "conduct an investigation as to whether smart meters pose a health hazard." The response,[179] dated December 20, 2011 and signed by the BC Health Officer and two officers from Vancouver Coastal Health, concluded that the smart meters installed and used by BC Hydro were not a health hazard. Furthermore, the letter stated that "the transmitters in Smart Meters produce electromagnetic fields at levels significantly lower than the maximum allowed for the Canadian public under Health Canada's Safety Code 6."

Other notable findings of the independent consultant, Planetworks Consulting Corporation include:[180,181]

1. Smart meters are active for only a very short duration at a time;
2. The average power density was 0.3795% of Safety Code 6 for a single smart meter;
3. For a bank of ten smart meters, the average power density was found to be 0.4507% of Safety Code 6 (a range from 0.0015% to 1.6835% of Safety Code 6); and
4. The highest power density value recorded from a bank of ten meters was less than 2% of Safety Code 6 limit, while the average power density for both single and a ten meter bank are less than 0.5% of Safety Code 6.

Note that Safety Code 6 requires the power density at the frequency used by the smart meters to be less than 600 $\mu W/cm^2$ for publicly accessible areas (compared to the FCC's limit of 610 $\mu W/cm^2$). One can see that the power density recorded for a ten meter bank is not ten times that of a single meter, as some may suspect. Instead, the average power density for the ten meter bank was found to be only about 1.2 times that of a single meter, while the maximum value from a bank of ten meters was slightly less than twice the maximum value recorded from a single meter.

Norwegian Institute of Public Health

In spring 2010, an Expert Committee was appointed by the Norwegian Institute of Health and commissioned by the Ministry of Health and Care Services and the Ministry of Transport and Communications. The committee was composed of individuals with expertise in environmental and occupational medicine, biology, physics, metrology, biophysics, biochemistry, epidemiology, and philosophy as well as administration and risk management. In 2012, the committee issued its report.

The committee assessed the health hazards from low-level electromagnetic fields generated by radio transmitters. The Committee evaluated the power of the fields, whether they posed a health risk, the current regulatory practice, and whether the threshold limit values for exposure were observed. A press release from the institute described the report conclusions: [182]

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[179] <http://www.health.gov.bc.ca/pho/pdf/vch-response-to-richmond-city-council-re-investigation-into-smart-meters.pdf>.

[180] <http://www.bchydro.com/etc/medialib/internet/documents/smi/SMI_SingleSmartMeter.Par.0001.File.SMI-SingleSmartMeter-2011-Oct-11.pdf>.

[181] <http://www.bchydro.com/etc/medialib/internet/documents/smi/SMI_MeterBank.Par.0001.File.SMI-MeterBank-2011-Oct-11.pdf>.

[182] <http://www.fhi.no/eway/default.aspx?pid=238&trg=MainLeft_5895&MainArea_5811=5895:0:15,2829:1:0:0:::0:0&MainLeft_5895=5825:99168::1:5896:1:::0:0>.

"There is no scientific evidence that low-level electromagnetic field exposure from mobile phones and other transmitting devices causes adverse health effects, according to a report presented by a Norwegian Expert Committee. In addition, the Committee provides advice to authorities about risk management and regulatory practice."

Swedish Council for Working Life and Social Research

The Swedish Council for Working Life and Social Research (FAS) was commissioned by the government of Sweden to monitor issues relating to research into EHS and to document and report on the state of research at regular intervals, starting in 2003. In the executive summary of its 2012 report, FAS stated:[183]

"Extensive research for more than a decade has not detected anything new regarding interaction mechanisms between radiofrequency fields and the human body and has found no evidence for health risks below current exposure guidelines. While absolute certainty can never be achieved, nothing has appeared to suggest that the since long established interaction mechanism of heating would not suffice as basis for health protection."

Health Council of the Netherlands

The Health Council of the Netherlands is an independent scientific advisory body.[184] Its task is to provide the Netherlands government and parliament with advice in the field of public health and health/healthcare research. The agency also addressed EHS in its report, *Electromagnetic Fields: Annual Update 2008*:[185]

"From the good quality scientific data emerges the picture that there is no causal relationship between exposure to radiofrequency electromagnetic fields and the occurrence of symptoms. However, there is a relationship between symptoms and the *assumption* of being exposed and therefore most likely with the risk perception."

World Health Organization

The WHO website contains a wealth of information about EMF, including what it is, links to a database of research citations, national standards, publications, information resources, and meetings. The site also has a link to Germany's EMF-Portal that provides access to research databases.

The organization also hosts the International EMF Project,[186] which was established in 1996 and is open to any WHO Member State government, such as department of health or representatives of other national institutions concerned with radiation protection. The project was established to assess health and environmental effects of exposure to static and time varying electric and magnetic fields in the frequency range 0-300 GHz. The site provides access to 39 ongoing studies, 322 published studies, and 12 studies that have been reported but not published.

There are 54 participating countries and eight international organizations involved in the project. It is fully funded by participating countries and agencies. Its stated key objectives are to:

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[183] <http://www.fas.se/pagefiles/5303/10-y-rf-report.pdf>.
[184] <http://www.gezondheidsraad.nl/en>.
[185] <http://www.gezondheidsraad.nl/sites/default/files/200902.pdf>
[186] <http://www.who.int/peh-emf/project/en/>.

- Provide a coordinated international response to concerns about possible health effects of exposure to EMF;
- Assess the scientific literature and make a status report on health effects;
- Identify gaps in knowledge needing further research to make better health risk assessments;
- Encourage a focused research program in conjunction with funding agencies;
- Incorporate the research results into WHO's Environmental Health Criteria monographs where formal health risk assessments will be made on exposure to EMF;
- Facilitate the development of internationally acceptable standards for EMF exposure;
- Provide information on the management of EMF protection programs for national and other authorities, including monographs on EMF risk perception, communication and management; and
- Provide advice to national authorities, other institutions, the general public and workers, about any hazards resulting from EMF exposure and any needed mitigation measures.

The WHO recognized the following independent scientific institutions for their collaboration:

- U.S. Air Force Research Laboratory, Human Effectiveness Directorate (Brooks Air Force Base, TX);
- Australian Radiation and Nuclear Safety Agency (ARPANSA);
- UK Health Protection Agency - Radiation Protection Division;
- German Federal Office for Radiation Protection (BfS); and
- Institute of Population Health, University of Ottawa, Ontario, Canada.

Some key points are made on the WHO website regarding EMF and health. Among them are the following:

- A wide range of environmental influences causes biological effects. 'Biological effect' does not equal 'health hazard'. Special research is needed to identify and measure health hazards;
- There is no doubt that short-term exposure to very high levels of electromagnetic fields can be harmful to health. Current public concern focuses on possible long-term health effects caused by exposure to electromagnetic fields at levels below those required to trigger acute biological responses;
- Despite extensive research, to date there is no evidence to conclude that exposure to low level electromagnetic fields is harmful to human health;
- The focus of international research is the investigation of possible links between cancer and electromagnetic fields, at power line and radiofrequencies;
- Finding a statistical association between some agent and a specific disease does not mean that the agent caused the disease;
- The absence of health effects could mean that there really are none. However, it could also signify that an existing effect is undetectable with present methods;
- Results of diverse studies (cellular, animal, and epidemiology) must be considered together before drawing conclusions about possible health risks of a suspected environmental hazard. Consistent evidence from these very different types of studies increases the degree of certainty about a true effect; and
- Due to a large safety factor, exposure above the guideline limits is not necessarily harmful to health. Furthermore, time-averaging for high frequency fields and the assumption of maximum coupling for low frequency fields introduce an additional safety margin.

Publications and other specific work outputs from efforts of the WHO, its divisions, and collaborating organizations are noted throughout this report and will not be repeated here.

Comments by Academia on Public Concerns about Wireless Smart Meters

Montréal Polytechnic and McGill University Open Letter

On May 18, 2012, an open letter was issued in support of smart meter technology[187] and signed by 61 scientists and engineers primarily affiliated with one of two universities located in Montréal, Québec, Canada: École Polytechnique de Montréal (Montreal Polytechnic) and McGill University. The few signatories who could be thought to have a conflict of interest through their affiliation with the telecommunications industry or Hydro Québec, the utility in the province deploying more than 3 million smart meters, declared their conflict alongside their names.

In the letter, the Québécois engineers and scientists commented:

> "We believe that the fear of wireless technologies is based primarily on i) a misunderstanding of the nature of radio waves and their interaction with the human body, ii) a misreading of the scientific literature on this subject, and iii) a distrust of local, national and international public health organizations."

The Québec Energy Board, the provincial regulator, took the letter into consideration when rendering its decision[188] to allow Hydro Québec to proceed with its plan to install wireless smart meters in its service territory. The agency stated in its summary[189] (translated from French):

> "The views presented by the public health authorities and the evidence heard by [the Board] on the state of scientific research on the impacts of non-thermal RF on health demonstrate that the emissions from the new generation of smart meters do not present a health risk."

University of Ottawa: RFcom Review Panel Reports

The University of Ottawa's McLaughlin Centre for Population Health Risk Assessment has a project called RFcom[190] that functions as an Internet-based information resource about health effects of wireless technologies. RFcom is managed by a science panel that reviews and reports[191] on the most recent research studies about wireless technology and health from around the world. All studies referenced on its website must meet the following criteria:

- The source must be credible and accountable;
- Material must be peer-reviewed research and data that has been accepted and validated in the Canadian and international communities; and
- All studies must have been carried out by an independent third-party person or organization.

The page contains conclusions and excerpts from reports issued by various organizations from within countries and international bodies including Canada, Denmark, the EC, Finland, France, Germany, Iceland, Netherlands, Norway, Spain, Sweden, the UK, and the U.S. These excerpts overwhelmingly indicate that there is no

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[187] <http://www.polymtl.ca/phys/doc/Lettre_ouverte_de_scientifiques_quebecois_les_compteurs_intelligents.pdf>.
[188] <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0163-DEC-DEC-2012_10_05.pdf>.
[189] <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0164-DEC-DEC-2012_10_05.PDF>.
[190] <http://www.rfcom.ca/welcome/index.shtml>.
[191] <http://www.rfcom.ca/panel/index.shtml>.

conclusive evidence to support many of the assertions smart meter opponents are making about the harms of RF EMF exposure and negative health outcomes.

Other Issues

Potential for Interference with Medical Devices

Some people have expressed concern that signals from smart meters could interfere with the operation of implanted electronic devices such as pacemakers or other medical equipment. According to the FCC, because they are electronic devices, there is a potential for such devices to be susceptible to electromagnetic signals that could cause them to malfunction. The FCC stated[192] that there have been anecdotal claims of such effects in the past which involved emissions from microwave ovens but that it has never been shown that the RF energy from a properly operating microwave oven is strong enough to cause such interference. The FCC also stated that the FDA requires pacemaker manufacturers to test their devices for susceptibility to electromagnetic interference (EMI) over a wide range of frequencies and to submit the results as a prerequisite for market approval. Electromagnetic shielding has been incorporated into the design of modern pacemakers to prevent RF signals from interfering with the electronic circuitry in the pacemaker.[193]

Both the FCC and FDA[194] refer to studies which have shown that mobile phones can interfere with implanted cardiac pacemakers if a phone is used in close proximity (within about eight inches) of a pacemaker. Such interference appears to be limited to older pacemakers which may no longer be in use. The agencies recommend that those with pacemakers avoid placing a phone in a pocket close to the location of their pacemaker or putting the phone near the pacemaker location when using the phone.

One of the studies to which the FCC and FDA refer was published in The New England Journal of Medicine[195] in which a total of 980 patients were tested. Seven hundred twenty-five patients were tested with six telephones and 255 were tested with five telephones, providing a total of 5625 tests. Ninety-two tests were eliminated because of incomplete data. Thus, statistical analyses were based on 5533 tests. The study concluded that no interference was observed in any pacemaker at base line. The study stated that while abnormalities of pacing were observed at base line in 23 of 976 patients (2.4%) during testing, evidence of these abnormalities was not considered to be due to interference.

Further, ANSI and the Association for the Advancement of Medical Instrumentation (AAMI) have devised a standard[196] known as ANSI/AAMI PC69:2007 which establishes electromagnetic compatibility test protocols for active implantable cardiovascular devices. The standard is intended for manufacturers of implantable medical devices and consultants who test implantable devices. It specifies test methods related to interference frequencies and their potential effects on implantable devices such as cardiac pacemakers and internal defibrillators. It also requires disclosure of a device's performance issues in the presence of EM emitters where appropriate and provides manufacturers of EM emitters with information about the level of immunity to be expected from active implantable cardiovascular devices.

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[192] <http://transition.fcc.gov/oet/rfsafety/rf-faqs.html#Q22>.

[193] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.

[194] <http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/ucm116311.htm>.

[195] <http://www.nejm.org/doi/pdf/10.1056/NEJM199705223362101>.

[196] <http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2FAAMI+PC69%3A2007>.

Claims of Electromagnetic Hypersensitivity

World Health Organization

The WHO is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries, and monitoring and assessing health trends.[197]

In December 2005, the WHO International EMF Project created a fact sheet on electromagnetic fields and public health in order to address EHS.[198] The fact sheet describes what was known about the condition, and it provided information for helping people with such symptoms. The information was based on a WHO Workshop on Electrical Hypersensitivity (Prague, Czech Republic, 2004),[199,200] an international conference on EMF and non-specific health symptoms (COST 244bis, 1998),[201] a European Commission report (Bergqvist and Vogel, 1997),[202] and reviews of the literature.

The fact sheet stated that EHS is characterized by a range of non-specific symptoms that lack apparent toxicological or physiological basis or independent verification and that it differs from individual to individual.[203] The sheet stated that the symptoms are certainly real and can vary widely in their severity, and they can be a disabling problem for the affected individual.

The WHO document noted that a number of scientific studies had been conducted where EHS individuals were exposed to EMF similar to what they had attributed to the cause of their symptoms. The aim of the studies was to elicit symptoms under controlled laboratory conditions. The WHO fact sheet stated that the majority of studies indicated that EHS individuals could not detect EMF exposure any more accurately than non-EHS individuals. Double-blind studies which were well-controlled and well-conducted had shown that symptoms were not correlated with EMF exposure. Therefore, it stated, EHS has no clear diagnostic criteria, and there is no scientific basis to link EHS symptoms to EMF exposure.

It had been suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF including flicker from fluorescent lights, glare and other visual problems with video displays, and poor ergonomic design of computer workstations. The fact sheet stated that other factors that may play a role included poor indoor air quality or stress in the workplace or living environment.

Finally, there were some indications that the symptoms may be due to pre-existing psychiatric conditions as well as stress reactions that were a result of worrying about EMF health effects, rather than EMF exposure itself. It explained that EHS is not a medical diagnosis, nor is it clear that it represents a single medical problem. Thus, some medical experts described EHS as an example of a psychogenic illness. A psychogenic illness is a constellation of symptoms suggestive of organic illness, but without an identifiable cause, that

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[197] <http://www.who.int/about/en/>.
[198] <http://www.who.int/mediacentre/factsheets/fs296/en/index.html>.
[199] <http://www.who.int/peh-emf/meetings/hypersensitivity_prague2004/en/index.html>.
[200] <http://ihcp.jrc.ec.europa.eu/our_activities/public-health/exposure_health_impact_met/emf-net/docs/publications/WHO_EMF-NET%20Book.pdf>.
[201] <ftp://ftp.cordis.europa.eu/pub/cost/docs/244bisfinalreport.pdf>.
[202] <https://gupea.ub.gu.se/bitstream/2077/4156/1/ah1997_19.pdf>.
[203] Idiopathic Environmental Intolerance attributed to Electromagnetic Fields (IEI-EMF) is a term that is being increasingly used to describe this disorder.

occurs between two or more people *who share beliefs about those symptoms* (emphasis added). Psychogenic illnesses have made headlines when they have become manifest as a widespread phenomenon.[204]

King's College London: Systematic Review of Provocation Studies for EHS

King's College London's School of Medicine is one of the UK's most renowned centers for medical research and teaching. It has three central London hospital campuses, and its research portfolio is closely aligned to its National Health Service partners. The school has ten research divisions and it hosts 12 externally awarded and funded specialist centers.[205]

In 2005, school researchers performed meta-analyses[206] to identify relevant blind or double-blind EMF provocation studies.[207] According to the researchers, thirty-one experiments testing 725 EHS participants were identified.[208] Out of the 31 studies, 24 found no evidence to support the existence of a biophysical hypersensitivity, whereas seven reported some supporting evidence. For two of these seven studies, the same research groups subsequently tried to replicate their findings but failed. In three of the seven studies, the positive results appeared to be statistical artifacts. The remaining two studies produced mutually incompatible results.

According to the King's College researchers, the meta-analyses found no evidence of an improved ability to detect EMF in EHS participants. They concluded that the symptoms described by EHS sufferers can be severe and are sometimes disabling but that it had proven difficult to demonstrate under blind conditions that exposure to EMF could trigger symptoms. The researchers stated that analyses suggested that EHS was unrelated to the presence of EMF. The researchers stated that more research into this phenomenon was required.

In 2009, a team of researchers from King's College performed an updated systematic review of provocation studies for EMF.[209] The researchers performed an extensive literature search and identified 15 new experiments. This time, 46 blind or double-blind provocation studies were analyzed in total, involving 1175 EHS volunteers to determine whether exposure to EMF is responsible for triggering symptoms in EHS individuals. The researchers determined that no robust evidence could be found to support the theory.

However, the researchers stated, the studies included in the review did support the role of the nocebo effect in triggering acute symptoms in EHS sufferers. A nocebo response is an unpleasant, harmful, or undesirable effect(s) that a subject manifests, typically after receiving a placebo. The nocebo effect has drawn increased interest from the medical community because studies show that patients are highly receptive to negative suggestion.[210]

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[204] <http://www.cmaj.ca/content/172/1/36.full.pdf>.

[205] <http://www.kcl.ac.uk/medicine/about/index.aspx>.

[206] A meta-analysis is a systematic method of evaluating statistical data based on results of several independent studies of the same problem.

[207] A provocation study is a form of medical clinical trial whereby participants are exposed to a substance or situation that is claimed to provoke a response or to a sham substance or device that should provoke no response.

[208] <http://www.aefu.ch/typo3/fileadmin/user_upload/aefu-data/b_documents/themen/elektrosmog/Position_Forschungstand/rubin_Elektrosensib.Provokationsstudie05.pdf>.

[209] <http://www.essex.ac.uk/psychology/EHS/Rubin%20et%20al%20REVIEW_2009.pdf>.

[210] <http://www.aerzteblatt.de/pdf.asp?id=127210>.

Recent Court Decision Regarding Claim of EHS

In a recent court decision in New Mexico, the plaintiff claimed to have health problems triggered by exposure to EMF generated by his neighbor's electrical equipment (e.g. cordless telephones, computer equipment, dimmer switches, and Wi-Fi routers and modems). The court concluded that EHS is not a scientifically recognized disease, excluded the testimony of the plaintiff's two experts, and dismissed the case.[211,212]

Use of EMF as a Weapon

Some opponents of smart meters have spoken of two kinds of weapons being developed by military organizations such as the U.S. Department of Defense[213] or by other countries. Because weapons are typically associated with causing bodily harm or death, they are addressed in this paper.

Both kinds of weapons utilize electromagnetic radiation, but they use it differently and have different end goals. The first kind of weapon to be discussed has been demonstrated to the public. The existence of the second kind of weapon seems to be more speculative.

Directed Energy Weapons

The first type of weapon is known as a directed energy weapon which delivers energy to a target. The target can be humans, electronic equipment, or other military targets, depending on the technology employed. It can be used for purposes other than to destroy a target or kill soldiers. For example, the Active Denial System (ADS) is a weapon under development that is intended for use against humans. It is non-lethal and designed for area denial,[214] perimeter security, and crowd control. The device is mountable on a small armored vehicle.

The ADS works by firing a narrow, high-powered beam of 95 GHz waves at a human target. The energy from an ADS works on a similar principle as a microwave oven, exciting the water and fat molecules in the skin, and instantly heating them (dielectric effect).

How deep a radio wave can penetrate an object depends upon the wave's frequency. The high frequency waves used in ADS penetrate 1/64th of an inch into the top layers of the subject's skin. At that skin depth lie "nociceptors" which are nerve endings sensitive to heat. *Wired* magazine indicated that documents it acquired from the government stated that 83% of the energy impacting the target was instantly absorbed by the top layer of the skin.[215] Being hit by the energy from the ADS gives the victim a sensation of his entire body being exposed to intense heat but without injury taking place. The pain reflex makes the targeted person instinctively pull away in less than a second. To avoid potential trauma to the subject, the trigger on the device only allows the weapon to be fired for three seconds.

The *Wired* article states that the energy delivered to a target is 12 joules per square centimeter.[216] The ADS delivers those 12 joules of energy over a three-second period, which is equivalent to delivering four watts (4000 mW) of power each second per square centimeter.

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[211] Firstenberg v. Monribot and Leith, No. D-101-CV-2010-00029, New Mexico 1st Dist, Santa Fe County, Sept 18, 2012.
[212] <http://www.casewatch.org/civil/firstenburg/dismissal_order.pdf>.
[213] <http://jnlwp.defense.gov/>.
[214] Area denial weapon is used to prevent an adversary from occupying or traversing an area of land. Land mines and punji sticks are examples of denial weapons, albeit ones which are potentially lethal.
[215] <http://www.wired.com/dangerroom/2012/03/pain-ray-shot/>.
[216] <http://www.wired.com/science/discoveries/news/2006/12/72134?currentPage=all>.

The Human Effects Advisory Panel of Penn State concluded that ADS is a non-lethal weapon that has a high probability of effectiveness with a low probability of injury.[217] The limit of damage was the occurrence of pea-sized blisters in less than 0.1% of the exposures (6 of 10,000 exposures).

While this information may be interesting, the existence of such a weapon cannot be credibly used as an argument against employing RF communication devices because:

- The ADS is specifically designed as a weapon, not communications equipment;
- The ADS is very dissimilar to a smart meter because it uses a frequency 100 times higher than the 902-928 MHz band used by the meters' communication module;
- The ADS has an enormous power output. It delivers more than 3.5 million times the instantaneous peak energy of a smart meter radio module; and[218]
- Although the ADS is considered a weapon, it does not cause injury, only brief discomfort.

Cold War Studies on Behavior Modification and Human Vulnerability

The second type of weapon mentioned by opponents of wireless communications technology does not seem to have been displayed or demonstrated as a functioning device. Instead, some people who have provided material to the PUCT or appeared before it, the Texas Senate, or regulatory bodies in other jurisdictions have referred to research that had been performed mostly by Soviet Bloc countries during the Cold War, especially the Soviet Union.

Opponents of wireless technology have pointed to unclassified documents[219,220] produced by the U.S. Defense Intelligence Agency (DIA)[221] during the early 1970s as evidence that the Soviet Union was doing research on EMF along with exploring subject matter that was more unconventional. The stated purpose of the DIA disseminating this information was for preparedness and to develop countermeasures. It may be speculative to assume that more detailed information existed but was kept classified. We are limited to the available documents.

The documents summarize the known research in which the Soviet Union was involved regarding human vulnerabilities to various environmental conditions and behavior modification through the application of certain stimuli. Of particular interest to opponents of wireless technology are the studies performed to determine human vulnerability to EMF and how it could be used to alter a subject's behavior. These weapons were intended for use against an individual rather than a group.

One may be intrigued by the fact that in addition to the cited studies on the effects of EMF on living organisms, the documents also discuss psychology and parapsychology research. For example, some experiments involved telepathic communication, mind altering drugs, sensory deprivation, psychokinesis, and many other

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[217] <http://jnlwp.defense.gov/pdf/heap.pdf>.

[218] ADS exposure: 12 joules/cm^2 delivered over a three-second burst = 4,000 mW/cm^2. Smart meter exposure: 0.0011346 mW/cm^2 instantaneous peak field exposure in front of meter, at a distance of three feet, assuming a 100% duty cycle. Calculated from Table 9-5 of EPRI Report "An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter," Page 9-15.

[219] <http://science.discovery.com/tv/dark-matters/documents/pdf/controlled-offensive-behavior.pdf>.

[220] <http://www.magdahavas.com/wordpress/wp-content/uploads/2011/02/BIOLOGICAL_EFFECTS_OF_ELECTROMAGNETIC_RADIATION-RADIOWAVES_AND_MICROWAVES-EURASIAN_COMMUNIST_COUNTRIES.pdf>.

[221] Although the specific focus of the DIA has changed over the years, its central function has been to provide military intelligence to various facets of the U.S. military community.

seemingly strange topics. The fact that EMF research is mentioned in the same context as these arcane studies may lead some readers to errantly conclude that EMF is equally mysterious.

While some may find the material offered in the documents regarding EMF experiments on animal subjects interesting and germane to the topic of this report, several caveats are in order:

- The material is unclassified (compared to declassified) and offers nothing new – it is a part of the extensive body of knowledge on EMF. Despite the Cold War, scientific research was published and shared between the two sides;
- The material is old and may be out of date;
- The descriptions of the research are only abstracts, providing very little detail;
- The citations are of individual studies. Other studies may have conclusions that are incompatible; and
- Some material sourced from Soviet Bloc nations may be of questionable value. The results could have been subject to the political environment of the era.

The Soviet Bloc was not alone in conducting such research. The U.S. Central Intelligence Agency had also conducted behavioral modification experiments from the 1950s until the early 1970s. These experiments, collectively known as Project MKULTRA, relied on mind-altering drugs, hypnosis, sleep deprivation and other forms of harassment.[222]

Claims have been made that the work done under Project MKULTRA may have been used in conjunction with EMF to create "psychotronic weaponry"[223] in the form of "Silent Sound" or "Voice to Skull" technology. Voice to Skull technology is based on what is known as the microwave auditory effect or "microwave hearing." Microwave hearing is caused by using pulsed EMF in the microwave frequency band to induce audible clicks or sounds described as buzzing, hissing, or knocking. The cause is thought to be thermoelastic expansion of portions of the ear.[224] The sounds are generated directly inside the human head without the need of any receiving electronic device and are not audible to other people, even if they are nearby. If the signal is modulated,[225] whole words can be produced.

The idea behind this technology was that the spoken words of a hypnotist could be conveyed through microwave hearing into an unknowing person's head. This would allow the hypnotist to control the actions of the targeted individual's subconscious mind. Some have speculated about another possibility - that a targeted individual who heard voices inside his head would be distressed over the notion of going insane or being viewed as such.

The microwave auditory effect was first reported by persons working in the vicinity of radar transponders during World War II. The effect was later discovered to be inducible by frequencies higher in the electromagnetic spectrum. American neuroscientist Allan H. Frey studied this phenomenon and first published information[226] on the nature of the microwave auditory effect.[227] At least one patent has been issued for "Voice to Skull" technology based on the material in Frey's studies - U.S. Patent 4,877,027.[228] Note that several

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[222] <http://upload.wikimedia.org/wikipedia/commons/0/01/ProjectMKULTRA_Senate_Report.pdf>.

[223] A psychotronic weapon is an alleged type of mind control device.

[224] <http://www.ncbi.nlm.nih.gov/pubmed/17495664>.

[225] In telecommunications, modulation is the process of varying one or more properties of a high-frequency periodic waveform: amplitude, phase, or frequency. The effective result is piggybacking a signal on top of the RF EMF.

[226] <http://jap.physiology.org/content/17/4/689>.

[227] <http://www.slavery.org.uk/Bioeffects_of_Selected_Non-Lethal_Weapons.pdf>.

[228] <http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=4&f=G&l=50&co1=AND&d=PTXT&s1=4,877,027&OS=4,877,027&RS=4,877,027>.

criteria must be met in order for a U.S. patent to be issued, but the existence of a functional device is not one of those criteria. There is no credible evidence to suggest that such a device exists.

While this may be an interesting phenomenon, it is not applicable to smart meters because:

- The energy intensity required to accomplish the microwave auditory effect would be greater than the output capability of the radio module in a smart meter – perhaps even above MPE levels;
- The frequencies involved (higher microwave bands) are outside the range emitted by smart meters;
- EMF is directional in nature. A device intended to produce these sounds would require a transmitting antenna that optimized this directionality, and the emitted energy would have to be aimed directly at a person's head. Studies performed by EPRI of emission patterns from smart meters show the transmitting antenna in a smart meter directs most of its RF energy outward, away from the wall on which it is mounted. The RF energy would be greatly attenuated inside the building. Also, meter antennas are not aimed at people's heads;
- The existence of psychotronic weapons as described above is merely speculative; and
- Smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. They may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

Other Material

Critics of wireless technology have called attention to various materials in order to further claims about adverse health effects of exposure to EMF, including non-thermal effects. Some people have made assertions that this material has been forgotten, hidden, or suppressed. One example of a paper that opponents of wireless technology characterize as neglected was originally written for the Naval Medical Research Institute (NMRI) in 1971 and updated six months later. The document is "Bibliography of Reported Biological Phenomena ('Effects') and Clinical Manifestations Attributed to Microwave and Radio-frequency Radiation, MF12.524.015-0004B, Report No 2 Revised."[229]

The first chapter of the document provides an outline of biological phenomena that had been reported in individual studies of biological exposure to microwave or RF radiation. The more than 120 reported phenomena are placed into 17 categories such as "changes in physiologic function," "central nervous system effects," "psychological disorders," and "endocrine gland changes." The remainder of the document makes up the bulk of its content and is a bibliography that identifies 2311 research papers, the oldest of which dates from 1925 and the most recent from 1972. The author stated that the paper was created to provide a listing of studies that may be "needed in the formulation and appraisal of criteria and limits of human exposure to non-ionizing radiation, and in the planning and conduct of future research."

The author noted that a few citations were of marginal and/or peripheral relationship but were nonetheless included so a reader could judge the applicability to his individual research needs. The author draws no conclusions and admits that the screening of the entries was limited to relevance of the topic, not the quality of the studies or the validity of their results:

> "Note: These effects are listed without comment or endorsement since the literature abounds with conflicting reports. In some cases the basis for reporting an "effect" was a single or a non-statistical observation, which may have been drawn from a poorly conceived (and poorly executed) experiment."

[229] <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=AD0750271>.

While there may be people who believe that the listing in the NMRI paper of purported effects resulting from exposure to EMF reveals damning evidence of harm, the document is limited in value for the following reasons:

- The paper merely compiles a list of reported effects without assessing their validity or prevalence;
- The document is primarily intended as a bibliography, citing research performed;
- The material does not offer abstracts for the cited studies (no findings are given);
- The report does not provide conclusions or determine causality - no meta-analysis was performed;
- The list is no longer comprehensive - it is over 40 years old (research dates from 1925 – 1972); and
- The cited studies do not yield any new information - they have been a part of the extensive body of knowledge on RF EMF for many years.

Further, the stated purpose of the NMRI paper was for planning and to conduct future research. When the FCC established its exposure standards in 1996, the results of the studies listed in the bibliography of the paper had been available for decades, and the standards took this research into consideration. Research on the biological effects of EMF has continued and will continue for the foreseeable future.

Conclusion

RF EMF, a form of non-ionizing radiation, has been utilized for nearly a century to broadcast radio and television programs and for many other types of telecommunication. Smart meters, an upgrade to our electrical infrastructure, emit EMF at only low intensity and within a narrow part of the RF band, close to the ranges where UHF TV, cordless phones, and cellular phones operate.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. Further, after performing a review of all available material, Staff found no credible evidence to suggest that smart meters emit harmful amounts of RF EMF.

At higher intensities, RF EMF can heat living tissue. As a result, the FCC established a more restrictive MPE for the general population that is 2% of the level where thermal effects are known to occur. This lower limit was established for the general population because exposure typically results from a situation that the recipient cannot control and a maximum possible time of exposure (24 hours per day) was presumed.

For decades, much scientific research has been performed to investigate the potential health effects of exposure to many kinds of EMF, including RF. Governmental health agencies from around the world, including but not limited to the U.S., Canada, the UK, and Australia, as well as academic institutions and other researchers, have stated that there are no known *non-thermal* effects from exposure to RF EMF. In other words, tissue heating is the only known risk of exposure to RF EMF. Nonetheless, substantial medical research on any potential non-thermal effects of non-ionizing radiation will continue in the future, and will include studies on emissions that fall into the RF bands.

Those concerned about health will often refer to the results of an individual research study or sometimes several studies to draw conclusions. It is important to use great caution when relying on the results of individual research studies because other studies may have inconsistent or even conflicting results. One must also consider that not all studies hold equal value in the scientific community; all research has some amount of inherent bias, and some studies arguably have flaws or lack scientific rigor.

EPRI, Naperville, the Vermont Department of Health, the Victorian State Government of Australia, and the City of Richmond in British Columbia, Canada have conducted investigations of smart meter RF EMF, and found that smart meters complied with the governmental exposure limits in their respective jurisdictions.

When measurements were taken at relative close proximity to smart meters or groups of smart meters, the RF EMF emissions were several orders of magnitude below the established exposure limits. It is important to note that increasing distance will decrease the intensity of an EM field by the square of the distance (i.e. decrease exponentially).

In addition to distance, in-residence exposure to emissions is further decreased by:

- Shielding of the meter enclosure;
- Building construction materials;
- Antenna orientation of the meter; and
- Meter duty cycle – data is transmitted only 1 - 5% of the time.

Some smart meter opponents have raised the concern that the meters may interfere with other electronic devices including implantable medical devices. Smart meters communicate using unlicensed spectrum. The FCC has mitigated the potential for interference among electronic devices operating in unlicensed spectrum by

requiring these devices to be tested and certified as compliant with its rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure. Medical devices must also comply with EMI standards.

Some opponents of smart meters have raised the idea of electromagnetic hypersensitivity and cite anecdotes of having witnessed or experienced various afflictions. After reviewing a substantial body of evidence, the WHO concluded that there was no scientific basis to link EHS symptoms to EMF exposure. It has suggested that symptoms experienced by some individuals described as EHS might arise from environmental factors unrelated to EMF or that the symptoms may be due to pre-existing psychiatric conditions or stress reactions resulting from worrying about EMF health effects, rather than the EMF exposure itself. Further, scientific studies show that people who are ill are highly receptive to negative suggestion and may demonstrate a "nocebo response" as a result of these suggestions.

The notion that EMF can be used as a weapon to cause pain, disrupt thought, or alter or control human behavior might be interesting to some people, but smart meters do not have the capabilities to do these things. First, the output energy from a smart meter radio module is miniscule. Second, the module does not transmit at frequencies near those used in directed energy weapons systems or which have been purportedly used in physiological or psychological experiments. Further, smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. A meter may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

A large number of scientific studies regarding the biological effects of EMF on living organisms have been performed over a period of at least seven decades. These studies are part of an extensive body of human knowledge on the subject, and safety standards have been devised based on the body of knowledge. One must be cautious when individuals make claims about research being suppressed, and when individual studies are cited as evidence that hazards or illnesses are being ignored. Other studies may produce conflicting results. One must be cognizant of what adherence to scientific principles entails and how to decipher research. Laymen often may not recognize poorly executed studies, or they can misinterpret the results of properly conducted scientific research. Either of these circumstances may lead a casual observer to draw errant conclusions.

Acronyms and Abbreviations

AAEM	American Academy of Environmental Medicine
AAMI	Association for the Advancement of Medical Instrumentation
ABEM	American Board of Environmental Medicine
ACMA	Australian Communications and Media Authority
AEIC	Association of Edison Illuminating Companies
AGNIR	Advisory Group on Non-ionising Radiation
AM	Amplitude Modulated
ANSI	American National Standards Institute
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BC	British Columbia
BCCA	BC Cancer Agency
BfS	German Federal Office for Radiation Protection
CCST	California Council on Science and Technology
CDC	Center for Disease Control and Prevention
cm	centimeter (0.01 meter)
CPUC	California Public Utilities Commission
CRT	Cathode Ray Tube
DDT	dichlorodiphenyltrichloroethane
EA	Equipment Authorizations
EC	European Commission
EEG	Electroencephalography
EEI	Edison Electric Institute
EHS	Electromagnetic Hypersensitivity
EIRP	Effective Isotropic Radiated Power
ELF	EMF Extremely Low Frequency electromagnetic fields
EM	Electromagnetic
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EMR	Electromagnetic Radiation
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERP	Effective Radiated Power
EU	European Union
eV	Electron Volt
FAQ	Frequently Asked Questions
FAS	Swedish Council for Working Life and Social Research
FCC	Federal Communications Commission
FDA	U.S. Food and Drug Administration
FM	Frequency Modulated
GAO	U.S. Government Accountability Office
GHz	Gigahertz (1 billion hertz)

GPS	Global Positioning System
HAN	Home Area Network
HHS	U.S. Department of Health and Human Services
Hz	Hertz (cycles per second)
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
kg	kilogram (1000 grams)
kHz	kilohertz (1000 hertz)
LBNL	Lawrence Berkeley National Laboratory
Maine CDC	Maine Center for Disease Control & Prevention
MHz	megahertz (1 million hertz)
MPE	Maximum Permissible Exposure
MPSC	Michigan Public Service Commission
MPUC	Maine Public Utilities Commission
mW	milliwatt (0.001 watts)
NCI	National Cancer Institute
NCRP	National Council on Radiation Protection and Measurements
NEMA	National Electrical Manufacturers Association
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NMRI	Naval Medical Research Institute
NSGI	Naperville Smart Grid Initiative
OET	FCC Office of Engineering and Technologies
OPA	Maine Office of the Public Advocate
OSHA	U.S. Occupational Safety and Health Administration
PG&E	Pacific Gas & Electric
PUCT	Public Utility Commission of Texas
RF	Radio Frequency
RF EMF	Radio Frequency Electromagnetic Field
RSC	Royal Society of Canada
SAR	Specific Absorption Rate
SGTAP	Smart Grid Technical Advisory Project
TV	Television
UHF	Ultra-high Frequency
UK	United Kingdom
U.S.	United States of America
UTC	Utilities Telecom Council
VHF	Very High Frequency
W	Watt
WHO	World Health Organization
μW	microwatt (1 millionth of a watt)
$\mu W/cm^2$	microwatts per square centimeter

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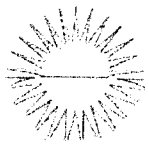
ATTACHMENT C -

RF EXPOSURE REPORT

CENTRAL MAINE POWER SMART METER NETWORK



RADIO FREQUENCY EXPOSURE REPORT

CENTRAL MAINE POWER SMART METER NETWORK

For the

Office of the Maine Public Advocate

Docket No. 2011-262

True North Associates

and

C^2 Systems

January 2013

Smart Meter RF Testing Report

True North Associates and C^2 Systems

January 2013

Re: ED FRIEDMAN, ET AL, Request for Commission Investigation Into Smart Meters & Smart Meter Opt-Out, Docket No. 2011-262

Overview

A new technology, the installation of smart meters and the creation of a 2.45 GHz wireless mesh network, serving residential and commercial buildings in the Central Maine Power (CMP) service territory, has caused public concern due to uncertainty over their operation and the possible effects that their operation may have on public health. In the context of Docket No. 2011-262, True North Associates was retained by the Office of the Maine Public Advocate (OPA) to measure the maximum and average power output of a sample of smart meters and other system components using the mesh network, and compare these readings to existing safety standards.

In consultation with the OPA, True North developed objectives for a limited program to measure radiofrequency output by and exposure from the digital meters installed as part of the Central Maine Power smart grid mesh network. The study was expanded to include the extender bridges (repeaters,) and collectors. True North contracted with C^2 Systems(C Squared,) a nationally-recognized radiofrequency emissions compliance testing organization, to perform the required field measurements, utilizing calibrated electromagnetic field measuring equipment certified by the FCC for measuring radiofrequency (RF) power density and exposure.

True North worked with OPA to ensure an independent and objective testing program. Based on earlier results provided to the Maine Public Utilities Commission in the report prepared by the Exponent Group[1], True North determined to focus its efforts on a selection of the most active meters and elements within the mesh network and to include all system components involved in broadcasting data within the network. To do this, limited consultation with representatives of CMP and the Trilliant Company was required to identify some of the specific locations meeting the objectives of this testing program.

In response to our requests for information, CMP, with the support of its network provider, Trilliant, identified groups of the most active utility meters, extender bridges, and data collectors in both Portland and Augusta. True North and C Squared tested one residential meter location that was identified on the list of meters supplied by CMP and two residential meter locations selected independent of CMP. The specific test locations or dates of testing were not disclosed to CMP.

[1] Exhibit B - Exponent, Inc. Report - Measurement Validation of Exposure Predictions from the Central Maine Power Smart Meter Network, September 19, 2012

The results obtained through the effort indicate that the measured exposure levels are well below the current FCC exposure limits. The testing methodology and detailed results are provided below.

Smart Meters and Mesh Network Operation

An advanced electric metering system is a "system of systems." This typically includes a range of interrelated components: in general, a digital meter measures and records a customer's electricity usage; a network interface delivers the meter data to the utility for processing and returns it to the customer in the form of an electronic or paper billing statement, as shown in Figure 1:

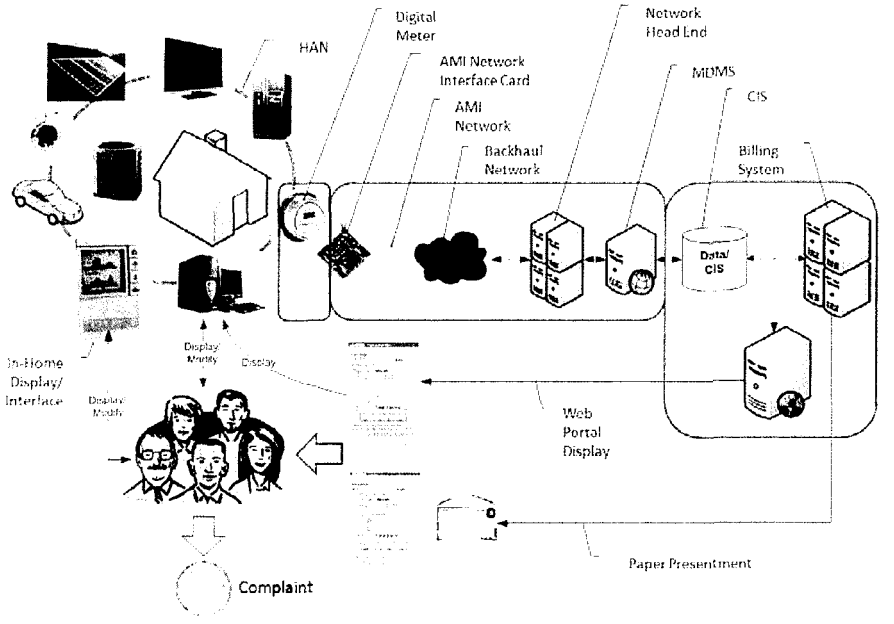


Figure 1 – Elements of a Typical Smart Meter Network

There are a number of product and service options that may be added to the network to facilitate various energy-conservation and load-management strategies. Many of these work through a home area network (HAN,) that may be stand-alone, or utilize 2-way Zigbee wireless communication capabilities that may be added to compliment the digital meter. The HAN features and services have not yet been enabled within the Central Maine Power mesh network. These elements, along with stand-alone Wi-Fi and cordless phone sets also generate RF signal output.

The key parts of CMP's Securemesh™ neighborhood-area smart grid mesh network considered in this study include the digital meter, the data extender bridges, or repeaters, which allow meters located outside the normal transmission range of the radio units that the meters use to communicate with the network, and the data collectors which receive data, either directly from nearby meters or from extender bridges. Collectors relay customer information into the system's backhaul network. The backhaul network ultimately feeds meter data into the utility's customer information and billing systems. While the repeaters and extender bridges also broadcast outbound signals to the meter network, a backhaul network typically utilizes fiber-optic cable to

allow faster rates of data transfer, which does not generate additional RF emissions. CMP's backhaul network was thus not considered in this investigation.

CMP's mesh network includes digital meters manufactured by General Electric and Landis & Gyr (LG). Both meters include a radio frequency transmitter/receiver unit that operates at a power output level of 1 W, in the range of 2402 MHz – 2472 MHz (2.4 to 2.47 GHz) in broadcast mode. The source of RF emissions originates in the electric meter's internal transceiver module whose output is .758 watts, which is connected to a printed circuit board antenna having a gain of 1 dBi. The total RF emissions, or effective isotropic radiated power (EIRP) out of the combined transceiver module and antenna, all housed within the meter, is 1.02 Watts, effectively 1 Watt. The strength of the RF signal emitted by each electric meter is fixed and does not change in response to the level of packet transmission activity. These meters are limited to a maximum duty cycle, or active broadcasting time, of no greater than 10%. These and other characteristics have previously been described in testimony filed as part of this investigation[2].

Extender bridges (repeaters) and data collectors broadcast at this same frequency range, at the same power output level (EIRP) as the residential meters. The radio units utilize channels 1-11 within this frequency range.

CMP's AMI network operates as a direct sequence spread spectrum (DSSS) data network, in which data signals are modulated, rather than pulsed. Data is transmitted and received within the network by the meters' transceiver units, which pass packets of information with customer energy usage to the utility (or send operating instructions from the utility) from meter to meter, up to a data collector. Within the DSSS mesh network, a meter may communicate directly with the network or it may transmit and receive information that passes through other meters. As noted in previous testimony, meters that are located closest to a network collector may retransmit the data for hundreds, up to several thousand dependent meters. This implies that these "parent" meters experience a greater level of activity due to rebroadcasting the data for other meters, than meters that are isolated or located farther away from a collector.

This greater activity increases an individual meter's duty cycle, the amount of time it is broadcasting, but not the antenna's signal strength, its effective isotropic radiated power (EIRP). Both of these factors, output duration and EIRP; affect human exposure to the broadcast electromagnetic field.

Duty Cycle and Exposure

Human exposure to an electromagnetic field occurs when an individual is subjected to electric, magnetic, or electromagnetic fields or to electric currents beyond those originating from physiological processes in the body and other natural sources. It is a function of the strength of the field or signal, and the amount of time that an individual is exposed to it.

The Federal Communications Commission (FCC), which regulates all equipment broadcasting radiofrequency signals, defines exposure in terms of the Maximum Permissible Exposure (MPE) to which an individual may be

[2] FRIEDMAN-01-09_Attachment_2_CONFIDENTIAL (2011-262)

exposed without harmful effect. The MPE limit varies with the frequency of the signal and the classification type of exposure (Controlled/Occupational vs. Uncontrolled/General Population). At the frequency used by the meters in CMP's smart grid network (2.45 GHz) the MPE limit for the general public is one milliwatt per square centimeter (1 mW per cm^2),averaged over a 30–minute time period. The occupational MPE, for reference, is averaged over a six-minute interval, making it five times higher than the limit for the general public.

Comparing the MPE values produced by the smart meters, repeaters, and data collectors selected for evaluation to the FCC standard was the core objective of this study. Key factors considered by True North and C Squared in assessing exposure for this study include:

- Digital meter duty cycle;
- Meter antenna broadcast power (EIRP);
- Broadcast channel (s) utilized by meter;
- Measurement meter characteristics matching meter broadcast characteristics and FCC standards;
- Strength of other sources of electromagnetic signals in the surrounding environment, such as proximity to other digital meters or sources of electromagnetic radiation exterior or interior to a structure, including: AM/FM radio broadcasts, wireless services, public safety, Wi-Fi, cordless phones, wireless routers, CCTV systems, cordless phones, car and home alarms, or Bluetooth;

As discussed below, several of these factors can complicate the accurate measurement of an individual meter's MPE.

The data from an individual digital meter operating in a mesh network is transmitted to the utility in short bursts which typically last only a few milliseconds. The total amount of time that a meter spends in transmitting data over a given standard time interval is referred to as the meter's duty cycle. A meter with a 100% duty cycle would be in broadcast mode continuously. A theoretical 1% duty cycle over the course of a day corresponds to 1% of 24 hours (1,440 minutes), or 14.4 min. per day.

The duty cycles of the meters evaluated in this study are typically small fractions of 1%. An individual meter sending only its own data to an extender bridge or collector has a total transmission time of 0.145 of a second per day, including hourly activity packets, or beacon signals, indicating meter status[3]. Roughly 99% of the meters in CMP's network have 60 or fewer dependent meters, and thus broadcast up to 8.6 seconds per day (0.145 seconds per day per meter times 60 meters). This is equivalent to a duty cycle of approximately .01% (8.6 seconds per day divided by 24 hours per day times 60 minutes per hour times 60 seconds per minute.)

One meter in the CMP mesh network was found to have nearly 5000 dependent meters[4]; its total broadcast time would be approximately 3 1/2 min. per day, equivalent to a duty cycle of 0.24% (0.145 seconds per day per meter times 5000 meters)/(24 hours per day times 60 minutes per hour times 60 seconds per minute.)

[3] Exhibit B - Exponent, Inc. Report - Measurement Validation of Exposure Predictions from the Central Maine Power Smart Meter Network, September 19, 2012, page 5-6.

[4] Exhibit B - Exponent, Inc. Report - Measurement Validation of Exposure Predictions from the Central Maine Power Smart Meter Network, September 19, 2012, page 12.

The majority of the CMP network activity occurs between midnight and 1:30 AM on a daily basis. Assessing exposure accurately requires that measurements be taken during the meter's "active" period, and that the exposure meter be set to the correct channel that the meter is using to broadcast within the 2.45 GHz frequency range.

The short duration of the meters' active transmission cycle, and the low power output level of the broadcast antenna pose inherent problems for capturing representative data that accurately characterizes human exposure, general or occupational. It is also difficult to distinguish the exposure from a utility meter from that of other sources of RF emissions in the surrounding environment.

In addition, an accurate assessment of exposure may be difficult to obtain where the utility meter has the capability to utilize different channels while broadcasting to avoid data congestion within the network, and the exposure test equipment, or exposure meter, used to measure the strength of the broadcast signal is not set to the same channel. In the case of this study, it was not possible to know beforehand which channel an individual meter would be using during the brief time it was broadcasting.

Exposure Test Equipment

The measurement program implemented by True North Associates and C Squared included a variety of steps in its evaluation of RF fields. The purpose of this evaluation was to determine exposure resulting from the RF fields emitted by the smart meters and AMI system components, at different distances from the broadcast antenna.

The Addendum to this report provides the details of the equipment and measurement procedures.

All exposure measurements were taken using a calibrated meter and isotropic probe manufactured by Narda Safety Test Solutions (Narda STS). Narda is the worldwide leader in research and development of EMF measuring equipment and holds 95% of all patents for EMF measurements. Their RF measurement equipment is certified by the FCC for determining RF exposure in the field. Technical descriptions of this equipment and its use in this study are presented in Addendum 1, along with copies of its calibration certificates.

Test Site Selection

True North and C Squared gave significant attention to defining criteria for the test measurement sites at which they would measure exposure and to selecting specific locations that have high packet traffic.

As noted, the consultant team ultimately worked through the OPA to obtain information from CMP that identified suitable test locations for residential meters, extender bridges, and data collectors. Ultimately, three (3) residential locations, including one location selected specifically for interior measurements, two (2)

extender bridges/repeaters, and one (1) data collector were identified, and MPE measurements were taken over a series of days in January, 2013.

To focus the search on those utility meters and AMI system components with the highest levels of transmission activity, the consultant team provided a list of requirements that included both the desired numbers of potential measurement locations of each type, and the stipulation that all utility meters and AMI equipment have above the 99th percentile of packet traffic/dependent meters. CMP asked its contractor, Trilliant, to assist with the identification of potential measurement sites and returned lists of possible locations located in both Portland and Augusta.

The specification provided to CMP deliberately requested the identification of more locations than the consultant team intended to subsequently include as measurement sites in this study. This was done to avoid disclosure of the specific sites of the consultant team's activity to the utility. The OPA also invited the complainants in the investigation to identify one or more candidate locations for this study, however, this invitation was declined.

Because the operation of the mesh network is dynamic, it is not possible, except in cases where a utility meter has no dependents relaying data through it, to establish with certainty the number of dependent meters served, or the number of packets being transmitted through a particular utility meter on any given day. Following discussion with CMP and Trilliant the consultant team relied on network data describing the numbers of residential meters located within a radius of one-half-mile from the location of each Extender Bridge and collector as a proxy for specific information.

Ultimately, two of the residential meter locations included in the results provided in Addendum 1 were chosen directly by the consultant team, wholly without reference to information provided by CMP. One of the meters identified independently by the consultant team was located within one of the areas of greatest meter density in Portland identified by Trilliant and CMP. The other was deliberately located in an area of very low density to reduce the number of nearby RF sources and potentially better isolate the utility meter's signal.

Findings Summary

The RF exposure measurement survey detailed in the report found that the included Smart Meters and associated AMI infrastructure devices produced emissions significantly below the maximum power density exposure levels as outlined by the FCC in the OET Bulletin 65 Ed. 97-01 for the general public.

In the extreme case the survey identified, the highest peak (short duration) percent of Maximum Permissible Exposure (MPE) was 13.4% of the FCC limit, measured near the Smart Meter at location M-1 outside of the Smart Meter's expected period of maximum activity. This reading likely included the RF signals from a number of possible nearby sources. The equivalent time-averaged exposure level would have been 4.6% of the FCC exposure limit for the General Population. See Addendum 1 for additional detail on the relationship between peak and time-averaged exposures.

Selected Glossary

Antenna – a device designed to efficiently convert conducted electrical energy into radiating electromagnetic waves in free space, and vice versa

Averaging Time – the Time. Over Which Exposure Is Averaged to Determine Compliance with Maximum Permissible Exposure (MPE) Standards at a Given Frequency;

Beacon Signal – a very short duration signal sent by a smart meter to indicate their availability to connect to other meters within a mesh network these signals typically occur periodically (hourly) and this may vary depending on conditions within the mesh network and any instructions to transmit data to other meters within the network;

Continuous Exposure – exposure times during exposure to an electromagnetic field that exceeds the typical averaging time: 6 min. for occupational exposure and 30 min. for the general public. Exposure periods of less than the averaging time typically describe short-term exposure;

Decibel (dB) – a dimensionless factor used to compare a measured value of power or signal strength to a reference level, using logarithms to base 10. For example: from a reference level of 1 milliwatt (mW), a 10dB increase in intensity (+10 dB) would be 10 mW; a 20 dB increase would be 100 mW. A decrease of 10 dB (-10 dB) would be 0.1 mW. A value referenced to a signal emitted (or received) by a theoretical antenna that does not have a preferential direction is designated as dB_i, where the "i" designates isotropic or equal strength in all directions;

Effective Isotropic Radiated Power (EIRP) – the apparent transmitted power from a theoretical isotropic antenna transmitting uniformly in all possible directions;

Electric Field Strength – a factor describing the force that an electrical charge has on other charges around it measured in volts per meter (V/m);

Electromagnetic Field – a combination of an electric field and a magnetic field related in a fixed way that can convey electromagnetic energy. And antenna transmitting a signal produces an electromagnetic field;

Gain, Antenna – a description of the ability of an antenna to concentrate signal strength into a directional beam. A laser is an example of a process with high or large gain, since it concentrates energy into a narrow directional beam. Cellular antennas may exhibit gains of 10 dB or more, concentrating signal power by a factor of 10 times in the direction of the main beam, creating an effective radiated power greater than actual transmitter output power. The strength of the antenna's emitted signals will be greatly decreased in other directions, for example behind the antenna. Since it radiates equally in all directions, the gain of a theoretical isotropic antenna is 0 dB;

Maximum Permissible Exposure (MPE) – the average (root mean square) and peak electromagnetic field strength or equivalent power density and the induced and contact currents to which a person may be exposed without harmful effect, including an appropriate safety factor;

Mesh Network – a self-healing network, typically wireless, in which multiple nodes (meters) communicate among themselves and relay data to a central access point. Data pathways within the network are automatically configured and reconfigured to transmit data in the event that a single node fails;

Power Density – is the power per unit area normal to the direction of an electric or magnetic field. This is normally expressed as watts per square meter (W/m^2), or milliwatts or microwatts per square centimeter;

Radiation Pattern – describes the distribution of radiofrequency energy emitted from an antenna in space. Two patterns are used to describe an antenna's radiation pattern: one for the horizontal plane and another for the vertical plane;

Radio Frequency (RF) – typically considered as the frequency range in the electromagnetic spectrum extending from 3 kHz to 300 GHz;

Spatial Average – the average value of power density along a vertical line representing a person's height;

Spectrum Analyzer – an electronic instrument that detects and displays electromagnetic signals occurring within a selected part of the RF spectrum. They typically appear as peaks on a visual display. Spectrum analyzers continuously sweep a given frequency range at a high rate allowing for the detection and observation of intermittent signals, similar to those emitted by smart meters;

Specific Absorption Rate (SAR) – guideline values for human exposure to radiofrequency fields, describing threshold values above which adverse biological effects may occur;

Time-Averaged Exposure – an average of the exposure occurring over a specified time. All scientifically-based RF exposure limits are expressed in terms of time averaged values. For occupational exposures the averaging time is 6 min. and for the general public this is increased to 30 min, making the allowable exposure limit for the general public one-fifth that of the corresponding occupational limit.

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ADDENDUM 1

RADIO FREQUENCY EXPOSURE MEASUREMENTS & FINDINGS

CENTRAL MAINE POWER SMART METER NETWORK

GREATER PORTLAND, ME

JANUARY 2013

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C2Systems

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1. Overview

The purpose of this report is to investigate the exposure levels of radiofrequency (RF) signals transmitting from Central Maine Power Company's Advanced Metering Infrastructure (AMI) Network, herein referred to as "Smart Meter" network. At the request of the Public Advocate Office and True North Associates, C Squared Systems, LLC (C Squared) performed field measurements of CMP's AMI network in and around the Greater Portland, ME area. These field measurements involved a sampling of AMI devices comprising CMP's smart Grid infrastructure including; meters and/or meter banks, repeaters/extender bridges and collectors.

In addition to field measurements of selected AMI meter locations, exposure measurement testing conducted by C Squared included two AMI repeaters and, one AMI collector/extender bridge.[1]

All radiofrequency field measurements were performed using FCC type-accepted and calibrated equipment and were completed during the period January 7 through January 22, 2013.

RF Engineer Conducting Survey	Dan Goulet, C Squared Systems, LLC
Survey Dates:	1/7/2013 through 1/22/2013
Surveys Times (Smart Meters)	Between the hours of 11:50 PM & 1:05AM
Survey Times: Repeater/Collectors	Between the hours of 11:00AM and 2:00PM

Table 1: Survey Summary Information

2. FCC Guidelines for Evaluating RF Radiation Exposure Limits

The FCC general population/uncontrolled limits set the maximum exposure to which most people may be subjected. General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure.

Public exposure to radio frequencies is regulated and enforced in units of milliwatts per square centimeter (mW/cm^2). The general population exposure limits for the various frequency ranges are defined in the attached "FCC Limits for Maximum Permissible Exposure (MPE)"and may be found in Attachment B of this Report.

Higher exposure limits are permitted under the occupational/controlled exposure category, but only for persons who are exposed as a consequence of their employment provided they are fully aware of the potential for exposure, and are able to exercise control over their exposure. General population/uncontrolled limits are five times more stringent than the levels considered acceptable for occupational, or radio frequency trained individuals. Attachment B contains excerpts from OET Bulletin 65 and defines the Maximum Exposure Limit.

[1] The field measurement of AMI repeaters, collectors/extender bridges was not included in the 2012 testing conducted by Exponent Inc.

3. Measurement Equipment & Procedure

Frequencies from 300 KHz to 50 GHz were measured using the Narda Probe EA 5091, E-Field, shaped, FCC probe in conjunction with the NBM550 survey meter. The EA 5091 probe is "shaped" such that in a mixed signal environment (i.e.: more than one frequency band is used in a particular location), it accurately measures the total percent of MPE.

From FCC OET Bulletin No. 65 - Edition 97-01 – "A useful characteristic of broadband probes used in multiple-frequency RF environments is a frequency-dependent response that corresponds to the variation in MPE limits with frequency. Broadband probes having such a "shaped" response permit direct assessment of compliance at sites where RF fields result from antennas transmitting over a wide range of frequencies. Such probes can express the composite RF field as a percentage of the applicable MPEs".

Probe Description - As suggested in FCC OET Bulletin No. 65 - Edition 97-01, the response of the measurement instrument should be essentially isotropic, (i.e., independent of orientation or rotation angle of the probe). For this reason, the Narda EA- 5091 probe was used for these measurements.

Sampling Description – Two types of sampling techniques were used for the AMI mesh network device exposure measurements. **"Spatial Averaging"** was used for exposure measurements taken at repeater, extender-bridge and collector locations. Spatial averaging is the technique used to measure ambient field exposure (E or H), or power density (S) averaged over a number of spatial locations. The measurements are performed by scanning (with a suitable measurement probe) a planar area equivalent to the area occupied by a standing adult human (projected area). In most instances, a simple vertical, scan of the fields along a 2 m high line, through the center of the projected area, is sufficient for determining compliance with the maximum permissible exposures (MPE) values. The NBM 550 survey meter collects time averaged measurements as the user slowly moves the probe vertically over a range of 20 cm (≈ 8 inches) to 200 cm (≈ 6 feet) above ground level. The results recorded at each measurement location include average values over the aforementioned spatial distance.

Instrumentation Information - A summary and specifications for the equipment used is provided in the table below.

Manufacturer	Narda Microwave			
Probe	EA 5091, Serial# 01088			
Calibration Date	December 2012			
Calibration Interval	24 Months			
Meter	NBM550, Serial# B-1149			
Calibration Date	December 2012			
Calibration Interval	24 Months			
Probe Specifications	**Frequency Range**	**Field Measured**	**Standard**	**Measurement Range**
	300 KHz-50 GHz	Electric Field	U.S. FCC 1997 Occupational/Controlled	0.5 – 600 % of Standard

Table 2: Instrumentation Information[2],[3]

For practical purposes and in consideration of the extended duration of each Smart Meter survey, exposure measurements for the meter locations involved a technique called **"Data Logging"**. Data logging is commonly used in scientific experiments and in monitoring systems where there is the need to collect information faster than a human can possibly

[2] Certificates of Calibration for the Narda Meter and EA5091 Probe used in these tests are provided as Attachments C & D of this Report.

[3] Instrument Measurement Uncertainty - The total measurement uncertainty of the NARDA measurement probe and meter is no greater than ±3 dB (0.5% to 6%), ±1dB (6% to 100%), ±2dB (100% to 600%). The factors which contribute to this include the probe's frequency response deviation, calibration uncertainty, ellipse ratio, and isotropic response.[3] Every effort is taken to reduce the overall uncertainty during measurement collection including pointing the probe directly at the likely highest source of emissions.

collect the information and in cases where accuracy is essential. In measuring the Smart Meters the Narda was set to record the Maximum E-Field exposure percentage, in one second intervals, over a specified period. For the data logging tests the EA-5091 Probe was positioned a fixed distance, directly in front of the meter. A test distance of 1 meter (≈ 36 inches) was used for meter bank scenarios, (locations having multiple meters on a single building), and a test distance of 20 cm was used at single meter locations (on a single residence).

4. Smart Meter Location Selection

The Smart Meter locations surveyed were selected to meet two differing criteria. The first criteria was that the meter selected would have a high probability of having at least 2,000 descendants, and therefore a higher than average duty cycle. The second criteria was that the meter selected would be located in an uncongested RF environment, where the presence of nearby RF sources would be less likely, minimizing overall sampling contribution from sources unrelated to the CMP mesh network. In order to meet the first criterion, two meter locations were selected in high density areas of Portland. The first meter bank is located in the Oakdale section of the city and the second meter bank is off of Brighton Avenue, just north of Dougherty Field. Figure 1 below shows the general area in which sites M-1 and M-2 are located.

Figure 1: Meter Survey Locations M-1 and M-2 (Portland Area)

To satisfy the second criterion, a remote and rural residential area of Coastal Maine was selected, where the subject Smart Meter was more likely to have greater isolation from other nearby RF sources. (Reference Figure 2 below.)

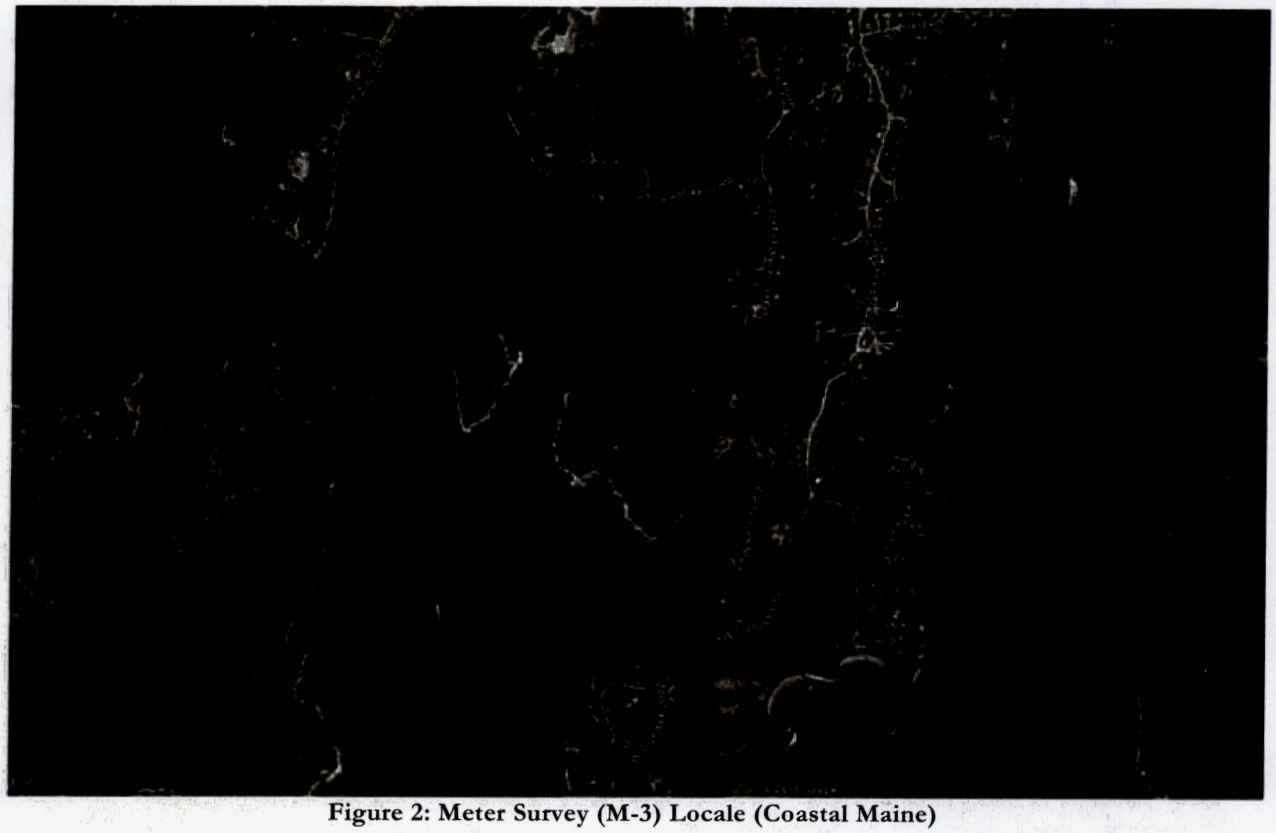

Figure 2: Meter Survey (M-3) Locale (Coastal Maine)

5. AMI Meter Information - Test Set Up & Measurement Results

Described below is the test methodology and survey set-up for each AMI meter location tested (herein referred to as Location M-1 through M-3). Where multiple meters were collocated at a residence, the meter located at the highest above ground level (AGL), relative to the other meters, was selected to be measured.[4] In each case, except where noted, the Narda Broadband Meter and Probe were stationed 36" from the selected meter and adjusted to meet the height of that meter. All meter locations were surveyed between the hours of 11:50PM and 1:10AM, to capture the peak duty cycle period of the Smart Meter and mesh network.

5.1. Location M-1: Meter Information & Measurement Results

Location M-1 was a three meter bank residence in a densely populated area of Portland. Measurements for Location M-1 were performed on January 7-8, 2013, between the hours of 11:50 PM and 1:00 AM. The Narda™ Meter and Probe were positioned 36 inches from the middle meter and, at the same height as the center of the meter (Reference Figure 3 below). Specific information for each of the three meters at this location is presented in Table 3 below, along with a plot of the data logging results for this location showing the measured power density over a period of one hour and ten minutes.

[4] Where this survey was performed without the assistance of CMP, C Squared Systems is not privy to information concerning which meter in any bank of meters is considered the "parent" meter and which meters are "descendants".

Figure 3: Location M-1 Meter Bank & NARDA Test Location

Meter Number	Manufacturer	Model Number	Serial Number	FCC ID	IC	CMP ID
1	Trilliant	RES-3000-FocusAX	NBZB0013448	TMB-G30Focus	6028A-G30Focus	108 086 888
2	Trilliant	RES-3000-FocusAX	NBZB0003280	TMB-G30Focus	6028A-G30Focus	108 086 886
3	Trilliant	RES-3000-FocusAX	NBZB0013413	TMB-G30Focus	6028A-G30Focus	108 086 887

Table 3: Meter Data – Location M-1

Standard procedures for measuring RF exposure and %MPE compliance typically involve spatially averaged measurements during active transmission periods of the RF source(s) under study. In the case of the Smart Meters, the extremely short duration of the pulses and the pulse periods (4.35ms over a 43.5ms time period) make it impractical to perform spatially averaged measurements over a one-hour period. Spatial averaging involves moving the probe in a slow sweeping vertical motion, across a height of 20cm to 200cm AGL (8in. to 6 ft.) at a fixed distance away from the source, for a period of 10 -

15 seconds. Because of duration required in these tests, the Narda Meter was set to data logging mode, capturing and recording Maximum E-Field %MPE records[5] at one second intervals for a period of one hour and 10 minutes.

Figure 4 below is a graph of the % MPE data logged and measured for Location M-1. The exposure measuring device was set to record in one second intervals for a period of one hour and ten minutes. Where the Narda NBM 550 measuring device reports %MPE referenced at Occupational/Controlled Exposure levels, each % Max E-Field STD data record has been manually increased by a multiple of five (5) to adjust the reference to the General Population/Uncontrolled Exposure levels. As reflected in Figure 4, the highest measured %MPE recorded at this location was 13.4% of the FCC limit for General Population/Uncontrolled Exposure. Attachment G shows the 35-second window containing the peak measurement shown in Figure 4 below.

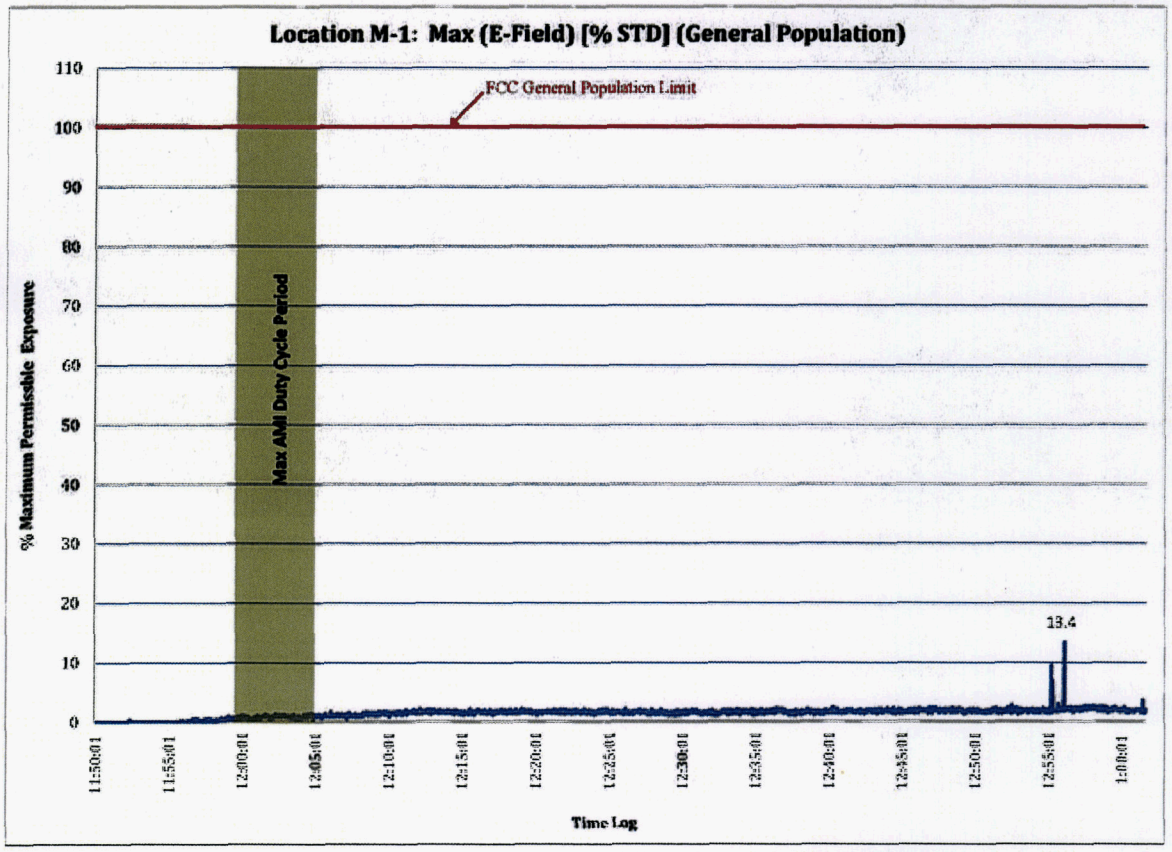

Figure 4: Location M-1 Data Logging Measurement Results

It should be noted that this reading was outside of the time period during which the Smart Meters operate at their maximum duty cycle (green-shaded area in Figure 4) and, that the source of the measurements taken during the test period include any and all potential RF sources in the area within the frequency range of the Narda broadband meter and probe (300 MHz to 50 GHz). Possible sources may include but are not limited to: Wifi, bluetooth, CATV, home security and automobile alarm systems. Therefore, it cannot be assumed that the Smart Meter monitored during this survey was the source of the peak readings reflected in the above graph for this location, or any levels measured during the field tests. [6] The only relative

[5] The data records captured by the Narda NBM 550 are %MPE values based on the FCC limits for Occupational/Controlled Exposure.

[6] While the majority of network broadcast activity occurs between 12:00 and 1:30 AM, information from CMP is that the most likely peak duty cycle period within that timeframe typically occurs between midnight and 12:05 AM. This particular value occurred outside the five minute window of expected maximum activity.

conclusion is that the Smart Meter may be contributing to the overall ambient power density measured. It should also be noted that 802.11b and 82.11g WiFi utilizes the same Industrial Scientific and Medical (ISM) frequency band (2.4 GHz) as the Smart Meter AMI Mesh Network. Figure 4 also shows that the highest %MPE occurred over a maximum period of one second.

5.2. Location M-2: Meter Information & Measurement Results

Location M-2 was a nine-meter bank configuration on an apartment building in a densely populated area of Portland, located approximately one-half mile away from Location M-1. Measurements for Location M-2 were performed on January 8-9, 2013, between the hours of 11:50 PM and 1:00 AM. The Narda™ Meter and Probe were positioned three feet from the Smart Meter designated as Meter 1 in Table 4 below. This particular meter was selected since it was the highest above ground relative to the other meters at this property making it the meter most likely to have the best line-of-sight path to the closest repeater, extender-bridge or collector. (Reference Figure 5 below for the test set up). Specific information for each of the nine Smart Meters at this location is presented below along with a plot of the data logging results for this location showing the measured power density over a period of one hour and ten minutes (Reference Figure 6 below).

Meter Number	Manufacturer	Model Number	Serial Number	FCC ID	IC	CMP ID
1	Trilliant	RES-3000-FocusAX	NBZB0001229	TMB-G30Focus	6028A-G30Focus	108 089 123
2	Trilliant	RES-3000-FocusAX	NBZB0012071	TMB-G30Focus	6028A-G30Focus	108 089 125
3	Trilliant	RES-3000-FocusAX	NBZB0001243	TMB-G30Focus	6028A-G30Focus	108 089 124
4	GE	RES-3000-1210+C	N/A	TMB-G301210	6028A-G301210	53 015 004
5	Trilliant	RES-3000-FocusAX	NBZB0001761	TMB-G30Focus	6028A-G30Focus	108 089 142
6	Trilliant	RES-3000-FocusAX	NBZB0012070	TMB-G30Focus	6028A-G30Focus	108 089 144
7	Trilliant	RES-3000-FocusAX	NBZB0001244	TMB-G30Focus	6028A-G30Focus	108 089 145
8	Trilliant	RES-3000-FocusAX	NBZB0001227	TMB-G30Focus	6028A-G30Focus	108 089 143
9	Trilliant	RES-3000-FocusAX	NBZB0013737	TMB-G30Focus	6028A-G30Focus	108 086 582

Table 4: Meter Data - Location M-2

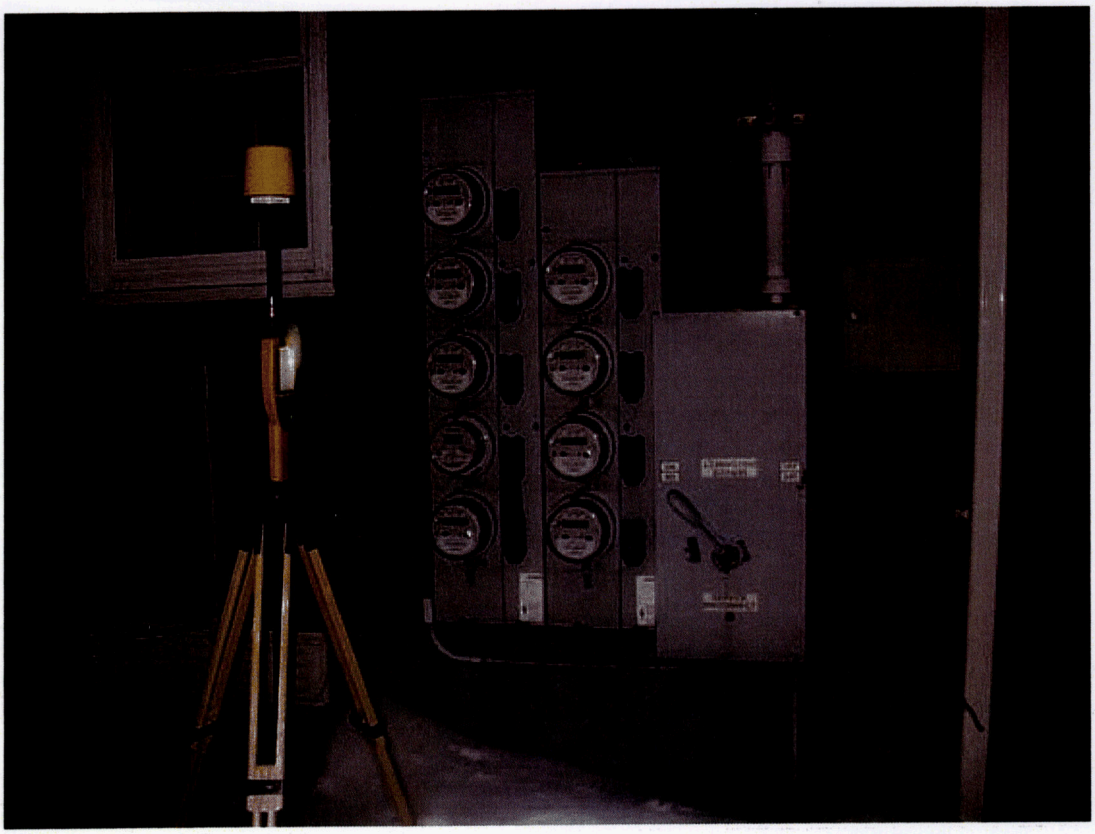

Figure 5: Location M-2 Meter Bank & NARDA Test Location

All % MPE values in the graph below are in reference to the FCC exposure limits for Uncontrolled/General Population. The highest measured %MPE was recorded at 5.39% of the FCC limit. It is important to note that the most reliable operating range of the Narda™ 550 NBM Meter and EA-5091 E-Field Shaped Probe is within the range of 6 to 100% Maximum Permissible Exposure (MPE). Levels below and above this range have varying degrees of linearity dependent upon the exact range of the field measurements. In the case of Location M-2, where the highest recorded reading is less than 6%, the linearity is +/- 3dB.[7]

[7] Reference Narda Safety Test Solutions NBM550 Probe specifications, p.64 http://www.narda-sts.us/pdf_files/DataSheets/NBM-Probes_DataSheet.pdf

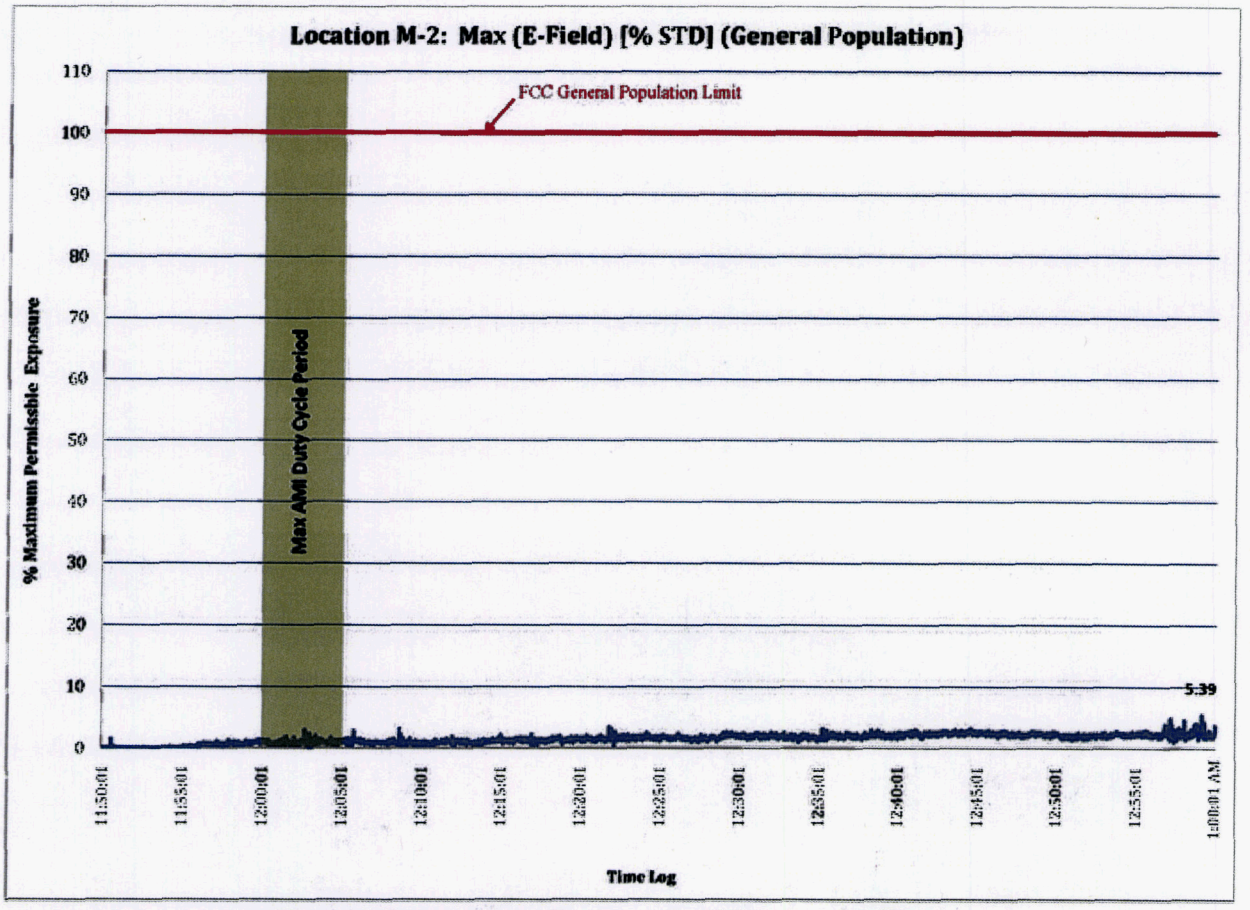

Figure 6: Location M-2 Data Logging Measurement Results

5.3. Location M-3: Meter Information & Measurement Results

To supplement Smart Meter measurements taken at meter bank locations in densely populated areas of Portland, it was decided that additional testing be performed at a single family residence/single meter location and, that these tests would include both exterior and interior measurements. The objective of these supplemental tests was first: to collect worst-case scenario exposure data in an RF environment less likely to have multiple contributing RF sources nearby, (unlike the environment in the urban test locations) and second, to measure RF exposure levels within a residence, at close proximity to the Smart Meter.

Location M-3 is single family residence having a single Smart Meter. The residence is approximately thirty miles away from Locations M-1 and M-2, in a rural area of Coastal Maine. The property owners agreed to allow us to perform interior and exterior measurements, between the hours of 11:50 PM and 1:05 AM, on two different nights.[8]

Exterior measurements for Location M-3 were performed on January 21st and 22nd, between the hours of 11:50 PM and 1:05 AM. For this location, The Narda™ Meter and Probe were positioned at a distance of 20 cm away from the subject Smart Meter, as shown in the Figure 7 below. The reduction in measuring distance from 36" (≈1 meter) to 20 cm was to gather worst-case scenario information of a single Smart Meter in this RF environment. Specific information for the meter at this location is shown below in Table 5.

Manufacturer	Model Number	Serial Number	FCC ID	IC	CMP ID
GE	RES-3000-1210+C	NDEB0399685	TMB-G301210	6028A-G301210	52 971 246

Table 5: Meter Data - Location M-3

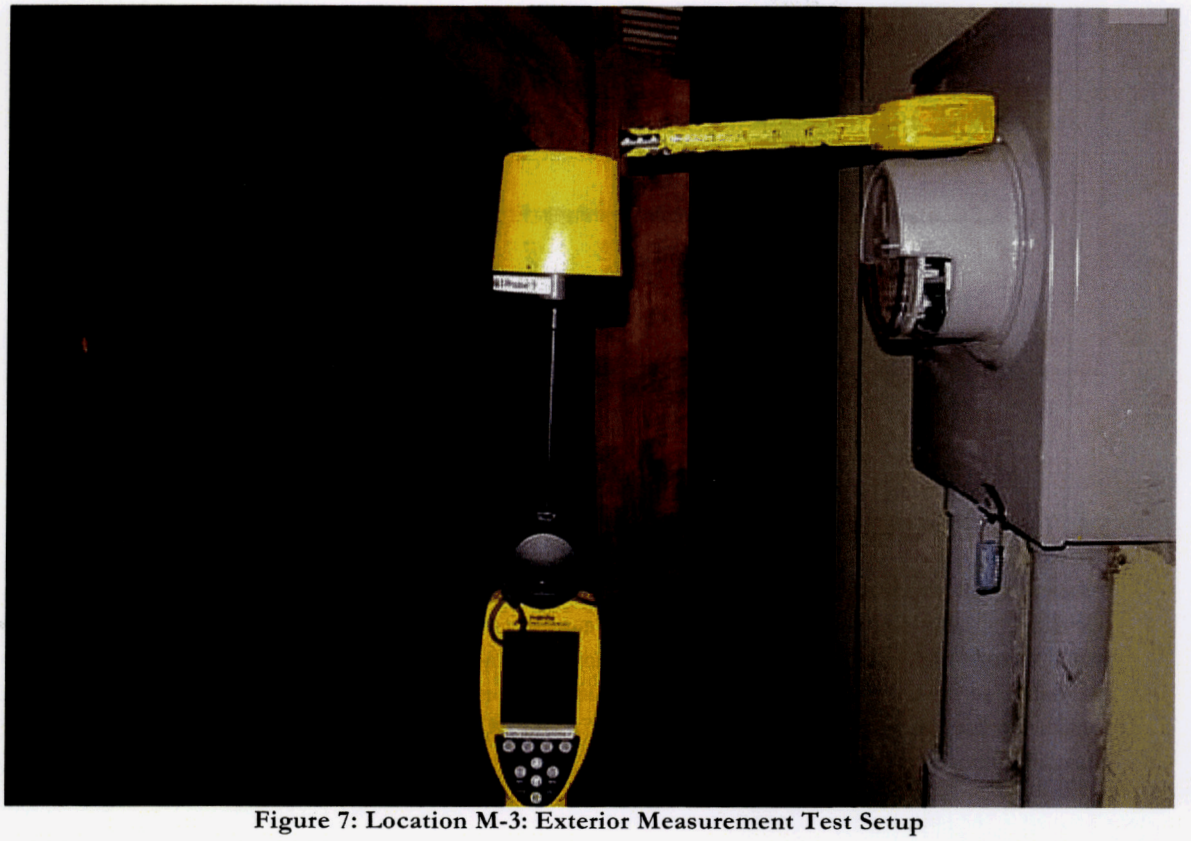

Figure 7: Location M-3: Exterior Measurement Test Setup

[8] In order to perform the tests using the same Narda equipment and test during the same peak duty cycle period of the AMI network (12:00 – 12:05 AM), two nights of testing were required.

Measurements were performed on the 21st and 22nd of January 2013, between the hours of 12:55 AM and 1:05 AM. All % MPE values are in reference to the FCC Uncontrolled/General Population exposure limit. As shown in Figure 8 below, the highest %MPE measured within 20 cm of the Smart Meter was 5.59% of the FCC Uncontrolled/General Population limit.

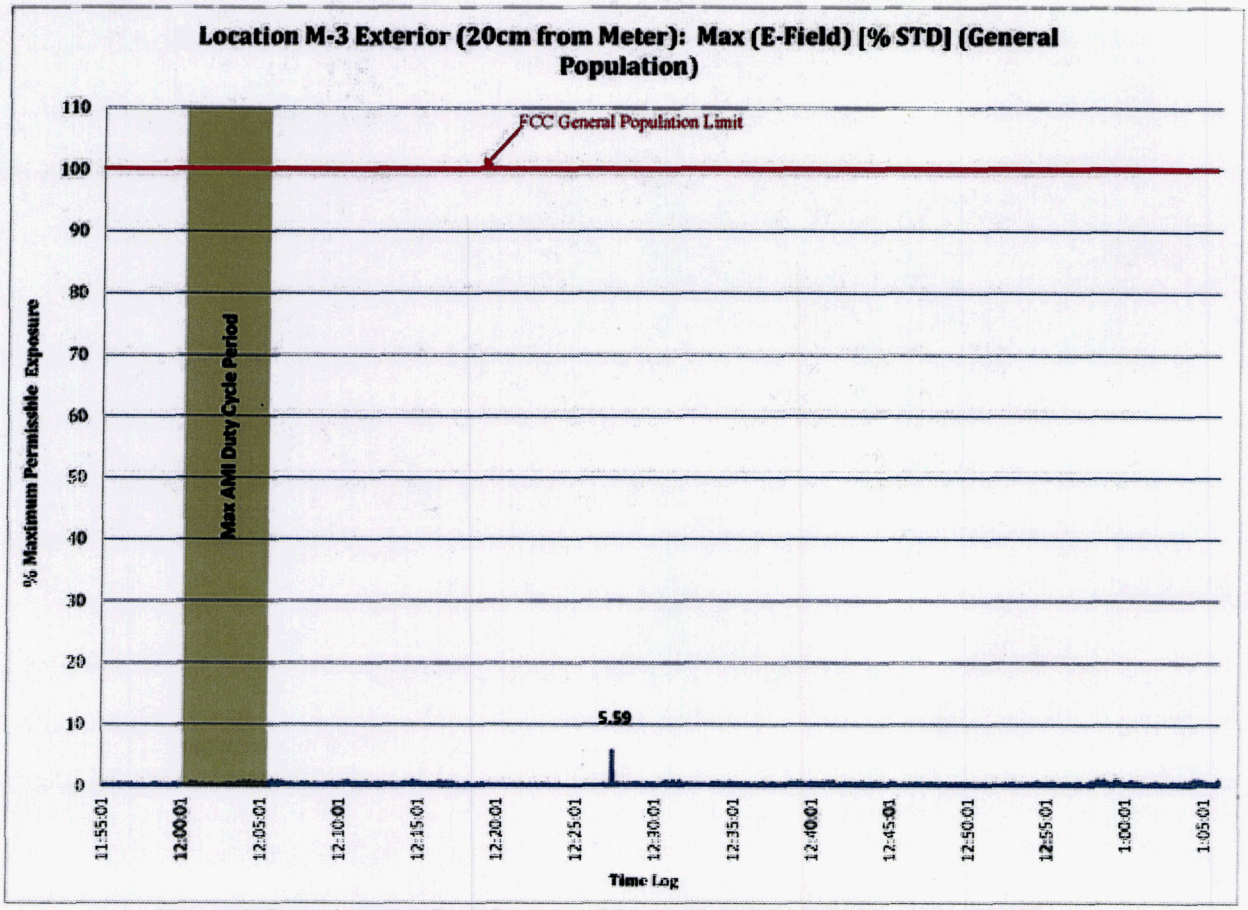

Figure 8: Location M-3 Data Logging Measurement Results (Exterior Readings)

This residence was equipped with multiple wireless devices including but not limited to; a home security system, WiFi, CATV, garage door openers, remote window shade devices, cordless and wireless mobile handsets. For this reason, one should not make the assumption that the maximum %MPE level recoded at 12:27:22 AM (shown in Figure 8) is attributable only to the Smart Meter.

Sample measurements of the ambient RF environment in and around the M-3 residence were taken using a WiSpy 2 Spectrum Analyzer show the presence of channel frequencies outside of the Smart Meter's frequency band. The WiSpy 2 analyzer measures both the magnitude and frequency of any the input signals detected.

As shown in Figure 9 below, the WiSpy 2 device captured channels within the frequency band of the Smart Meters (2.402 – 2.472 GHz) but it also recorded channels outside of the AMI meter's operating band, starting at 2.484 GHz. While these channels are not associated with the AMI Meter network their presence may still contribute to the %MPE levels recorded by the broadband probe of the Narda Meter

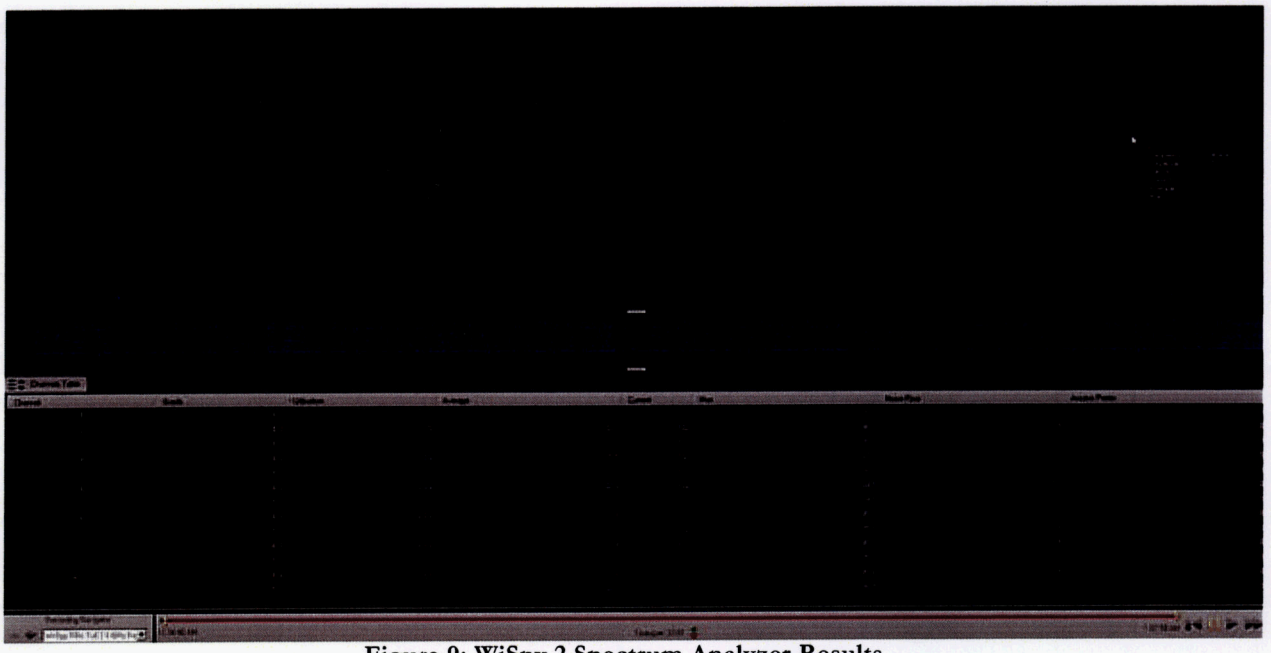

Figure 9: WiSpy 2 Spectrum Analyzer Results

5.4. Location M-3: Interior Meter Testing & Measurement Results

In addition to the exterior measurements performed at Location M-3, measurements were performed inside the residence on a different night but during the same maximum duty cycle period (12:00 AM – 12:05 AM). The Narda Meter and Probe were positioned inside the building, 20 cm from the interior wall at the same height and location of the exterior meter. Figure 10 below is a plot of the readings recorded within the residence.

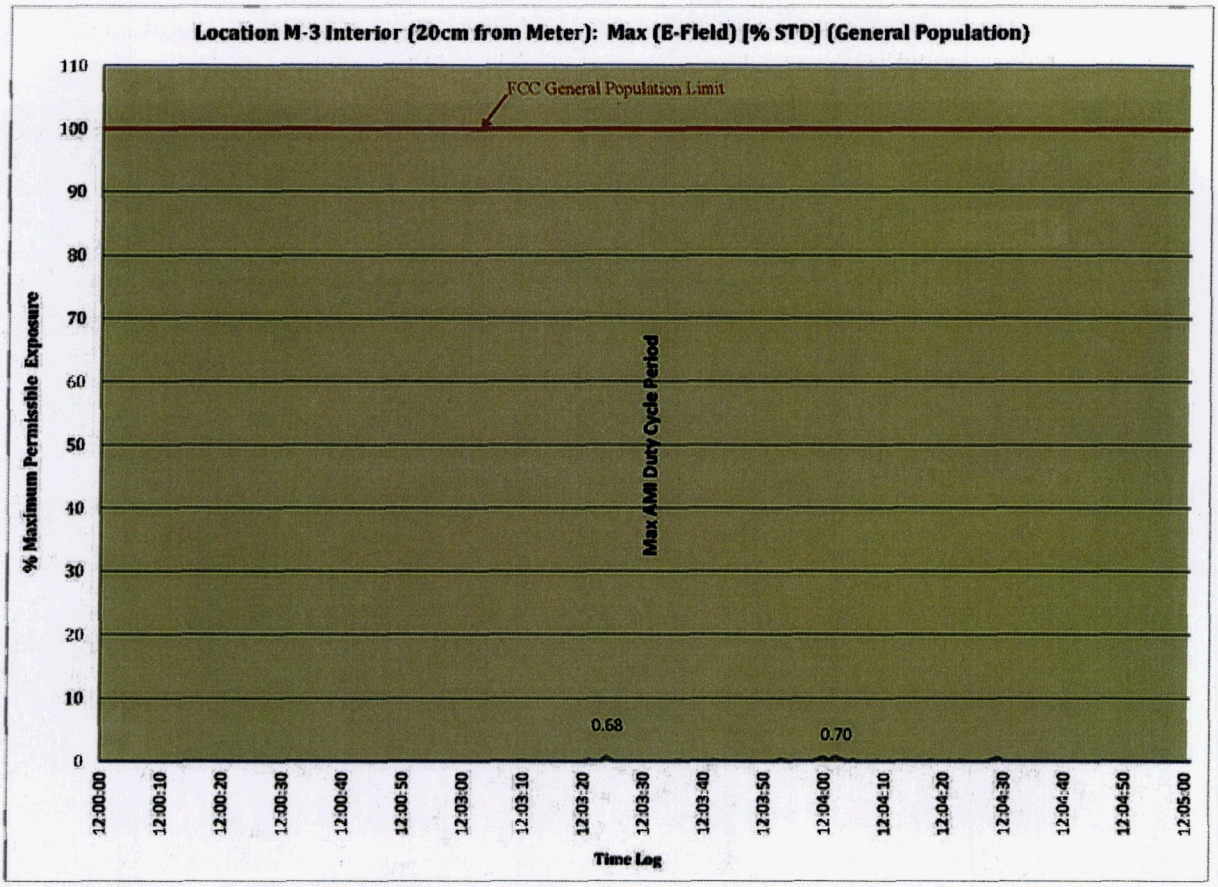

Figure 10: Location M-3 Data Logging Measurement Results (Interior Readings)

Note that the maximum %MPE readings were well below the recommended range of the EA 5091 Probe for optimum linearity (6% - 100%) and well below the less-than-optimal range (0.5% - 6%). Even by doubling the power density to account for the worse-case linearity of the probe at these recorded levels (+/- 3dB when < 6% of the standard), the maximum %MPE inside the building would be 1.4% of the FCC limit for the General Population (0.70 x 2 = 1.4%).[9]

6. Repeater/Extender Bridge and Collector Location Selection, Measurements, and Results

In addition to RF exposure measurements for the Smart Meters, C Squared Systems performed measurements at two repeater locations and one extender bridge/collector location. The repeaters and collectors measured in this testing were selected from a ranking of AMI Mesh Network devices based on the number of meters the devices potentially supported. The two repeaters chosen for the test had over 5,000 meters within a .5 mile of each repeater's location. The extender bridge/collector selected was listed as supporting over 2,000 Smart Meters.

[9] Every +/- 3 dB of probe linearity adjustment equates to doubling or halving of the %MPE. For worse-case scenarios the %MPE is increased by a factor of 2.

The two repeaters selected were in high population areas of Portland and the extender bridge/collector was located in a hybrid commercial/residential area of Westbrook. Figure 11 provides a mapping of these locations.

Figure 11: Repeater and Extender Bridge/Collector Survey Locations

Where CMP provided the initial ranking list but was not consulted in the final selection process, there is no method of confirming the actual number of meters communicating with the repeaters and collectors selected for these tests, hence there is no implied statistical reference concerning the actual number of meters communicating with these devices. These tests were performed in response to concerns raised by the public that exposure measurements of these devices had not previously been conducted.

As discussed earlier in this Report, spatial averaging is the ambient field exposure (E or H), or power density (S) averaged over a number of spatial locations. [10] The averaging occurs across a vertical scan of the E-fields along a 2 meter high line, through the center of the projected area. It is the accepted method for exposure measurements of the ambient environment and appropriately used to collect power density and %MPE levels for the repeaters and collectors.

In the case of the Smart Meters measurements, data logging was the preferred method because of the short duration of the measurement process and the need to keep the measurement devices in a fixed position, relative to the meters and their internal antenna. The objective here was to measure the maximum %MPE at a fixed point from the meters, for a set period, in lieu of averaging spatial locations across a planar area.

The power density and %MPE levels for the repeaters and collectors were more appropriately measured using spatial averaging, the same methodology used industry-wide in measuring RF fields for both the general population and occupational workers exposed to single or multiple RF sources in the environment. Spatial averaging accounts for the distance from any source over the height of the human body, typically measured between 2' and 6' above ground level to account for the average height of any individual. Exposure measurements were made in the vicinity of each repeater and extender bridge/collector shown in Figure 11. Each spatial average measurement was taken for a period of no less than 15 seconds.

For each repeater, extender bridge/collector selected, measurement sample locations were derived based on the AGL centerline of the transmitting antenna on the transmission pole and, the vertical pattern of the transmitting antenna. The purpose of the latter was to ensure that the test measurement points were within the main beam of the device's transmitting antenna and not located within a null of the vertical antenna pattern, thus ensuring a worse-case scenario.

Measurement results and aerial views of the all locations surveyed are shown below. Photographs of each sample point surveyed and the subject AMI device may be found in Attachment E of this report.

[10] As defined in IEEE Std C95.7™-2005:§3.1.46: Different spatial averaging schemes are defined in various standards and guidelines. For frequencies up to 3 GHz, the average of the field strength squared or equivalent power density over an area equivalent to the vertical cross section of the adult human body, as applied to the measurement of electric or magnetic fields in the assessment of whole-body exposure.

6.1. Measured Results – EB-119 Westbrook

Figure 12 below is a mapping of the Westbrook extender bridge/collector and the measurement points surveyed on January 8th between 2:00 and 3:00 PM.

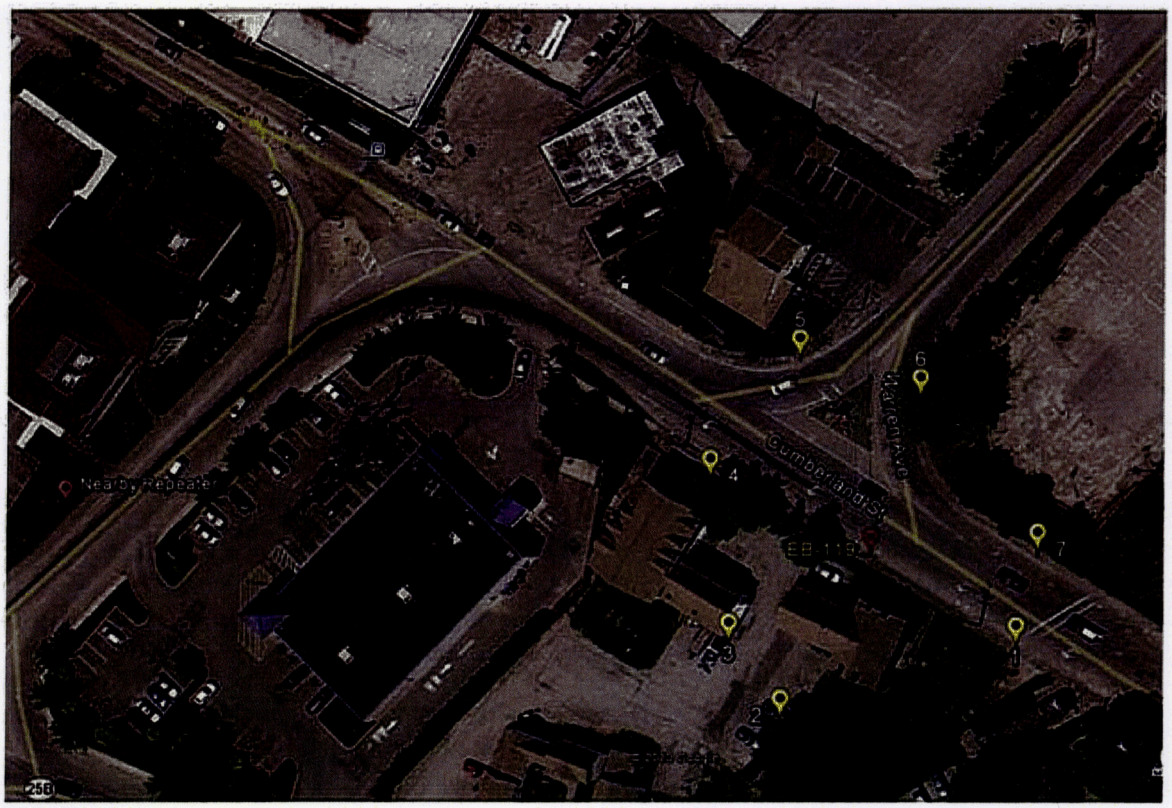

Figure 12: Aerial View of Westbrook Collector and Measurement Locations

Results and a description of each survey location measured for the Westbrook extender bridge/collector are detailed in the table below. It is important to note that there are a number of nearby RF sources in the area that could contribute to the recorded %MPE levels measured in the area of the collector, including the Public Safety antennas on the roof of a neighboring building located within 275' of the collector.

Measurement Point	Latitude	Longitude	Distance to Collector (Ft.)	Ave %MPE Controlled/ Occupational	Ave %MPE Uncontrolled/General
1	43°40'55.64"N	70°20'54.91"W	99'	0.00%	0.02%
2	43°40'54.67"N	70°20'53.86"W	114'	0.00%	0.01%
3	43°40'54.22"N	70°20'54.49"W	84'	0.02%	0.10%
4	43°40'54.79"N	70°20'55.49"W	8'	0.02%	0.10%
5	43°40'54.45"N	70°20'56.28"W	70'	0.01%	0.06%
6	43°40'55.11"N	70°20'56.49"W	88'	0.02%	0.08%
7	43°40'53.61"N	70°20'56.35"W	134'	0.11%	0.53%
8	43°40'55.87"N	70°20'56.28"W	132'	0.03%	0.17%

Table 6: Collector Survey Data – Westbrook, ME

6.2. Measured Results: Repeater #080 (Houlton St.)

Figure 13 below is a mapping of the Houlton St repeater and the surrounding measurement points surveyed on January 9th between 11:00 AM and 12:05 PM.

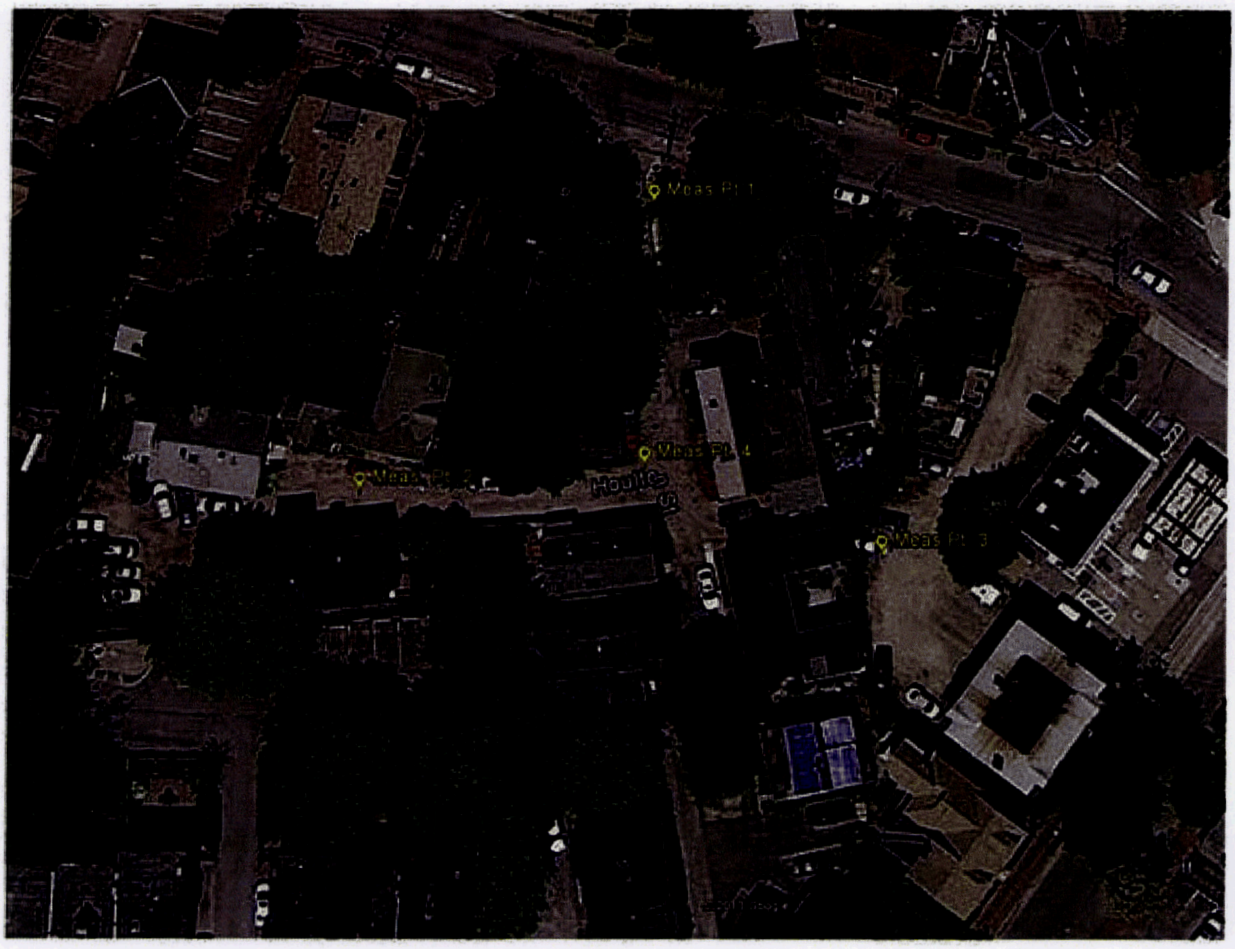

Figure 13: Aerial View of Houlton St Repeater and Measurement Locations

Results and a description of each survey location measured for the Houlton St repeater are detailed in the table below.

Measurement Point	Latitude	Longitude	Distance to Collector (Ft.)	Ave %MPE Controlled/ Occupational	Ave %MPE Uncontrolled/General
1	43°39'06.36"N	70°16'09.38"W	113'	0.00%	0.02%
2	43°39'04.97"N	70°16'11.06"W	116'	0.01%	0.03%
3	43°39'04.98"N	70°16'08.42"W	86'	0.00%	0.02%

Table 7: Repeater PORT01-080 Survey Data – Houlton St

6.3. Measured Results: Repeater #131 (Deering St.)

Figure 14 below is a mapping of the Deering St repeater and the surrounding measurement points surveyed on January 9th between 12:30PAM and 1:00 PM.

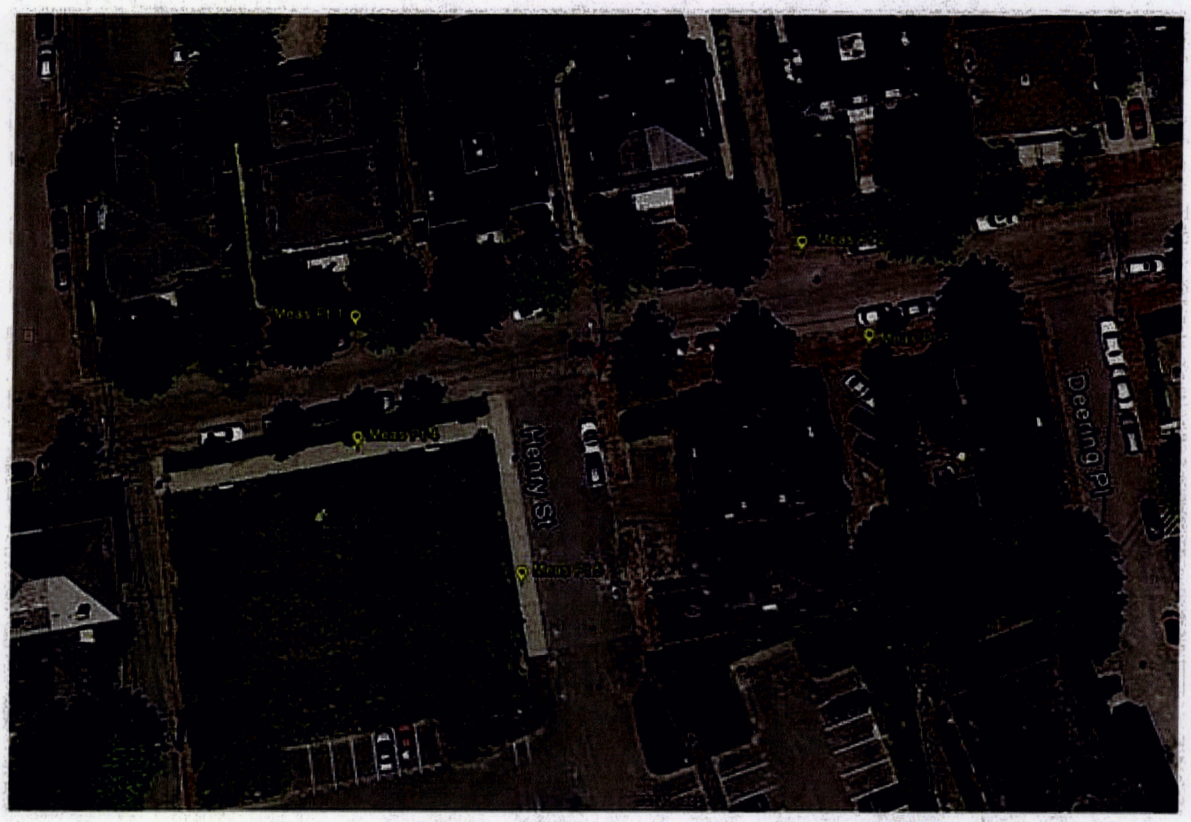

Figure 14: Aerial View of Deering St Repeater and Measurement Locations

Results and a description of each survey location measured for the Deering St repeater are detailed in the table below.

Measurement Point	Latitude	Longitude	Distance to Collector (Ft.)	Ave %MPE Controlled/ Occupational	Ave %MPE Uncontrolled/General
1	43°39'16.33"N	70°15'57.50"W	106'	0.00%	0.00%
2	43°39'16.54"N	70°15'55.53"W	78'	0.03%	0.16%
3	43°39'16.00"N	70°15'54.71"W	108'	0.06%	0.29%
4	43°39'15.63"N	70°15'57.51"W	103'	0.06%	0.28%
5	43°39'15.23"N	70°15'56.55"W	76'	0.05%	0.26%

Table 8: Repeater NCPO1-131 Survey Data – Deering St

6.4. Repeater, Extender Bridge/Collector Measurement Findings

All %MPE levels measured for the repeaters and collectors were found to be well below the lower range of the Narda Meter and Probe (.5% - 6%). Even by doubling the power density to account for the worse-case linearity of the meter at these recorded levels (+/- 3dB when < 6% of the standard), the maximum %MPE measured near any of the repeaters or collector was 1.06% of the FCC limit for the General Population (0.53 x 2 = 1.06%). The latter was recorded at Measurement Point 7 in Westbrook.

7. Summary of Findings

The RF exposure measurement survey completed by this office in January of 2013 verifies that emissions from the Smart Meters and associated AMI infrastructure devices surveyed are well below the maximum power density levels as outlined by the FCC in the OET Bulletin 65 Ed. 97-01 for the General Population/Uncontrolled Exposure. Even when using conservative methods, the cumulative power densities around the devices measured are well below the limits established for the general public. The highest measured ambient Maximum Permissible Exposure near a Smart Meter was **13.4%** of the FCC limit. The same point with averaging applied (as is recommended when measuring exposure levels), would be **4.6%** of the FCC limit. (Reference Max vs. Avg. Graph presented as Figure 16)

This measurement was taken at Location M-1 and occurred outside of the maximum duty cycle of the Smart Meter. There were a number of nearby sources in the area that may have contributed to this higher than average reading, (previously cited within this Report).

RF exposure measurements taken within the main lobe of the transmitting antennas of the repeaters and extender bridge/collectors were found to be below the limits of the Narda Probe and well below the FCC limits for the General Population. The maximum level measured was 0.53% of the General Population/Uncontrolled limit.

8. Statement of Certification

I certify to the best of my knowledge that the statements in this report are true and accurate. The measurement procedures follow guidelines set forth in ANSI/IEEE Std. C95.3, ANSI/IEEE Std. C95.1, ANSI/IEEE Std. C95.7 and FCC OET Bulletin 65 Edition 97-01.

January 25, 2013

Daniel L. Goulet — Date

C Squared Systems, LLC

C2Systems

Attachment A: References

OET Bulletin 65 - Edition 97-01 - August 1997 Federal Communications Commission Office of Engineering & Technology

ANSI C95.1-1982, American National Standard Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz. IEEE-SA Standards Board

IEEE Std C95.3-1991 (Reaff 1997), IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave. IEEE-SA Standards Board

IEEE Std C95.7-2005, IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz. IEEE-SA Standards Board

C2Systems

Attachment B: FCC Limits for Maximum Permissible Exposure (MPE)

(A) Limits for Occupational/Controlled Exposure[11]

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (E) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	($900/f^2$)*	6
30-300	61.4	0.163	1.0	6
300-1500	-	-	f/300	6
1500-100,000	-	-	5	6

(B) Limits for General Population/Uncontrolled Exposure[12]

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (E) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	($180/f^2$)*	30
30-300	27.5	0.073	0.2	30
300-1500	-	-	f/1500	30
1500-100,000	-	-	1.0	30

f = frequency in MHz * Plane-wave equivalent power density

Table 9: FCC Limits for Maximum Permissible Exposure

[11] Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure

[12] General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure.

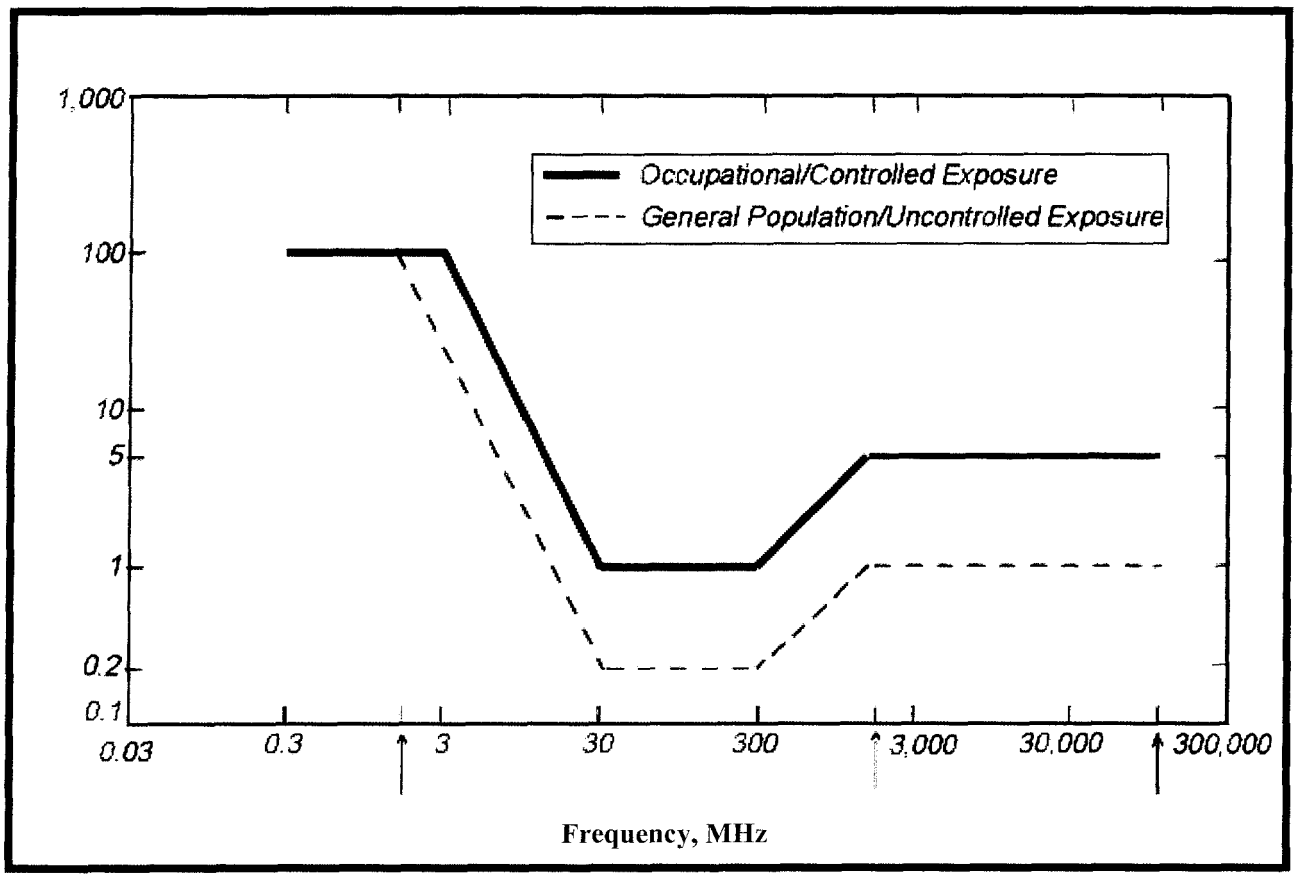

Figure 15: Graph of FCC Limits for Maximum Permissible Exposure (MPE)

C² Systems

Attachment C: Certificate of Calibration - Narda NBM-550 Meter

L3 communications
Narda Microwave-East

Certificate of Calibration

L-3 Communications, Narda Microwave-East, hereby certifies that the referenced instrument has been calibrated by qualified personnel to Narda's approved test procedures.

Furthermore, the instrument meets, or exceeds, all published specifications and the calibration has been performed with test instrumentation that, where applicable, is traceable to the National Institute of Standards and Technology.

Narda's calibration measurements are traceable to the National Institute of Standards and Technology to the extent allowed by the bureau's calibration facilities.

Customer: C SQUARED SYSTEMS LLC
AUBURN, NH 03032

Certificate #: 126539 1

Model #: 2401/01

Serial #: B-1149

Description: NBM-550 METER, BASIC UNIT

PO #: 10004511

Date Calibrated: 12/06/2012

R.O. #: 126539

Hugh Saunders
Hugh Saunders
Test

Ken Peck
Quality Assurance

This certificate shall not be reproduced, except in full, without written approval from L-3 Communications, Narda Microwave-East

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C2 Systems

Attachment D: Certificate of Calibration – FCC EA 5091 Shaped Probe

L3 communications
Narda Microwave-East

Certificate of Calibration

L-3 Communications, Narda Microwave-East, hereby certifies that the referenced instrument has been calibrated by qualified personnel to Narda's approved test procedures.

Furthermore, the instrument meets, or exceeds, all published specifications and the calibration has been performed with test instrumentation that, where applicable, is traceable to the National Institute of Standards and Technology.

Narda's calibration measurements are traceable to the National Institute of Standards and Technology to the extent allowed by the bureau's calibration facilities.

Customer: C SQUARED SYSTEMS LLC
AUBURN, NH 03032

Certificate #: 126539 2

Model #: 2402/07

Serial #: 01088

Description: FCC SHAPED PROBE 300 KHZ-50 G

PO #: 10004511

Date Calibrated: 12/13/2012

R.O. #: 126539

Hugh Saunders
Hugh Saunders
Test

Ken Peck
Quality Assurance

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C2Systems

Attachment E: Survey Photographs

Photo 1: Westbrook Extender Bridge/Collector EB#119

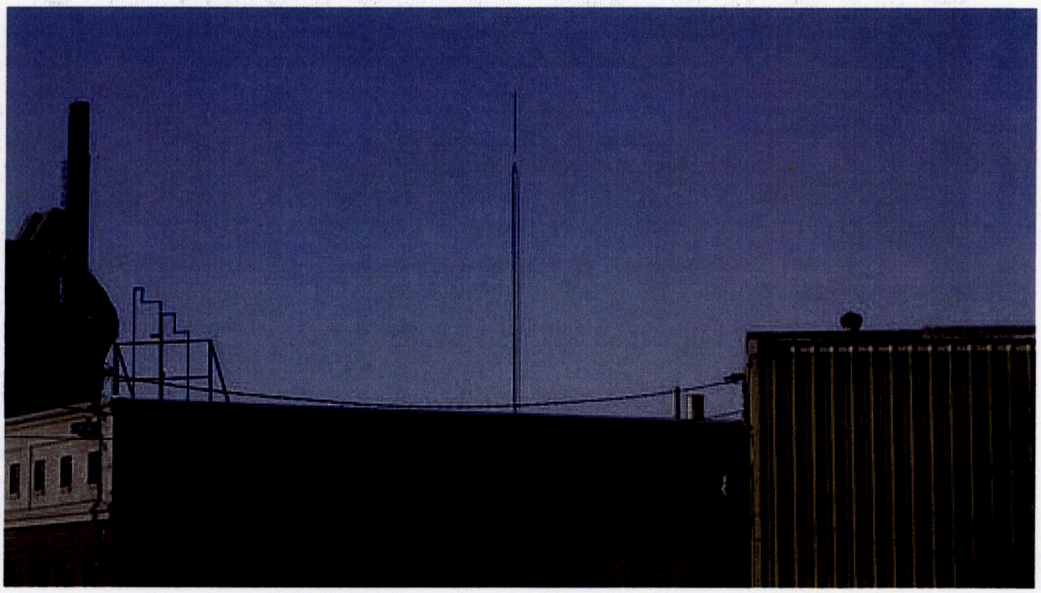

Photo 2: Westbrook Extender Bridge/Collector EB#119 Nearby RF Sources

Photo 3: Deering St Repeater RR#131and Nearby RF Sources

Photo 4: Deering St Smart Meter Bank Near Repeater RR#131

Photo 5: Houlton St Repeater RR#080

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Attachment F: Narda Data Logging Sample Results Location M-1

Time	Max (E-Field)% [Occupational Standard]	Avg (E-Field)% [Occupational Standard]	Max (E-Field)% [General Population]	Avg. (E-Field)% [General Population]
12:55:50	0.3951	0.3348	1.9755	1.674
12:55:51	0.3549	0.3388	1.7745	1.694
12:55:52	0.3817	0.3375	1.9085	1.6875
12:55:53	0.3817	0.3603	1.9085	1.8015
12:55:54	0.4487	0.4045	2.2435	2.0225
12:55:55	0.4018	0.3496	2.009	1.748
12:55:56	0.442	0.3938	2.21	1.969
12:55:57	0.4018	0.3563	2.009	1.7815
12:55:58	0.4018	0.3549	2.009	1.7745
12:55:59	0.4688	0.4018	2.344	2.009
12:56:00	0.4621	0.4112	2.3105	2.056
12:56:01	0.4554	0.3844	2.277	1.922
12:56:02	0.375	0.3134	1.875	1.567
12:56:03	0.375	0.304	1.875	1.52
12:56:04	0.3817	0.3576	1.9085	1.788
12:56:05	0.3817	0.3147	1.9085	1.5735
12:56:06	0.6831	0.4299	3.4155	2.1495
12:56:07	0.3616	0.2987	1.808	1.4935
12:56:08	2.679	0.8799	**13.395**	**4.3995**
12:56:09	0.3951	0.3545	1.9755	1.7725
12:56:10	0.3884	0.3763	1.942	1.8815
12:56:11	0.3817	0.3522	1.9085	1.761
12:56:12	0.4286	0.3616	2.143	1.808
12:56:13	0.3683	0.3455	1.8415	1.7275
12:56:14	0.3951	0.363	1.9755	1.815
12:56:15	0.4554	0.4072	2.277	2.036
12:56:16	0.4286	0.3777	2.143	1.8885
12:56:17	0.4219	0.3924	2.1095	1.962
12:56:18	0.3951	0.3616	1.9755	1.808
12:56:19	0.4889	0.4607	2.4445	2.3035
12:56:20	0.4554	0.4139	2.277	2.0695
12:56:21	0.4085	0.3536	2.0425	1.768
12:56:22	0.4955	0.4018	2.4775	2.009
12:56:23	0.442	0.3951	2.21	1.9755
12:56:24	0.4688	0.4005	2.344	2.0025
12:56:25	0.4152	0.383	2.076	1.915

Table 10: Data Logging Location M-1 (Period: 12:55:50 – 12:56:25)[13]

[13] The %MPE values recorded in this Report were derived by taking the recorded "Max E-Field % Occupational Standard and multiplying it by a factor of 5 to yield the "Max E-Field % General Population Standard" shaded in blue.

C2Systems

Attachment G: Data Log Segment - Location M-1 Max vs. Avg.

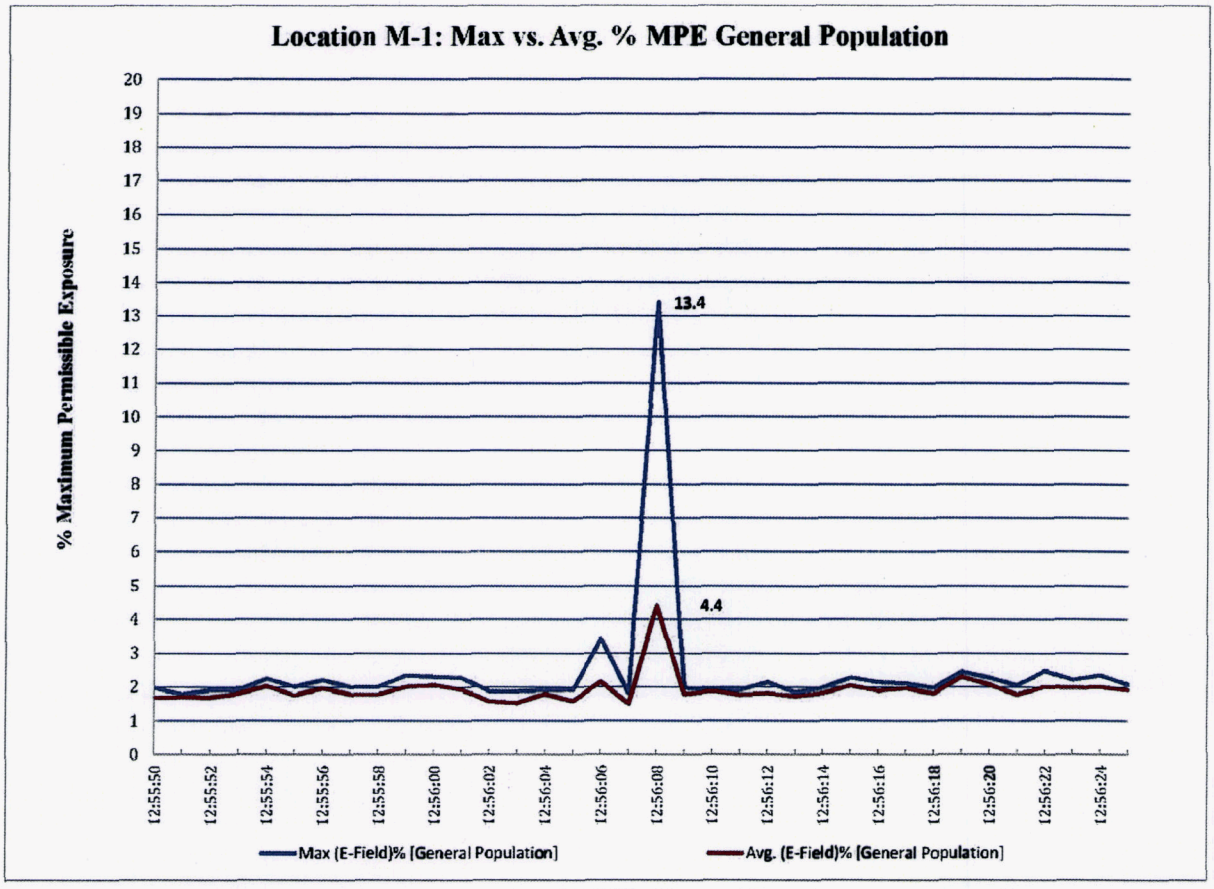

Figure 16: Maximum vs. Average %MPE [General Population Standard][14]

[14] Please note that the range for the maximum value used for the vertical axis of the graph shown in Figure 16 has been decreased from a maximum value of "110" to a maximum value of "20" to provide the resolution needed to view the Max vs. Avg. of the plotted data points.

ATTACHMENT D -

MAINE CDC EXECUTIVE SUMMARY OF REVIEW OF HEALTH ISSUES

MAINE CDC

MAINE CDC EXECUTIVE SUMMARY OF REVIEW OF HEALTH ISSUES RELATED TO SMART METERS
November 8, 2010

Background

On October 25th, 2010 a complaint was filed with the Maine Public Utilities Commission (PUC) focusing on concerns related to health, safety (malfunctioning, shorting out, and igniting), and security (vulnerability to hacking) of smart meters, also known as advanced metering infrastructure. The complaint requests several steps related to the stated health concerns, including asking the PUC for:

- A moratorium on the installation of smart meters, repeaters, nodes, antennas, and related wireless equipment in Maine in order for there to be a "thorough, independent and transparent investigation of the health, safety and security impacts relative to the CMP 'Smart Meter Initiative'";
- A consideration of "scientific, peer-reviewed studies on the safety of Smart Meter mesh networks and the pulsing radiofrequency signals to which the utility seeks to expose Maine families";
- An "opt-out" from smart meters, including for those with electro-sensitivities and other qualifying medical conditions;
- A requirement that CMP accommodate those who "opt out" by ensuring mesh networks and pulsing radiofrequencies "do not permeate their residences at unacceptable and/or unhealthy levels" and to consider creating "safe zones"; and
- An opportunity to hear from national and international experts.

Maine CDC Approach

Since the end of September, Maine CDC has received and reviewed numerous emails and other communications on the issue of smart meters. During October and early November Dr. Mills reviewed numerous materials sent to her by both opponent and proponents of smart meters. She assembled several Maine CDC staff to review these materials. These staff, comprising a "Maine CDC Smart Meters Team" include: Jay Hyland, Andy Smith, ScD, Molly Schwenn, MD, Lauren Ball, DO, MPH, and Nancy Beardsley. Brief descriptions of their credentials are included at the end of this document.

After reviewing the large amount of materials sent to us, the Maine CDC team decided to increasingly focus our reviews on health studies and assessments by government agencies and some affiliated private and academic organizations, including the:

- World Health Organization (WHO),
- U.S. Federal Communications Commission (FCC),
- National Cancer Institute (NCI) in the National Institutes of Health (NIH),
- Health Canada (Canada's public health agency),
- Health Protection Agency of the United Kingdom (U.K.'s public health agency),
- International Commission on Non-Ionizing Radiation Protection (ICNRP),
- Institute of Electrical and Electronics Engineers (IEEE),

- University of Ottawa's McLaughlin Centre for Population Health Risk Assessment,
- Ontario Agency for Health Protection and Promotion,
- Swedish Radiation Protection Authority, and
- Australian Radiation Protection and Nuclear Safety Agency.

A compilation of the summaries of these agencies' studies and assessments is included in the attached document "Smart Meter Review of Government Resources 11 08 10" (referred to as "review document"). These agency reviews focus on the health effects of the radiofrequency (RF) band of non-ionizing radiation, ie frequencies on the EMF (electromagnetic field) spectrum below those of visible light and X-rays, and higher than those of power lines.

Public Statements

Additionally, Dr. Mills received several press calls the past few weeks. Her speaking points with all of them are as follows:

- We (Maine CDC) received information from opponents of smart meters starting the end of September. We received information from CMP about a week later. We are reviewing both sets of information as well as reviewing some peer-reviewed literature and other materials on the matter. We have not had time yet to fully vet these materials, especially because of their volume.

- However, thus far, it appears from the information we have collected and vetted, that smart meters emit non-ionizing radiation, and not the kind that is found in X-Rays (which over-exposure from can change the structure and function of cells).

- It also appears that smart meters emit (non-ionizing) radiation that has a similar frequency and power as that of wireless routers, which many homes now have. And, that smart meters are used at the most about 10% of the time. So, smart meters appear to be similar to having a wireless router on the side of a house that we understand operates about 10% of the time. The frequencies and power of smart meters are also in the range of those found in cordless phones and cell phones. Therefore, there does not seem to be an analogy to having a cell phone tower on the side of one's house, as is reported by some of the emails we have received.

- Some of the same arguments we heard last winter in relation to cell phone use are similar to what we've seen presented with smart meters.

- Although we are commenting on possible health issues related to smart meters, this does not mean we are weighing in on whether or not people should have a choice in having them on their homes. We are also not analyzing the security or safety issues raised by some opponents, as these are not within our areas of expertise.

Brief Summary of Maine CDC's Findings

Our review of these national and international government or government-affiliated assessments indicate a broad consensus that studies to date give no consistent or convincing evidence of a causal relation between RF exposure in the range of frequencies and power used by smart meters and adverse health effects.

We found little information in these assessments that spoke directly about the safety of RF exposure from smart meters. There is, however, much discussion about the safety of mobile phones. Mobile phone use represents an RF exposure qualitatively similar to smart meters in range of frequency, but because the power is higher and typical use results in exposure closer to the body, the resulting exposure to RF appears to be quantitatively much greater than that from smart meters. Thus, it appears to us that the lack of any consistent and convincing evidence of a causal relation between RF exposure from mobile phones and adverse health effects would indicate even less concern for potential health effects from use of smart meters.

Cell Phones

The most comprehensive study to date on cell phones and cancer concerns, called the Interphone study, is an international pooled analysis of data gathered from 13 participating countries that was released in May of 2010 in the *International Journal of Epidemiology* (see relevant excerpts from this study in the accompanying review document).

Interphone researchers reported that overall, cell phone users have no increased risk for two of the most common types of brain tumor - glioma and meningioma. In addition, they found no evidence of increasing risk with progressively increasing number of calls, longer call time, or years since beginning cell phone use. For the small proportion of study participants who reported spending the most total time on cell phone calls, there was some increased risk of glioma, but the researchers and a number of reviewers considered this finding inconclusive because of the limitations resulting from biases and errors in the study. The researchers and most reviewers have noted the lack of data for mobile phone use over time periods longer than 15 years or data on exposure during childhood years, and thus recommend further research of mobile phone use and brain cancer risk.

We also are aware of a very recently published study (this month, November, 2010, see accompanying review document) by the National Cancer Institute (NCI) in the National Institutes of Health looking at brain cancer incidence in the U.S. The NCI study examined trends in brain cancer between 1992 and 2006, a time during which mobile phone subscribers in the U.S. increased from 50 million to nearly 250 million. The investigators concluded, "these incidence data do not provide support to the view that cellular phone use causes brain cancer."

Electromagnetic Hypersensitivity
Several of the national and international assessments included in the accompanying review document discuss electromagnetic hypersensitivity or EHS. The assessments report that a number of studies have been conducted in which EHS individuals were exposed to EMF similar to those that they attributed to the cause of their symptoms, with the aim to elicit symptoms under controlled laboratory conditions. The assessments further state that the majority of studies indicated that EHS individuals cannot detect EMF exposure any more accurately than non-EHS individuals, and that well controlled and conducted double-blind studies have shown that symptoms were not correlated with EMF exposure.

Other Health-Related Issues
Some of the concerns expressed in the complaint filed with PUC related to mesh networks are addressed in the accompanying document labeled "Smart Meter FCC Letter August 2010". This letter from the FCC explains that multiple meters in the same geographical area can only communicate to a controller one at a time, therefore "eliminating the potential for exposure to multiple signals at the same time." The letter goes on to address some concerns related to interference with medical devices.

In the accompanying review document, we have included relevant excerpts from the President's Cancer Panel 2008-2009 report and a link to the entire document. We do not see a "global call for the 'precautionary principle'" related to cell phones, smart meters, or similar technologies as is iterated in the complaint filed with PUC.

Dr. Mills has also been in contact with her colleagues from other states, including New Mexico (since it is cited in the complaint filed with PUC), and has asked the Complainant for the names of any government health official who is concerned about health effects related to smart meter technologies. At this time, Dr. Mills cannot find any state health department or official representing the health department who is taking action or is of the opinion the health department should take action to stop the conversion to smart meters.

Conclusion
In conclusion, our review of these agency assessments and studies do not indicate any consistent or convincing evidence to support a concern for health effects related to the use of radiofrequency in the range of frequencies and power used by smart meters. They also do not indicate an association of EMF exposure and symptoms that have been described as electromagnetic sensitivity.

It should be noted, however, that our review is subject to several limitations related to the complaint filed with PUC.

First, our review focused primarily on assessments and studies conducted by agencies we typically rely on for such work, such as government (U.S. and international governments) or government affiliated institutions. We were unable to review the entire body of literature on the subject of non-ionizing radiation and health because this would be a

massive undertaking for a small public health agency. We therefore are making the assumption that these agency reviews have considered all credible published findings.

Second, the Maine CDC staff involved with this review have not spent their entire careers nor work fulltime in the topic area of health effects of RF radiation.

Third, some of the focus of the complaint filed with the PUC is on safety and security issues, both of which are topics we do not have expertise to analyze.

If further health analysis is desired, we recommend consultation with credible non-biased experts in the fields of non-ionizing radiation pathophysiology, non-ionizing radiation dosimetry, and epidemiology of non-ionizing radiation health effects. The ICNIRP (http://www.icnirp.net/what.htm), FCC, RF-COM at the University of Ottawa (http://www.rfcom.ca/about/index.shtml), and other agencies listed above may provide potential resources for experts on the health issues related to smart meters.

Comparisons of Common Sources of Non-Ionizing Radiation

Item	Frequency in GHz	Power (max) in Watts	Power (average) Watts
Smart meter	2.4	1	0.100
G router	2.4	1	depends on use
N router	2.4 or 5.0	1	depends on use
Cordless Phone	2.4	0.25	0.010
Cell Phone	1.9	3	depends on use
FM Radio Tower	0.1	100,000	100,000
Cell Phone Tower	0.8 to 1.99	48,000	depends on use/loc

GHz = 10^9 Hz

Maine CDC Smart Meters Team

Lauren Ball has a D.O. from the Philadelphia College of Osteopathic Medicine, a Masters of Public Health with a focus on epidemiology and community health from Temple University, a Preventive Medicine Residency from the U.S. CDC, service with the National Center for Environmental Health section of the Epidemic Intelligence Service at the U.S. CDC, and currently serves as the Deputy State Epidemiologist at Maine CDC.

Nancy Beardsley has a degree in geology and has worked in the environmental health field for over 20 years, including working at Maine DEP, directing Maine's Drinking Water Program for 7 years, and directing Maine CDC's Environmental Health Division for the last 3 years.

Jay Hyland has worked in the Maine Radiation Control Program for 22 years (1988), including 13 years as the director. He has a B.S. degree in Engineering Physics with a minor in Chemical Engineering from the University of Maine, and is a Professional Environmental Engineer

Dora Anne Mills has an M.D. from the University of Vermont College of Medicine, a Masters in Public Health from the Harvard School of Public Health, a residency in pediatrics at the Children's Hospital of Los Angeles, and has served as Maine's Public Health Director since 1996.

Molly Schwenn has an M.D. from Stanford University Medical School, did coursework in biostatics and epidemiology from the Harvard School of Public Health, was a postdoctoral fellow in Radiobiology, is a pediatrician (residency at Massachusetts General Hospital), a pediatric oncologist (fellowship at Dana-Farber Cancer Institute), and has a masters in cancer biology. For the last 7 years she has headed Maine CDC's Cancer Registry.

Andy Smith has a doctorate (ScD) and masters (SM) from Harvard School of Public Health in Toxicology and Environmental Health, and has served as Maine's Toxicologist and the Director of Environmental and Occupational Health Programs since 1996.

Government or Government-Affiliated Resources Reviewed on the
HEALTH EFFECTS OF
NON-IONIZING RADIATION
By the Maine CDC
November, 2010

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Introduction to Radiation, HEALTH CANADA, April 2010 23

Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case–control study, May 2010, International Journal of Epidemiology 24

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Electric and Magnetic Fields at Power Frequencies, HEALTH CANADA, April 2010 . 57

Electromagnetic Hypersensitivity, IEEE, 2002 58

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Wireless Technology and Health Outcomes: Evidence and Review, ONTARIO AGENCY FOR HEALTH PROTECTION AND PROMOTION, September, 2010..... 65

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Press Release on Wireless Networks, SWEDISH RADIATION SAFETY AUTHORITY, November 2009..... 69

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Comparisons of Common Sources of Non-Ionizing Radiation

Item	Frequency in GHz	Power (max) in Watts	Power (average) Watts
Smart meter	2.4	1	0.100
G router	2.4	1	depends on use
N router	2.4 or 5.0	1	depends on use
Cordless Phone	2.4	0.25	0.010
Cell Phone	1.9	3	depends on use
FM Radio Tower	0.1	100,000	100,000
Cell Phone Tower	0.8 to 1.99	48,000	depends on use/loc

GHz = 10^9 Hz

RF Safety, FEDERAL COMMUNICATIONS COMMISSION (FCC), August 2010

Frequently asked questions about the safety of radiofrequency (RF) and microwave emissions from transmitters and facilities regulated by the FCC

For further information on these (and other) topics please refer to OET Bulletin 56. You may also contact the FCC's RF Safety Program at rfsafety@fcc.gov or 1-888-225-5322

Index (click on topic below)

- What is "radiofrequency" and microwave radiation?
- What is non-ionizing radiation?
- How is radiofrequency energy used?
- How is radiofrequency radiation measured?
- What biological effects can be caused by RF energy?
- Can people be exposed to levels of radiofrequency radiation and microwaves that could be harmful?
- Can radiofrequency radiation cause cancer?
- What research is being done on RF biological effects?
- What levels are safe for exposure to RF energy?
- Why has the FCC adopted guidelines for RF exposure?
- How safe are mobile phones? Can they cause cancer?
- How can I obtain the specific absorption rate (SAR) value for my mobile phone?
- Do "hands-free" ear pieces for mobile phones reduce exposure to RF emissions? What about mobile phone accessories that claim to shield the head from RF radiation?
- Can mobile phones be used safely in hospitals and near medical telemetry equipment?
- Are cellular and PCS towers and antennas safe?
- Are cellular and other radio towers located near homes or schools safe for residents and students?
- Are emissions from radio and television antennas safe?
- How safe are radio antennas used for paging and "two-way" communications? What about "push-to-talk" radios such as "walkie-talkies?"
- How safe are microwave and satellite antennas?
- Are RF emissions from amateur radio stations harmful?
- What is the FCC's policy on radiofrequency warning signs? For example, when should signs be posted, where should they be located and what should they say?
- Can implanted electronic cardiac pacemakers be affected by nearby RF devices such as microwave ovens or cellular telephones?
- Does the FCC regulate exposure to radiation from microwave ovens, television sets and computer monitors?
- Does the FCC routinely monitor radiofrequency radiation from

antennas?

- Does the FCC maintain a database that includes information on the location and technical parameters of all the towers and antennas it regulates?
- Which other federal agencies have responsibilities related to potential RF health effects?
- Can local and state governmental bodies establish limits for RF exposure?
- Where can I obtain more information on potential health effects of radiofrequency energy?

WHAT ARE "RADIOFREQUENCY" AND MICROWAVE RADIATION?

Electromagnetic radiation consists of waves of electric and magnetic energy moving together (*i.e.*, radiating) through space at the speed of light. Taken together, all forms of electromagnetic energy are referred to as the electromagnetic "spectrum." Radio waves and microwaves emitted by transmitting antennas are one form of electromagnetic energy. They are collectively referred to as "radiofrequency" or "RF" energy or radiation. Note that the term "radiation" does not mean "radioactive." Often, the terms "electromagnetic field" or "radiofrequency field" may be used to indicate the presence of electromagnetic or RF energy.

The RF waves emanating from an antenna are generated by the movement of electrical charges in the antenna. Electromagnetic waves can be characterized by a wavelength and

a frequency. The wavelength is the distance covered by one complete cycle of the electromagnetic wave, while the frequency is the number of electromagnetic waves passing a given point in one second. The frequency of an RF signal is usually expressed in terms of a unit called the "hertz" (abbreviated "Hz"). One Hz equals one cycle per second. One megahertz ("MHz") equals one million cycles per second.

Different forms of electromagnetic energy are categorized by their wavelengths and frequencies. The RF part of the electromagnetic spectrum is generally defined as that part of the spectrum where electromagnetic waves have frequencies in the range of about 3 kilohertz (3 kHz) to 300 gigahertz (300 GHz). Microwaves are a specific category of radio waves that can be loosely defined as radiofrequency energy at frequencies ranging from about 1 GHz upward. (Back to Index)

WHAT IS NON-IONIZING RADIATION?

"Ionization" is a process by which electrons are stripped from atoms and molecules. This process can produce molecular changes that can lead to damage in biological tissue, including effects on DNA, the genetic material of living organisms. This process requires interaction with high levels of electromagnetic energy. Those types of electromagnetic radiation with enough energy to ionize biological material include X-radiation and gamma radiation. Therefore, X-rays and gamma rays are examples of ionizing radiation.

The energy levels associated with RF and microwave radiation, on the other hand, are not great enough to cause the ionization of atoms and molecules, and RF energy is, therefore, is a type of non-ionizing radiation. Other types of non-ionizing radiation include visible and infrared light. Often the term "radiation" is used, colloquially, to imply that ionizing radiation (radioactivity), such as that associated with nuclear power plants, is present. Ionizing radiation should not be confused with the lower-energy, non-ionizing radiation with respect to possible biological effects, since the mechanisms of action are quite different. (Back to Index)

HOW IS RADIOFREQUENCY ENERGY USED?

Probably the most important use for RF energy is in providing telecommunications services. Radio and television broadcasting, cellular telephones, personal communications services (PCS), pagers, cordless telephones, business radio, radio communications for police and fire departments, amateur radio, microwave point-to-point links and satellite communications are just a few of the many telecommunications applications of RF energy. Microwave ovens are an example of a non-communication use of RF energy. Radiofrequency radiation, especially at microwave frequencies, can transfer energy to water molecules. High levels of microwave energy will generate heat in water-rich materials such as most foods. This efficient absorption of microwave energy via water molecules results in rapid heating throughout an object, thus allowing food to be cooked more quickly in a microwave oven than in a conventional oven. Other important non-communication uses of RF energy include radar and industrial heating and

sealing. Radar is a valuable tool used in many applications range from traffic speed enforcement to air traffic control and military surveillance. Industrial heaters and sealers generate intense levels of RF radiation that rapidly heats the material being processed in the same way that a microwave oven cooks food. These devices have many uses in industry, including molding plastic materials, gluing wood products, sealing items such as shoes and pocketbooks, and processing food products. There are also a number of medical applications of RF energy, such as diathermy and magnetic resonance imaging (MRI). (Back to Index)

HOW IS RADIOFREQUENCY RADIATION MEASURED?

An RF electromagnetic wave has both an electric and a magnetic component (electric field and magnetic field), and it is often convenient to express the intensity of the RF environment at a given location in terms of units specific to each component. For example, the unit "volts per meter" (V/m) is used to express the strength of the electric field (electric "field strength"), and the unit "amperes per meter" (A/m) is used to express the strength of the magnetic field (magnetic "field strength"). Another commonly used unit for characterizing the total electromagnetic field is "power density." Power density is most appropriately used when the point of measurement is far enough away from an antenna to be located in the "far-field" zone of the antenna.

Power density is defined as power per unit area. For example, power density is commonly expressed in terms of watts per square meter (W/m2), milliwatts per square centimeter (mW/cm2), or microwatts per square centimeter (μW/cm2). One mW/cm2 equals 10 W/m2, and 100 μW/cm2 equal one W/m2. With respect to frequencies in the microwave range, power density is usually used to express intensity of exposure.

The quantity used to measure the rate at which RF energy is actually absorbed in a body is called the "Specific Absorption Rate" or "SAR." It is usually expressed in units of watts per kilogram (W/kg) or milliwatts per gram (mW/g). In the case of exposure of the whole body, a standing ungrounded human adult absorbs RF energy at a maximum rate when the frequency of the RF radiation is in the range of about 70 MHz. This means that the "whole-body" SAR is at a maximum under these conditions. Because of this "resonance" phenomenon and consideration of children and grounded adults, RF safety standards are generally most restrictive in the frequency range of about 30 to 300 MHz. For exposure of parts of the body, such as the exposure from hand-held mobile phones, "partial-body" SAR limits are used in the safety standards to control absorption of RF energy (see later questions on mobile phones). (Back to Index)

WHAT BIOLOGICAL EFFECTS CAN BE CAUSED BY RF ENERGY?

Biological effects can result from exposure to RF energy. Biological effects that result from heating of tissue by RF energy are often referred to as "thermal" effects. It has been known for many years that exposure to very high levels of RF radiation can be harmful due to the ability of RF energy to heat biological tissue rapidly. This is the principle by which microwave ovens cook food. Exposure to very high RF intensities can result in

heating of biological tissue and an increase in body temperature. Tissue damage in humans could occur during exposure to high RF levels because of the body's inability to cope with or dissipate the excessive heat that could be generated. Two areas of the body, the eyes and the testes, are particularly vulnerable to RF heating because of the relative lack of available blood flow to dissipate the excess heat load.

At relatively low levels of exposure to RF radiation, *i.e.*, levels lower than those that would produce significant heating; the evidence for production of harmful biological effects is ambiguous and unproven. Such effects, if they exist, have been referred to as "non-thermal" effects. A number of reports have appeared in the scientific literature describing the observation of a range of biological effects resulting from exposure to low-levels of RF energy. However, in most cases, further experimental research has been unable to reproduce these effects. Furthermore, since much of the research is not done on whole bodies (*in vivo*), there has been no determination that such effects constitute a human health hazard. It is generally agreed that further research is needed to determine the generality of such effects and their possible relevance, if any, to human health. In the meantime, standards-setting organizations and government agencies continue to monitor the latest experimental findings to confirm their validity and determine whether changes in safety limits are needed to protect human health. (Back to Index)

CAN PEOPLE BE EXPOSED TO LEVELS OF RADIOFREQUENCY RADIATION THAT COULD BE HARMFUL?

Studies have shown that environmental levels of RF energy routinely encountered by the general public are typically far below levels necessary to produce significant heating and increased body temperature. However, there may be situations, particularly in workplace environments near high-powered RF sources, where the recommended limits for safe exposure of human beings to RF energy could be exceeded. In such cases, restrictive measures or mitigation actions may be necessary to ensure the safe use of RF energy. (Back to Index)

CAN RADIOFREQUENCY RADIATION CAUSE CANCER?

Some studies have also examined the possibility of a link between RF exposure and cancer. Results to date have been inconclusive. While some experimental data have suggested a possible link between exposure and tumor formation in animals exposed under certain specific conditions, the results have not been independently replicated. Many other studies have failed to find evidence for a link to cancer or any related condition. The Food and Drug Administration has further information on this topic with respect to RF exposure from mobile phones at the following Web site: www.fda.gov/cellphones/ . (Back to Index)

WHAT RESEARCH IS BEING DONE ON RF BIOLOGICAL EFFECTS?

For many years, research into the possible biological effects of RF energy has been carried out in laboratories around the world, and such research is continuing. Past

research has resulted in a large number of peer-reviewed scientific publications on this topic. For many years the U.S. Government has sponsored research into the biological effects of RF energy. The majority of this work has been funded by the Department of Defense, due in part, to the extensive military interest in using RF equipment such as radar and other relatively high-powered radio transmitters for routine military operations. In addition, some U.S. civilian federal agencies responsible for health and safety, such as the Environmental Protection Agency (EPA) and the U.S. Food and Drug Administration (FDA), have sponsored and conducted research in this area. At the present time, most of the non-military research on biological effects of RF energy in the U.S. is being funded by industry organizations, although relatively more research by government agencies is being carried out overseas, particularly in Europe.

In 1996, the World Health Organization (WHO) established a program called the International EMF Project, which is designed to review the scientific literature concerning biological effects of electromagnetic fields, identify gaps in knowledge about such effects, recommend research needs, and work towards international resolution of health concerns over the use of RF technology. The WHO maintains a Web site that provides extensive information on this project and about RF biological effects and research (www.who.ch/peh-emf).

The FDA, the EPA and other federal agencies responsible for public health and safety have worked together and in connection with the WHO to monitor developments and identify research needs related to RF biological effects. More information about this can be obtained at the FDA Web site: www.fda.gov/cellphones/. (Back to Index)

WHAT LEVELS ARE SAFE FOR EXPOSURE TO RF ENERGY?

Exposure standards for radiofrequency energy have been developed by various organizations and countries. These standards recommend safe levels of exposure for both the general public and for workers. In the United States, the FCC has adopted and used recognized safety guidelines for evaluating RF environmental exposure since 1985. Federal health and safety agencies, such as the EPA, FDA, the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have also been involved in monitoring and investigating issues related to RF exposure.

The FCC guidelines for human exposure to RF electromagnetic fields were derived from the recommendations of two expert organizations, the National Council on Radiation Protection and Measurements (NCRP) and the Institute of Electrical and Electronics Engineers (IEEE). Both the NCRP exposure criteria and the IEEE standard were developed by expert scientists and engineers after extensive reviews of the scientific literature related to RF biological effects. The exposure guidelines are based on thresholds for known adverse effects, and they incorporate prudent margins of safety. In adopting the most recent RF exposure guidelines, the FCC consulted with the EPA, FDA, OSHA and NIOSH, and obtained their support for the guidelines that the FCC is using.

Many countries in Europe and elsewhere use exposure guidelines developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The ICNIRP safety limits are generally similar to those of the NCRP and IEEE, with a few exceptions. For example, ICNIRP recommends somewhat different exposure levels in the lower and upper frequency ranges and for localized exposure due to such devices as hand-held cellular telephones. One of the goals of the WHO EMF Project (see above) is to provide a framework for international harmonization of RF safety standards. The NCRP, IEEE and ICNIRP exposure guidelines identify the same threshold level at which harmful biological effects may occur, and the values for Maximum Permissible Exposure (MPE) recommended for electric and magnetic field strength and power density in both documents are based on this level. The threshold level is a Specific Absorption Rate (SAR) value for the whole body of 4 watts per kilogram (4 W/kg).

In addition, the NCRP, IEEE and ICNIRP guidelines for maximum permissible exposure are different for different transmitting frequencies. This is due to the finding (discussed above) that whole-body human absorption of RF energy varies with the frequency of the RF signal. The most restrictive limits on whole-body exposure are in the frequency range of 30-300 MHz where the human body absorbs RF energy most efficiently when the whole body is exposed. For devices that only expose part of the body, such as mobile phones, different exposure limits are specified (see below).

The exposure limits used by the FCC are expressed in terms of SAR, electric and magnetic field strength and power density for transmitters operating at frequencies from 300 kHz to 100 GHz. The actual values can be found in either of two informational bulletins available at this Web site (OET Bulletin 56 or OET Bulletin 65), see listing for "OET Safety Bulletins." (Back to Index)

WHY HAS THE FCC ADOPTED GUIDELINES FOR RF EXPOSURE?

The FCC authorizes and licenses devices, transmitters and facilities that generate RF radiation. It has jurisdiction over all transmitting services in the U.S. except those specifically operated by the Federal Government. However, the FCC's primary jurisdiction does not lie in the health and safety area, and it must rely on other agencies and organizations for guidance in these matters.

Under the National Environmental Policy Act of 1969 (NEPA), all Federal agencies are required to implement procedures to make environmental consideration a necessary part of an agency's decision-making process. Therefore, FCC approval and licensing of transmitters and facilities must be evaluated for significant impact on the environment. Human exposure to RF radiation emitted by FCC-regulated transmitters is one of several factors that must be considered in such environmental evaluations. In 1996, the FCC revised its guidelines for RF exposure as a result of a multi-year proceeding and as required by the Telecommunications Act of 1996.

Facilities under the jurisdiction of the FCC having a high potential for creating significant RF exposure to humans, such as radio and television broadcast stations, satellite-earth

stations, experimental radio stations and certain cellular, PCS and paging facilities are required to undergo routine evaluation for compliance with RF exposure guidelines whenever an application is submitted to the FCC for construction or modification of a transmitting facility or renewal of a license. Failure to show compliance with the FCC's RF exposure guidelines in the application process could lead to the preparation of a formal Environmental Assessment, possible Environmental Impact Statement and eventual rejection of an application. Technical guidelines for evaluating compliance with the FCC RF safety requirements can be found in the FCC's OET Bulletin 65 (see "OET Safety Bulletins" listing elsewhere at this Web site).

Low-powered, intermittent, or inaccessible RF transmitters and facilities are normally "categorically excluded" from the requirement of routine evaluation for RF exposure. These exclusions are based on calculations and measurement data indicating that such transmitting stations or devices are unlikely to cause exposures in excess of the guidelines under normal conditions of use. The FCC's policies on RF exposure and categorical exclusion can be found in Section 1.1307(b) of the FCC's Rules and Regulations [47 CFR 1.1307(b)]. It should be emphasized, however, that these exclusions are not exclusions from compliance, but, rather, only exclusions from routine evaluation. Transmitters or facilities that are otherwise categorically excluded from evaluation may be required, on a case-by-case basis, to demonstrate compliance when evidence of potential non-compliance of the transmitter or facility is brought to the Commission's attention [see 47 CFR 1.1307(c) and (d)]. (Back to Index)

HOW SAFE ARE MOBILE AND PORTABLE PHONES?

In recent years, publicity, speculation, and concern over claims of possible health effects due to RF emissions from hand-held wireless telephones prompted various research programs to investigate whether there is any risk to users of these devices There is no scientific evidence to date that proves that wireless phone usage can lead to cancer or a variety of other health effects, including headaches, dizziness or memory loss. However, studies are ongoing and key government agencies, such as the Food and Drug Administration (FDA) continue to monitor the results of the latest scientific research on these topics. Also, as noted above, the World Health Organization has established an ongoing program to monitor research in this area and make recommendations related to the safety of mobile phones.

The FDA, which has primary jurisdiction for investigating mobile phone safety, has stated that it cannot rule out the possibility of risk, but if such a risk exists, "it is probably small." Further, it has stated that, while there is no proof that cellular telephones can be harmful, concerned individuals can take various precautionary actions, including limiting conversations on hand-held cellular telephones and making greater use of telephones with hands-free kits where there is a greater separation distance between the user and the radiating antenna. The Web site for the FDA's Center for Devices and Radiological Health provides further information on mobile phone safety: www.fda.gov/cellphones/.

The Government Accounting Office (GAO) prepared a report of its investigation into safety concerns related to mobile phones. The report concluded that further research is needed to confirm whether mobile phones are completely safe for the user, and the report recommended that the FDA take the lead in monitoring the latest research results.

The FCC's exposure guidelines specify limits for human exposure to RF emissions from hand-held mobile phones in terms of Specific Absorption Rate (SAR), a measure of the rate of absorption of RF energy by the body. The safe limit for a mobile phone user is an SAR of 1.6 watts per kg (1.6 W/kg), averaged over one gram of tissue, and compliance with this limit must be demonstrated before FCC approval is granted for marketing of a phone in the United States. Somewhat less restrictive limits, *e.g.*, 2 W/kg averaged over 10 grams of tissue, are specified by the ICNIRP guidelines used in Europe and most other countries.

Measurements and analysis of SAR in models of the human head have shown that the 1.6 W/kg limit is unlikely to be exceeded under normal conditions of use of cellular and PCS hand-held phones. The same can be said for cordless telephones used in the home. Testing of hand-held phones is normally done under conditions of maximum power usage, thus providing an additional margin of safety, since most phone usage is not at maximum power. Information on SAR levels for many phones is available electronically through the FCC's Web site and database (see next question). (Back to Index)

HOW CAN I OBTAIN THE SPECIFIC ABSORPTION RATE (SAR) VALUE FOR MY MOBILE PHONE?

As explained above, the Specific Absorption Rate, or SAR, is the unit used to determine compliance of cellular and PCS phones with safety limits adopted by the FCC. The SAR is a value that corresponds to the rate at which RF energy absorbed in the head of a user of a wireless handset. The FCC requires mobile phone manufacturers to demonstrate compliance with an SAR level of 1.6 watts per kilogram (averaged over one gram of tissue).

Information on SAR for a specific cell phone model can be obtained for almost all cellular telephones by using the FCC identification (ID) number for that model. The FCC ID number is usually printed somewhere on the case of the phone or device. In many cases, you will have to remove the battery pack to find the number. Once you have the number proceed as follows. Go to the following website: Equipment Authorization. Click on the link for "FCC ID Search". Once you are there you will see instructions for inserting the FCC ID number. Enter the FCC ID number (in two parts as indicated: "Grantee Code" is comprised of the first three characters, the "Equipment Product Code" is the remainder of the FCC ID). Then click on "Start Search." The grant(s) of equipment authorization for this particular ID number should then be available. Click on a check under "Display Grant" and the grant should appear. Look through the grant for the section on SAR compliance, certification of compliance with FCC rules for RF exposure or similar language. This section should contain the value(s) for typical or maximum SAR for your phone.

For portable phones and devices authorized since June 2, 2000, maximum SAR levels should be noted on the grant of equipment authorization. For phones and devices authorized between about mid-1998 and June 2000, detailed information on SAR levels is typically found in one of the "exhibits" associated with the grant. Therefore, once the grant is accessed in the FCC database, the exhibits can be viewed by clicking on the appropriate entry labeled "View Exhibit." Electronic records for FCC equipment authorization grants were initiated in 1998, so devices manufactured prior to this date may not be included in our electronic database.

Although the FCC database does not list phones by model number, there are certain non-government Web sites such as www.cnet.com that provide information on SAR from specific models of mobile phones. However, the FCC has not reviewed these sites for accuracy and makes no guarantees with respect to them. In addition to these sites, some mobile phone manufacturers make this information available at their own Web sites. Also, phones certified by the Cellular Telecommunications and Internet Association (CTIA) are now required to provide this information to consumers in the instructional materials that come with the phones.

If you want additional consumer information on safety of cell phones and other transmitting devices please consult the information available below at this Web site. In particular, you may wish to read or download our OET Bulletin 56 (see "OET RF Safety Bulletins" listing) entitled: "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields." If you have any problems or additional questions you may contact us at: rfsafety@fcc.gov or you may call: 1-888-225-5322. You may also wish to consult a consumer update on mobile phone safety published by the U.S. Food and Drug Administration (FDA) that can be found at: www.fda.gov/cellphones/. (Back to Index)

DO "HANDS-FREE" EAR PIECES FOR MOBILE PHONES REDUCE EXPOSURE TO RF EMISSIONS? WHAT ABOUT MOBILE PHONE ACCESSORIES THAT CLAIM TO SHIELD THE HEAD FROM RF RADIATION?

"Hands-free" kits with ear pieces can be used with cell phones for convenience and comfort. In addition, because the phone, which is the source of the RF emissions, will not be placed against the head, absorption of RF energy in the head will be reduced. Therefore, it is true that use of an ear piece connected to a mobile phone will significantly reduce the rate of energy absorption (or "SAR") in the user's head. On the other hand, if the phone is mounted against the waist or other part of the body during use, then that part of the body will absorb RF energy. Even so, mobile phones marketed in the U.S. are required to meet safety limit requirements regardless of whether they are used against the head or against the body. So either configuration should result in compliance with the safety limit. Note that hands-free devices using "Bluetooth" technology also include a wireless transmitter; however, the Bluetooth transmitter operates at a much lower power than the cell phone.

A number of devices have been marketed that claim to "shield" or otherwise reduce RF absorption in the body of the user. Some of these devices incorporate shielded phone cases, while others involve nothing more than a metallic accessory attached to the phone. Studies have shown that these devices generally do not work as advertised. In fact, they may actually increase RF absorption in the head due to their potential to interfere with proper operation of the phone, thus forcing it to increase power to compensate.(Back to Index)

CAN MOBILE PHONES BE USED SAFELY IN HOSPITALS AND NEAR MEDICAL TELEMETRY EQUIPMENT?

The FCC does not normally investigate problems of electromagnetic interference from RF transmitters to medical devices. Some hospitals have policies, which limit the use of cell phones, due to concerns that sensitive medical equipment could be affected. The FDA's Center for Devices and Radiological Health (CDRH) has primary jurisdiction for medical device regulation. FDA staff has monitored this potential problem and more information is available from the CDRH Web site: www.fda.gov/cdrh . (Back to Index)

ARE CELLULAR AND PCS TOWERS AND ANTENNAS SAFE?

Cellular radio services transmit using frequencies between 824 and 894 megahertz (MHz). Transmitters in the Personal Communications Service (PCS) use frequencies in the range of 1850-1990 MHz. Antennas used for cellular and PCS transmissions are typically located on towers, water tanks or other elevated structures including rooftops and the sides of buildings. The combination of antennas and associated electronic equipment is referred to as a cellular or PCS "base station" or "cell site." Typical heights for free-standing base station towers or structures are 50-200 feet. A cellular base station may utilize several "omni-directional" antennas that look like poles, 10 to 15 feet in length, although these types of antennas are less common in urbanized areas.

In urban and suburban areas, cellular and PCS service providers commonly use "sector" antennas for their base stations. These antennas are rectangular panels, *e.g.*, about 1 by 4 feet in size, typically mounted on a rooftop or other structure, but they are also mounted on towers or poles. Panel antennas are usually arranged in three groups of three each. It is common that not all antennas are used for the transmission of RF energy; some antennas may be receive-only.

At a given cell site, the total RF power that could be radiated by the antennas depends on the number of radio channels (transmitters) installed, the power of each transmitter, and the type of antenna. While it is theoretically possible for cell sites to radiate at very high power levels, the maximum power radiated in any direction usually does not exceed 50 watts.

The RF emissions from cellular or PCS base station antennas are generally directed toward the horizon in a relatively narrow pattern in the vertical plane. In the case of sector (panel) antennas, the pattern is fan-shaped, like a wedge cut from a pie. As with

all forms of electromagnetic energy, the power density from the antenna decreases rapidly as one moves away from the antenna. Consequently, ground-level exposures are much less than exposures if one were at the same height and directly in front of the antenna.

Measurements made near typical cellular and PCS installations, especially those with tower-mounted antennas, have shown that ground-level power densities are thousands of times less than the FCC's limits for safe exposure. This makes it extremely unlikely that a member of the general public could be exposed to RF levels in excess of FCC guidelines due solely to cellular or PCS base station antennas located on towers or monopoles.

When cellular and PCS antennas are mounted at rooftop locations it is possible that a person could encounter RF levels greater than those typically encountered on the ground. However, once again, exposures approaching or exceeding the safety guidelines are only likely to be encountered very close to and directly in front of the antennas. For sector-type antennas, RF levels to rear are usually very low. (Back to Index)

For further information on cellular services go to
http://wireless.fcc.gov/services/index.htm?job=service_home&id=cellular

ARE CELLULAR AND OTHER RADIO TOWERS LOCATED NEAR HOMES OR SCHOOLS SAFE FOR RESIDENTS AND STUDENTS?

As discussed above, radiofrequency emissions from antennas used for cellular and PCS transmissions result in exposure levels on the ground that are typically thousands of times below safety limits. These safety limits were adopted by the FCC based on the recommendations of expert organizations and endorsed by agencies of the Federal Government responsible for health and safety. Therefore, there is no reason to believe that such towers could constitute a potential health hazard to nearby residents or students.

Other antennas, such as those used for radio and television broadcast transmissions, use power levels that are generally much higher than those used for cellular and PCS antennas. Therefore, in some cases there could be a potential for higher levels of exposure to persons on the ground. However, all broadcast stations are required to demonstrate compliance with FCC safety guidelines, and ambient exposures to nearby persons from such stations are typically well below FCC safety limits. (Back to Index)

ARE EMISSIONS FROM RADIO AND TELEVISION BROADCAST ANTENNAS SAFE?

Radio and television broadcast stations transmit their signals via RF electromagnetic waves. There are thousands of radio and TV stations on the air in the United States. Broadcast stations transmit at various RF frequencies, depending on the channel, ranging from about 540 kHz for AM radio up to about 800 MHz for UHF television stations. Frequencies for FM radio and VHF television lie in between these two extremes.

Broadcast transmitter power levels range from a few watts to more than 100,000 watts. Some of these transmission systems can be a significant source of RF energy in the local environment, so the FCC requires that broadcast stations submit evidence of compliance with FCC RF guidelines.

The amount of RF energy to which the public or workers might be exposed as a result of broadcast antennas depends on several factors, including the type of station, design characteristics of the antenna being used, power transmitted to the antenna, height of the antenna and distance from the antenna. Note that the power normally quoted for FM and TV broadcast transmitters is the "effective radiated power" or ERP not the actual transmitter power mentioned above. ERP is the transmitter power delivered to the antenna multiplied by the directivity or gain of the antenna. Since high gain antennas direct most of the RF energy toward the horizon and not toward the ground, high ERP transmission systems such as used for UHF-TV broadcast tend to have less ground level field intensity near the station than FM radio broadcast systems with lower ERP and gain values. Also, since energy at some frequencies is absorbed by the human body more readily than at other frequencies, both the frequency of the transmitted signal and its intensity is important. Calculations can be performed to predict what field intensity levels would exist at various distances from an antenna.

Public access to broadcasting antennas is normally restricted so that individuals cannot be exposed to high-level fields that might exist near antennas. Measurements made by the FCC, EPA and others have shown that ambient RF radiation levels in inhabited areas near broadcasting facilities are typically well below the exposure levels recommended by current standards and guidelines. There have been a few situations around the country where RF levels in publicly accessible areas have been found to be higher than those recommended in applicable safety standards. As they have been identified, the FCC has required that stations at those facilities promptly bring their combined operations into compliance with our guidelines. Thus, despite the relatively high operating powers of many broadcast stations, such cases are unusual, and members of the general public are unlikely to be exposed to RF levels from broadcast towers that exceed FCC limits

Antenna maintenance workers are occasionally required to climb antenna structures for such purposes as painting, repairs, or lamp replacement. Both the EPA and OSHA have reported that in such cases it is possible for a worker to be exposed to high levels of RF energy if work is performed on an active tower or in areas immediately surrounding a radiating antenna. Therefore, precautions should be taken to ensure that maintenance personnel are not exposed to unsafe RF fields. (Back to Index)

HOW SAFE ARE RADIO ANTENNAS USED FOR PAGING AND "TWO-WAY" COMMUNICATIONS? WHAT ABOUT "PUSH-TO-TALK" RADIOS SUCH AS "WALKIE-TALKIES?"

"Land-mobile" communications include a variety of communications systems, which require the use of portable and mobile RF transmitting sources. These systems operate in several frequency bands between about 30 and 1000 MHz. Radio systems used by the

police and fire departments, radio paging services and business radio are a few examples of these communications systems. They have the advantage of providing communications links between various fixed and mobile locations.

There are essentially three types of RF transmitters associated with land-mobile systems: base-station transmitters, vehicle-mounted transmitters, and hand-held transmitters. The antennas and power levels used for these various transmitters are adapted for their specific purpose. For example, a base-station antenna must radiate its signal to a relatively large area, and therefore, its transmitter generally has to use higher power levels than a vehicle-mounted or hand-held radio transmitter. Although base-station antennas usually operate with higher power levels than other types of land-mobile antennas, they are normally inaccessible to the public since they must be mounted at significant heights above ground to provide for adequate signal coverage. Also, many of these antennas transmit only intermittently. For these reasons, base-station antennas are generally not of concern with regard to possible hazardous exposure of the public to RF radiation. Studies at rooftop locations have indicated that high-powered paging antennas may increase the potential for exposure to workers or others with access to such sites, *e.g.*, maintenance personnel. This could be a concern especially when multiple transmitters are present. In such cases, restriction of access or other mitigation actions may be necessary.

Transmitting power levels for vehicle-mounted land-mobile antennas are generally less than those used by base-station antennas but higher than those used for hand-held units. Some manufacturers recommend that users and other nearby individuals maintain some minimum distance (*e.g.*, 1 to 2 feet) from a vehicle-mounted antenna during transmission or mount the antenna in such a way as to provide maximum shielding for vehicle occupants. Studies have shown that this is probably a conservative precaution, particularly when the percentage of time an antenna is actually radiating is considered. Unlike cellular telephones, which transmit continuously during a call, two-way radios normally transmit only when the "push-to-talk" button is depressed. This significantly reduces exposure, and there is no evidence that there would be a safety hazard associated with exposure from vehicle-mounted, two-way antennas when the manufacturer's recommendations are followed.

Hand-held "two-way" portable radios such as walkie-talkies are low-powered devices used to transmit and receive messages over relatively short distances. Because of the low power levels used, the intermittency of these transmissions ("push-to-talk"), and due to the fact that these radios are held away from the head, they should not expose users to RF energy in excess of safe limits. Although FCC rules do not require routine documentation of compliance with safety limits for push-to-talk two-way radios as it does for cellular and PCS phones (which transmit continuously during use and which are held against the head), most of these radios are tested and the resulting SAR data are available from the FCC's Equipment Authorization database. Click on the link for "FCC ID Search <imbed hypertext link>.". (Back to Index)

HOW SAFE ARE MICROWAVE AND SATELLITE ANTENNAS?

Point-to-point microwave antennas transmit and receive microwave signals across relatively short distances (from a few tenths of a mile to 30 miles or more). These antennas are usually circular ("dish") or rectangular in shape and are normally mounted on a supporting tower, rooftop, sides of buildings or on similar structures that provide clear and unobstructed line-of-sight paths between both ends of a transmission path. These antennas have a variety of uses, such as relaying long-distance telephone calls, and serving as links between broadcast studios and transmitting sites.

The RF signals from these antennas travel in a directed beam from a transmitting antenna to the receiving antenna, and dispersion of microwave energy outside of this narrow beam is minimal or insignificant. In addition, these antennas transmit using very low power levels, usually on the order of a few watts or less. Measurements have shown that ground-level power densities due to microwave directional antennas are normally thousands of times or more below recommended safety limits. Moreover, microwave tower sites are normally inaccessible to the general public. Significant exposures from these antennas could only occur in the unlikely event that an individual were to stand directly in front of and very close to an antenna for a period of time.

Ground-based antennas used for satellite-earth communications typically are parabolic "dish" antennas, some as large as 10 to 30 meters in diameter, that are used to transmit ("uplink") or receive ("downlink") microwave signals to or from satellites in orbit around the earth. These signals allow delivery of a variety of communications services, including television network programming, electronic newsgathering and point-of-sale credit card transactions. Some satellite-earth station antennas are used only to receive RF signals (*i.e.*, like the satellite television antenna used at a residence), and because they do not transmit, RF exposure is not an issue for those antennas.

Since satellite-earth station antennas are directed toward satellites above the earth, transmitted beams point skyward at various angles of inclination, depending on the particular satellite being used. Because of the longer distances involved, power levels used to transmit these signals are relatively large when compared, for example, to those used by the terrestrial microwave point-to-point antennas discussed above. However, as with microwave antennas, the beams used for transmitting earth-to-satellite signals are concentrated and highly directional, similar to the beam from a flashlight. In addition, public access would normally be restricted at uplink sites where exposure levels could approach or exceed safe limits.

Although many satellite-earth stations are "fixed" sites, portable uplink antennas are also used, *e.g.*, for electronic news gathering. These antennas can be deployed in various locations. Therefore, precautions may be necessary, such as temporarily restricting access in the vicinity of the antenna, to avoid exposure to the main transmitted beam. In general, however, it is unlikely that a transmitting earth station antenna would routinely expose members of the public to potentially harmful levels of RF energy. (Back to Index)

ARE RF EMISSIONS FROM AMATEUR RADIO STATIONS HARMFUL?

There are hundreds of thousands of amateur radio operators ("hams") worldwide. Amateur radio operators in the United States are licensed by the FCC. The Amateur Radio Service provides its members with the opportunity to communicate with persons all over the world and to provide valuable public service functions, such as making communications services available during disasters and emergencies. Like all FCC licensees, amateur radio operators are required to comply with the FCC's guidelines for safe human exposure to RF fields. Under the FCC's rules, amateur operators can transmit with power levels of up to 1500 watts. However, most operators use considerably less power than this maximum. Studies by the FCC and others have shown that most amateur radio transmitters would not normally expose persons to RF levels in excess of safety limits. This is primarily due to the relatively low operating powers used by most amateurs, the intermittent transmission characteristics typically used and the relative inaccessibility of most amateur antennas. As long as appropriate distances are maintained from amateur antennas, exposure of nearby persons should be well below safety limits.

To help ensure compliance of amateur radio facilities with RF exposure guidelines, both the FCC and American Radio Relay League (ARRL) have issued publications to assist operators in evaluating compliance for their stations. The FCC's publication (Supplement B to OET Bulletin 65 can be viewed and downloaded elsewhere at this Web site (see "OET RF Safety Bulletins"). (Back to Index)

WHAT IS THE FCC'S POLICY ON RADIOFREQUENCY WARNING SIGNS? FOR EXAMPLE, WHEN SHOULD SIGNS BE POSTED, WHERE SHOULD THEY BE LOCATED AND WHAT SHOULD THEY SAY?

Radiofrequency warning or "alerting" signs should be used to provide information on the presence of RF radiation or to control exposure to RF radiation within a given area. Standard radiofrequency hazard warning signs are commercially available from several vendors. Appropriate signs should incorporate the format recommended by the Institute for Electrical and Electronics Engineers (IEEE) and as specified in the IEEE standard: IEEE C95.2-1999 (Web address: www.ieee.org). Guidance concerning the placement of signs can be found in IEEE Standard C95.7-2005. When signs are used, meaningful information should be placed on the sign advising affected persons of: (1) the nature of the potential hazard (*i.e.*, high RF fields), (2) how to avoid the potential hazard, and (3) whom to contact for additional information. In some cases, it may be appropriate to also provide instructions to direct individuals as to how to work safely in the RF environment of concern. Signs should be located prominently in areas that will be readily seen by those persons who may have access to an area where high RF fields are present. (Back to Index)

CAN IMPLANTED ELECTRONIC CARDIAC PACEMAKERS BE AFFECTED BY NEARBY RF DEVICES SUCH AS MICROWAVE OVENS OR CELLULAR TELEPHONES?

Over the past several years there has been concern that signals from some RF devices could interfere with the operation of implanted electronic pacemakers and other medical devices. Because pacemakers are electronic devices, they could be susceptible to electromagnetic signals that could cause them to malfunction. Some anecdotal claims of such effects in the past involved emissions from microwave ovens. However, it has never been shown that the RF energy from a properly operating microwave oven is strong enough to cause such interference.

Some studies have shown that mobile phones can interfere with implanted cardiac pacemakers if a phone is used in close proximity (within about 8 inches) of a pacemaker. It appears that such interference is limited to older pacemakers, which may no longer be in use. Nonetheless, to avoid this potential problem, pacemaker patients can avoid placing a phone in a pocket close to the location of their pacemaker or otherwise place the phone near the pacemaker location during phone use. Patients with pacemakers should consult with their physician or the FDA if they believe that they may have a problem related to RF interference. Further information on this is available from the FDA: www.fda.gov/cdrh . (Back to Index)

DOES THE FCC REGULATE EXPOSURE TO THE ELECTROMAGNETIC RADIATION FROM MICROWAVE OVENS, TELEVISION SETS AND COMPUTER MONITORS?

The Commission does not regulate exposure to emissions from these devices. Protecting the public from harmful radiation emissions from these consumer products is the responsibility of the U.S. Food and Drug Administration (FDA). Inquires should be directed to the FDA's Center for Devices and Radiological Health (CDRH), and, specifically, to the CDRH Office of Compliance at (301) 594-4654. (Back to Index)

DOES THE FCC ROUTINELY MONITOR RADIOFREQUENCY RADIATION FROM ANTENNAS?

The FCC does not have the resources or the personnel to routinely monitor the emissions for all of the thousands of transmitters that are subject to FCC jurisdiction. However, the FCC does have measurement instrumentation for evaluating RF levels in areas that may be accessible to the public or to workers. If there is evidence of potential non-compliance with FCC exposure guidelines for an FCC-regulated facility, staff from the FCC's Office of Engineering and Technology or the Enforcement Bureau can conduct an investigation, and, if appropriate, perform actual measurements. It should be emphasized that the FCC does not perform RF exposure investigations unless there is a reasonable expectation that the FCC exposure limits may be exceeded. Potential exposure problems should be brought to the FCC's attention by contacting the FCC at: 1-888-225-5322 or by e-mailing: rfsafety@fcc.gov. (Back to Index)

DOES THE FCC MAINTAIN A DATABASE THAT INCLUDES INFORMATION ON THE LOCATION AND TECHNICAL PARAMETERS OF ALL OF THE TRANSMITTER SITES IT REGULATES?

The Commission does not have a comprehensive, transmitter-specific database for all of the services it regulates. The Commission has information for some services such as radio and television broadcast stations, and many larger antenna towers are required to register with the FCC if they meet certain criteria. In those cases, location information is generally specified in terms of degrees, minutes, and seconds of latitude and longitude. In some services, licenses are allowed to utilize additional transmitters or to increase power without notifying the Commission. Other services are licensed by geographic area, such that the Commission has no knowledge concerning the actual number or location of transmitters within that geographic area.

The *FCC General Menu Reports* (GenMen) search engine unites most of the Commission's licensing databases under a single umbrella. Databases included are the Wireless Telecommunications Bureau's ULS, the Media Bureau's CDBS, COALS (cable data) and BLS, and the International Bureau's IBFS. Entry points or search options in the various databases include frequency, state/county, latitude/longitude, call sign and licensee name.

The FCC also publishes, generally on a weekly basis, bulk extracts of the various Commission licensing databases. Each licensing database has it own unique file structure. These extracts consist of multiple, very large files. OET maintains an index to these databases.

OET has developed a *Spectrum Utilization Study Software* tool-set that can be used to create a Microsoft Access version of the individual exported licensing databases and then create MapInfo "mid" and "mif" files so that radio assignments can be plotted. This experimental software is used to conduct internal spectrum utilization studies needed in the rulemaking process. While the FCC makes this software available to the public, no technical support is provided.

For further information on the Commission's existing databases, please contact Donald Campbell at donald.campbell@fcc.gov or 202-418-2405. (Back to Index)

WHICH OTHER FEDERAL AGENCIES HAVE RESPONSIBILITIES RELATED TO POTENTIAL RF HEALTH EFFECTS?

Certain agencies in the Federal Government have been involved in monitoring, researching or regulating issues related to human exposure to RF radiation. These agencies include the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), the National Telecommunications and Information Administration (NTIA) and the Department of Defense (DOD).

By authority of the Radiation Control for Health and Safety Act of 1968, the Center for Devices and Radiological Health (CDRH) of the FDA develops performance standards for the emission of radiation from electronic products including X-ray equipment, other medical devices, television sets, microwave ovens, laser products and sunlamps. The

CDRH established a product performance standard for microwave ovens in 1971 limiting the amount of RF leakage from ovens. However, the CDRH has not adopted performance standards for other RF-emitting products. The FDA is, however, the lead federal health agency in monitoring the latest research developments and advising other agencies with respect to the safety of RF-emitting products used by the public, such as cellular and PCS phones.

The FDA's microwave oven standard is an emission standard (as opposed to an exposure standard) that allows specific levels of microwave energy leakage (measured at five centimeters from the oven surface). The standard also requires ovens to have two independent interlock systems that prevent the oven from generating microwaves if the latch is released or if the door of the oven is opened. The FDA has stated that ovens that meet its standards and are used according to the manufacturer's recommendations are safe for consumer and industrial use. More information is available from: www.fda.gov/cdrh.

The EPA has, in the past, considered developing federal guidelines for public exposure to RF radiation. However, EPA activities related to RF safety and health are presently limited to advisory functions. For example, the EPA chairs an Inter-agency Radiofrequency Working Group, which coordinates RF health-related activities among the various federal agencies with health or regulatory responsibilities in this area.

OSHA is part of the U.S. Department of Labor, and is responsible for protecting workers from exposure to hazardous chemical and physical agents. In 1971, OSHA issued a protection guide for exposure of workers to RF radiation [29 CFR 1910.97]. However, this guide was later ruled to be only advisory and not mandatory. Moreover, it was based on an earlier RF exposure standard that has now been revised. At the present time, OSHA uses the IEEE and/or FCC exposure guidelines for enforcement purposes under OSHA's "general duty clause" (for more information see: www.osha.gov/SLTC/radiofrequencyradiation/).

NIOSH is part of the U.S. Department of Health and Human Services. It conducts research and investigations into issues related to occupational exposure to chemical and physical agents. NIOSH has, in the past, undertaken to develop RF exposure guidelines for workers, but final guidelines were never adopted by the agency. NIOSH conducts safety-related RF studies through its Physical Agents Effects Branch in Cincinnati, Ohio.

The NTIA is part of the U.S. Department of Commerce and is responsible for authorizing Federal Government use of the RF electromagnetic spectrum. Like the FCC, the NTIA also has NEPA responsibilities and has considered adopting guidelines for evaluating RF exposure from U.S. Government transmitters such as radar and military facilities. (Back to Index)

CAN LOCAL AND STATE GOVERNMENTAL BODIES ESTABLISH LIMITS FOR RF EXPOSURE?

In the United States, some local and state jurisdictions have also enacted rules and regulations pertaining to human exposure to RF energy. However, the Telecommunications Act of 1996 contained provisions relating to federal jurisdiction to regulate human exposure to RF emissions from certain transmitting devices. In particular, Section 704 of the Act states that, "No State or local government or instrumentality thereof may regulate the placement, construction, and modification of personal wireless service facilities on the basis of the environmental effects of radio frequency emissions to the extent that such facilities comply with the Commission's regulations concerning such emissions." Further information on FCC policy with respect to facilities siting is available from the FCC's Wireless Telecommunications Bureau (see http://wireless.fcc.gov/siting/). (Back to Index)

WHERE CAN I OBTAIN MORE INFORMATION ON POTENTIAL HEALTH EFFECTS OF RADIOFREQUENCY ENERGY?

Although relatively few offices or agencies within the Federal Government routinely deal with the issue of human exposure to RF fields, it is possible to obtain information and assistance on certain topics from the following federal agencies, all of which also have Internet Web sites.

FDA: For information about radiation from microwave ovens and other consumer and industrial products contact: Center for Devices and Radiological Health (CDRH), Food and Drug Administration. [http://www.fda.gov/cdrh/radhealth/]

EPA: The Environmental Protection Agency's Office of Radiation Programs is responsible for monitoring potential health effects due to public exposure to RF fields. Contact: Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C. 20460, (202) 564-9235. [Click on EPA's website: Frequent Questions on EMF, RF, & Other Nonionizing Radiation]

OSHA: The Occupational Safety and Health Administration's (OSHA) Health Response Team has been involved in studies related to occupational exposure to RF radiation. [http://www.osha.gov/SLTC/radiation_nonionizing/index.html]

NIOSH: The National Institute for Occupational Safety and Health (NIOSH) conducts research on RF-related safety issues in workplaces and recommends measures to protect worker health. Contact: NIOSH, Engineering and Physical Hazards Branch, Mail Stop R-5, 4676 Columbia Parkway, Cincinnati, Ohio 45226, or phone 1-513-841-4221. Toll-free public inquiries: 1-800-CDC-INFO (1-800-232-4636), or by email: cdcinfo@cdc.gov. Internet information on workplace RF safety: http://www.cdc.gov/niosh/topics/emf/#rffields.

NCI: The National Cancer Institute, part of the U.S. National Institutes of Health, conducts and supports research, training, health information dissemination, and other programs with respect to the cause, diagnosis, prevention, and treatment of cancer. Contact: NCI Public Inquiries Office, 6116 Executive Boulevard, Room 3036A,

Bethesda, MD 20892-8322.
[http://www.cancer.gov/cancertopics/factsheet/Risk/cellphones]

Toll-free number: 1-800-4-CANCER (1-800-422-6237).

FCC: Questions regarding potential RF hazards from FCC-regulated transmitters can be directed to the Federal Communications Commission, Consumer & Governmental Affairs Bureau, 445 12th Street, S.W., Washington, D.C. 20554; Phone: 1-888-225-5322; E-mail: rfsafety@fcc.gov; or go to: www.fcc.gov/oet/rfsafety.

In addition to federal government agencies, there are other sources of information regarding RF energy and health effects. Some states and localities maintain non-ionizing radiation programs or, at least, some expertise in this field, usually in a department of public health or environmental control. The following table lists some representative Internet Web sites that provide information on this topic. However, the FCC neither endorses nor verifies the accuracy of any information provided at these sites. They are being provided for information only. (Back to Index)

- **Bioelectromagnetics Society:** http://www.bioelectromagnetics.org/
- **EPA's RadTown USA:** http://www.epa.gov/radtown/basic.html
- **International Commission on Non-Ionizing Radiation Protection (ICNIRP Europe):** http://www.icnirp.de/
- **IEEE Committee on Man & Radiation**: http://ewh.ieee.org/soc/embs/comar/
- **Microwave News:** http://www.microwavenews.com/
- **National Council on Radiation Protection & Measurements:** http://www.ncrponline.org/
- **NJ Dept Radiation Protection:** http://www.nj.gov/dep/rpp/nrs/index.htm
- **RFcom (Canada):** http://www.rfcom.ca/welcome/index.shtml
- **Wireless Industry (CTIA):** http://www.ctia.org/
- **World Health Organization (WHO):** http://www.who.ch/peh-emf
- **Germany's EMF Portal:** http://www.emf-portal.de/

For more information on this topic please note:

OET Bulletin 56*: Questions and Answers About the Biological Effects and Potential Hazards of Radiofrequency Radiation.*

Introduction to Radiation, HEALTH CANADA, April 2010

http://www.phac-aspc.gc.ca/publicat/cdic-mcc/29-1-supp/ar_02-eng.php

Radiation is energy in the form of particles or electromagnetic waves. Based on the effects it can produce in matter, two classes of radiation have been defined: ionizing and non-ionizing.[1a] Ionizing radiation has sufficient energy to remove electrons from atoms and break atomic bonds. Both classes can alter the genetic material (DNA) of a cell. Approximately 80% of our exposure to ionizing radiation is from *natural* sources, usually at very low dose rates, such as cosmic rays and naturally occurring radioactive elements in the Earth's crust and air.[2a] Most of the *artificial* (man-made) radionuclides (unstable nuclei of atoms) released into the global environment have come from nuclear weapons tests. Other artificial sources of ionizing radiation include nuclear facilities, uranium mines, mills and plants and X ray devices.

Non-ionizing radiation has lower energy than ionizing radiation and does not ordinarily have enough intensity to endanger living things from acute exposure. Exposure to non-ionizing radiation includes ultraviolet radiation (UVR) from the sun, radiofrequency radiation (radar, radio and television towers, mobile telephones) and extremely low frequency electric and magnetic fields (ELF EMF) from electrical wires and appliances. Although a portion of the ultraviolet spectrum has sufficient energy to ionize atoms, it is traditionally considered a non-ionizing form of radiation. Human exposure to ELF EMF has risen dramatically this century because of our increasing use of electricity, giving rise to concerns about the effects of long-term exposures. Also, over the past few years, the ozone layer—a thin veil of gas in the atmosphere that screens out harmful solar UVR—has become thinner, resulting in slightly more of the sun's harmful radiation reaching the Earth's surface.[3]

Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case–control study, May 2010, International Journal of Epidemiology

http://ije.oxfordjournals.org/content/39/3/675.full

Excerpts from the Interphone Study:

Background The rapid increase in mobile telephone use has generated concern about possible health risks related to radiofrequency electromagnetic fields from this technology.

Methods An interview-based case–control study with 2708 glioma and 2409 meningioma cases and matched controls was conducted in 13 countries using a common protocol.

Results A reduced odds ratio (OR) related to ever having been a regular mobile phone user was seen for glioma [OR 0.81; 95% confidence interval (CI) 0.70–0.94] and meningioma (OR 0.79; 95% CI 0.68–0.91), possibly reflecting participation bias or other methodological limitations. No elevated OR was observed ≥10 years after first phone use (glioma: OR 0.98; 95% CI 0.76–1.26; meningioma: OR 0.83; 95% CI 0.61–1.14). ORs were <1.0 for all deciles of lifetime number of phone calls and nine deciles of cumulative call time. In the 10th decile of recalled cumulative call time, ≥1640 h, the OR was 1.40

(95% CI 1.03–1.89) for glioma, and 1.15 (95% CI 0.81–1.62) for meningioma; but there are implausible values of reported use in this group. ORs for glioma tended to be greater in the temporal lobe than in other lobes of the brain, but the CIs around the lobe-specific estimates were wide. ORs for glioma tended to be greater in subjects who reported usual phone use on the same side of the head as their tumour than on the opposite side.

Conclusions Overall, no increase in risk of glioma or meningioma was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation.

Introduction

Mobile phone use has increased dramatically in many countries since its introduction in the early-to-mid 1980s. The expanding use of this technology has been accompanied by concerns about health and safety. In the late 1990s, several expert groups critically reviewed the evidence on health effects of low-level exposure to radiofrequency (RF) electromagnetic fields, and recommended research into the possible adverse health effects of mobile telephony.[1–4] As a result, the International Agency for Research on Cancer (IARC) coordinated a feasibility study in 1998 and 1999, which concluded that an international study of the relationship between mobile phone use and brain tumour risk would be feasible and informative.[5,6]

INTERPHONE was therefore initiated as an international set of case–control studies focussing on four types of tumours in tissues that most absorb RF energy emitted by mobile phones: tumours of the brain (glioma and meningioma), acoustic nerve (schwannoma) and parotid gland. The objective was to determine whether mobile phone use increases the risk of these tumours and, specifically, whether RF energy emitted by mobile phones is tumourigenic.

This article presents the results of analyses of brain tumour risk in relation to mobile phone use in all INTERPHONE study centres combined. Analyses of brain tumours in relation to mobile phone use have been reported from a number of cohort[7–9] and case–control studies, including several of the national components of INTERPHONE.[10–25] No studies, however, have included as many exposed cases, particularly long-term and heavy users of mobile phones, as this study.

Discussion

The INTERPHONE study is the largest case–control study of mobile phones and brain tumours conducted to date, including the largest numbers of users with at least 10 years of exposure and the greatest cumulative hours of use of any study. An exhaustive analysis of this large data set involved estimation of hundreds of ORs; rather than focus on the most extreme values, the interpretation should rest on the overall balance of evidence. The null hypothesis of no association would be expected to produce an approximately symmetric pattern of negative and positive log ORs. A skewed distribution could be due to a bias or to a true effect. Our results include not only a disproportionately high number of ORs <1, but also a small number of elevated ORs. This could be taken to indicate an underlying lack of association with mobile phone use, systematic bias from one or more sources, a few random but essentially meaningless increased ORs, or a small effect detectable only in a subset of the data.

For meningioma, there is little evidence to counter a global null hypothesis, and we conclude that INTERPHONE finds no signs of an increased risk of meningioma among users of mobile telephones.

For glioma, an increased OR was seen in analyses in the highest decile of cumulative call time, including tumours in the temporal lobe and subjects who reported having used the mobile phone mainly on the same side as where the tumour occurred. Still, the evidence for an increased risk of glioma among the highest users was inconclusive, as the increase could be due to one or more of the possible sources of error discussed below.

In the following sections, we explore possible explanations for the apparently decreased risk of meningioma and glioma for regular users compared with never regular users, and the apparently increased risk of glioma in a subset of users.

Decreased risk with ever regular use of a mobile phone

An apparently decreased risk of brain tumours with ever regular use of a mobile phone (relative to never regular use) has been seen in other studies.[18,23] Putting aside a genuine protective effect as implausible, we have considered other reasons for these observations.

Sampling bias

In all but two centres, a population-based design was used. This requires that the cases in the study were representative of all cases in the respective population and that the controls represented all non-cases, within matching strata. In practice, it is difficult to demonstrate that these conditions have been fulfilled in any case–control study. Cases may be missed due to lack of detection, misdiagnosis or incomplete registration (such problems may be more likely for meningioma than for glioma). It is uncertain whether the sampling frames used to select controls represented the study base in some countries. To the extent possible, we conducted sensitivity analyses that examined the effects of different recruitment strategies between centres; they did not show substantial changes in the results (Table 6).

Levels of participation

Constrained by the requirements of ethical review committees and facing the population's increasing reluctance to participate in interview studies, we attained participation rates of 78% among meningioma cases, 64% among glioma cases and 53% among controls.[26] Although such proportions are not unusually low, they raise the possibility of selection bias with respect to mobile phone use.

Controls in 11 centres and cases in 9 centres who refused the full interview were asked to respond to a brief non-respondent questionnaire on mobile phone use. The cases and controls who complied with this short inquiry reported a lower lifetime prevalence of ever regular use of a mobile phone than did respondents to the full interview, implying that information from those who participated in the full interview may overestimate prevalence among all eligible subjects. Because participation and refusal differed between cases and controls, such non-representativeness may have distorted the OR estimates.[30] Although caution is required in extrapolating from the findings of the sub-study, we estimated, in the more plausible scenarios, that non-participation bias may have led to a reduction in the ORs for regular use of 5–15%,[30] which is less than the observed

reductions below the null in the ORs in ever regular mobile phone users for meningioma (21%, 95% CI 32–9) and glioma (19%, 95% CI 30–6; Table 2).

Prodromal symptoms

Prodromal symptoms of a brain tumour could dissuade subjects from becoming phone users or reduce their use before diagnosis (reverse causation). Glioma is typically diagnosed quite soon after first symptoms. Although prodromal symptoms might result in lowered ORs among very recent users (e.g. <2 years since starting use), these are unlikely to explain the reduction in ORs observed among the vast majority of the users in our study population who started using mobile phones 2–10 years before disease onset.

Timing of interviews

As the use of mobile phones has become more common over time, the later interview dates of controls could have spuriously increased the prevalence of exposure in the control group. However, restricting analyses to matched sets in which the cases and controls were interviewed within 1 month of each other resulted in very little change in the OR for regular use ≥1 year in the past (Table 6) and hence seems unlikely to explain the low ORs overall. Further, the use of a common reference date for each case and its matched control should have minimized any bias induced by differential timing of interviews.

Confounding

Higher socio-economic status has been associated with a higher risk of brain cancer in some but not all relevant studies,[31,32] and with mobile phone use, particularly when the technology was new.[9] We adjusted for education level in all analyses, but acknowledge this is an imperfect indicator of SES. Otherwise, there are few well-established risk factors for brain tumours; analyses adjusting for measured potential confounders had little impact on the ORs (Appendix 1, Table 4, Supplementary data are available at *IJE* online).

Low overall risks among mobile phone users

The reduced OR for regular users compared with never regular users seems unlikely to reflect a genuine protective effect and makes our results difficult to interpret.[33] It could result from the sources of error discussed above, although based on the evidence we have regarding their magnitude and effects[30,34] they may not account fully for the observed reduction in risk.

It might be possible to correct, at least crudely, for assumed downwards bias in the ORs for mobile phone use by undertaking a series of analyses using the lowest category of users as the reference category for OR estimates in higher categories. Results of such an analysis of the mobile phone use variables in Table 2 are shown in the Table of Appendix 2 (see Supplementary data available at *IJE* online), accompanied by a discussion of the strengths and weaknesses of this approach. We have also done some work to characterize possible sources of bias[30,34] and are currently exploring the possibility of correcting the OR estimates mathematically for their effects.

Elevated risks of glioma among heavy users

There was some evidence of an elevated risk of glioma in the highest decile of cumulative call time, with the highest point estimates seen for tumours in the temporal lobe and for subjects who reported having used their mobile phone mainly on the same side as that on which the tumour occurred. We explore here possible interpretations of these findings.

Biases related to possible differential quality of exposure data

When compared with controls, glioma cases had a higher proportion of proxy respondents, a higher number of imputations for missing values, and a higher proportion of subjects judged by their interviewer to be non-responsive or having poor memory (data not shown). However, sensitivity analyses showed that these differences, on their own, did not explain the results seen in the highest decile of cumulative call time (Table 6).

Differential error between cases and controls in reporting of mobile phone use could substantially affect our results; such information bias could arise from several sources. First, a brain tumour, particularly in the frontal or temporal lobes, may adversely affect cognition and memory.[35] Secondly, cases may be more motivated to recall and report a publicized potential risk factor for their disease.

To investigate the accuracy of self-reported phone use, two validation sub-studies were conducted in some of the INTERPHONE centres. Amongst healthy volunteers using software-modified phones (recording number and times of calls), phone use in the past year was reported with substantial random error; with over- and under-estimation both frequent.[36] Errors were larger for duration of calls than for number of calls, and phone use was under-estimated by light users and over-estimated by heavy users. In another sub-study, records of mobile phone use up to 6 years previously were obtained for some participants in three INTERPHONE centres, allowing us to compare the interview responses with the records.[37] Overall, there was little evidence that recall quality differed between cases and controls, but there was some indication of greater over-reporting by cases than by controls for the period 3–5 years before interview. These sub-studies provide no information regarding differential reporting error for periods more distant than 5 years before interview.

Some subjects reported very high daily average call times and this was more common among cases than controls. Thirty-eight cases and 22 controls reported >5 h use/day and 10 cases and no controls reported ≥12 h/day. There is reasonable doubt about the credibility of such reports. Excluding all subjects who reported >5 h use/day reduced the ORs in the highest decile of cumulative time from 1.40 to 1.27 (95% CI 0.92–1.74). In contrast, truncating the average call time to 5 h/day had little effect on the OR. It is not clear which of these two approaches (if either) is more appropriate. However, the key question is whether these cases with unreasonably high values reflect a general tendency for cases to overestimate more than controls, which could contribute to the apparent excess risk in the highest decile. As noted earlier, there is evidence that cases tended to overestimate their past exposure more than controls did.[37]

Non-differential error (random variability or uncertainty in the exposure estimates) may also affect the findings. With dichotomous exposure indicators such bias is towards the null, but for polytomous variables the effect is difficult to predict.[38–40]

Location of tumours and laterality of use of phones

Absorption of RF energy from mobile phones is highly localized.[29] Thus, an association of phone use with tumours occurring near the location of the phone would constitute stronger evidence for aetiology than an association with more distant tumours.

Ipsilateral ORs were almost always greater than contralateral ORs. There was no consistent pattern with regard to level of exposure, although a trend towards a stronger effect of ipsilateral use relative to contralateral use with increasing exposure was observed for cumulative number of calls. Results of case–case analyses (using Inskip's method[18]) also suggested higher risks of gliomas with ipsilateral phone use, but again no consistent trend with increasing exposure. The observation of an unlikely ipsilateral effect in low exposure categories suggests that cases might have over-reported use on the side of the tumour.

There is, though, evidence of lack of such reporting bias from a sub-study. In three centres (Australia, Canada and Japan), participants (172 glioma and 160 meningioma cases and 340 controls who were regular users) were asked at the end of their interview to put a mobile phone to their ear as if answering a call. The concordance between the reported side of use of the phone and the side where it was held was lower for cases (72% glioma cases, 66% meningioma) than controls (95%). The greater degree of concordance among controls suggests differential reporting quality. Among cases, however, there was as much discrepancy in the contralateral direction (52 instances) as in the ipsilateral direction (48 instances). Thus, it is possible that the ipsilateral effect is a true effect, is due to reporting bias or is a mixture of both.

Few studies have related field strength to anatomic structures, but a recent investigation of 110 phone models found that exposure is generally highest in the temporal lobe.[29] While laterality analyses may be biased by the respondent's knowledge of the side of the tumour, results for tumours in different lobes are probably less susceptible to reporting bias. ORs for glioma in the highest exposure categories were higher for tumours in the temporal lobe than in other lobes, but the CIs around the lobe-specific estimates for each measure were wide.

Coherence and consistency

The strongest evidence of an increased risk of glioma was found for cumulative call time, which is a function of the number and duration of calls. Conceptually, cumulative call time might be the most relevant measure of exposure. However, in validation studies, the number of calls was recalled more accurately than the duration of calls.[36,37] For the cumulative number of calls, the ORs, while highest in the highest deciles, were consistently below one. In the absence of a known biological mechanism, it is hard to know whether more weight should be put on results from the more accurate or the conceptually preferred exposure measure.

The apparently increased risk of glioma for cumulative call time was restricted to the top decile, ≥1640 h. There was no upward trend across the first nine deciles of cumulative call time. In contrast with the excess risk seen on the scale of cumulative call time, risk did not appear to be increased by length of time since first exposure or by duration of exposure. The pattern of point estimates of ORs in the high call time categories in three

strata of time since exposure started—3.8 in the most recent and 1.3 in the more distant ones (Table 3)—is not what one would expect if there were a causal association; although the CI in the newest users was wide and encompassed the point estimates for heavy use in the two longer use groups. By analogy with known carcinogens, the lack of a consistently increasing risk with dose, duration of exposure and time since first exposure weigh against cause and effect. Nevertheless, given the uncertainty surrounding possible effects of RF on the brain, no strong case can be made for the plausibility or implausibility of any observed exposure response pattern.

Comparison of meningioma and glioma results

While the ORs for meningioma were lower than that for glioma in high exposure subgroups, there were some similar patterns. First, the OR for all regular users compared with never regular users was very similar. Secondly, there was no trend in relation to cumulative call time except for an elevated OR in the highest decile. Thirdly, the increase in the last decile was more pronounced for cumulative call time than number of calls. Fourthly, the highest OR for cumulative call time was seen among subjects who had recently started regular use. Fifthly, the ORs were greater for ipsilateral than contralateral use and the ratios of ipsilateral ORs divided by their corresponding contralateral ORs were of a similar magnitude. However, while there was evidence of a higher risk of gliomas in the temporal lobe than elsewhere with several different exposure metrics, there was no such evidence for meningioma. Although ORs for meningioma were generally lower than that for glioma, the otherwise similar patterns of associations of mobile phone use with meningioma and glioma could indicate shared aetiology or shared bias.

Interpretation of these findings

We have no certain explanation for the overall reduced risk of brain cancer among mobile phone users in this study, although selection bias is almost certainly a contributor. There is some evidence that very high users experienced excess risk of glioma, but that evidence is inconclusive because of possible bias. Further light may be shed on dose–response relations by work now being undertaken with the INTERPHONE data using precise coordinate localization of tumours within the brain in relation to estimates of absorbed RF energy.

The possibility of raised risk in heavy users of mobile phones is an important issue because of their ever-increasing use. Moreover, few subjects in our study had used mobile phones for >12 years; therefore, our results are uninformative with respect to lag periods longer than this.

Consistency with previous research

Our results are consistent with most of the research published to date. A large Danish cohort study of mobile telephone subscribers,[8,9] with an average follow-up time of 8.5 years, found no increased risk of brain tumours in subscribers of ≥10 years. The first case–control studies conducted included cases diagnosed in the mid-to-late 1990s and therefore could only address possible risks among short-term mobile phone users.[10,12,18,23] In addition, the highest cumulative call times in these studies were much less than in ours. Generally, these studies reported 'negative' results. In contrast, increased risks of malignant brain tumours at higher levels of accumulated use of analogue and digital

mobile phones and cordless desktop phones were reported from a sequence of three case–control studies from the same authors with cases in the last diagnosed as late as 2003.[13–15] However, the methods of these studies have been questioned.[41]

Some of the INTERPHONE centres have published their results for brain tumours[11,16,17,19,22,24,25] and two pooled analyses from Northern European centres have also been published.[20,21] Most cases in these reports are included in the present analyses and constitute 69% of gliomas and 57% of meningiomas. The centre-specific analyses are consistent with our all-centre results.

Much biological research has been done in recent years on possible biological effects of RF fields. This work covers *in vitro* and *in vivo* exposure, alone and in combination with other physical or chemical agents, and has found no evidence that RF fields are carcinogenic in laboratory rodents or cause DNA damage in cells in culture.[42] Possible effects of RF fields on other biological endpoints are still being explored.

The possible effects of long-term heavy use of mobile phones on risk of brain tumours require further investigation, given increasing mobile phone use, its extension to children and its penetration worldwide. The problems presented by selection and information bias in this and probably other studies suggest that new studies should, in general, only be done if they can substantially reduce or eliminate selection bias, obtain detailed and high-quality exposure information over the full period of use and offer sufficient statistical power to detect comparatively small effects in people with heavy or long continued exposure. Monitoring of age- and gender-specific incidence rates may also be valuable, particularly if informed by good longitudinal data on mobile phone use by age and sex, and having regard to features such as brain tumour location that may allow more specific inferences about possible mobile phone use effects.

Conclusion

This is the largest study of the risk of brain tumours in relation to mobile phone use conducted to date and it included substantial numbers of subjects who had used mobile phones for ≥10 years. Overall, no increase in risk of either glioma or meningioma was observed in association with use of mobile phones. There were suggestions of an increased risk of glioma, and much less so meningioma, at the highest exposure levels, for ipsilateral exposures and, for glioma, for tumours in the temporal lobe. However, biases and errors limit the strength of the conclusions we can draw from these analyses and prevent a causal interpretation.

Exposure to High Frequency Electromagnetic Fields, Biological Effects and Health Consequences, INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION (ICNRP), 2009

A Review of the Scientific Evidence on Dosimetry, Biological Effects, Epidemiological Observations, and Health Consequences Concerning Exposure to High Frequency Electromagnetic Fields.

http://www.icnirp.net/40.htm#

Summary of Review of Experimental Studies of RF Biological Effects

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Overall, it is concluded that:

- The mechanisms by which RF exposure heats biological tissue are well understood and the most marked and consistent effect of RF exposure is that of heating, resulting in a number of heat-related physiological and pathological responses in human subjects and laboratory animals. Heating also remains a potential confounder in *in vitro* studies and may account for some of the positive effects reported.
- Recent concern has been more with exposure to the lower level RF radiation characteristic of mobile phone use. Whilst it is in principle impossible to disprove the possible existence of non-thermal interactions, the plausibility of various non-thermal mechanisms that have been proposed is very low.
- Concerning cancer-related effects, the recent *in vitro* and animal genotoxicity and carcinogenicity studies are rather consistent overall and indicate that such effects are unlikely at SAR levels up to 4 W kg-1. With regard to *in vitro* studies of RF effects on non-genotoxic end-points such as cell signaling and gene/protein expression, the results are more equivocal, but the magnitudes of the reported RF radiation induced changes are very small and of limited functional consequence. The results of studies on cell proliferation and differentiation, apoptosis and cell transformation are mostly negative.
- There is some evidence of small changes in brain physiology, notably on spontaneous EEG, and somewhat more variable evidence of changes in sleep EEG and regional cerebral blood flow but these may be of limited functional consequence; no changes were seen in cognitive function. With regard to more general physiological end-points, the evidence suggests that there are no consistent effects of non-thermal RF exposures on cardiovascular physiology, circulating hormone levels or on auditory or vestibular function, except for the auditory perception of pulsed RF such as that characteristic of radar.
- The evidence from double-blind provocation studies suggests that subjective symptoms, such as headaches, that have been identified by some individuals as associated with RF exposure, whilst real enough to the individuals concerned, are not causally related to EMF exposure.
- The experimental data do not suggest so far that children are more susceptible than adults to RF radiation, but few relevant studies have been conducted.
- Studies of the effects of RF modalities such as high peak power pulses have been somewhat diverse and sporadic; no effects have been seen other than those associated with heating and with acoustic perception.

Summary of Review of Health Effects of RF Exposure

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III.A.8. GENERAL CONCLUSIONS AND RECOMMENDATIONS

Results of epidemiological studies to date give no consistent or convincing evidence of a causal relation between RF exposure and any adverse health effect. On the other hand, these studies have too many deficiencies to rule out an association.

A key concern across all studies is the quality of assessment of RF exposure, including the question of whether such exposure was present at all. Communication sources have increased greatly in recent years, and there is continuing change in the frequencies used and the variety of applications. Despite the rapid growth of new technologies using RF, little is known about population exposure from these and other RF sources and even less about the relative importance of different sources. Certain studies that are currently under way have made serious attempts to improve exposure assessment, based on attempts to learn more about determinants of RF exposure levels. A key element in improving future studies would be the use of a meter that monitors individual exposure. In the absence of information on what biological mechanism is relevant, if any, it is unclear what aspect of exposure needs to be captured in epidemiological studies. Ideally, the dose needs to be assessed not just as external field intensity, but also as cumulative exposure, as well as SAR, for specific anatomical sites.

The need for better exposure assessment is particularly strong in relation to transmitter studies, because the relation between distance and exposure is very weak. There is no point in conducting such studies unless it has been established that exposure levels vary substantially within the study area, and measurements of these RF levels are available. In the future, methods need to be developed to infer exposure based on some combination of knowledge regarding the sources of exposure, the levels of exposure, and location of people in relation to those sources, ideally informed by selective measurements.

Although the likelihood is low that fields emanating from base stations would create a health hazard, because of their weakness, this possibility is nevertheless a concern for many people. To date no acceptable study on any outcome has been published on this. On the one hand, results from valid studies would be of value in relation to a social concern; on the other hand, it would be difficult to design and conduct a valid study, and there is no scientific point in conducting an invalid one.

Another general concern in mobile phone studies is that the lag periods that have been examined to date are necessarily short. The implication is that if a longer lag period is required for a health effect to occur, the effect could not be detected in these studies. Only in the few countries where mobile phones were introduced very early has it been possible to look at ten years of usage or more. Much longer lag periods have been examined for occupational RF exposures, however. The published studies include some large occupational cohorts of good design and quality, except that there has been poor assessment of the degree of RF exposure, which render the results difficult to interpret.

The majority of research has focused on brain tumors and to some extent on leukemia. However, because the RF research questions are not driven by a specific biophysical hypothesis but rather by a general concern that there are unknown or misunderstood effects of RF fields, studies on other health effects may be equally justified. Examples are eye diseases, neurodegenerative diseases, and cognitive function. Given the increase of new mobile phone technologies, it is essential to follow various possible health effects from the very beginning, particularly since such effects may be detected only after a long duration, due to the prolonged latency period of many chronic diseases. Thus, research is needed to address long-term exposure, as well as diseases other than those included in the ongoing case-control studies.

Another gap in the research is children. No study population to date has included children, with the exception of studies of people living near radio and TV antennas. Children are increasingly heavy users of mobile phones, they might be particularly susceptible to harmful effects (although there is no evidence of this), and they are likely to accumulate many years of exposure during their lives..

Electromagnetic Fields and Public Health: Mobile Phones, WORLD HEALTH ORGANIZATION, May 2010

http://www.who.int/mediacentre/factsheets/fs193/en/index.html

KEY FACTS

Mobile phone use is ubiquitous with an estimated 4.6 billion subscriptions globally.
To date, no adverse health effects have been established for mobile phone use.
Studies are ongoing to assess potential long-term effects of mobile phone use.
There is an increased risk of road traffic injuries when drivers use mobile phones (either handheld or "hands-free") while driving.

Mobile or cellular phones are now an integral part of modern telecommunications. In many countries, over half the population use mobile phones and the market is growing rapidly. At the end of 2009, there were an estimated 4.6 billion subscriptions globally. In some parts of the world, mobile phones are the most reliable or the only phones available. Given the large number of mobile phone users, it is important to investigate, understand and monitor any potential public health impact.
Mobile phones communicate by transmitting radio waves through a network of fixed antennas called base stations. Radiofrequency waves are electromagnetic fields, and unlike ionizing radiation such as X-rays or gamma rays, cannot break chemical bonds nor cause ionization in the human body.

EXPOSURE LEVELS

Mobile phones are low-powered radiofrequency transmitters, operating at frequencies between 450 and 2700 MHz with peak powers in the range of 0.1 to 2 watts. The handset

only transmits power when it is turned on. The power (and hence the radiofrequency exposure to a user) falls off rapidly with increasing distance from the handset. A person using a mobile phone 30–40 cm away from their body – for example when text messaging, accessing the Internet, or using a "hands free" device – will therefore have a much lower exposure to radiofrequency fields than someone holding the handset against their head.

In addition to using "hands-free" devices, which keep mobile phones away from the head and body during phone calls, exposure is also reduced by limiting the number and length of calls. Using the phone in areas of good reception also decreases exposure as it allows the phone to transmit at reduced power. The use of commercial devices for reducing radiofrequency field exposure has not been shown to be effective.

Mobile phones are often prohibited in hospitals and on airplanes, as the radiofrequency signals may interfere with certain electro-medical devices and navigation systems.

Related link

Interphone study on mobile phone use and brain cancer risk

The International Electromagnetic Fields Project

Electromagnetic fields and public health: base stations and wireless technologies

Electromagnetic fields and public health: electromagnetic hypersensitivity

WHO research agenda for electromagnetic fields

ARE THERE ANY HEALTH EFFECTS?

A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established for mobile phone use.

Short-term effects

Tissue heating is the principal mechanism of interaction between radiofrequency energy and the human body. At the frequencies used by mobile phones, most of the energy is absorbed by the skin and other superficial tissues, resulting in negligible temperature rise in the brain or any other organs of the body.

A number of studies have investigated the effects of radiofrequency fields on brain electrical activity, cognitive function, sleep, heart rate and blood pressure in volunteers. To date, research does not suggest any consistent evidence of adverse health effects from exposure to radiofrequency fields at levels below those that cause tissue heating. Further, research has not been able to provide support for a causal relationship between exposure to electromagnetic fields and self-reported symptoms, or "electromagnetic hypersensitivity".

In contrast, research has clearly shown an increased risk of road traffic injuries when drivers use mobile phones (either handheld or "hands-free") while driving. In several countries, motorists are prohibited or strongly discouraged from using mobile phones while driving.

Long-term effects

Epidemiological research examining potential long-term risks from radiofrequency exposure has mostly looked for an association between brain tumours and mobile phone use. However, because many cancers are not detectable until many years after the interactions that led to the tumour, and since mobile phones were not widely used until the early 1990s, epidemiological studies at present can only assess those cancers that become evident within shorter time periods. However, results of animal studies consistently show no increased cancer risk for long-term exposure to radiofrequency fields.

Several large multinational epidemiological studies have been completed or are ongoing, including case-control studies and prospective cohort studies examining a number of health endpoints in adults. To date, results of epidemiological studies provide no consistent evidence of a causal relationship between radiofrequency exposure and any adverse health effect. Yet, these studies have too many limitations to completely rule out an association.

A retrospective case-control study on adults, INTERPHONE, coordinated by the International Agency for Research on Cancer (IARC), was designed to determine whether there are links between use of mobile phones and head and neck cancers in adults. The international pooled analysis of data gathered from 13 participating countries found no increased risk of glioma or meningioma with mobile phone use of more than 10 years. There are some indications of an increased risk of glioma for those who reported the highest 10% of cumulative hours of cell phone use, although there was no consistent trend of increasing risk with greater duration of use. Researchers concluded that biases and errors limit the strength of these conclusions and prevent a causal interpretation. While an increased risk of brain tumors is not established from INTERPHONE data, the increasing use of mobile phones and the lack of data for mobile phone use over time periods longer than 15 years warrant further research of mobile phone use and brain cancer risk. In particular, with the recent popularity of mobile phone use among younger people, and therefore a potentially longer lifetime of exposure, WHO has promoted further research on this group. Several studies investigating potential health effects in children and adolescents are underway.

EXPOSURE LIMIT GUIDELINES

Radiofrequency exposure limits for mobile phone users are given in terms of Specific Absorption Rate (SAR) – the rate of radiofrequency energy absorption per unit mass of the body. Currently, two international bodies [1,2] have developed exposure guidelines for workers and for the general public, except patients undergoing medical diagnosis or treatment. These guidelines are based on a detailed assessment of the available scientific evidence.

WHO'S RESPONSE

In response to public and governmental concern, WHO established the International Electromagnetic Fields (EMF) Project in 1996 to assess the scientific evidence of possible adverse health effects from electromagnetic fields. WHO will conduct a formal health risk assessment of radiofrequency fields exposure by 2012. Meanwhile, the

International Agency for Research on Cancer (IARC), a WHO specialized agency, is expected to review the carcinogenic potential of mobile phones in 2011.
WHO also identifies and promotes research priorities for radiofrequency fields and health to fill gaps in knowledge through its Research Agendas.
WHO develops public information materials and promotes dialogue among scientists, governments, industry and the public to raise the level of understanding about potential adverse health risks of mobile phones.

[1] International Commission on Non-Ionizing Radiation Protection – ICNIRP. Statement on the "Guidelines for limiting exposure to time-varying electric, magnetic and electromagetic fields (up to 300 GHz)", 2009.
[2] Institute of Electrical and Electronics Engineers IEEE Std C95.1 – 2005. *IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz.*

Electromagnetic Fields and Public Health, Electromagnetic Hypersensitivity, WORLD HEALTH ORGANIZATION, 2005

http://www.who.int/mediacentre/factsheets/fs296/en/index.html
Electromagnetic hypersensitivity
As societies industrialize and the technological revolution continues, there has been an unprecedented increase in the number and diversity of electromagnetic field (EMF) sources. These sources include video display units (VDUs) associated with computers, mobile phones and their base stations. While these devices have made our life richer, safer and easier, they have been accompanied by concerns about possible health risks due to their EMF emissions.
For some time a number of individuals have reported a variety of health problems that they relate to exposure to EMF. While some individuals report mild symptoms and react by avoiding the fields as best they can, others are so severely affected that they cease work and change their entire lifestyle. This reputed sensitivity to EMF has been generally termed "electromagnetic hypersensitivity" or EHS.
This fact sheet describes what is known about the condition and provides information for helping people with such symptoms. Information provided is based on a WHO Workshop on Electrical Hypersensitivity (Prague, Czech Republic, 2004), an international conference on EMF and non-specific health symptoms (COST244bis, 1998), a European Commission report (Bergqvist and Vogel, 1997) and recent reviews of the literature.
What is EHS?
EHS is characterized by a variety of non-specific symptoms, which afflicted individuals attribute to exposure to EMF. The symptoms most commonly experienced include dermatological symptoms (redness, tingling, and burning sensations) as well as neurasthenic and vegetative symptoms (fatigue, tiredness, concentration difficulties, dizziness, nausea, heart palpitation, and digestive disturbances). The collection of symptoms is not part of any recognized syndrome.

EHS resembles multiple chemical sensitivities (MCS), another disorder associated with low-level environmental exposures to chemicals. Both EHS and MCS are characterized by a range of non-specific symptoms that lack apparent toxicological or physiological basis or independent verification. A more general term for sensitivity to environmental factors is Idiopathic Environmental Intolerance (IEI), which originated from a workshop convened by the International Program on Chemical Safety (IPCS) of the WHO in 1996 in Berlin. IEI is a descriptor without any implication of chemical etiology, immunological sensitivity or EMF susceptibility. IEI incorporates a number of disorders sharing similar non-specific medically unexplained symptoms that adversely affect people. However since the term EHS is in common usage it will continue to be used here.

Prevalence

There is a very wide range of estimates of the prevalence of EHS in the general population. A survey of occupational medical centres estimated the prevalence of EHS to be a few individuals per million in the population. However, a survey of self-help groups yielded much higher estimates. Approximately 10% of reported cases of EHS were considered severe.

There is also considerable geographical variability in prevalence of EHS and in the reported symptoms. The reported incidence of EHS has been higher in Sweden, Germany, and Denmark, than in the United Kingdom, Austria, and France. VDU-related symptoms were more prevalent in Scandinavian countries, and they were more commonly related to skin disorders than elsewhere in Europe. Symptoms similar to those reported by EHS individuals are common in the general population.

Studies on EHS individuals

A number of studies have been conducted where EHS individuals were exposed to EMF similar to those that they attributed to the cause of their symptoms. The aim was to elicit symptoms under controlled laboratory conditions.

The majority of studies indicate that EHS individuals cannot detect EMF exposure any more accurately than non-EHS individuals. Well controlled and conducted double-blind studies have shown that symptoms were not correlated with EMF exposure.

It has been suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF. Examples may include "flicker" from fluorescent lights, glare and other visual problems with VDUs, and poor ergonomic design of computer workstations. Other factors that may play a role include poor indoor air quality or stress in the workplace or living environment.

There are also some indications that these symptoms may be due to pre-existing psychiatric conditions as well as stress reactions as a result of worrying about EMF health effects, rather than the EMF exposure itself.

Conclusions

EHS is characterized by a variety of non-specific symptoms that differ from individual to individual. The symptoms are certainly real and can vary widely in their severity. Whatever its cause, EHS can be a disabling problem for the affected individual. EHS has no clear diagnostic criteria and there is no scientific basis to link EHS symptoms to EMF exposure. Further, EHS is not a medical diagnosis, nor is it clear that it represents a single medical problem.

Physicians: Treatment of affected individuals should focus on the health symptoms and the clinical picture, and not on the person's perceived need for reducing or eliminating EMF in the workplace or home. This requires:
a medical evaluation to identify and treat any specific conditions that may be responsible for the symptoms,
a psychological evaluation to identify alternative psychiatric/psychological conditions that may be responsible for the symptoms,
an assessment of the workplace and home for factors that might contribute to the presented symptoms. These could include indoor air pollution, excessive noise, poor lighting (flickering light) or ergonomic factors. A reduction of stress and other improvements in the work situation might be appropriate.
For EHS individuals with long lasting symptoms and severe handicaps, therapy should be directed principally at reducing symptoms and functional handicaps. This should be done in close co-operation with a qualified medical specialist (to address the medical and psychological aspects of the symptoms) and a hygienist (to identify and, if necessary, control factors in the environment that are known to have adverse health effects of relevance to the patient).
Treatment should aim to establish an effective physician-patient relationship, help develop strategies for coping with the situation and encourage patients to return to work and lead a normal social life.
EHS individuals: Apart from treatment by professionals, self help groups can be a valuable resource for the EHS individual.
Governments: Governments should provide appropriately targeted and balanced information about potential health hazards of EMF to EHS individuals, health-care professionals and employers. The information should include a clear statement that no scientific basis currently exists for a connection between EHS and exposure to EMF.
Researchers: Some studies suggest that certain physiological responses of EHS individuals tend to be outside the normal range. In particular, hyper reactivity in the central nervous system and imbalance in the autonomic nervous system need to be followed up in clinical investigations and the results for the individuals taken as input for possible treatment.
What WHO is doing
WHO, through its International EMF Project, is identifying research needs and co-ordinating a world-wide program of EMF studies to allow a better understanding of any health risk associated with EMF exposure. Particular emphasis is placed on possible health consequences of low-level EMF. Information about the EMF Project and EMF effects is provided in a series of fact sheets in several languages www.who.int/emf/.
FURTHER READING
WHO workshop on electromagnetic hypersensitivity (2004), October 25 -27, Prague, Czech Republic, www.who.int/peh-emf/meetings/hypersensitivity_prague2004/en/index.html
COST244bis (1998) Proceedings from Cost 244bis International Workshop on Electromagnetic Fields and Non-Specific Health Symptoms. Sept 19-20, 1998, Graz, Austria
Bergqvist U and Vogel E (1997) Possible health implications of subjective symptoms and electromagnetic field. A report prepared by a European group of experts for the European

Commission, DGV. Arbete och Hälsa, 1997:19. Swedish National Institute for Working Life, Stockholm, Sweden. ISBN 91-7045-438-8.
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Seitz H, Stinner D, Eikmann Th, Herr C, Roosli M. (2005) Electromagnetic hypersensitivity (EHS) and subjective health complaints associated with electromagnetic fields of mobile phone communication---a literature review published between 2000 and 2004. Science of the Total Environment, June 20 (Epub ahead of print).
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Electromagnetic Fields and Public Health: Base Stations and Wireless Technologies, WORLD HEALTH ORGANIZATION, 2006

http://www.who.int/mediacentre/factsheets/fs304/en/index.html
Mobile telephony is now commonplace around the world. This wireless technology relies upon an extensive network of fixed antennas, or base stations, relaying information with radiofrequency (RF) signals. Over 1.4 million base stations exist worldwide and the number is increasing significantly with the introduction of third generation technology. Other wireless networks that allow high-speed internet access and services, such as wireless local area networks (WLANs), are also increasingly common in homes, offices, and many public areas (airports, schools, residential and urban areas). As the number of base stations and local wireless networks increases, so does the RF exposure of the population. Recent surveys have shown that the RF exposures from base stations range from 0.002% to 2% of the levels of international exposure guidelines, depending on a variety of factors such as the proximity to the antenna and the surrounding environment. This is lower or comparable to RF exposures from radio or television broadcast transmitters.

There has been concern about possible health consequences from exposure to the RF fields produced by wireless technologies. This fact sheet reviews the scientific evidence on the health effects from continuous low-level human exposure to base stations and other local wireless networks.

Health concerns
A common concern about base station and local wireless network antennas relates to the possible long-term health effects that whole-body exposure to the RF signals may have. To date, the only health effect from RF fields identified in scientific reviews has been related to an increase in body temperature (> 1 °C) from exposure at very high field intensity found only in certain industrial facilities, such as RF heaters. The levels of RF exposure from base stations and wireless networks are so low that the temperature increases are insignificant and do not affect human health.

The strength of RF fields is greatest at its source, and diminishes quickly with distance. Access near base station antennas is restricted where RF signals may exceed international exposure limits. Recent surveys have indicated that RF exposures from base stations and wireless technologies in publicly accessible areas (including schools and hospitals) are normally thousands of times below international standards.
In fact, due to their lower frequency, at similar RF exposure levels, the body absorbs up to five times more of the signal from FM radio and television than from base stations. This is because the frequencies used in FM radio (around 100 MHz) and in TV broadcasting (around 300 to 400 MHz) are lower than those employed in mobile telephony (900 MHz and 1800 MHz) and because a person's height makes the body an efficient receiving antenna. Further, radio and television broadcast stations have been in operation for the past 50 or more years without any adverse health consequence being established.

While most radio technologies have used analog signals, modern wireless telecommunications are using digital transmissions. Detailed reviews conducted so far have not revealed any hazard specific to different RF modulations.

Cancer: Media or anecdotal reports of cancer clusters around mobile phone base stations have heightened public concern. It should be noted that geographically, cancers are unevenly distributed among any population. Given the widespread presence of base stations in the environment, it is expected that possible cancer clusters will occur near base stations merely by chance. Moreover, the reported cancers in these clusters are often a collection of different types of cancer with no common characteristics and hence unlikely to have a common cause.
Scientific evidence on the distribution of cancer in the population can be obtained through carefully planned and executed epidemiological studies. Over the past 15 years, studies examining a potential relationship between RF transmitters and cancer have been published. These studies have not provided evidence that RF exposure from the transmitters increases the risk of cancer. Likewise, long-term animal studies have not established an increased risk of cancer from exposure to RF fields, even at levels that are much higher than produced by base stations and wireless networks.

Other effects: Few studies have investigated general health effects in individuals exposed to RF fields from base stations. This is because of the difficulty in distinguishing possible health effects from the very low signals emitted by base stations from other higher strength RF signals in the environment. Most studies have focused on the RF exposures of mobile phone users. Human and animal studies examining brain wave patterns, cognition and behaviour after exposure to RF fields, such as those generated by mobile phones, have not identified adverse effects. RF exposures used in these studies were about 1000 times higher than those associated with general public exposure from base stations or wireless networks. No consistent evidence of altered sleep or cardiovascular function has been reported.

Some individuals have reported that they experience non-specific symptoms upon exposure to RF fields emitted from base stations and other EMF devices. As recognized

in a recent WHO fact sheet "Electromagnetic Hypersensitivity", EMF has not been shown to cause such symptoms. Nonetheless, it is important to recognize the plight of people suffering from these symptoms.

From all evidence accumulated so far, no adverse short- or long-term health effects have been shown to occur from the RF signals produced by base stations. Since wireless networks produce generally lower RF signals than base stations, no adverse health effects are expected from exposure to them.

Protection standards

International exposure guidelines have been developed to provide protection against established effects from RF fields by the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998) and the Institute of Electrical and Electronic Engineers (IEEE, 2005).

National authorities should adopt international standards to protect their citizens against adverse levels of RF fields. They should restrict access to areas where exposure limits may be exceeded.

Public perception of risk

Some people perceive risks from RF exposure as likely and even possibly severe. Several reasons for public fear include media announcements of new and unconfirmed scientific studies, leading to a feeling of uncertainty and a perception that there may be unknown or undiscovered hazards. Other factors are aesthetic concerns and a feeling of a lack of control or input to the process of determining the location of new base stations.

Experience shows that education programmes as well as effective communications and involvement of the public and other stakeholders at appropriate stages of the decision process before installing RF sources can enhance public confidence and acceptability.

Conclusions

Considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects.

WHO Initiatives

WHO, through the International EMF Project, has established a programme to monitor the EMF scientific literature, to evaluate the health effects from exposure to EMF in the range from 0 to 300 GHz, to provide advice about possible EMF hazards and to identify suitable mitigation measures. Following extensive international reviews, the International EMF Project has promoted research to fill gaps in knowledge. In response national governments and research institutes have funded over $250 million on EMF research over the past 10 years.

While no health effects are expected from exposure to RF fields from base stations and wireless networks, research is still being promoted by WHO to determine whether there are any health consequences from the higher RF exposures from mobile phones.
The International Agency for Research on Cancer (IARC), a WHO specialized agency, is expected to conduct a review of cancer risk from RF fields in 2006-2007 and the International EMF Project will then undertake an overall health risk assessment for RF fields in 2007-2008.

Further Reading
ICNIRP (1998) www.icnirp.org/documents/emfgdl.pdf
IEEE (2006) IEEE C95.1-2005 "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz"
Related links
- Base stations & wireless networks: Exposures & health consequences
- Fact sheet: Electromagnetic fields and public health: Electromagnetic Hypersensitivity
- WHO handbook on "Establishing a Dialogue on Risks from Electromagnetic Fields"
- 2006 WHO Research Agenda for Radio Frequency Fields [pdf 100kb]
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Electromagnetic Fields and Public Health: Exposure to Extremely Low Frequency Fields, WORLD HEALTH ORGANIZATION, 2007

http://www.who.int/mediacentre/factsheets/fs322/en/index.html

The use of electricity has become an integral part of everyday life. Whenever electricity flows, both electric and magnetic fields exist close to the lines that carry electricity, and close to appliances. Since the late 1970s, questions have been raised whether exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) produces adverse health consequences. Since then, much research has been done, successfully resolving important issues and narrowing the focus of future research.

In 1996, the World Health Organization (WHO) established the International Electromagnetic Fields Project to investigate potential health risks associated with technologies emitting EMF. A WHO Task Group recently concluded a review of the health implications of ELF fields (WHO, 2007).

This Fact Sheet is based on the findings of that Task Group and updates recent reviews on the health effects of ELF EMF published in 2002 by the International Agency for Research on Cancer (IARC), established under the auspices of WHO, and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 2003.
ELF field sources and residential exposures

Electric and magnetic fields exist wherever electric current flows - in power lines and cables, residential wiring and electrical appliances. **Electric** fields arise from electric charges, are measured in volts per metre (V/m) and are shielded by common materials, such as wood and metal. **Magnetic** fields arise from the motion of electric charges (i.e. a current), are expressed in tesla (T), or more commonly in millitesla (mT) or microtesla (μT). In some countries another unit called the gauss, (G), is commonly used (10,000 G = 1 T). These fields are not shielded by most common materials, and pass easily through them. Both types of fields are strongest close to the source and diminish with distance. Most electric power operates at a frequency of 50 or 60 cycles per second, or hertz (Hz). Close to certain appliances, the magnetic field values can be of the order of a few hundred microtesla. Underneath power lines, magnetic fields can be about 20 μT and electric fields can be several thousand volts per metre. However, average residential power-frequency magnetic fields in homes are much lower - about 0.07 μT in Europe and 0.11 μT in North America. Mean values of the electric field in the home are up to several tens of volts per metre.

Task group evaluation

In October 2005, WHO convened a Task Group of scientific experts to assess any risks to health that might exist from exposure to ELF electric and magnetic fields in the frequency range >0 to 100,000 Hz (100 kHz). While IARC examined the evidence regarding cancer in 2002, this Task Group reviewed evidence for a number of health effects, and updated the evidence regarding cancer. The conclusions and recommendations of the Task Group are presented in a WHO Environmental Health Criteria (EHC) monograph (WHO, 2007).

Following a standard health risk assessment process, the Task Group concluded that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus the remainder of this fact sheet addresses predominantly the effects of exposure to ELF magnetic fields.

Short-term effects

There are established biological effects from acute exposure at high levels (well above 100 μT) that are explained by recognized biophysical mechanisms. External ELF magnetic fields induce electric fields and currents in the body which, at very high field strengths, cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system.

Potential long-term effects

Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans". This classification is used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals (other examples include coffee and welding fumes). This classification was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-

fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT. The Task Group concluded that additional studies since then do not alter the status of this classification.

However, the epidemiological evidence is weakened by methodological problems, such as potential selection bias. In addition, there are no accepted biophysical mechanisms that would suggest that low-level exposures are involved in cancer development. Thus, if there were any effects from exposures to these low-level fields, it would have to be through a biological mechanism that is as yet unknown. Additionally, animal studies have been largely negative. Thus, on balance, the evidence related to childhood leukaemia is not strong enough to be considered causal.

Childhood leukaemia is a comparatively rare disease with a total annual number of new cases estimated to be 49,000 worldwide in 2000. Average magnetic field exposures above 0.3 μT in homes are rare: it is estimated that only between 1% and 4% of children live in such conditions. If the association between magnetic fields and childhood leukaemia is causal, the number of cases worldwide that might be attributable to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000, representing 0.2 to 4.95% of the total incidence for that year. Thus, if ELF magnetic fields actually do increase the risk of the disease, when considered in a global context, the impact on public health of ELF EMF exposure would be limited.

A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them.

International exposure guidelines

Health effects related to short-term, high-level exposure have been established and form the basis of two international exposure limit guidelines (ICNIRP, 1998; IEEE, 2002). At present, these bodies consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering these quantitative exposure limits.

WHO's guidance

For high-level short-term exposures to EMF, adverse health effects have been scientifically established (ICNIRP, 2003). International exposure guidelines designed to protect workers and the public from these effects should be adopted by policy makers. EMF protection programs should include exposure measurements from sources where exposures might be expected to exceed limit values.

Regarding long-term effects, given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, the benefits of exposure reduction on health are unclear. In view of this situation, the following recommendations are given:
Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure. Through the ELF risk assessment process, gaps in knowledge have been identified and these form the basis of a new research agenda.

Member States are encouraged to establish effective and open communication programmes with all stakeholders to enable informed decision-making. These may include improving coordination and consultation among industry, local government, and citizens in the planning process for ELF EMF-emitting facilities.

When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted.

Further reading
WHO - World Health Organization. Extremely low frequency fields. Environmental Health Criteria, Vol. 238. Geneva, World Health Organization, 2007.
IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. Lyon, IARC, 2002 (Monographs on the Evaluation of Carcinogenic Risks to Humans, 80).
ICNIRP - International Commission on Non-Ionizing Radiation Protection. Exposure to static and low frequency electromagnetic fields, biological effects and health consequences (0-100 kHz). Bernhardt JH et al., eds. Oberschleissheim, International Commission on Non-ionizing Radiation Protection, 2003 (ICNIRP 13/2003).
ICNIRP – International Commission on Non-Ionizing Radiation Protection (1998). Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz). Health Physics 74(4), 494-522.
IEEE Standards Coordinating Committee 28. IEEE standard for safety levels with respect to human exposure to electromagnetic fields, 0-3 kHz. New York, NY, IEEE - The Institute of Electrical and Electronics Engineers, 2002 (IEEE Std C95.6-2002).
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Non-Ionizing Radiation, HEALTH PROTECTION AGENCY OF THE UNITED KINGDOM, August 2010

Health Advice on Mobile Phones

http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/ElectromagneticFields/MobilePhones/info_HealthAdvice/

Mobile phones operate by using radio waves, a form of non-ionising radiation. There is a large body of scientific evidence on the effects of exposure to radio waves because they have been widely used for decades. For example, radio, TV and radar signals are radio waves.

There are thousands of published scientific papers covering research about the effects of various types of radio waves on cells, tissues, animals and people. The scientific consensus is that, apart from the increased risk of a road accident due to mobile phone use when driving, there is no clear evidence of adverse health effects from the use of mobile phones or from phone masts. However there is now widespread use of this relatively new technology and more research is needed in case there are long term effects.

Some of the published research has produced contradictory results, particularly biology experiments using cell cultures. An important role of radiological protection specialists at the Health Protection Agency is to review the scientific evidence impartially and provide clear advice. The Agency also has an Advisory Group of experts who study the scientific evidence and provide independent advice (AGNIR, independent Advisory Group on Non-Ionising Radiation).

Basic Advice

In 2000, an independent expert group in the UK first reviewed the evidence about the health effects of mobile phones. Its report "Mobile Phones and Health" (Independent Expert Group on Mobile Phones; IEGMP) has become known as the Stewart Report after its chairman Sir William Stewart. This expert group concluded that there was no clear scientific evidence of harm to health from exposure to mobile phone signals.

However, the expert group was concerned about the widespread adoption of a new technology involving exposure from radio waves to people's heads, including those of children, at levels that are significant fractions of international guidelines. This, and some uncertainties in biological evidence, led the expert group to advise some precaution, particularly in the use of mobile phones by children.

This advice was accepted by the Department of Health and leaflets and other information were provided for the public in 2000 and 2004. The basic advice from the Stewart Report continues to be the advice of the Health Protection Agency. The benefits of mobile telecommunications are widely recognised but, given the uncertainties in the science, some precaution is warranted particularly regarding the use of handsets held against the head. This is especially relevant to the use of handsets by children and the Agency recommends that excessive use by children should be discouraged.

Regarding the siting of telephone masts, this is a planning matter and therefore Government decides the law and any permitted development rights. However the Health Protection Agency notes that measurements in the UK and elsewhere, show that exposure levels to the signals from phone masts are much less than those from using mobile phone handsets, typically by factors of 100, 1000 and even 10,000, including when people are quite close to a mast.

Since 2000, expert reviews of the evidence have been carried out in many other countries and they have come to very similar conclusions about the lack of clear scientific evidence for any adverse health effects. For more details, see the sections below on the Stewart Report and other expert reviews of the scientific evidence.

Advice on Exposure Guidelines

The Health Protection Agency published advice on limiting exposure to electromagnetic fields in 2004 and recommended the adoption in the UK of the established international guidelines from the International Commission on Non-Ionizing Radiation Protection (ICNIRP, see below). This advice was supported by a comprehensive scientific review covering the broad base of the scientific evidence.

The scientific evidence included published studies of human and animal health, the effects on biological cell cultures and the physics of the interaction of radio waves with matter (epidemiological studies, animal studies, experimental biology and dosimetry). The ICNIRP guidelines are based on a critical in-depth evaluation of the established scientific literature. The guidelines represent the international scientific consensus about this evidence and ensure the avoidance of known biological effects.

The Health Protection Agency review also gave recommendations for the research needed to fill the gaps in scientific knowledge and to improve the rigour of the guidelines.

The Health Protection Agency is committed to monitoring the results of further research related to the effects of radio waves on health and to revising its advice when appropriate.

ICNIRP Guidelines

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an independent international scientific organisation formally recognised by the World Health Organization. ICNIRP reviews the science relating to exposure to electromagnetic fields and produces guidelines for limiting people's exposure. ICNIRP has a website from which a copy of its guidelines and other background information may be downloaded.

ICNIRP published a comprehensive set of guidelines in 1998 restricting exposures to electromagnetic fields, including radio waves. The Commission reconfirmed the basic restrictions in the frequency range 100 kHz-300 GHz (which includes the mobile phone frequency range) in 2009.

The ICNIRP guidelines contain basic restrictions on exposure that are set at levels which avoid the known adverse health effects of exposure. At the mobile phone frequencies, compliance with the ICNIRP guidelines will avoid heating by absorption of radio frequency signals. This is because the evidence from scientific studies of animals, cells and people shows clearly that biological effects occur at levels where heating occurs. The ICNIRP guidelines are therefore used as an input to the development of standards in very many countries, including those of the European Union.

The basic restrictions are specified in terms of fundamental dose quantities that occur inside the body; consequently, they are not easy to measure in living people. Reference levels are needed which are expressed in terms of quantities measurable outside the body such as electric field strength and power density.

Mobile phone handsets expose those parts of the body that are closest to the phone when the phone is in use, and most often this is the head. Therefore, for mobile phones, the most important restriction in the guidelines is the one on the localised Specific Energy Absorption Rate (SAR), a measure of the energy absorbed in the head.

Base station antennas tend to be very much further away from the body than a mobile phone and in this situation the reference level in terms of power density is usually meaningful as an indicator of SAR averaged over the whole body.

The Independent Expert Group on Mobile Phones (Stewart Report)

The Independent Expert Group on Mobile Phones (IEGMP) published its report of May 2000. It has become known subsequently as the Stewart Report.

The Stewart Report supported the conclusion of ICNIRP that heating remains the best basis for setting exposure limits. The report also supported the approach of ICNIRP to have separate exposure guidelines for workers and for members of the public. The public guidelines are more restrictive because within the general public there may be people with illnesses or other characteristics that render them more susceptible to the heating effects of radio waves.

The Stewart Report concluded that the balance of evidence was that exposures to radio frequency waves below ICNIRP guidelines did not cause adverse health effects to the general population. However there were uncertainties in the science and further research needed to be carried out. Given the uncertainties and the widespread use of mobile phone technology, the Stewart Report recommended a precautionary approach. This included a recommendation that excessive use of mobile phones by children should be discouraged.

Other Expert Reviews of the Scientific Evidence

Since 2000 there have been a number of reviews of the evidence carried out by scientific expert groups in the UK and in other countries, and most have come to conclusions very similar to those in the Stewart Report. A selection is given here

The Zmirou Report was published in France in 2001 and the Health Council of the Netherlands published its first report on the topic in 2002. Both reports came to conclusions about the scientific evidence that were similar to those in the Stewart Report. In December 2003, the Swedish Radiation Protection Authority published its first review and concluded that there was no significant change in the scientific evidence and the conclusions of the Stewart Report were still valid. Following these initial reports, both the Health Council of the Netherlands and the Swedish Radiation Protection Authority have published annual reviews of the evidence. The general conclusions about the evidence have not changed. These annual reports can be found on the website links given above.

In December 2003 the HPA's independent Advisory Group on Non-Ionising Radiation (AGNIR) published a follow up review of the scientific evidence since the Stewart Report. AGNIR concluded that the research published since the Stewart Report did not change the balance of evidence, but stressed the continued need for research.

In 2004, the ICNIRP Standing Committee on Epidemiology published a detailed review of epidemiological studies of health effects from exposure to radio waves (A Ahlbom, A Green, L Kheifets, D Savitz and A Swerdlow. Epidemiology of Health Effects of Radiofrequency Exposure. *Environmental Health Perspectives* 2004; **112**(17): 1741-1754). This was a review of many studies carried out over several decades, looking at cancer, fertility, heart problems and cataracts in people who worked with radio waves. It also looked at studies of public exposure from radio and TV transmissions, focusing on leukaemia and studies of mobile phone users, but also looking at brain tumours and other cancers and symptoms. The reviewers concluded that "Results of these studies to date give no consistent or convincing evidence of a causal relation between RF exposure and any adverse health effect." However the authors did not rule out the possibility of an association because of the rapid introduction of mobile phones and their widespread use. Also, "A key concern across all studies is the quality of assessment of RF exposure" and there is "...almost no data is available on the consequences of childhood exposure".

In 2007, the UK Mobile Telecommunications and Health Research (MTHR) programme published a report summarising the results of the work it had funded since 2001. It concluded that none of the research had provided evidence of biological effects or health effects below guideline levels. Nevertheless there is still a need for good research and it could not rule out the possibility of long-term effects. The MTHR research programme was set up in response to a recommendation from the Stewart Report and is jointly funded by Government and industry. Its independence is safeguarded by a committee of experts who review the research proposals and monitor each project. Scientists receiving funds from MTHR are encouraged to publish their results in peer reviewed science journals.

In 2008 the US National Cancer Institute published a detailed factsheet on mobile phone use and cancer. The NCI concluded that although research has not demonstrated a consistent link between mobile phone use and cancer, scientists still caution that further surveillance is needed before conclusions can be drawn.

The European Commission set up a Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) in 2004 and this committee has published reports on the Possible Effects of Electromagnetic Fields on Human Health in 2007 and 2009. In the 2009 report (http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf) the Committee concluded "....from three independent lines of evidence (epidemiological, animal and in vitro studies) that exposure to RF fields is unlikely to lead to an increase in cancer in humans. However, as the widespread duration of exposure of humans to RF fields from mobile phones is shorter than the induction time of some cancers, further studies are required to identify whether considerably longer-term (well beyond ten years) human exposure to such phones might pose some cancer risk."

In 2009 the French Agency for Environmental and Occupational Health Safety (Afsset) published an opinion from an expert group on biological and health effects from radiofrequency waves.
After reviewing the biological, epidemiological and health evidence, this expert group concluded "that the majority of the studies carried out do not show effects for exposures at non-thermal powers" and "that available work does not currently allow the mechanism of a non-thermal effect nor a cumulative mechanism of action of radiofrequencies to be identified". Nevertheless, the expert group recognised the continuing uncertainties in the scientific evidence and Afsset issued precautionary advice aimed at minimising radiofrequency exposures to people, and to children in particular.

In 2009, members of the ICNIRP Standing Committee on Biology published a review of the effects of radiofrequency fields on the human nervous system (E van Rongen, R Croft, J Juutilainen, I Lagroye, R Saunders, R de Seze, T Tenforde, L Vershaeve, B Veyret and Z Xu. Effects of radiofrequency electromagnetic fields on the human nervous system. *J Toxicol and Env. Health* 2009 Part B; **12**: 572-597). They concluded that "There is some evidence of an effect of exposure to a Global System for Mobile Telecommunication (GSM)-type signal on the spontaneous electroencephalogram (EEG). They noted however, that the effect may be of little functional significance since, "No consistent significant effects on cognitive performance in adults have been observed. If anything, any effect is small and exposure seems to improve performance." With regard to subjective symptoms such as headaches and migraine, the authors noted that these had been "attributed to various radiofrequency sources both at home and at work. However, in provocation studies a causal relation between EMF exposure and symptoms has never been demonstrated. There are clear indications, however, that psychological factors such as the conscious expectation of effect may play an important role in this condition.

In 2009, members of the ICNIRP Standing Committee on Epidemiology published an update of their 2004 review mentioned above (A Ahlbom, M Feychting, A Green, L Kheifets, D Savitz and A Swerdlow. Epidemiologic evidence on mobile phones and Tumor Risk: A Review. *Epidemiology* 2009; **20**(5): 639-652) They noted that the number of papers on this topic had grown since 2004, but methodological problems remain. These are primarily the selective non-response of participants, and the inaccuracy and bias in their recall of phone use. Most studies had shown small increased or decreased

risk amongst users, but a subset of studies showed an elevated risk. The subset of elevated results comes from a particular research group and there is no obvious explanation of why they obtain such different results from other studies. Overall, the ICNIRP Standing Committee conclude that the available data do not suggest a causal association between mobile phone use and fast growing tumours in the brain such as malignant glioma. The similar absence of an association for slow growing tumours (such as meningioma and acoustic neuroma) is far less conclusive, because the period of observation is simply too short.

The INTERPHONE Study

The results of this important study were published in May 2010. The authors concluded

"Overall, no increase in risk of glioma or meningioma was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation"

This multi-national study was set up in 2000, following a successful feasibility study during 1998/99. It involves research in 13 countries to see whether mobile phone use is associated with an increased risk of head and neck tumours (including brain and salivary gland tumours).

The study was undertaken as a collaborative effort between a number of partner institutions, co-ordinated by the International Agency for Research on Cancer (IARC), part of the World Health Organization (WHO). The participating countries were Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden and the UK.

Most individual studies in the various countries were published between 2004 and 2008. The pooled INTERPHONE study has combined the results from individual countries into one study involving nearly 6,500 cases and over 7,500 controls. This pooled study (see link below) contained more detailed data and analysis than in the studies from individual countries.
http://www.oxfordjournals.org/our_journals/ije/press_releases/freepdf/dyq079.pdf

The first step was to identify people with head and neck tumours (cases) and a similar number of people without such tumours (controls). The researchers then asked the individuals about their usage of mobile phones (both cases and controls) so they could be classified into groups reflecting heavy, light or non users. All the participants were asked to recall the side of the head that the mobile phone was normally, or most frequently, used. This information was obtained via an in-person, computer-assisted interview.

In view of the way the information was gathered, there are many considerations that have to be taken into account when interpreting the results of the Interphone Study. These are discussed at length in the published paper and some examples are given below.

The results from the individual INTERPHONE studies in different countries and the pooled study appear to show a protective effect, correlating the use of mobile phones with a reduced risk of head and neck tumours. These unexpected findings could be due to selection bias. In most countries the participation rate was fairly high for cases, but lower among potential controls. If mobile phone use differed between those controls who took part in the studies and those potential controls who did not take part, then this would lead to biased findings. Such a situation could arise if people with a relatively high level of education and socio-economic status were more willing than others to participate in this research and tended to use mobile phones more often than other members of the population. As a consequence, over-estimation of exposure among controls due to selective participation might result in an apparent protective effect of mobile phone use.

In contrast, results from individual countries also show that people with cancers in the head and neck tend to associate the use of mobile phones with the side of the head or neck where the tumour has appeared. This is a relatively strong association for some tumours (glioma and acoustic neuromas) after more than 10 years' usage. These findings might be due, at least in part, to bias in recalling the side of the head on which the mobile phone was generally used. The cases might have tended to over-report use on same side of head as that where the tumour arose, because some of them may have thought that mobile phone use caused their tumour. Conversely, they may have tended to under-report use on the other side of the head from where the tumour did not arise. In contrast, the controls are unlikely to have systematically over-reported use on one side of the head. Therefore, the overall interpretation of these results should bear in mind both selection and recall biases.
In order to estimate how strong an influence this recall bias and other biases in the INTERPHONE study could be, various validation studies have been carried out. These studies showed that mobile phone use was being under-estimated by light users and over-estimated by heavy users, and the over-estimation of use was greater for the more remote time periods. The possibility of a selection bias caused by light users refusing to participate as controls in the study was also identified as a possible contributor to the apparent protective effect of mobile phone use.

There is also some uncertainty in the classification of tumours as right sided or left sided, and precisely where they are in the head. Measurements and modelling show that the exposure to radio waves from mobile phones is very localised and decreases rapidly with depth. More data on the precise location of tumours and their proximity to the mobile phone usage area is needed, rather than a simple classification on the left or right side of the head.

Comments on the pooled INTERPHONE study (2010)

Following its publication in May 2010, the INTERPHONE pooled study has attracted attention and comment. Here we show extracts from comments made by an independent advisory group and also comments from the international commission responsible for advising on exposure restrictions.

Advisory Group on Non-ionising Radiation (AGNIR)

The Advisory Group made the following comments shortly after the publication of the INTERPHONE study

"The INTERPHONE study was well designed and carefully conducted, and has contributed importantly to our understanding of possible health risks from use of mobile phones. As with all epidemiological studies, and particularly case-control investigations that rely on recall of complex past exposures from memory, there are uncertainties in interpretation. Nevertheless, within the limits of those uncertainties, which are discussed at some length in the report, the study provides no clear, or even strongly suggestive, evidence of a hazard. Moreover, it indicates that if there is any hazard of brain cancer or meningioma from use of mobile phones then the risk during the initial 10-15 years of use must be small.

"This conclusion is consistent with the findings of most other epidemiological studies that have examined the relation of brain tumours to use of mobile phones, and also with the absence of demonstrable effects on cancer incidence when laboratory animals have been exposed to radiofrequency radiation experimentally.

"Because mobile phones have only been in widespread use for less than 20 years, the INTERPHONE study could not address the possibility of longer term risks to health. Given the enormous scale on which the technology has been adopted, there is therefore a need for continuing epidemiological surveillance to ensure that any adverse effects are detected at the earliest possible stage. The recently launched COSMOS study, which is being funded in the UK as part of the Mobile Telecommunications and Health Research (MTHR) programme, will contribute importantly to meeting this need."

See the full statement from AGNIR

International Commission on Non-Ionizing Radiation Protection (ICNIRP)

ICNIRP has published a note on the INTERPHONE study, commenting that it is by far the largest study on mobile phones and health to date.

The Commission concludes, "Overall, the study did not find an increase in the risks of glioma or meningioma in relation to mobile phone use."

However, it notes, "No raised risk of brain tumours was found among people who reported the largest number of calls but an apparent raised risk was observed in people in the highest of ten categories of reported cumulative hours of mobile phone use. This category included a number of people who were recorded with highly improbable hours of use, presumably reflecting erroneous reports, and there was no general dose response gradient of increasing risk with increasing amount of use."

It also comments, "There are serious methodological limitations inherent in studies of this type, which depend on study participants trying to remember and report their entire lifetime use of mobile phones. Such recall is problematic particularly for brain tumour patients. ICNIRP agrees with the Interphone authors that the biases and errors in the study preclude a causal interpretation of the results."

The full note from ICNIRP can be found at
http://www.icnirp.org/documents/ICNIRPnote.pdf

Last reviewed: 17 August 2010

WI-FI and Health, HEALTH PROTECTION AGENCY OF THE UNITED KINGDOM, October, 2009

http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/ElectromagneticFields/WiFi/

General position

There is no consistent evidence to date that Wi-Fi and WLANs adversely affect the health of the general population. The signals are very low power, typically 0.1 watt (100 milliwatts) in both the computer and the router (access point) and the results so far show exposures are well within internationally accepted (ICNIRP) guidelines. Based on current knowledge and experience, radio frequency (RF) exposures from Wi-Fi are likely to be lower than those from mobile phones. Also, the frequencies used in Wi-Fi are broadly the same as those from traditional RF applications.

On the basis of the studies so far carried out in house, the HPA sees no reason why Wi-Fi should not continue to be used in schools. However with any new technology it is a sensible precautionary approach, as happened with mobile phones, to keep the situation under ongoing review so that parents and others can have as much reassurance as possible. That is why Sir William Stewart, formerly the chairman of the HPA, stated that it would be timely to carry out further studies as this new technology is rolled out. The HPA continues to discuss this with relevant parties.

Basics

Wi-Fi is a particular type of wireless local area network (WLAN) - ie it is not necessary to plug a computer into a phone network via a cable. There are many types of WLAN but all of them allow two or more computers to form a network using radio frequency (RF) signals. They allow users to access and share data, applications, internet access or other

network resources in the same way as wired (cable) systems. For more information, view the Wireless Local Area Networks (WLANs) page.

ICNIRP is the International Commission on Non-Ionizing Radiation Protection. See the ICNIRP website at http://www.icnirp.org.

Key points

- There is no consistent evidence to date that exposure to RF signals from Wi-Fi and WLANs adversely affect the health of the general population.
- The signals from Wi-Fi are very low power, typically 0.1 watt (100 milliwatts) in both the computer and the mast (or router) and resulting exposures should be well within internationally-accepted guidelines.
- The frequencies used are broadly the same as those from other RF applications such as FM radio, TV and mobile phones.
- Based on current knowledge, RF exposures from Wi-Fi are likely to be lower than those from mobile phones.
- On the basis of current scientific information, exposures from Wi-Fi equipment satisfy international guidelines. There is no consistent evidence of health effects from RF exposures below guideline levels and no reason why schools and others should not use Wi-Fi equipment.

Exposure to electromagnetic fields from wireless computer networks (Wi-Fi) - update on project progress

Following the announcement by the Board of HPA on 12 October 2007, a systematic programme of research into WLANs and their use started at the HPA Radiation Protection Division. At the start of the project, comprehensive Wi-Fi test facilities were set up at the HPA Chilton site and a review of technical standards and wireless equipment used in UK schools was carried out.

Due to the popularity of laptops in classrooms and the likelihood that the majority of Wi-Fi exposure would come from these devices because they are generally nearer to children than the access points, it was decided that the experimental measurements would begin with laptops transmitting in the 2.4 GHz frequency band. A total of 15 laptops were chosen from among the most popular models used in the education sector in the UK.

The objective of the laboratory measurements was to establish the radiation pattern (ie the angular distribution of electric field strength around each laptop) during transmission and identify the angles at which the field was a maximum. The electric field strength at these angles was then measured as a function of distance.

The results have so far shown that, for a given position, the field strength fluctuated between 2 (and sometimes 3) distinct levels because of the existence of several transmitting antennas within each laptop. Overall, similar radiation pattern measurements for all 15 laptops have been observed with a minimum in the direction from the front of

the laptop (towards the torso of the user). Generally, two angular maxima were observed that were symmetrically opposed across a vertical plane bisecting the screen and keyboard. All 15 laptops tested had electric field strength values indicating they had output powers during transmission in the range 6-20 mW. Taking into account the directional properties, the Equivalent Isotropically Radiated Power (EIRP) calculated for all laptops was in the range 17-57 mW and well below the 100 mW (EIRP) limit set for Europe.

A more detailed description of the project and some early results are presented here Wi-Fi in schools (PDF, 276 KB). Furthermore, these results have been presented at the Bioelectromagnetics Society (BEMS) and the European BioElectromagnetics Association (EBEA) BioEM2009 conference (June 2009), see paper 9-2 at http://bioem2009.org/session-9/.

These results are consistent with the HPA position that exposures to the radio waves from Wi-Fi equipment are not expected to exceed internationally-accepted guidelines and that they are less than from mobile phones. Further results will be published on the HPA website after they have been finalised.

Further work

The remainder of the laboratory measurements includes the assessment of the electric field strength around access points operating at 2.4 GHz. Measurements will also be carried out on a selection of laptops and access points operating in the 5 GHz band.

Further work will then involve the modelling of Wi-Fi equipment and its internal RF structures (antennas) in order to assess the localised specific energy absorption rates (SARs) in users, including children. In addition, measurements of radiated powers and transmit time proportions in schools are planned.

The experimental results, together with information from other studies on radio signals and health, will then be used as the basis for a wider health risk review.

Last reviewed: 26 October 2009

Electric and Magnetic Fields at Power Frequencies, HEALTH CANADA, April 2010

http://www.phac-aspc.gc.ca/publicat/cdic-mcc/29-1-supp/ar_05-eng.php

- The current evidence relating to averaged magnetic field exposures greater than 0.4 μT and leukemia in children suggests, but does not prove, a causal relationship.

- Studies of workers occupationally exposed to high levels of electric and magnetic fields also suggests an association between high level ELF EMF exposure and an increased risk of cancer, specifically acute non-lymphocytic leukemia.
- There is inadequate evidence that residential exposures to electric or magnetic fields are associated with increased cancer risks for adults.

Electromagnetic Hypersensitivity, IEEE, 2002

COMAR is a Technical Committee of the Engineering in Medicine and Biology Society (EMBS) of the Institute of Electrical and Electronics Engineers (IEEE). It reports to the EMBS President and Administrative Committee.
COMAR's primary area of interest is biological effects of non-ionizing electromagnetic radiation. It examines and interprets the biological effects and presents its findings in an authoritative manner, usually in Technical Information Statements (TIS's) or Position Papers. These papers are subject to an extensive review process within the Committee and represent the consensus of the Committee

http://ewh.ieee.org/soc/embs/comar/Hypersensitivity.htm

Electromagnetic Hypersensitivity
Certain individuals experience a variety of health symptoms, which they attribute to exposure to electric or magnetic fields from sources such as power lines, household appliances, visual display units (VDUs), light sources, mobile telephones and mobile phone base stations. Some individuals are so severely afflicted that they cease work and change their entire lifestyle, or take exceptional measures such as sleeping under aluminium blankets.

This perceived sensitivity to electromagnetic fields has the general name "electromagnetic hypersensitivity" or EHS. The fields that electromagnetically hypersensitive individuals consider to be the cause of their symptoms vary considerably, but they are invariably far below recommended exposure limits, and very far below field levels that are known to produce adverse effects in unaffected humans.

This Technical Information Statement describes what is known about EHS and summarizes recommendations from medical groups for helping people with EHS.

Prevalence of Symptoms Associated with EHS

The most comprehensive survey of EHS was reported by Bergqvist and colleagues in 1997. This study identified a list of symptoms reported by electromagnetically hypersensitive individuals. In decreasing order of frequency the symptoms are:

- Nervous system symptoms (e.g. fatigue, stress, sleep disturbances)
- Skin symptoms (e.g. facial prickling, burning sensations, rashes)

- Various body symptoms (e.g. pain and ache in muscles)
- Eye symptoms (e.g. burning sensations).
- Various less common symptoms, including ear, nose, and throat symptoms, digestive disorders.

The severity of the symptoms varied greatly. In some cases they were sufficiently severe to prevent the EHS individual from carrying out normal life activities.

The Bergqvist committee obtained a range of estimates of the number of electromagnetically hypersensitive individuals in the general population. Its survey of Swedish centers for occupational medicine suggested that a few individuals per million in the population are electromagnetically hypersensitive. By contrast, the committee's survey of self-help groups for electromagnetically hypersensitive individuals led to a much higher estimate, of up to a few tenths of a percent the population that experiences some form of EHS. The first estimate may be too low, since it would include only individuals who are treated in occupational health clinics. The second estimate is almost certainly too high, since it was based on individuals who were self-selected for EHS.

Both the prevalence of EHS, and the reported symptoms, vary considerably with geographic location. EHS has a higher prevalence in Sweden, Germany, and Denmark than in the United Kingdom, Austria, and France. EHS individuals in Nordic countries are more likely to report symptoms from use of visual display units, and their symptoms are more commonly related to skin disorders, than elsewhere in Europe (Bergqvist,1997).

Provocation Studies

In provocation studies, investigators expose electromagnetically hypersensitive individuals to electric or magnetic fields similar to those that they considered to be the cause of their symptoms, in an attempt to elicit the EHS symptoms under controlled laboratory conditions. Such studies are valuable in probing for links between the symptoms and exposure to fields.

So far, at least 9 provocation studies have been reported on electromagnetically hypersensitive individuals (for a review of work through the mid-1990s see Bergqvist 1997). The studies have been overwhelmingly unsuccessful in being able to link EHS symptoms in these subjects to exposures to electric or magnetic fields.

For example, Flodin et al (2000) exposed 15 electromagnetically hypersensitive individuals and normal controls to electric and magnetic fields in their homes or workplaces. The electromagnetically hypersensitive individuals were no better than control subjects in identifying their exposure to electric or magnetic fields during the experiment.

Some users of mobile telephones have reported headaches and other health symptoms connected with the use of the phones (Chia et al 2000). Hietanen and colleagues (2002) tested 20 subjects who considered themselves to be sensitive to fields from mobile

telephones. During real or sham (simulated) exposures to radiofrequency (RF) energy from mobile telephone handsets, the subjects reported a variety of symptoms. However, the authors report, "the number of reported symptoms was higher during sham exposure than during real exposure conditions," and "none of the test subjects could distinguish real RF exposure from sham exposure".

One early study, by Rea and colleagues (1991) did elicit responses from electromagnetically hypersensitive individuals by exposing them to magnetic fields at levels comparable to those found in many ordinary environments. In that study, electromagnetically hypersensitive individuals were exposed to magnetic fields over a range of frequencies (from 0.1 Hz to 5 MHz), from a coil positioned 0.3 meters from their feet. However, other investigators criticised that study because of the possibility that the coils produced audible cues, and other technical problems (Bergqvist 1993). It is well known that such cues can easily confound studies that seek to establish the sensitivity of individuals to weak electric and magnetic fields (eg. Tucker et al (1978)).

Taken as a whole, the provocation studies strongly suggest that EHS symptoms are not related to actual exposures to electric or magnetic fields, and that electromagnetically hypersensitive individuals are no better than non-hypersensitive individuals in detecting the presence of fields.

Resemblance to Other Disorders

The symptoms reported by electromagnetically hypersensitive individuals, such as headache, fatigue, and stress, are common and nonspecific, i.e. they may have many causes.

In some cases, the symptoms experienced by electromagnetically hypersensitive individuals may result from environmental factors other than electromagnetic fields. These might include "flicker" of fluorescent lights, glare and other visual problems with VDUs, and effects resulting from poor ergonomic design of workstations. Other factors might include poor indoor air quality or emotional stress in the workplace or living environment. Sensations of warmth when using a mobile telephone might be caused by heat generated in the electrical circuits within the handsets, or from lack of air circulation around the ear when the handset is held against it.

There is also clear evidence that psychological factors are important in some cases. For example, some of the subjects in the study by Tucker (1978) reported headaches during placebo experiments in which the fields had never been turned on.

EHS bears close resemblance to idiopathic environmental intolerances (IEI), otherwise known as multiple chemical sensitivities (MCS). In MCS, individuals report a variety of symptoms which they attribute to exposure to chemicals in the environment (Bornschein et al, 2001). In both EHS and MCS the symptoms are nonspecific (might have a variety of causes), the exposure levels to chemicals or electromagnetic fields are invariably far below those that are expected to produce adverse effects, and provocation studies are

typically unable to link the symptoms with exposure. Both syndromes remain poorly understood.

Finally, EHS has apparent similarities to "microwave illness", which has been reported in the Russian and Eastern European medical literature at various times since at least the 1970s. This syndrome is characterized by nonspecific symptoms such as headache and malaise in workers with presumed exposure to electromagnetic fields. However, the syndrome is not recognized by Western physicians. Moreover, the Russian data consist largely of case reports (and not well-controlled epidemiology studies, which would be more informative) with little if any attempt to determine the fields to which the workers were actually exposed. Consequently, the nature of the electromagnetic field exposure that produced the symptoms is not established (Gluszcz 1979). Other physicians have complained about the vagueness of the diagnostic criteria for the illness (eg. Djordjevic 1983).

Helping electromagnetically hypersensitive individuals

Whatever its cause, EHS is a real, and sometimes disabling, problem for the affected individual. The Bergqvist committee offered recommendations for helping electromagnetically hypersensitive individuals, which are summarized below.

The Bergqvist committee recommended that the starting point for all treatment should be the health symptoms of the individual, and not his or her perceived need for electrical "sanitation" of the workplace or home. Electromagnetic field surveys in normal workplace and residential environments are extremely unlikely to uncover the presence of fields that can be related to the symptoms of the EHS individual.

In helping electromagnetically hypersensitive individuals, it is important to try to identify and treat any relevant health, environmental, or occupational hygiene problems that might be present, without assuming that they are caused by exposure to electric or magnetic fields.

This requires, for severely affected individuals:

- Medical evaluation of the EHS individual to identify and treat any specific medical conditions that may be responsible for the symptoms.
- Evaluation of the workplace or home for factors that might contribute to the presented symptoms. These might include indoor air pollution, excessive noise, poor lighting, or ergonomic factors. In the workplace this evaluation would normally be conducted by an industrial hygienist.

Apart from identifying any treatable causes of the patient's symptoms, physicians need to initiate communication with the EHS individual and help develop strategies for coping with the situation.

For electromagnetically hypersensitive individuals with long lasting symptoms and severe handicaps, therapy should be directed principally at reducing symptoms and functional handicaps. As recommended by the Bergqvist committee, this should be done in close co-operation between

- Physicians (for handling the medical aspects of the symptoms)
- A hygienist (for identifying and if necessary controlling factors in the environment that are known to have adverse health effects of relevance to the \ A psychotherapist, where appropriate.

The Bergqvist committee also stressed the importance of providing electromagnetically hypersensitive individuals, health-care professionals, and employers with information about health and safety hazards of electromagnetic fields, and their possible relation to EHS. The committee stressed that this information should be balanced and appropriate for different target groups, including the general population and various professional groups. The committee also stressed that the information should include a clear statement that no scientific basis currently exists for a connection between EHS and exposure to electromagnetic fields.

Given the similarity of EHS to multiple chemical sensitivities, medical advice for handling MCS patients might also be helpful. For example, Magill and Suruda (1998) recommend that treatment should aim to establish an effective physician-patient relationship, and encourage patients to return to work and to a normal social life.

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Abstract

Idiopathic Environmental Intolerance attributed to electromagnetic fields (IEI-EMF; formerly 'electromagetic hypersensitivity') is a medically unexplained illness in which subjective symptoms are reported following exposure to electrical devices. In an earlier systematic review, we reported data from 31 blind provocation studies which had exposed IEI-EMF volunteers to active or sham electromagnetic fields and assessed whether volunteers could detect these fields or whether they reported worse symptoms when exposed to them. In this article, we report an update to that review. An extensive literature search identified 15 new experiments. Including studies reported in our earlier review, 46 blind or double-blind provocation studies in all, involving 1175 IEI-EMF volunteers, have tested whether exposure to electromagnetic fields is responsible for triggering symptoms in IEI-EMF. No robust evidence could be found to support this theory. However, the studies included in the review did support the role of the nocebo effect in triggering acute symptoms in IEI-EMF sufferers. Despite the conviction of IEI-EMF sufferers that their symptoms are triggered by exposure to electromagnetic fields, repeated experiments have been unable to replicate this phenomenon under controlled conditions. A narrow focus by clinicians or policy makers on bioelectromagnetic mechanisms is therefore, unlikely to help IEI-EMF patients in the long-term.
(c) 2009 Wiley-Liss, Inc.

Electromagnetic Field Hypersensitivity, UNIVERSITY OF OTTAWA, MCLAUGHLIN CENTRE FOR POPULATION HEALTH RISK ASSESSMENT

http://www.rfcom.ca/faq/answers.shtml#q13

13. Are some individuals hypersensitive to electromagnetic fields?

Some individuals report health symptoms that they relate to exposure to EMF. These effects have been termed electromagnetic hypersensitivity (EHS). On occasion these effects can have profound effects on the individuals' way of life. They complain of a variety of non-specific symptoms, which vary from person to person, and include general complaints like tiredness and dizziness, as well as skin, digestive, and other symptoms. There are more reports of EHS in Scandinavian countries than elsewhere. Provocation studies almost all have shown that individuals with EHS cannot detect EMF exposure any more accurately than non-EHS individuals. A WHO workshop on EHS in Prague in 1994 concluded that: "The symptoms are certainly real and can vary widely in their severity. Whatever its cause, EHS can be a disabling problem for the affected individual. EHS has no clear diagnostic criteria and there is no scientific basis to link EHS symptoms to EMF exposure".

For more information on the subject, see WHO's web site at www.who.int/peh-emf/en/ and search for "Electrical hypersensitivity".

The web site of the Committee on Man and Radiation of the Institute of Electric and Electronic Engineers also has a useful report on electromagnetic hypersensitivity. This can be accessed at http://ewh.ieee.org/soc/embs/comar/ or through "Links".

For more on this subject, see "Research-Clinical-Other".

Wireless Technology and Health Outcomes: Evidence and Review, ONTARIO AGENCY FOR HEALTH PROTECTION AND PROMOTION, September, 2010

http://www.oahpp.ca/about/whatsnew/201009_2.html

Conclusions

Research on potential health effects from exposure to RF energy is an active field of investigation. Not surprisingly there is inconsistency and in some cases conflict between the results of individual studies.

Given this inconsistency, it is possible to select the results of individual research studies in support of a variety of opinions; which may range from no risk of health effects on the one hand, to a clear need to reduce current exposure limits on the other.
For this reason, up-to-date reviews of literature which follow a weight of evidence approach are far more useful for informing debate and sound policymaking than reliance on individual studies.

The Royal Society of Canada performed a highly credible review in 1999. Updates to this review have been published; the most recent in 2009. While the most recent review continues to call for additional research to follow up on new findings, after a decade of additional research, there is still no conclusive evidence of adverse effects on health at exposure levels below current Canadian guidelines.

While far from conclusive, there is emerging evidence that long-term frequent use of cellphones may be associated with an increased risk of tumours on the side of the head where the cellphone is used. This is an active area of research and additional studies may confirm or refute this association.

The degree of 'precaution' that should be incorporated into exposure limits for the public is always a subject for debate. There is general agreement that the exposure limits in Health Canada's Safety Code 6 are protective against effects produced through tissue heating. Consistent evidence on the level at which this occurs is available and exposure limits can be set on the basis of this well-established effect and use of safety factors selected by the standard setting organization.

Recently published research demonstrates that Wi-Fi exposure are not only well within recommended limits, but are only a small fraction (less than 1%) of what is received during typical use of cellphones3.

For this reason much of the research on possible effects of RF energy has been focused, and will likely continue to focus, on exposures from cellphones rather than the lower exposures associated with RF uses such as Wi-Fi. RF exposures to the public, including school children, from Wi-Fi are far lower than occur with cellphone use and to date there is no plausible evidence that would indicate current public exposures to Wi-Fi are causing adverse effects on health.

Given the experience with other sources of non-ionizing radiation (e.g. power lines) that have been in use much longer than cellphones or Wi-Fi, it is unlikely that all controversies related to potential RF effects will be resolved even after decades of additional research.

Recent Research on EMF and Health Risks, SWEDISH STATE RADIATION PROTECTION AUTHORITY, 2009

Swedish State Radiation Protection Authority: Recent Research on EMF and Health Risks⊞

Executive summary

A large number of cell studies are done on both genotoxic and non-genotoxic outcomes, such as apoptosis and gene expression. There are no new positive findings from cellular studies that have been well established in terms of experimental quality and replication. Potential heating of the samples is still seen as a major source of artefacts. Moreover, these few positive results are not related to each other and/or are not relevant for health risk assessment.

There are animal studies on brain structure and brain function as well as on genotoxicity and cancer. Also reproductive effects are looked at. However, animal studies have not identified any clear effects on any of a number of different biological endpoints following exposure to RF radiation typical of mobile phone use, generally at levels too low to induce significant heating.

Many human laboratory studies reviewed here are provocation studies with rather short exposures. Most use methods that are too crude, or look at phenomena that are too small, or non-existent, for the research to be informative. However, EEG alpha- and betafrequencies seem to be sensitive to modulation by some pulse-modulation frequencies of the microwave- or GSM-signal. This curious effect does not have any behavioural counterpart, since similar types of EMF have been applied in various behavioural studies with negative results. This needs to be pursued. Surprisingly few studies have been done on children. In light of all official recommendations in different countries with special emphasis on children's use of mobile phones, this is rather peculiar.

Several epidemiological studies on mobile phone use and cancer have been presented since the previous report, including national studies from the Interphone group as well as other studies. There are also studies on reproductive outcomes. A few recent studies on

people living near transmitters have also appeared. None of this changes any of the Groups previous conclusions. For conclusions, see the section on conclusions based on currently available data. However, one can draw some methodological conclusions at this point. One is that the problems in case control studies are too large for more such studies to be warranted at present. Another one is that cross- sectional research on symptoms, or other end points for that matter, also have too big inherent methodological problems to be warranted.

Conclusions on RF fields based on research available to date

Cancer and mobile phones

Overall the studies published to date do not demonstrate an increased risk of cancer related to mobile phone use within approximately ten years of use for any tumour of the brain or any other head tumour. Despite the methodological shortcomings and the limited data on long latency and long-term use, the available evidence does not suggest a causal association between mobile phone use and fast-growing tumours such as malignant glioma in adults (at least for tumours with short induction periods). For slow-growing tumours such as meningioma and acoustic neuroma, as well as for glioma among longterm users, the absence of association reported thus far is less conclusive because the observation period has been too short. This is consistent with results from animal and cellular research, which does not indicate that exposure of the type that is generated by mobile telephony, might be implicated in the origin or development of cancer. Long-term animal data on balance do not indicate any carcinogenic effect.

However, there are currently no data on mobile telephone use and cancer risk in children. For tumours other than intracranial, few epidemiological studies have been completed, but reasons to suspect an association with mobile telephony are even weaker than for tumours of the head.

Cancer and transmitters

The majority of studies on cancer among people who are exposed to RF from radio- or TV- transmitters or from mobile phone base stations have relied on too crude proxies for exposure to provide meaningful results. Indeed, only two studies, both on childhood leukaemia, have used models to assess individual exposure and both of those provide evidence against an association. One cannot conclusively exclude the possibility of an increased cancer risk in people exposed to RF from transmitters based on these results. However, these results in combination with the negative animal data and very low exposure from transmitters make it highly unlikely that living in the vicinity of a transmitter implicates an increased risk of cancer.

"Electromagnetic hypersensitivity, EHS"

While the symptoms experienced by patients with perceived electromagnetic hypersensitivity are very real and some subjects suffer severely, there is no evidence that RF exposure is a causal factor. In a number of experimental provocation studies, persons who consider themselves electrically hypersensitive and healthy volunteers have been exposed to either sham or real RF fields, but symptoms have not been more prevalent during RF exposure than during sham in any of the experimental groups. Several studies

have indicated a nocebo effect, i.e. an adverse effect caused by an expectation that something is harmful. Associations have been found between self-reported exposure and the outcomes, whereas no associations were seen with measured RF exposure.

President's Cancer Panel, NATIONAL INSTITUTES OF HEALTH, 2009

http://deainfo.nci.nih.gov/advisory/pcp/pcp.htm
This is a panel of three – an oncologist, an immunologist, and a tumor virologist. Early in 2009 the panel held a session on nuclear fallout, electromagnetic fields, and radiation exposure. A number of people presented, including Devra Davis, the author of a book on radiofrequency and health effects as well as David O. Carpenter, who has also written on the topic and recommends against using cell phones unless a landline is unavailable.

We do not see a "global call for the 'precautionary principle'" as is iterated in the Complaint filed with PUC.

Page iv
"Sharp controversy exists in the scientific community as to possible adverse health effects from exposure to low frequency electromagnetic energy. The use of cell phones and other wireless technology is of great concern, particularly since these devices are being used regularly by ever larger and younger segments of the population. At this time, there is no evidence to support a link between cell phone use and cancer. However, the research on cancer and other disease risk among long-term and heavy users of contemporary wireless devices is extremely limited. Similarly, current and potential harms from extremely low frequency radiation are unclear and require further study."

Page 60
"Mechanisms by which ELF EMR may be harmful have been proposed, but are not supported by peer-reviewed research. For example, it has been suggested that these exposures can cause cells to produce stress proteins (i.e., indicating that the cell recognizes the energy as harmful).290 The scant peer-reviewed literature on ELF EMR health effects highlights an important area in which research is needed to elucidate if, and how, ELF EMR raises risks for specific cancers in defined populations and at defined exposure levels.'"
"Findings of a lack of association between ELF EMR from power lines or other sources and cancer are consistent among numerous international organizations, including WHO,296,297 IARC,298 the EU Scientific Committee on Emerging and Newly Identified Health Risks,299 and the International Commission for Non-ionizing Radiation Protection.288 All emphasize the need for further research in this area. U.S. environmental organizations such as the National Institute of Environmental Health Sciences (NIEHS),300 the Occupational Safety & Health Administration (OSHA),301 and the American Industrial Hygiene Association302 generally conclude that the link between ELF EMR and cancer is controversial or weak."

Press Release on Wireless Networks, SWEDISH RADIATION SAFETY AUTHORITY, November 2009

The Nordic radiation Safety authorities see no need to reduce public exposure generated by mobile base stations and wireless networks, November 16, 2009
http://www.stralsakerhetsmyndigheten.se/In-English/About-the-Swedish-Radiation-Safety-Authority1/News/Press-release-The-Nordic-radiation-Safety-authorities-see-no-need-to-reduce-public-exposure-generated-by-mobile-base-stations-and-wireless-networks/

AUSTRALIAN RADIATION PROTECTION AND NUCLEAR SAFETY AGENCY

http://www.arpansa.gov.au/eme/index.cfm

Cell Phones and Cancer Risks, NATIONAL CANCER INSTITUTE (NCI), NATIONAL INSTITUTES OF HEALTH (NIH), May, 2010

http://www.cancer.gov/cancertopics/factsheet/Risk/cellphones

Key Points from NCI on Cell Phones and Cancer

- Cell phones emit radiofrequency (RF) energy, which is another name for radio waves.
- Research suggests that the amount of RF energy produced by cell phones is too low to cause significant tissue heating or an increase in body temperature.
- Concerns have been raised that RF energy from cell phones may pose a cancer risk to users.
- Researchers are studying tumors of the brain and central nervous system and other sites of the head and neck because cell phones are typically held next to the head when used.
- Research studies have not shown a consistent link between cell phone use and cancer. A large international study (Interphone) published in 2010 found that, overall, cell phone users have no increased risk for two of the most common types of brain tumor—glioma and meningioma. For the small proportion of study participants who reported spending the most total time on cell phone calls there was some increased risk of glioma, but the researchers considered this finding inconclusive.

Cell Phones and Brain Cancer, NATIONAL CANCER INSTITUTE (NCI), NATIONAL INSTITUTES OF HEALTH (NIH), November, 2010

http://www.ncbi.nlm.nih.gov/pubmed/20639214
The use of cellular telephones has grown explosively during the past two decades, and there are now more than 279 million wireless subscribers in the United States. If cellular phone use causes brain cancer, as some suggest, the potential public health implications could be considerable. One might expect the effects of such a prevalent exposure to be reflected in general population incidence rates, unless the induction period is very long or confined to very long-term users. To address this issue, we examined temporal trends in brain cancer incidence rates in the United States, using data collected by the Surveillance, Epidemiology, and End Results (SEER) Program. Log-linear models were used to estimate the annual percent change in rates among whites. With the exception of the 20-29-year age group, the trends for 1992-2006 were downward or flat. Among those aged 20-29 years, there was a statistically significant increasing trend between 1992 and 2006 among females but not among males. The recent trend in 20-29-year-old women was driven by a rising incidence of frontal lobe cancers. No increases were apparent for temporal or parietal lobe cancers, or cancers of the cerebellum, which involve the parts of the brain that would be more highly exposed to radiofrequency radiation from cellular phones. Frontal lobe cancer rates also rose among 20-29-year-old males, but the increase began earlier than among females and before cell phone use was highly prevalent. **Overall, these incidence data do not provide support to the view that cellular phone use causes brain cancer.**

POTENTIAL SOURCES OF CONSULTING EXPERTS

ICNIRP
http://www.icnirp.net/what.htm

What is ICNIRP?
ICNIRP is the International Commission on Non-Ionizing Radiation Protection. It is a body of independent scientific experts consisting of a main Commission of 14 members, 4 Scientific Standing Committees covering Epidemiology, Biology, Dosimetry and Optical Radiation and a number of consulting experts. This expertise is brought to bear on addressing the important issues of possible adverse effects on human health of exposure to non-ionising radiation.

ICNIRP Commission Members:
http://www.icnirp.net/commission.htm
ICNIRP Consulting Experts:
http://www.icnirp.net/cm.htm

RF-COM at the UNIVERSITY OF OTTAWA
http://www.rfcom.ca/about/index.shtml

RFcom is an internet-based information resource about health effects of wireless technologies.

The project is based at the McLaughlin Centre for Population Health Risk Assessment, Institute for Population Health, University of Ottawa.
This project is supported by the McLaughlin Centre for Population Risk Assessment at the University of Ottawa, which was established in 2000 with an initial grant from the R. Samuel McLaughlin Foundation. Additional funding is provided by the Natural Sciences and Engineering Research Council of Canada (NSERC), through a peer-reviewed university-industry partnership program, in which the Canadian Wireless Telecommunications Association (CWTA) is one of the participants.
The contents of the site are the sole responsibility of the Project Team. Neither the public or private sector liaison members of the Project Team nor the funders are involved in decisions taken by the Project Team about information to be posted on the site.

RFcom is managed by a Science Panel that reviews and reports on the most recent research studies about wireless technology and health from around the world. All studies referenced on this website must meet the following criteria:the source must be credible and accountable material must be peer-reviewed-research and data that has been accepted and validated in the Canadian and international communities all studies must have been carried out by an independent third-party person or organization

The use of wireless phones is now an established part of many societies today, with billions of users around the world. This technology has greatly improved our ability to communicate at home or at work in our local and global communities. People use mobile telephones not only for work, but also for the convenience and safety of their families.

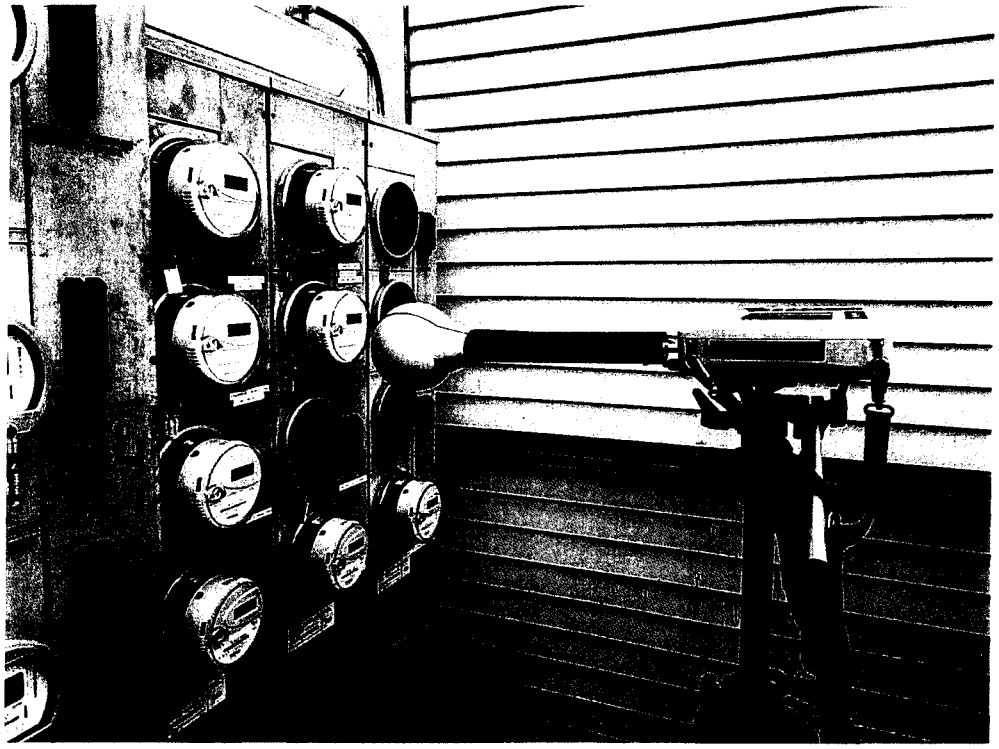
The rapid growth in the use of wireless phones has been accompanied by public concerns about the safety of this new technology. Although numerous scientific reviews have concluded that there is no evidence of a health risk from wireless phones or other wireless communication devices, the concerns continue to be reflected in media reports.
This web site attempts to answer the following questions about wireless phones:
How do they work?
How are safety standards established for them?
What have scientific authorities to say about their safety?
What has research found about their biological effects?
What research is planned in the future?

ATTACHMENT E -

AN EVALUATION OF RF PRODUCED BY SMART METERS

DEPLOYED IN VERMONT

An Evaluation of Radio Frequency Fields Produced by Smart Meters Deployed in Vermont



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- Rick Hackett, Chief Meter Engineer, Green Mountain Power
- Michael Butler, AMI Operations Analyst, Green Mountain Power
- Jim Corbo, AMI Operations Analyst, Green Mountain Power
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- York Sherry, Working Crew Leader Metering, Burlington Electric Department
- Michael Leach, Load and Forecasting Analyst, Burlington Electric Department

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An Evaluation of Radio Frequency Fields Produced by Smart Meters Deployed in the State of Vermont

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An Evaluation of Radio Frequency Fields Produced by Smart Meters Deployed in the State of Vermont

Summary

During November and December, 2012, a comprehensive series of measurements was performed for the Vermont Department of Public Service to evaluate radiofrequency (RF) emissions produced by electric smart meters deployed within the state. A primary impetus for the study is the current public concern about smart meter generated RF fields (the signals produced by the meters) and the potential for such fields to cause adverse biological effects. This study was aimed at assessing compliance of smart meter signal intensities with regulations established by the Federal Communications Commission (FCC) that prescribe limits for safe exposure of humans.

As commonly implemented in many parts of the country, the smart meter systems investigated in Vermont are configured as mesh networks wherein each end point meter installed on a home can wirelessly communicate with other neighboring meters as well as data collection points referred to as Gatekeepers by Green Mountain Power (GMP) and Cell Routers by Burlington Electric Department (BED). Each data collection point can serve some hundreds of end point meters and send the electric energy consumption data received from the meters back to the electric utility company via a wireless wide area network (WWAN) or over a fiber optic network.

The study included extensive measurements of smart meter RF fields in one of the GMP service territories in the Rutland, VT area and in the BED service territory within Burlington, VT. In total, measurements were conducted at 37 different locations in the state which included 18 residential sites, six banks of smart meters (four of which were on residences), two data collection points (one each in the GMP and BED areas), one isolated meter and 14 general environmental measurement sites. Field measurements were accomplished with a spectrum analyzer based selective radiation meter (Narda model SRM-3006) permitting direct measurement of the intensity of RF fields expressed as a percentage of the FCC maximum permissible exposure (MPE) values. The instrumentation also allowed for time analysis of the detected RF fields from which the duty cycle of the RF emissions could be determined.

The meters deployed by both GMP (manufactured by Elster) and BED (manufactured by Itron) operate as RF local area networks (RF LANs) in the configuration of a mesh network and communicate within the FCC designated license free band of 902-928 MHz. The internal radio transceivers operate at low powers of 182 milliwatts (mW) and 304 mW by GMP and BED respectively.

Summary

Besides the RF LAN that operates in the 900 MHz region, an additional radio is contained in both the GMP and BED meters that, in the future, can be used to facilitate home area networks (HANs) at customer homes. A HAN, utilizing radios that operate in the 2.4 GHz band, will allow, for example, the customer to observe in real time their residential consumption of electric energy. This feature had not been implemented within the BED service territory at the time of the field measurements but GMP has a pilot project of evaluating customer reactions to a HAN in a sample of residences in the Rutland area. During this study, it was observed that all GMP meters emitted short, infrequent RF pulses from the HAN radios though some 500 meters were commissioned to communicate with in home display (IHD) devices. Hence, field measurements included determining the same characteristics for the HAN radio emissions in Rutland as was performed for the RF LAN emissions.

RF fields were measured as a function of distance in front of smart meters and throughout most of the homes to which the meters were attached. The measurement approach involved detecting the instantaneous peak value of the pulsed RF fields emitted by smart meters to examine how the RF field decreases with distance from the meter. Separately, strategic measurements were made to assess the duty cycle of meter emissions at many locations with a focus on determining the greatest duty cycle that could be achieved. The duty cycle of a smart meter is a measure of how the average value of RF field is related to the peak value of RF field. By knowing the duty cycle, the peak values could be adjusted to arrive at their corresponding time-averaged values. Field work in Vermont was supplemented with measurements on two test meters provided by GMP and BED in Colville, WA. Many measurements were performed over half-hour periods, both in Vermont and in Colville; 30 minutes is the averaging time specified in the FCC RF exposure regulations.

As a means for forming a perspective on potential smart meter RF exposures, additional measurements of ambient levels of FM radio and television (TV) broadcast signals as well as mobile phone base station signals were made in Rutland, Burlington, Montpelier and Saint Albans, VT. Additionally, as the opportunity presented itself, limited measurements were also made of RF emissions of microwave ovens, wireless routers used for distribution of Internet connectivity and a mobile phone. Azimuth and elevation plane patterns of RF emissions of the smart meters were determined and measurements were made of low frequency electric and magnetic fields from 0 to 100 kHz with the test meters in Colville.

Measurement data collected during the project support the following conclusions in regard to potential exposure associated with the smart meters investigated in Vermont:

- The instantaneous peak value of RF field, during the pulses, may be as high as 3.9% of the MPE at the closest distance measured of one foot.

Summary

- Consistent with certification reports filed with the FCC on behalf of smart meter manufacturers by independent test labs, the instantaneous peak values of RF fields found in this study, without any consideration of time or spatial averaging, comply with the MPE.

- Smart meters produce intermittent bursts of pulsed RF fields that are small when compared to the FCC MPE for public exposure[1]. When the field is adjusted for duty cycle and spatial averaging, in accord with FCC rules, the resulting maximum value of potential exposure at one foot directly in front of the meter represents about 0.068% of the time-averaged/spatial-averaged exposure limit for GMP meters and 0.032% in the case of BED meters.

- The smart meter emissions decrease sharply with increasing distance from the meter being equivalent to about 0.0013% of the exposure limit (time averaged and spatial averaged) at 10 feet from the meter (equivalent to 3,800,000 times less than the actual hazard threshold).

- Maximum duty cycles were in the 3–4% range and were comparable to duty cycles found in earlier studies [1, 2].

- Exposure, in terms of instantaneous peak as well as time-averaged RF fields, caused by deployed smart meters in Vermont is small in comparison to that related to many other sources of RF fields in the environment. For instance, local values of long term, time-averaged RF fields (as a fraction of the MPE) from FM radio broadcasting can, in some areas as found in this study, be as much as ten to hundreds of times greater than those values found immediately near smart meters. The common use of normal appliances within a home or office, such as microwave ovens and wireless routers, can lead to RF fields that are comparable to or substantially greater than those produced by smart meters. This applies to the use of mobile phones as well; both mobile phones and smart meters operate with roughly the same transmitter peak powers. In this context, however, mobile phones are normally held against the head during use while smart meters are not.

- Low frequency electric and magnetic fields produced by the smart meters and their internal switch mode power supplies, at one foot from the meters, were substantially smaller in value than recommended limits [13].

[1] For convenience in this report, the term pulse is used interchangeably with the term burst.

Summary

- Smart meters make use of pulsed RF signals, a characteristic common to other devices found in the everyday environment such as wireless routers, radar systems used for air traffic control and most mobile phones.

- Peak RF fields associated with large banks of smart meters are not materially different from those of a single meter. Average RF field levels can be greater due to the number of meters. However, there is no general correlation between overall higher average RF fields associated with large banks of meters since the greatest duty cycle of any given smart meter appears to be more related to a specific meter's position within the wireless network's hierarchy, i.e., how close it is, from a communications perspective, to its data collection point. Hence, a single meter that serves to relay energy consumption data from many other meters to the data collection point can exhibit a greater time-averaged RF field than a large group of meters that are not close, network wise, to a data collection point.

- Of 141 interior RF field measurements inside residences, the greatest measured value was equivalent to 0.0014% of the MPE in term of time-averaged and spatially-averaged exposure. This maximum value was associated with a location directly behind the installed smart meter but inside the home. The average interior residential RF field, time and spatially averaged, was equivalent to 0.000058% of the MPE.

The FCC MPE values were derived with the inclusion of a safety factor of 50 below the actual threshold of hazard from prolonged exposure. When the above estimated RF field exposures for GMP and BED meters at the closest distance of one foot are considered in this light, this means that the most conservative estimates of potential exposure range between approximately 75,000 and 156,000 times less than the hazard threshold respectively.

Using the highest indicated results from the measurements performed in this study, potential exposure of individuals to the RF fields associated with the currently deployed smart meters in the GMP and BED service territories is small when compared to the limits set by the FCC. It is concluded that any potential exposure to the investigated smart meters will comply with the FCC exposure rules by a wide margin.

Introduction

The work documented in this report is related to an evaluation of the radiofrequency (RF) emissions associated with the operation of electric smart meters in Vermont. A proliferation of smart meters across the nation, as a component of the so-called smart grid initiative in the United States, has raised the question among some in the public of how the RF emissions of these new technology meters compare with limits that have been set for safe human exposures. Recent studies have determined that the low power of the radio transceivers inside the meters results in only low level RF fields that comply with Federal standards, generally by wide margins [1, 2, 3]. Nonetheless, this relatively new technology that includes the production of brief but numerous pulses of RF energy and the sheer number of emitters (one on each home and business) continues to elicit questions regarding smart meter emissions and has influenced a more in-depth examination of smart meters in Vermont. This study, commissioned by the Vermont Department of Public Service, explored the RF emission characteristics associated with smart meters being deployed by two electric utilities in Vermont, Green Mountain Power (GMP) and the Burlington Electric Department (BED). These two utilities employ smart meters that were presumed to be representative of most smart meters within the state (GMP makes use of meters manufactured by Elster and BED uses meters by Itron). At the time of the study, GMP had deployed approximately 95,000 smart meters of a future total estimated number of 180,000 meters in its service territory. BED had deployed approximately 14,000 meters within its relatively small service territory within the city of Burlington extending some six miles north and south and three miles east and west. The field work in Vermont occurred during November and December, 2012.

Electric power meters are designed to measure the amount of electric energy used by a customer and are calibrated to read in terms of the unit kilowatt-hour (kWh).[2] Older style electro-mechanical power meters, with rotating disks, were first widely introduced by Westinghouse and have been used for over 100 years [3]. Such meters are referred to as analog meters and have proved to be extremely reliable. Usually, monthly, a utility meter reader visits the site of the meter to manually record how much energy has been consumed during the previous month. However, with the introduction of digital electronics in electric power meters, and RF technology more recently (approximately 2006), the smart meter communicates energy consumption data wirelessly to the electric utility company. Wireless smart meters are generally referred to as a part of advanced metering infrastructure (AMI).

This study examined the strengths of the RF fields emitted by smart meters with attention to both the instantaneous peak values of field power density and average values. The work also included measurements of the duration of the brief emissions and

[2] A kilowatt-hour (kWh) represents an amount of energy used by an electric load of one kilowatt of electric power over a period of one hour.

the number of emissions that could be observed to occur over sampling intervals so that the amount of time that the meters actually transmit could be determined[3]. Effort was made to identify the maximum amount of transmitter activity that might occur during smart meter operation.

A primary focus of the measurements was, ultimately, to develop data to allow for an accurate and precise comparison of smart meter emissions in Vermont with the regulatory exposure limits promulgated by the Federal Communications Commission (FCC) [4], as well as to other common RF emission sources.

[3] This is related to a term called duty cycle, described later in this report.

Smart Meter Mesh Networks

To better understand the challenge of characterizing RF fields of smart meters, it is helpful to envision how the meters work and how they are configured in a geographic area to report energy consumption data. Both of the meter types used by GMP and BED are deployed as so-called mesh networks. The term "mesh" refers to the geographic distribution of smart meters throughout a neighborhood area wherein each meter has the ability to communicate with other neighboring meters and each meter can be called a node in the network. When the many nodes of the network are viewed on a diagram, it resembles the rough geometrical shape of a mesh.

Associated with operation of the mesh network is the requirement that the data that each meter generates, somehow, gets back to the electric utility company. This can be accomplished via alternative means including land line telephone, fiber optic network coverage or a wireless link, typically through use of a wireless data plan with a cellular carrier that serves the area with a Wireless Wide Area Network (WWAN). So, each end point meter (the meter attached to a home) would ideally be able to communicate directly to the data collection point from where the data would then be uplinked via a wireless Internet connection (as used by GMP) back to the utility or placed on an area fiber optic network (as used by BED). However, this ideal link between each end point meter and the data collection point is rarely achieved in a single "hop" except for meters that happen to be located close to the collection point and, rather, the data from each meter is relayed to the data collection point via the data signals hopping between various smart meters such that the data eventually arrives at the collection point. Each end point meter identifies a suitable communications route by briefly communicating with other meters from time to time, storing this path information in its memory and, then, when sending its data, using the routing information it has retained to communicate to the data collection point via some number of "hops"[4]. Mesh networks are complex in that if, for some reason, a communication path is blocked, the network can identify an alternative routing, ultimately, to get the data to the collection point. This aspect of mesh networks is sometimes referred to as the network being "self healing"; i.e., it has the ability to dynamically adjust to conditions for reliable communication by invoking the use of different end point meters in the region for communications assistance. Larger geographic areas are typically broken into different networks where each network may consist of about 400 to 500 end point meters each. Figure 1 illustrates a simple smart meter mesh network topology (physical configuration).

The electric utility company receives "load profile" data for each end point meter from the data collection points several times each day. In the case of GMP, data is

[4] In this context, a hop refers to a transmission between two end point meters.

received every six hours or four times per day. For BED, load profile data is obtained every eight hours or three times per day. The load profile data consists of 15-minute

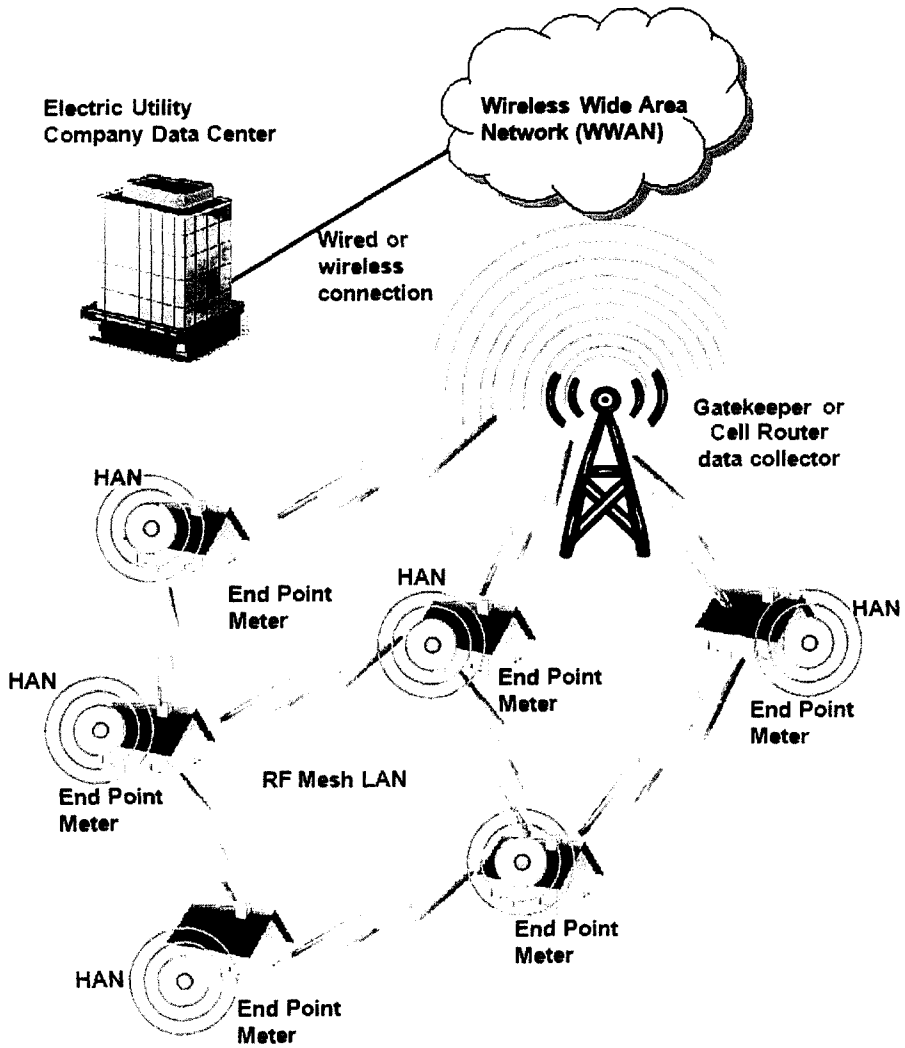

Figure 1. Simplified diagram of a smart meter mesh network configuration. Some meters communicate directly with the data collector while the signal from some meters must hop from meter to meter to reach the tower-mounted data collector. Data is sent to the electric utility company, in this example, from the data collector via a WWAN connection to the Internet. The RF LAN for the two smart meter systems studied operates in the 902-928 MHz license free band. HANs are illustrated if such capability is implemented in the future.

interval reads from the meter. The interval reads may consist of energy consumption, voltage levels and other electrical parameters. The total amount of time that smart meters actually emit RF fields over the period of a day, however, is extremely small with transmission of signals increasing when each meter receives a request to report past interval data. However, smart meters are not totally "silent" during other times; meter

RF activity typically occurs throughout the day with periodic signals used to maintain its organization within the network and to assist other meters in relaying data upstream toward the data collection point. Hence, although the meter transmissions consist of only very brief signals, lasting typically only fractions of a second in duration, it is common to observe these intermittent emissions all during the day with the amount of activity varying according to what the meter is doing at the time. At locations where a bank of meters exists, it is normal to observe more transmitter activity due to the cumulative number of meters.

Different smart meter manufacturers call the data collection points by different names but they serve the same basic purpose. In the case of Elster meters, the term "Gatekeeper" is used while for the Itron meters, the term "Cell Router" is used[5]. A difference between the GMP networks and the BED networks is that GMP makes use of a digital cellular link (WWAN) for transmitting data from all of the meters served by the Gatekeeper back to the company. In the case of BED, the company takes the data collected by its Cell Routers and places it on a fiber optic network that exists throughout the city of Burlington for transmission back to the company (in this case, there are no RF emissions associated with this delivery of data from the Cell Router to the company). In each case, either the Gatekeeper or Cell Router queries each end point meter via the RF LAN 900 MHz radio, receives the data from the end point meters associated with the particular Gatekeeper or Cell Router, stores these data and then communicates the aggregate data back to the utility either four or three times throughout the day. At the time of the study, GMP employed some 267 Gatekeepers (out of a future potential number of some 500) while BED made use of 27 Cell Routers as data collection points. Both GMP and BED used elevated locations for the Gatekeeper or Cell Router, typically on telephone or power poles within the region served by the device.

Both the Elster and Itron meters use low power radio transceivers inside the meters for the meter-to-meter communications within the mesh networks, referred to as an RF LAN (RF local area network), that operate in a license free band designated by the FCC in the 902 MHz to 928 MHz frequency range (the terminology of the 900 MHz band and 900 MHz radios will be used commonly throughout this report in the interest of brevity). Each Gatekeeper or Cell Router also contains a similar 900 MHz radio transceiver for the communication between it and various end point meters. In the case of the Gatekeeper, a WWAN transceiver (very similar to an AirCard that might be used with a laptop computer for connection to a high speed digital network)[6] is the device responsible for connection to the WWAN. This WWAN transceiver module (also commonly called a modem) is similar to a cell phone and operates with approximately

[5] Itron uses the name Cell Router since the device has the ability to transmit via a WWAN but in the case of the Cell Routers used by BED, the transmission is via a fiber optic link installed by the city.

[6] Note that a WWAN is different from common WiFi which allows wireless connectivity between computers and so-called hot spots and wireless routers typically used within homes for distribution of the Internet.

the same power as a cell phone. Depending on the particular wireless carrier that provides the WWAN service to the utility company, the operating frequency of the WWAN transceiver may be in several different bands but typically either the 800-900 MHz or 1.9 GHz bands.

A common and additional feature of smart meters is the provision of the means for implementing a Home Area Network (HAN). A HAN provides for a separate wireless connection between the meter and devices inside the home such as an "in home display" (IHD) for displaying electric energy consumption from moment to moment. This communication feature is accomplished with a lower power radio transceiver that normally operates in the license free band of 2.4 to 2. 5 GHz (referred to as the 2.4 GHz band in this report). The HAN radio, as it is referred to, makes use of a low data rate digital communications protocol with the name ZigBee and often, this radio is simply called a ZigBee radio. Not all smart meters are equipped with a HAN radio but it is a rather common practice to do so. Both the Elster and Itron meters deployed by GMP and BED, respectively, contain HAN radios. However, at the time of this study, neither GMP nor BED had implemented the HAN radios for day-to-day use by customers. Only in the case of some homes in the Rutland area, in the GMP service territory, have the HAN radios been "commissioned" to communicate with an IHD on an experimental basis to test the ability of the HAN to operate properly. Richard Tell Associates discovered during the course of the study that, contrary to what GMP had originally told the Department of Public Service, all the HAN radios within the GMP smart meters were observed to emit short, infrequent RF pulses[7]. The BED had not activated the use of the HAN radio at any end point meter.

[7] After learning that HAN or Zigbee radios in GMP and Stowe Electric Department smart meters are actively emitting RF pulses, the DPS sent a letter to the utilities on December 11, 2012, and GMP and Stowe responded on January 2, 2013 to say that meter manufacturer Elster is working on a firmware update to be released by the end of June 2013 that would shut off the HAN radio emissions until such time that the devices are ready to be commissioned to pair with IHDs.

Basic Meter Specifications

This study examined RF fields associated with two different meter types manufactured by Elster and Itron (Figure 2). Both meters are of the 200 ampere class rated for residential service and contain both 900 MHz and 2.4 GHz radios.

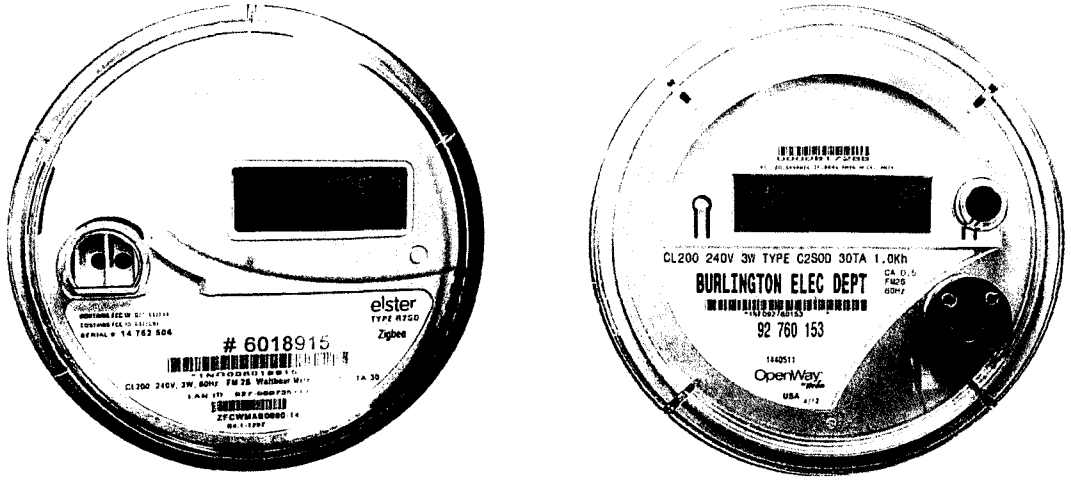

Figure 2. The Elster (left) and Itron smart meters deployed within the state of Vermont by Green Mountain Power (GMP) and the Burlington Electric Department (BED).

Prior to sale of these meters, the manufacturers must submit the meters to a series of laboratory tests to insure that they meet technical requirements of the FCC[8] such as compliance with transmitter output power, harmonic production, etc. such that they may be used within the FCC's license free bands. Once entered into the FCC's database of equipment authorizations, an FCC identification number is assigned to each device for which testing has been accomplished.[9] The relevant reports provided to the FCC for the Elster and Itron meters to support the finding of compliance with FCC rules on human RF exposure are reproduced in Appendices A and B respectively. Table 1 summarizes the relevant technical specifications of each meter in terms relevant to assessing RF fields.

[8] This process is designated as a part of the FCC's equipment authorization process.
[9] The FCC equipment database is found at: http://transition.fcc.gov/oet/ea/fccid/

Basic Meter Specifications

Table 1. RF specifications of the Elster and Itron smart meters being used in Vermont that are relevant to consideration of RF fields that may be produced by them.				
	Elster		Itron	
	FCC ID Numbers			
Specification	QZC-RX2EA4/G8JZGB1		SK9AMI6	
Band of operation	RF LAN (900 MHz)	HAN (2.4 GHz)	RF LAN (900 MHz)	HAN (2.4 GHz)
Transmitter power output- dBm (mW)	22.6 dBm (182)	18.7 dBm (74.8)	24.8 dBm (304)	18.9 dBm (78.3)
Antenna gain (dBi)	5.64	0	2.2	3.8
Maximum EIRP- dBm (mW)	28.2 (667)	18.7 (74.8)	27.0 (505)	22.7 (188)
Frequency range (MHz)	902-928	2400-2500	902-928	2400-2500

The 900 MHz RF LAN transceivers in the smart meters use a frequency hopping spread spectrum digital modulation scheme wherein the emitted RF signal hops randomly over a series of frequencies across the band. In the Elster meter, the transceiver hops over 25 different, specific frequency channels within the 902-915 MHz part of the band while the Itron meter uses 52 hopping frequency channels distributed across the entire 902-928 MHz band.

The HAN radios employ direct sequence spread spectrum modulation on 16 possible channels across the 2.4 to 2.5 GHz (2,400 MHz to 2,500 MHz) band. It is relevant to note that the 2.4 GHz band is also widely used for other applications including, most notably, operation of microwave ovens, cordless telephones and wireless routers used for distribution of Internet content.

The data collection points, represented by Gatekeepers (GMP) and Cell Routers (BED), are composed of 900 MHz radios that are essentially the same as those found in end point meters for connectivity with the RF LAN and with the end point meters that they serve. For the WWAN connection, for sending data back via the Internet to the electric utility, a cellular modem designed to operate on one of the WWAN frequencies is employed that has nominally the same power characteristics of a mobile (cell) phone. Also, since the Gatekeepers and Cell Routers used by GMP and BED are mounted high above ground, common public access to the immediate region of the units is eliminated.

The in home display (IHD) used during measurements for evaluating the HAN radio characteristics was the Tendril model IHD-5 that carries the FCC ID of TFB-APEXLT. This unit has a manufacturer's specified output power of 20 dBm (100 mW) but during laboratory testing for its certification was found to produce only 18.56 dBm (72 mW). The IHD contains an internal "inverted F" type of antenna on the unit's printed circuit card.

Assessing Potential Exposure to Smart Meter RF Fields

Smart meters present a considerable challenge to the assessment of potential exposure that can occur in their vicinity. Issues include the fact that the transceivers in the meters are low power, less than one watt, the RF fields are not uniform around the meter due to directional properties of the internal antenna and the effects of the meter box in which the meter is installed and the typical emissions of smart meters consist of very brief bursts of pulses of RF energy lasting normally less than one-tenth of a second or far less. Additionally, the amount of transmitting activity of a smart meter typically varies throughout the day and depends not only on its normal transmission of data at prescribed times during the day but, also, on whether it is assisting other meters in relaying data to other meters. Further, current human exposure limits are specified in terms of time-averaged levels of RF fields and in terms of spatial averages over the body dimensions [5]. Finally, for frequency hopping systems, such as those employed by the meters deployed by both GMP and BED, the frequency of the emission can rapidly change. Characterizing the RF emissions is, therefore, not always straightforward.

Several factors determine the magnitude of RF fields that can be produced by any source at a given point. These include the effective isotropic radiated power (EIRP) in the relevant direction, the mounting location of the source relative to where an individual may be and the duty cycle of the source (i.e., a measure related to the amount of time that the transmitter actually transmits a signal). For evaluating compliance with RF exposure standards, the time-averaged value of plane wave equivalent power density is usually the most fundamental aspect of specifying exposure. Existing RF exposure standards specify averaging times of either six minutes, normally applied to assessing occupational exposures, or 30 minutes, usually applied to exposure assessment for members of the general public.

The antennas contained within smart meters are not omnidirectional, although the pattern of emitted field is commonly very broad and can approximate the pattern of an omnidirectional source; there is, however, usually a preferred direction in which the strongest RF field is transmitted, normally away from the front of the meter with directions of reduced RF fields usually to the sides and almost always toward the rear of the meter. When a wireless smart meter is installed in a meter socket (typically in the electric service panel on a home), the metal electrical box that contains the meter socket interacts with the RF fields to distort what the antenna pattern would be in the absence of the meter box. The meter box can also provide significant shielding in directions to the rear of the meter, generally in directions toward the home on which the meter is installed, such that interior RF field strengths (or power densities) inside the home will be significantly less than at equivalent distances but in front of the meter.

The signal pattern of the smart meter antenna determines the intensity of the transmitted RF field in both the azimuth (horizontal) plane and elevation (vertical)

plane. The significance of this is that the RF fields found near smart meters can be relatively non-uniform due to the metal components of the meter itself and the metal box within which it is mounted. This results in exposure of the body that can be highly non-uniform. Since exposure limits are based on spatial averages over the body as well as time averages over time, compliance assessments normally include a measure of the spatial variation of field along the vertical axis of a person standing near the meter. This means that the body-averaged value of exposure will be less than the spatial peak value that might occur directly in front of the meter where the field is most intense. Nonetheless, for purposes of this study, measurements of RF fields at the height of the meter were obtained for exterior locations near the meter. Limited data were also obtained to document the variation in field over a distance from ground level to six feet (1.83 m) above ground so that spatial average values of field could be estimated from the measured spatial peak values of fields.

Because the transmitted fields from smart meters can exhibit a dependency on direction away from the meter, mounting locations will strongly influence the exposure values for a person near the meter. If the meter is mounted relatively high above ground, most of the body may be exposed to only very weak RF fields. If the meter is mounted lower, more of the body may be subjected to stronger emissions since the body may intercept most of the transmitted fields within the elevation plane. The issue of how much more localized exposure of the body is when compared with the average over the entire body dimension depends strongly on the distance between the meter and a person; the greater the distance from the meter, the more uniform the field across the body will be but, at the same time, the weaker the field will also be, simply because of the typical rapid decrease in RF field with distance.

The RF exposure limits adopted by the FCC are based on averages over time [5]. For the smart meters used by GMP and BED, this is determined by the duty cycle of emissions and, as discussed above, exposure will depend on occupancy of areas near the meter. Closer distances can result in greater exposure while farther distances result in lower exposure. The issue of averaging of RF field power density, based on the duty cycle of emissions, with specific reference to smart meter emissions has been addressed by the FCC [6]. The FCC states that the "source based" time-averaged value of power density is the relevant factor with respect to compliance with their exposure rules. In summary, estimates of potential exposure to the GMP and BED smart meters were accomplished by determining both the instantaneous peak and average values of RF field power density near the smart meters directly in front of the meters as well as inside homes equipped with smart meters.

In total, smart meter measurements were performed at 23 sites in the GMP Rutland (13 sites) and BED (10 sites) service territories. These sites included measurements at 18 residences (12 detached homes and six apartments) as well as six meter banks (four meter banks were on apartment buildings included as residences),

two data collection points (one GMP Gatekeeper and one BED Cell Router) and a single, isolated smart meter mounted on a pole in Rutland. Measurement locations for the Rutland and Burlington areas are illustrated on maps shown in Figures 3 and 4 respectively.

Because present day RF exposure limits are based on time-averaged values of RF power densities, considerable effort was applied to collecting data on smart meter duty cycles at many of the measurement locations (see section below on technical approach used in this project).

Figure 3. Smart meter measurement locations (13 total) in the Rutland, VT GMP service territory. Sites 9 and 10 and 12 and 13 are close together.

Figure 4. Smart meter measurement locations (10 total) in Burlington, VT in the BED service territory.

RF Exposure Limits

Recommended safe exposure limits in the United States have existed since the 1960's. Over the years, these limits have evolved to account for more recent research findings relative to biological effects of RF fields. Internationally, the three most prominent exposure limits include those of the FCC [4] and the Institute of Electrical and Electronic Engineers (IEEE) [7] in the U.S. and the guidelines of the International Commission on Non-ionizing Radiation Protection (ICNIRP) in Europe [8].

In the United States, the controlling limits for human exposure are those adopted by the FCC[10]. FCC maximum permissible exposures (MPEs) apply to FCC licensees but also apply to the use of RF emitting equipment used in the license-free bands. Because of this, smart meters are evaluated prior to sale to utility companies for compliance with the FCC's RF exposure limits and such evaluations are documented in equipment certification reports provided by the manufacturer to the FCC (see above discussion of where these reports can be found). Table 2 summarizes the MPEs from the FCC that are applicable to the emission frequencies associated with the smart meters evaluated as part of this project[11].

Table 2. FCC MPEs applicable to the RF fields produced by smart meters operated by GMP and BED in the state of Vermont. MPE values are in terms of power densities averaged over 6 minutes for occupational exposure and 30 minutes for exposure of the general public. The limits given are in terms of spatially-averaged values of power density averaged over the dimensions of the body and averages over 6 minutes or 30 minutes as the case may be.

Frequency	902-928 MHz		2.4-2.5 GHz	
	General public	Occupational	General public	Occupational
MPE (mW/cm^2)	0.601-0.619	3.00-3.10	1.0	5.0

It is relevant to note that compliance with the FCC MPEs for general public exposures allows for time averaging so long as the modulation of the field is source based, i.e., inherently a consequence of the way the source operates. Examples include the pulsed RF fields produced by radars, the typically intermittent operation of two-way mobile and portable radios and, in this case, the normal intermittency of smart meter emissions [6]. For situations in which the continuous RF field exceeds the MPE, however, the FCC has taken the position that time averaging is not permissible for showing compliance with the exposure rules in the case of public exposure. This is based on the

[10] The FCC MPEs are somewhat greater in value than the ICNIRP guidelines in the 900 MHz band. For example, at 915 MHz, the ICNIRP reference level is 0.457 mW/cm^2 vs. 0.610 mW/cm^2 used by the FCC.

[11] The MPE is a value of exposure in terms of a time-averaged value that is 50 times less than the threshold for potentially adverse biological effects (i.e., the MPE contains a safety factor of 50) for general public exposure and 10 times less for occupational exposure (i.e., the MPE contains a safety factor of 10).

conservative assumption that compliance would only be achievable if an individual physically moved about to result in a variable exposure level that could, upon averaging, be reduced below the MPE. Thus for smart meter emissions, a comprehensive determination of compliance with the FCC exposure rules includes assessing the average RF field across the dimensions of the body (spatial average) and the average over time (time average). In practice, and as found in virtually all of the certification reports filed with the FCC for smart meter emissions by manufacturers, a simplifying assumption is made that if the maximum, instantaneous field[12], without inclusion of time or spatial averaging, is compliant with the MPE, then no further evaluation is necessary. In this investigation, however, the issues of how duty cycle and spatial averaging can affect exposure assessment were addressed so that a more accurate assessment of compliance with the exposure rules could be performed; for both the time averaging and spatial averaging factors, potential exposures will be found that are less than maximum, instantaneous field values. The MPEs are based on the assumption of uniform exposure over the whole body; the non-uniform fields, common to real-world exposure, are normally spatially averaged to obtain the best estimate of an equivalent, uniform exposure. For convenience in interpreting the reported values of measured RF fields, measured RF fields are expressed in terms of a percentage of the public MPE; i.e., a value of 100% represents the exposure limit. The rationale for this approach is that the MPE varies with frequency and reporting of RF fields simply in terms of power density requires adjustment of the power density values to determine how the value compares to the actual limit for evaluating compliance. Note that the MPE varies across the 900 MHz license free band (by approximately 3%) and is also different for the 2.4 GHz license free band (approximately 66% different from the MPE for the 900 MHz band).

The MPEs listed in Table 2 are based on limiting the underlying basic restriction on RF energy absorption within the body, as averaged over the whole body, and on local tissue absorption. The energy absorption rate is referred to as the specific absorption rate (SAR) which is expressed in the unit watts per kilogram (W/kg) of tissue. The FCC MPEs, for general public exposures, are based on a whole-body averaged SAR limit of 0.08 W/kg with a local, peak SAR of 1.6 W/kg averaged over any one gram of tissue (defined as a tissue volume in the shape of a cube) except for the extremities (hands, wrists, feet and ankles) in which a local SAR of 4 W/kg averaged over any 10 grams of tissue is permitted. For occupational exposures, the FCC MPEs correspond to a whole body averaged (WBA) SAR of 0.4 W/kg with a local, peak SAR of 8 W/kg averaged over any one gram of tissue except for the extremities in which the SAR limit is 20 W/kg averaged over any 10 grams of tissue.

RF exposure limits are derived from a presumption that the resultant RF field, taking all possible polarization components of the field into account, complies with the

[12] The term instantaneous refers to the absolute peak magnitude of the RF field in the time domain, similar to the peak power of a radar pulse.

limit. The MPE values vary with frequency because of the frequency dependent variation of RF energy absorption of the body. The limits presume the possibility of the resultant magnitude of the RF field being oriented in such a way as to result in the greatest energy absorption possible within the body. Thus, the limits are, generally, conservative since such alignment of the polarization of the incident RF field with the body orientation during real world exposure is often not the case. Hence, for compliance assessments, relative to exposure limits, RF fields are to be measured such that the overall resultant magnitude of the field is obtained, regardless of the different polarization components that may exist. The RF field measurements accomplished in this project included the measurement of three mutually orthogonal polarization components and the formation of the resultant magnitude of the incident RF field.

Technical Approach Used in this Project

RF Instrumentation Used in the Measurements

The principal measurement effort in this study was directed toward determining two things about the RF fields emitted by the GMP and BED smart meters: (a) the instantaneous peak magnitude of RF fields emitted by the meters and the (b) duty cycle of the various emissions. The very intermittent nature of the smart meter emissions as well as the fact that the emissions can occur over a range of frequencies requires an instrument that has both frequency resolution and brief signal capture ability. Broadband probes, commonly used for RF field exposure assessment, for smart meter measurements, suffer from two perspectives. They do not discriminate the frequency of the field that is causing a response of the instrument and they typically have response times that are entirely too long to be able to accurately measure the RF field during the very brief pulses of RF energy produced by smart meters. For example, a common response time of most broadband RF field probes is approximately one second. This means that the instrument requires that the signal (RF field) that is being measured must exist for at least one second before the meter response can reach the peak or full value of the field. For the typical emissions of smart meters of the type explored in this study, that are often less than 1/10 of a second in duration, this places a significant disadvantage on the broadband type of measurement instrument. Further, if the broadband probe has a flat frequency response (the output of the probe does not change with frequency for a constant RF field level), it cannot properly weight the detected RF field in accordance with the frequency dependence of the MPE. The MPE for RF emissions in the 900 MHz band are about 60% of the MPE values applicable to the 2.4 GHz band. Hence, the flat responding probe, while it may indicate the presence of pulses of RF field, will not accurately add up the RF fields across all frequencies to obtain a proper measure of the aggregate RF field relative to permissible exposure levels.

Because of the above instrumentation issues, a spectrum analyzer based detector was used for these measurements (Narda Selective Radiation Meter model SRM-3006, SN D-0069). Figure 5 shows the instrument which consists of a wideband probe/antenna (SN K-0242) that is connected to a spectrum analyzer base unit that is controlled with firmware that allows for measurement and display of detected RF fields.

This instrument permits display of the detected RF signals from the probe/antenna in the frequency domain so that the strength of any individual signal can be determined. Further, the probe/antenna contains a solid state switch that provides for a very fast sequential sampling of the measured RF field over the three axes of the probe/antenna elements. This allows for display of the resultant field magnitude as a function of frequency. Illustrative spectral displays of the RF LAN (900 MHz band) fields observed in front of the Elster and Itron smart meters are shown in Figures 6 and 7

respectively. These figures represent the capture of absolute peak values of momentary RF fields on any frequency emitted during the measurement period. The spectra shown in these figures develop over time since an RF emission on any specific frequency may only exist for an extremely brief period. The spectrum in Figure 7 shows the result of a less active meter over the measurement period. In practice, the RF field measurement data acquired during the many measurements of the project were stored in the digital memory of the SRM instrument and downloaded to a computer for subsequent further analysis and display.

A powerful feature of the SRM-3006 is that measurements can be displayed in alternative units of measure and, for these measurements, directly as a percentage of the FCC MPE for general public exposure, automatically adjusting the measured field for the frequency dependency of the FCC MPEs. Notice that the spectrum displays of RF fields (Figure 6 and 7) are presented against a logarithmically calibrated vertical scale of percent of the FCC's public MPE. With the instrument settings used in most measurements, the noise floor of the instrument, in terms of peak values, was less than 10^{-5} percent of the FCC public MPE (i.e., less than 0.00001% of the MPE).

Figure 5. The Narda SRM-3006 Selective Radiation Meter is based on fast Fourier transform (FFT) spectrum analyzer technology and uses a probe/antenna to measure the absolute magnitude of incident RF fields across the frequency range of 26 MHz to 3,000 MHz and digitally converts the detected field to the equivalent percentage of the FCC MPE.

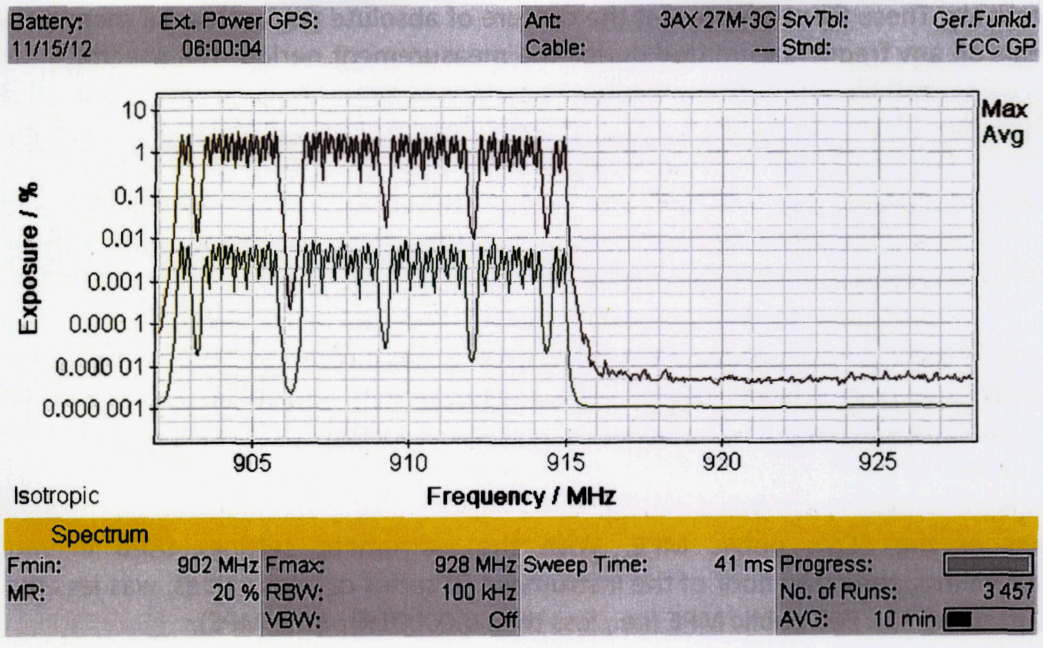

Figure 6. *Illustrative maximum-hold RF spectrum display* at one foot in front of a GMP smart meter showing the peak signal strengths of intermittent signals occurring randomly on 25 channels across the 902-915 MHz band during transmission of historical load profile data.

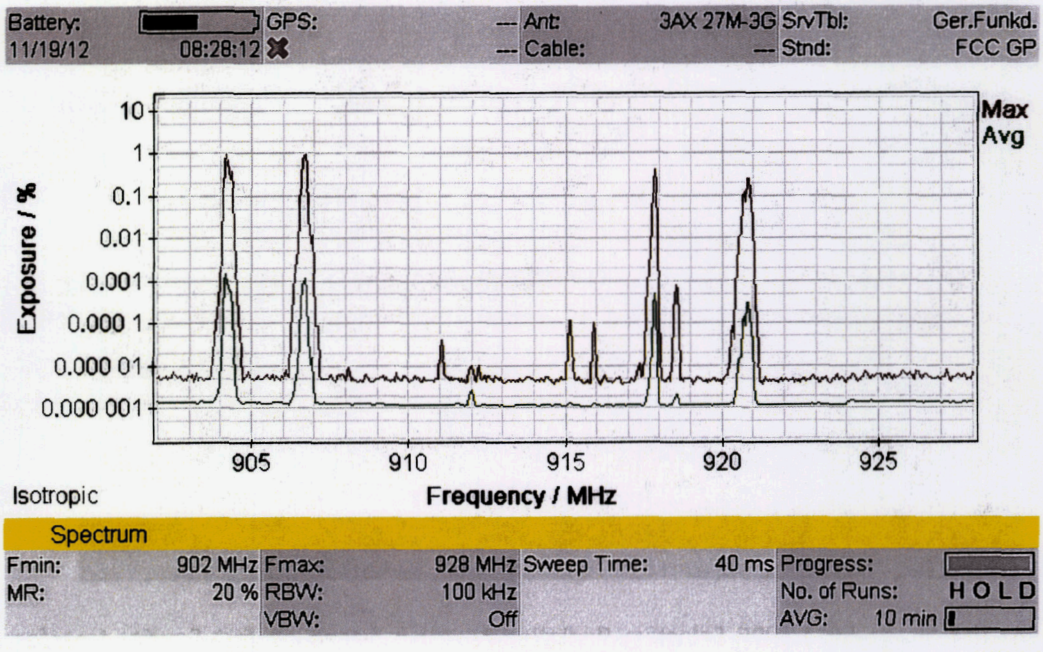

Figure 7. Illustrative RF spectrum display at one foot in front of a BED smart meter showing the peak signal strengths of intermittent signals occurring randomly across the 902-928 MHz band during transmission from a less active meter.

An additional feature of the SRM-3006 that made it particularly useful in this investigation was a scope or time-analysis mode in which the instrument can be tuned to a specific frequency with an adjustable resolution bandwidth (RBW) so that detected signals can be measured in the time domain. For pulsed RF fields that may have a fast rise time, a sufficiently wide RBW is necessary to properly detect the pulse. This facilitated capture of bursts of RF signals emitted by the smart meters. For the measurements performed in time-analysis mode, a RBW of 32 MHz (the widest possible on the SRM-3006) was used when centered on the specific signal frequency of interest. In this mode, the instrument becomes a "tuned oscilloscope" allowing observation and capture of the time domain waveform of RF signals within its RBW. The RBW may be thought of as a measure of the instrument's ability to discriminate two frequencies; the narrower the RBW, the better the instrument can show the presence of two frequencies that are close together. When used in time-analysis mode, however, wider RBWs permit detection of fast rise time pulses.

The SRM-3006, with accompanying probe/antenna, is capable of performing narrowband measurements of signals from 26 MHz to 3,000 MHz (3 GHz). For spectral measurements of the smart meter emissions, a RBW of 100 kHz was used for both the 900 MHz RF LAN signals as well as the 2.4 GHz HAN signals. The significantly wider RBW (32 MHz) was used for the time domain measurements to accommodate the fast rise time of the pulses. This value was deemed sufficient to allow accurate detection of the peak value of pulsed fields from the smart meter but was arrived at through evaluation of the indicated peak value of smart meter pulses with different RBWs.

For measurement of the 900 MHz band RF fields associated with the RF LAN emissions of smart meters, the instrument exhibited a sweep time of approximately 40 milliseconds (ms) for most of the measurements. During this period, measurements are made of the three polarization components of the RF field; the three values obtained at each frequency are assembled as the resultant value and the resulting spectrum is displayed on the instrument's screen. While this is a very fast process to accomplish this task, the capture of signals emanating from the meters which are only fleetingly present requires that the measurement process extend for a period sufficiently long to acquire a spectral display wherein the peak signal values are stable. As the pulsed fields on any given frequency across the band are only present for very brief periods, the challenge presented to the instrument is to sample each frequency where a signal exists for enough times that the displayed resultant field no longer changes over additional sweeps of the analyzer. When the spectral peaks no longer continue to increase in magnitude, the indicated resultant represents the true value of the peak RF field. Sampling for shorter durations can lead to an underestimate of the actual magnitude of the field since the analyzer may have not captured sufficient samples of the field strength on a specific frequency to insure that the peak value has been obtained. This means that most measurements, especially when they were not as frequent as at other times, required that the measurement might take as much as a minute or more to

obtain a stable peak height of the signals. For the 900 MHz RF LAN fields, the typical emission (pulse) duration is in the range of 30 to 100 ms; this length of pulse is easily captured in terms of its peak value. For much shorter pulses, a different method is needed.

The approach used for evaluation of RF fields was, after acquisition of a spectrum of signal peaks (each peak representing the signal on a given frequency), to have the instrument identify the maximum peak value in terms of a percentage of the MPE. For all of the measurements reported here, only the greatest measured RF field from the spectrum of signals measured was used for assessing potential exposure. As the spectra shown in Figures 6 and 7 illustrate, there is typically some variation in the peak heights of the measured RF fields, i.e., not all peaks are exactly of the same magnitude. This variation can be related to the power output characteristics of the transceiver within the meters [9], the difference in MPE value at different frequencies, the possibility that not all spectral peaks were sufficiently sampled to arrive at a completely stable value for each peak and instrument measurement repeatability. Nonetheless, the maximum peak value from each measured spectrum was always used in the subsequent evaluation of fields.

For measurements of the HAN radio emissions, in the case of the GMP smart meters, an alternative method was determined to be necessary to capture meaningful measures of the resultant RF field magnitudes. Because of the very narrow pulses produced by the HAN radio, typically less than 2 ms, and the long period between each emission, the spectrum analyzer method of scanning across the entire frequency band was insufficient to allow collection of the resultant field magnitude due to the scan time being too long, even at 40 ms per scan. In this case, the SRM-3006 was configured in time-analysis mode with the center frequency of the analyzer placed on the fixed frequency produced by the HAN radio (although the HAN radio can operate over the entire band, it remains fixed during communication with an IHD or is simply attempting to connect with an IHD). In practice, at each site where HAN radio measurements were performed, the 2.4 GHz band was scanned to observe for the frequency at which the radio was transmitting. Once this frequency was identified, the instrument was then set to time-analysis mode, centered on the operating frequency of the HAN radio as observed from the spectrum measurement, and then adjusted to permit capture of the peak value of the emission by use of a 32 MHz RBW and fast sweep time. Even with this approach, each polarization component was measured separately to insure capture of the peak RF field. Data for the X, Y and Z probe axis readings were recorded for subsequent computation of the resultant magnitude of field.

Duty cycles were determined by the ability of the SRM-3006 to automatically indicate the duty cycle produced by time domain measurements over any period of time. A unique aspect of the instrument is its ability to collect RF field values across the time domain of a full 30 minutes but still respond to the momentary, very brief pulses

presented by the smart meters. The duty cycle was calculated internally in the instrument as the ratio of the overall average power of the measured RF fields to the highest peak value of RF fields. For RF fields that are always exactly of the same amplitude, when they are present, this is equivalent to the ratio of the total signal on-time to the overall observation time.

Low Frequency Instrumentation Used in the Measurements

Although the prime effort in this study was that of characterizing the RF fields emitted by the GMP and BED smart meters, supplementary measurements were also performed of low frequency fields that might be associated with the operation of the meters. Such emissions, for example, could result from the use of switch mode power supplies within the smart meters to power the radios. Measurements of low frequency electric and magnetic fields were conducted in Colville with test meters provided by both GMP and BED using a Narda model EHP-50D electric and magnetic field analyzer (SN 000WX10510). This device, shown in Figure 8, provides for isotropic measurements with a dynamic range of 140 dB for electric and magnetic fields (depending on the specific configuration of the device). Internal to the sensor cube are three mutually orthogonal coil sensors for magnetic fields and three orthogonal sets of capacitor plates used as electric field sensors. Minimum detectable electric field strength is nominally 1 V/m and minimum magnetic field flux density is nominally 1 nanotesla (nT). The instrument is battery powered and is connected to a personal computer (PC) via an optical fiber cable for spectral analysis. Built-in fast Fourier transform (FFT) spectrum analysis allows evaluation of the frequency content of the electric and magnetic fields over the frequency range of 5 Hz to 100 kHz. Measured values of electric and magnetic field are displayed on the PC and saved to disc memory for subsequent analysis. Measurements with the EHP-50D were performed at a distance of 1 foot directly in front of each of the test meters. Electric and magnetic field spectra were measured across the 0 to 1 kHz, 0 to 10 kHz and 0 to 100 kHz frequency ranges.

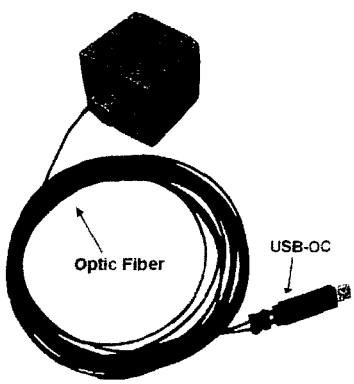

Figure 8. The Narda model EHP-50D Electric and Magnetic Isotropic Field Analyzer. The analysis of output from the sensor is performed via FFT in a connected laptop computer running special software.

Technical Approach Used in this Project

Background measurements of both electric and magnetic fields were made with each test meter unpowered for comparison to the measurements with the meters being powered up. All measurements were performed for a period of 2 minutes each to obtain the RMS value of fields detected by the probe. During these measurements, the smart meters were powered up but not connected to either an RF LAN or HAN IHD (in the case of the Elster meter).

Instrument Calibrations

Both the SRM-3006 and associated probe/antenna as well as the EHP-50D were used within 24 months of the respective instruments having been placed in service. Factory generated calibration certificates are provided in Appendix C for the SRM-3006 and Appendix D for the EHP-50D. The SRM system used in this project was calibrated by Narda on October 7 (probe) and October 13, 2010 (spectrum analyzer unit), but was not placed into service until February 22, 2011 (next factory calibration due February 22, 2013).

Prior to the measurements in Vermont, the SRM-3006 and associated probe/antenna were evaluated for their response to RF fields at 915 MHz, the center of the 902-928 MHz band in which the smart meter RF LANs operate, by comparing the indicated value of RF field to a similar probe/antenna (SN H-0368) that had been calibrated by Narda on October 27, 2011. The calibration certificate for the comparison probe is shown in Appendix E.

The probe/antenna comparison was performed in Colville, WA by positioning each probe at one foot directly in front of a test smart meter operating in the 900 MHz band, acquiring a spectrum of the observed smart meter emissions for approximately two minutes and, then, comparing the indicated value of the maximum peak RF field from the two units. This procedure yielded readings that differed by 6.5% in terms of percentage of the public MPE. This is equivalent to 0.27 dB, this value being well within the uncertainty of the manufacturer's calibration method of 1 dB. Through this quality assurance process, it was deemed that the SRM system as used for measurements in Vermont was in compliance with the manufacturer's stated specifications

How the Measurements Were Made

The measurements performed for this project were accomplished in the state of Vermont at installed smart meter sites, primarily residential locations, and in Colville, WA where measurements on test meters provided by both GMP and BED were conducted. The Colville measurements allowed for examining the time domain waveforms of the signals under alternative scenarios. For example, in the case of the GMP Elster meter, the HAN radio was used to connect with an IHD so that differences in RF performance could be observed.

RF fields were measured as a function of distance from the front face of the meters in both Vermont and Washington from 1 foot to 10 feet from the meters as illustrated in Figure 9. Measurements were performed by holding the instrument probe/antenna at the height of the meter face, standing to the side as illustrated in Figure 9, with the probe/antenna perpendicular to the front surface of the meter face. A tape measure was used to locate the measurement distance relative to the front surface of the meter as well as adjusting the probe/antenna to the correct height.

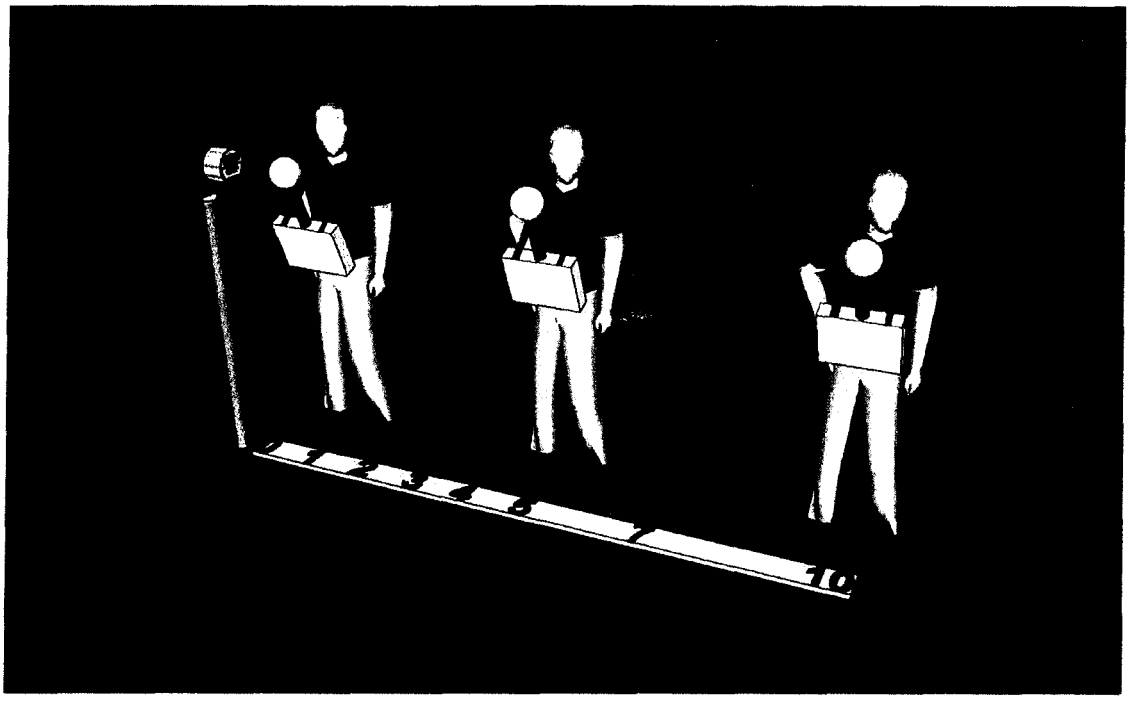

Figure 9. Illustration of the measurement of RF fields at different distances, ranging from one foot to 10 feet from the front surface of a smart meter.

At the Vermont sites, measurements were performed inside most of the buildings on which the meters were attached. RF fields as a function of height above ground were also measured in both Vermont and Washington. Measurements related to the directional properties of the meters were made in Washington. In Colville, there are no smart meter networks and, hence, the meters could not connect with a mesh network as they did in Vermont. Figure 10 shows measurements being made at a site in Burlington using the SRM-3006.

Figure 10. Measurement of RF fields in front of a residential smart meter installation. Measurements were made at distances from 1 foot to 10 feet in front of the meters.

For determining meter emission duty cycles, the SRM-3006 was supported on a tripod as shown in Figure 11 so that the probe could be held fixed in position for the 30-minute measurement periods typically used.

Measurement of Other Wireless Devices

During the indoor measurements of smart meter RF fields, on a few occasions, the opportunity to measure fields produced by other common devices occurred. Hence, measurement data were also collected near two microwave ovens and six wireless routers used for distribution of Internet connectivity.

Environmental RF Field Measurements

To help provide some perspective on the relative amplitude of smart meter RF fields, additional environmental measurements were made of signals produced by VHF FM radio and TV broadcast, UHF TV broadcast, and mobile phone base stations and a long range FAA air traffic control radar at 14 different sites within the state. Figure 12 illustrates these measurement locations within the state. Areas where measurements were performed included Rutland, Burlington, Montpelier and Saint Albans, Vermont. To facilitate rapid measurement of RF fields in many locations, a portable, spectrum

analyzer based instrumentation system that could be used with a vehicle was determined as the most practical approach for acquiring data. These measurements were made from a vehicle with the SRM-3006 probe/antenna connected to the analyzer via a 1.5 meter long cable and held with a 24 inch PVC pipe to support the probe/antenna above the roof level of the vehicle. All measurements were performed with the vehicle stopped and turned off.

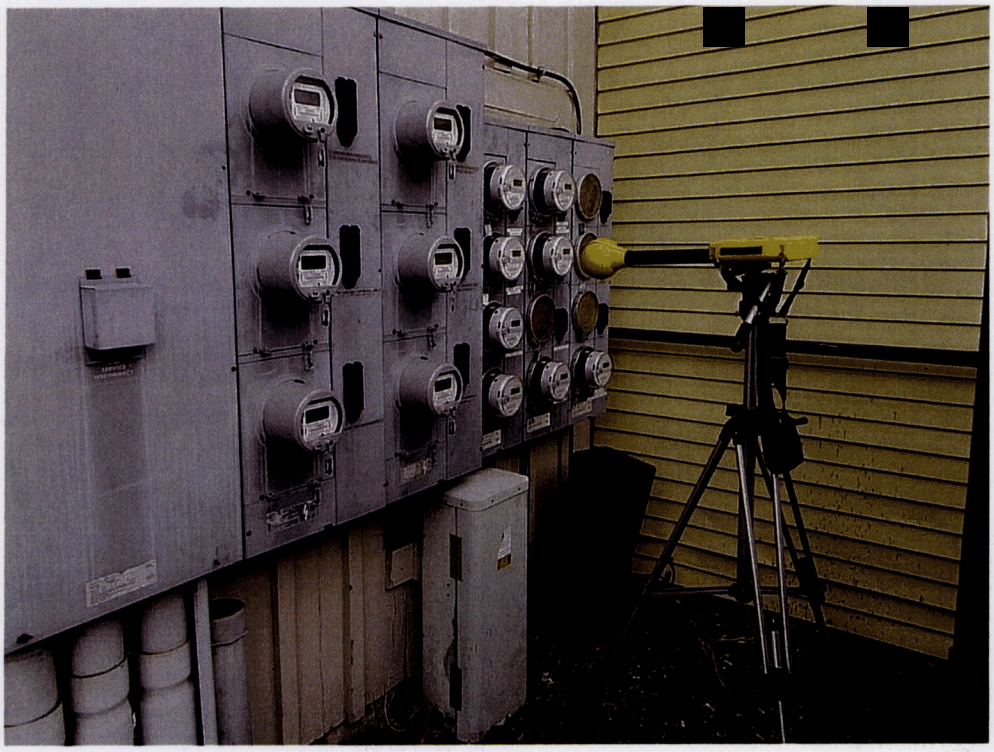

Figure 11. Use of the SRM-3006 to measure the duty cycle of smart meter emissions over a 30-minute period at a meter bank in Rutland.

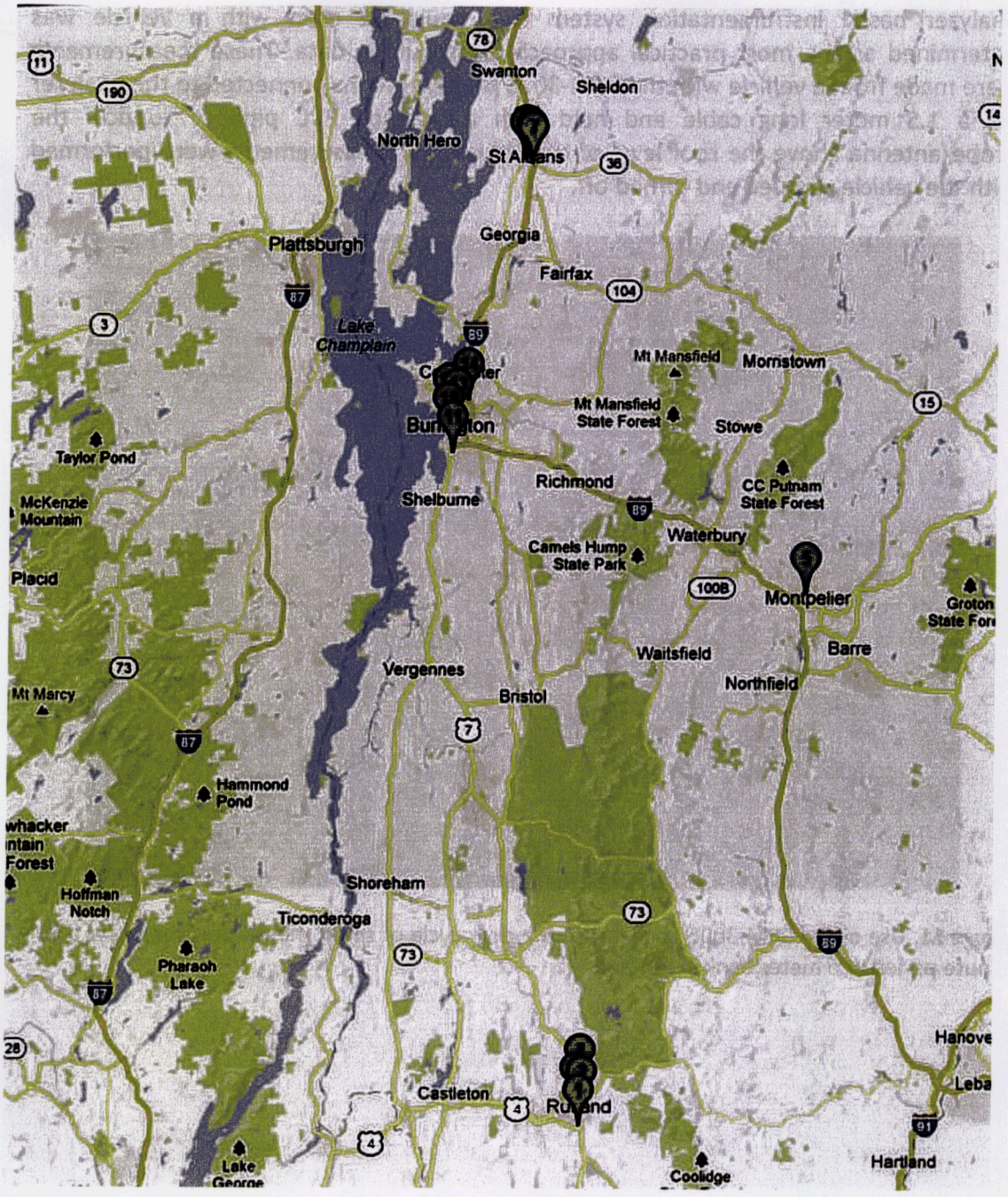

Figure 12. Environmental RF measurement locations within Vermont included in the study.

Results

RF Fields of Smart Meters vs. Distance

Field measurements were made no closer to a smart meter than 1 ft (0. 3m). IEEE Standard C95.3-2002 [10] recommends a minimum measurement distance of 0.2 m to minimize nearfield coupling and field gradient effects when using common broadband field probes. Measurement data can be distorted when using an isotropic probe to measure steep spatial gradients close to a radiating element of a smart meter. These gradients can lead to considerable variation of the indicated amplitude of the field being measured over the volume of space occupied by the measurement probe elements. Nearfield coupling, and associated erroneously high field readings, can be particularly troublesome when employing field probes in the reactive near field that are comparable to the size of the source antenna. The elements inside the SRM-3006 probe/antenna are approximately 10 cm long. Based on the potential for significant probe nearfield coupling with the smart meter internal transmitting antenna, measured values with surface contact between the probe/antenna and a smart meter should be avoided and considered likely substantial over-estimates of the true field. It was deemed appropriate that the minimum distance at which fields would be measured with the SRM-3006 should be one foot. A distance of one foot (~0.3 m) is equivalent to approximately one wavelength at 915 MHz.

The process of measuring smart meter RF emissions was facilitated by instructing each meter to transmit in the 900 MHz band during the measurement period. Since most of the time there is only intermittent activity from smart meters, performing reliable field strength measurements can be problematic since the emissions, when they do occur, are so brief. In the measurements in the GMP service territory, GMP assisted with the process by providing access to a device which could be used to "ping" the specific meter being measured. The device, variously called a field service unit, can issue wireless signals directed to the meter and cause the meter to respond by sending an acknowledgment and data. This method insured that when the RF field measurements were made, there was sufficient signal activity to allow for an accurate capture of the instantaneous peak field magnitudes. The device, a Radix model FW-950, is a handheld portable computer equipped with a 900 MHz band radio and associated software that provides communication with the smart meter. By invoking a "continuous ping" feature on the FW-950, smart meter transmitter activity could be started and this procedure was used during the measurements of the GMP meters. To insure that the measurement process was not "contaminated" by any signal sent from the FW-950 to the smart meters, the device was kept typically about 50 feet from the smart meters being measured.

While the on-site use of the field service unit was used with the GMP meters in the Rutland area, an alternative approach to insuring smart meter transmission was

pursued with the BED meters in Burlington. The BED issued commands from their network head-end at the utility headquarters over the network to invoke a response from the meter targeted for measurements. This required relaying the meter network number to personnel at the utility via a mobile phone. BED technical staff accompanying the measurement team attended to this task prior to each set of measurements. Once the request for transmission was issued from the network head-end, it would typically take a few seconds for the request to be received by the smart meter before it began its transmission response. A field service unit was provided by GMP to facilitate measurements on the GMP test meter sent to Colville. In the case of the BED test meter, once powered up, the meter begins to issue 900 MHz band signals as a means of "discovering" a smart meter network to which it can connect. These signals, while not present as often as those elicited for the GMP meter, served for the measurements of the Itron meter in Colville.

Peak RF fields, obtained at the various smart meter locations, expressed as a percent of the FCC MPE for general public exposure, are tabulated for the different distances at which measurements were made in Table 3 for the GMP and BED meters. The designation 'T' refers to the test meters provided by both GMP and BED for testing in Colville, WA. Measurements at a distance of 10 feet were not possible at GMP site 11 and BED site 3 due to nearby obstructions.

Table 3. Peak 900 MHz RF field magnitudes obtained at different individual smart meter sites in the GMP (Rutland) and BED (Burlington) service territories. These values represent the greatest instantaneous RF field observed at any frequency within the 902-928 MHz band and are expressed as a percentage of the FCC MPE for public exposure. The 'T' designates test meters measured in Colville. Data for sites at meter banks, GateKeepers and Cell Routers are shown elsewhere.

	Distance (ft) from meter face						
Site	1	2	3	4	5	7	10
GMP-1	3.540	1.146	0.492	0.304	0.179	0.093	0.020
GMP-2	3.533	0.945	0.145	0.283	0.136	0.079	0.012
GMP-4	1.325	0.536	0.305	0.109	0.034	0.076	0.046
GMP-5	3.924	1.312	0.586	0.342	0.204	0.224	0.078
GMP-6	3.097	0.756	0.508	0.461	0.284	0.146	0.087
GMP-7	2.462	0.976	0.588	0.250	0.277	0.081	0.046
GMP-9	1.190	0.408	0.161	0.087	0.118	0.063	0.033
GMP-10	2.566	1.134	0.183	0.214	0.083	0.076	0.049
GMP-11	1.532	0.423	0.231	0.130	0.089	0.053	
GMP-T	1.300	0.276	0.183	0.065	0.055	0.016	0.010
BED-2	0.863	0.097	0.059	0.101	0.038	0.029	0.00716
BED-3	0.982	0.434	0.259	0.316	0.173	0.056	
BED-4	0.564	0.162	0.051	0.040	0.092	0.042	0.017

Table 3 continued.							
BED-5	0.355	0.184	0.076	0.041	0.028	0.043	0.0096
BED-7	0.263	0.149	0.036	0.060	0.026	0.027	0.104
BED-8	2.498	0.351	0.386	0.127	0.103	0.100	0.029
BED-T	1.356	0.373	0.255	0.193	0.119	0.046	0.030

The data in Table 3 are graphically displayed in Figures 13-14 for the Rutland area meters (linear and logarithmic plots). Variations in the measured value of fields are expected to be caused by measurement uncertainty and the real-world presence of uneven ground over which the measurements were performed and nearby objects that undoubtedly introduced ground reflections and scattering of RF fields that resulted in the observed variations in field values. Figure 15 plots the mean values of individual smart meter fields with plus and minus one standard deviation of measured values at each distance for the nine sites Vermont sites.

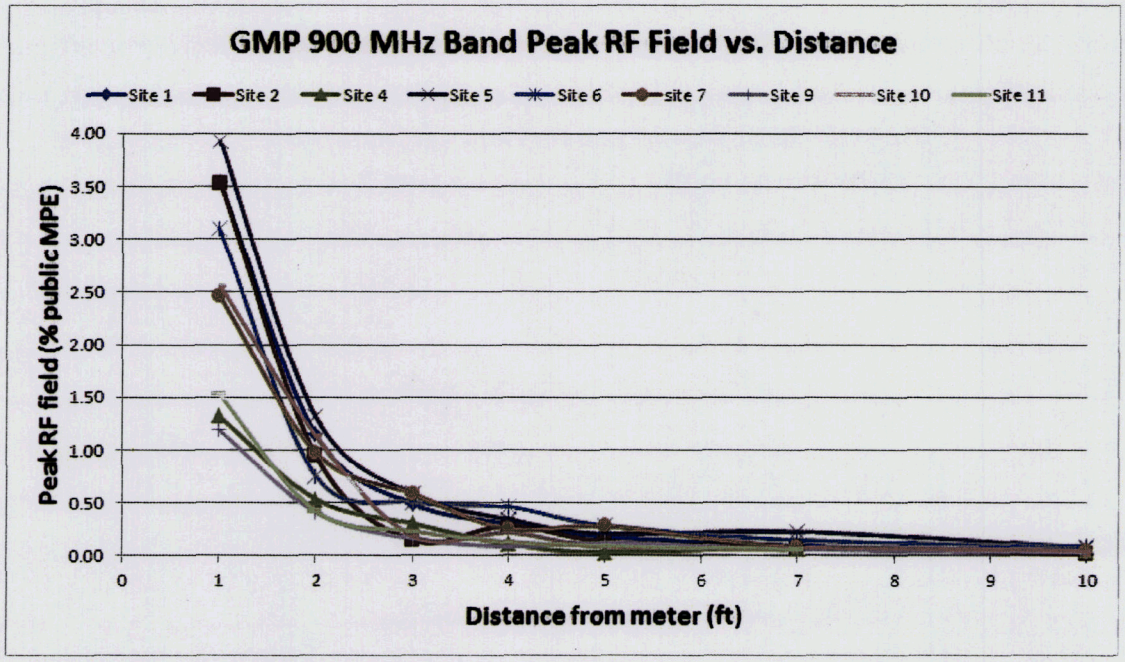

Figure 13. Linear display of measured peak values of RF fields at distances up to 10 feet in front of individual smart meters operated by GMP.

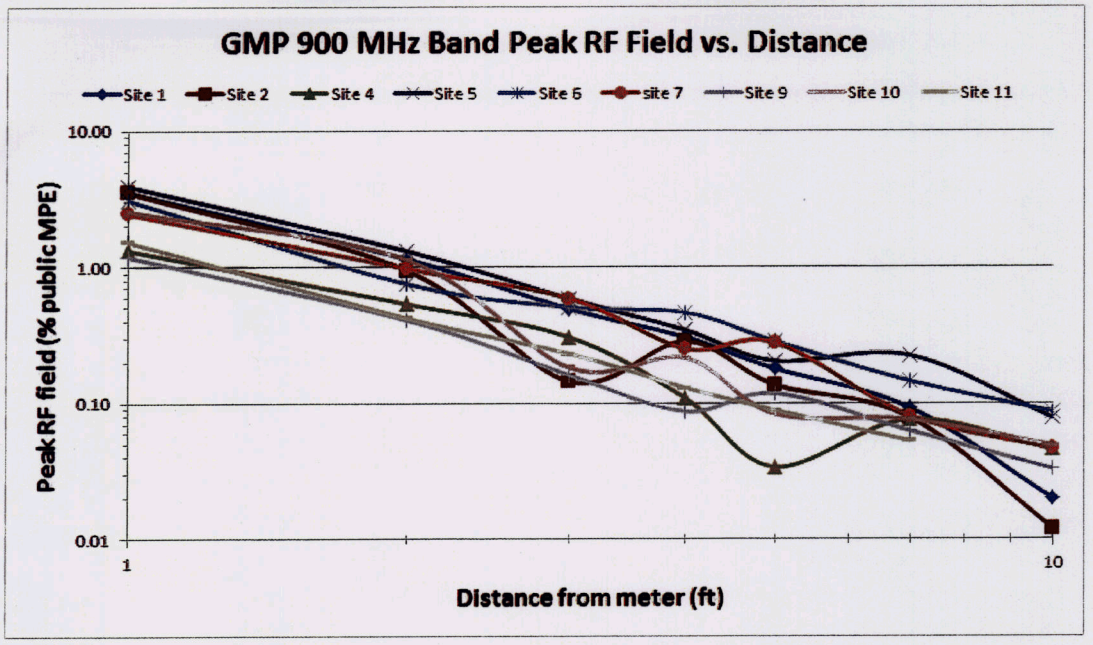

Figure 14. Logarithmic display of measured peak values of RF fields at distances up to 10 feet in front of individual smart meters operated by GMP.

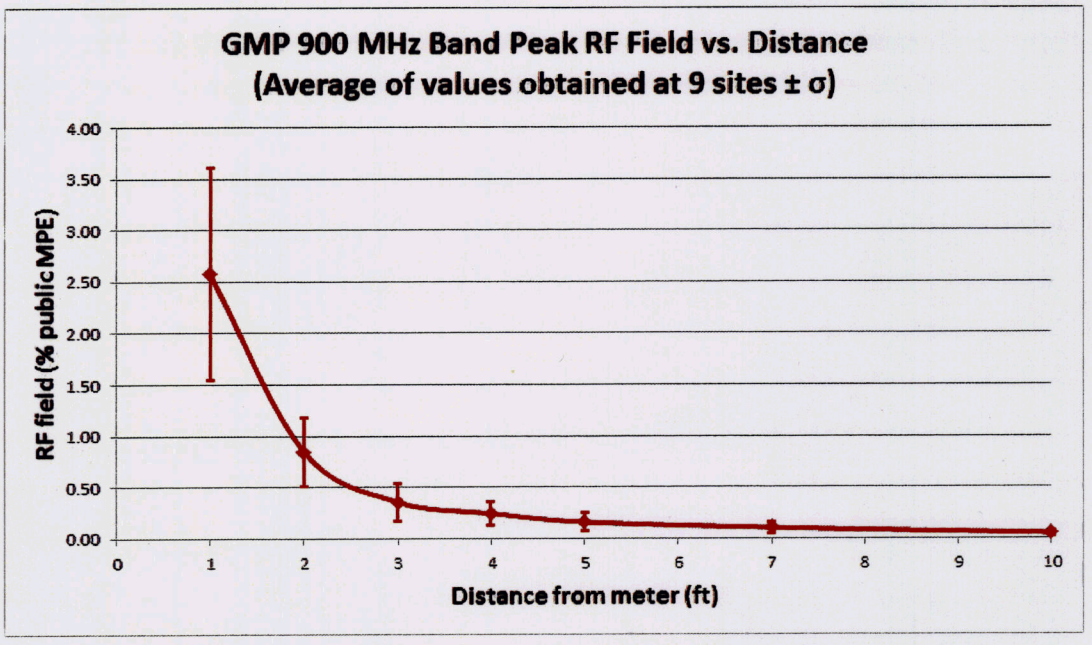

Figure 15. Average of 900 MHz band peak RF fields vs. distance ± 1 standard deviation of values obtained at nine individual smart meter sites in the GMP Rutland area.

Results

Similar graphical plots of RF fields obtained near individual BED smart meters in Burlington are provided in Figures 16 and 17 (linear and logarithmic plots). Figure 18 shows a plot of the mean values with the standard deviations at the six sites.

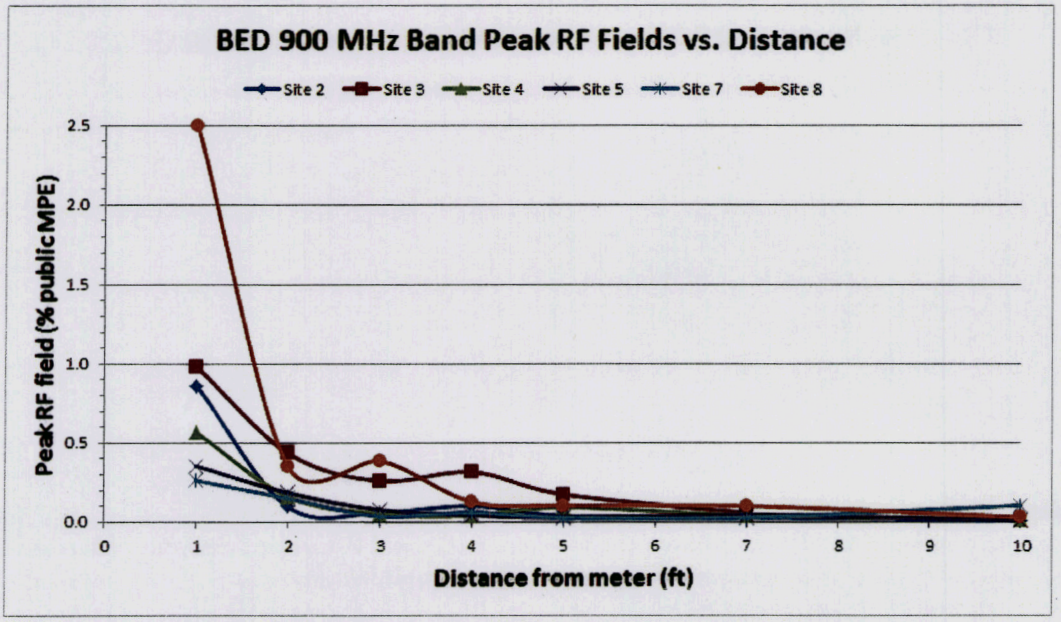

Figure 16. Linear display of measured peak values of RF fields at distances up to 10 feet in front of individual smart meters operated by BED.

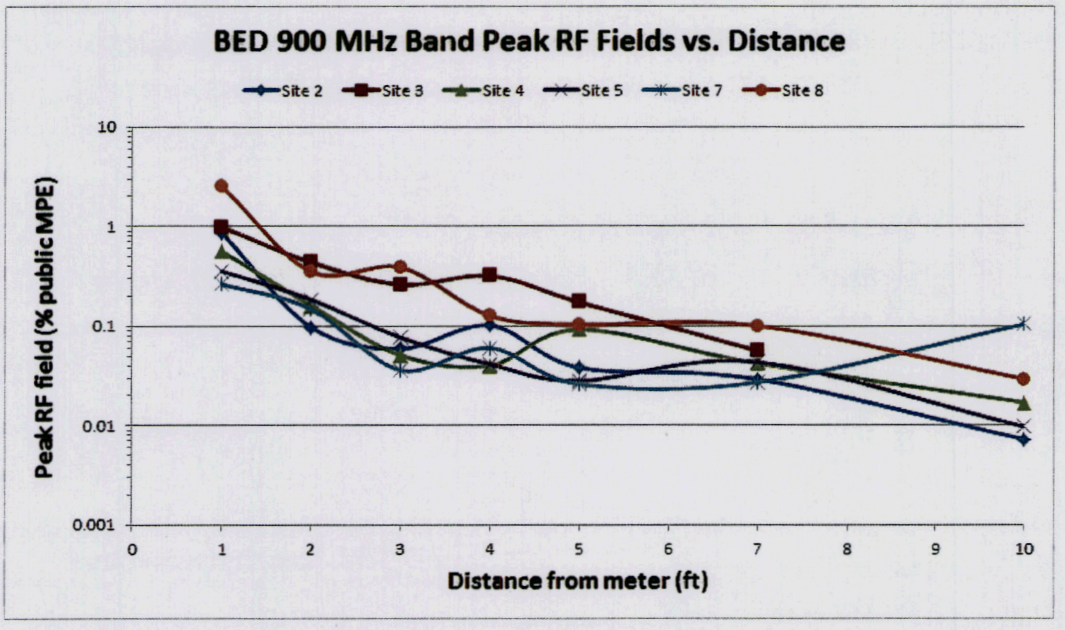

Figure 17. Logarithmic display of measured peak values of RF fields at distances up to 10 feet in front of individual smart meters operated by BED.

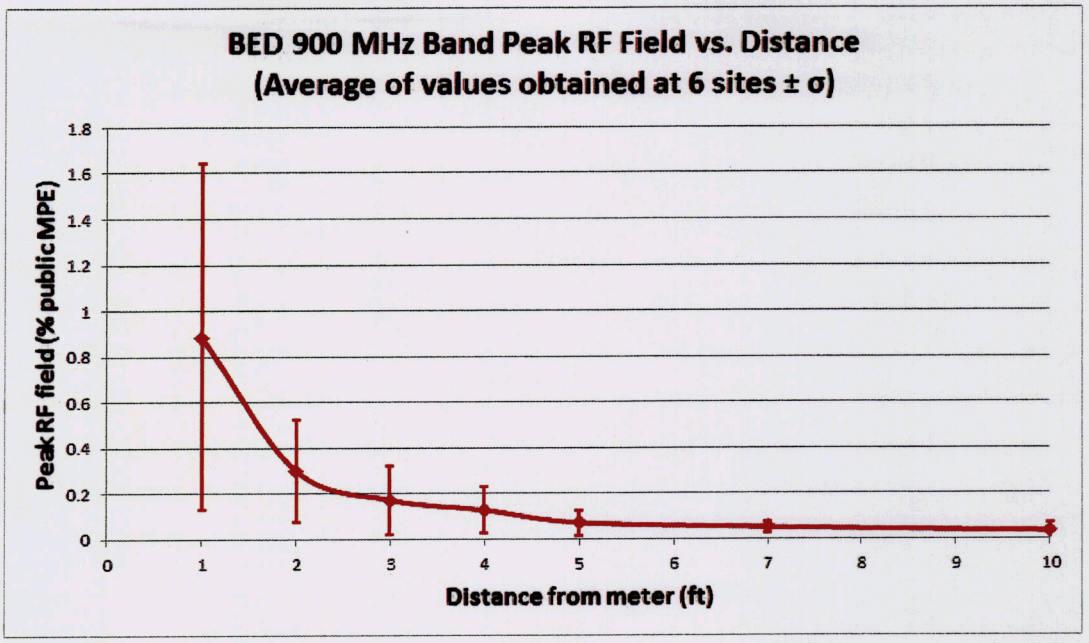

Figure 18. Average of 900 MHz band peak RF fields vs. distance ± 1 standard deviation of values obtained at nine individual smart meter sites in the BED service territory.

Separate measurements of RF fields were performed on two test meters shipped to Colville by GMP and BED. Figure 19 shows the variation of measured peak RF fields vs. distance for these two meters.

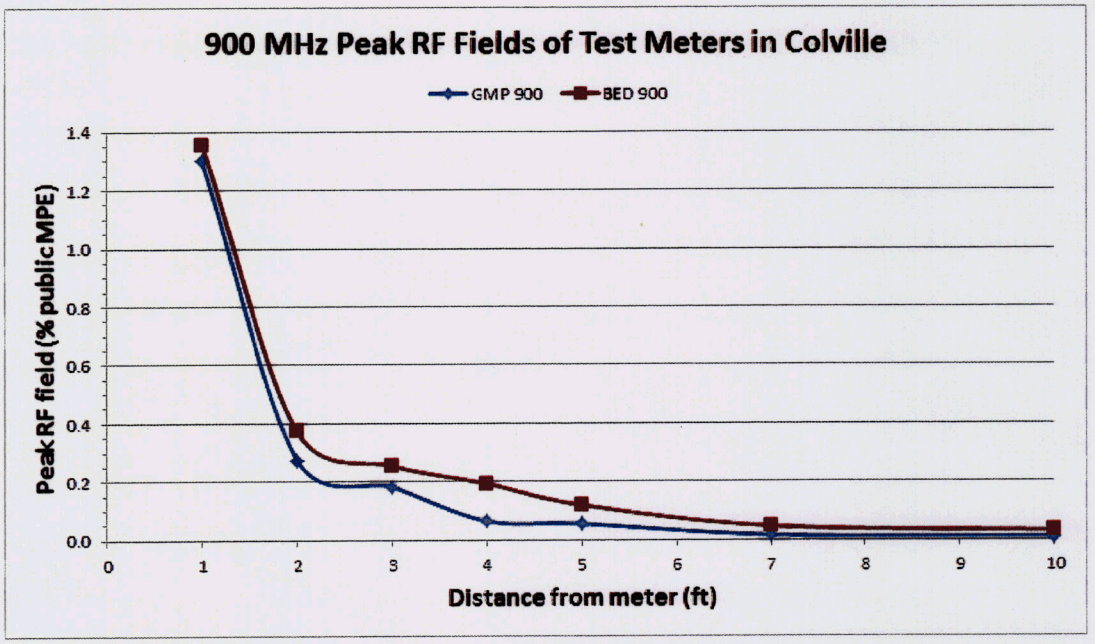

Figure 19. Measured peak RF fields produced by the Elster and Itron test meters in Colville, WA.

Results

RF fields associated with 900 MHz band emissions from a total of five different meter banks (collections of more than one meter) were also measured. Field variation with distance was measured at two of the locations while duty cycles were measured at four of the five sites. The variation of field with distance was determined by centering the meter on one of the meters in the bank and increasing the distance from that meter. The results for the two meter banks at which this was accomplished in the BED service territory are shown in Figure 20. It is noted that BED site 10 was inside a large closed, below ground electrical room (Figure 21) with irregular interior walls.

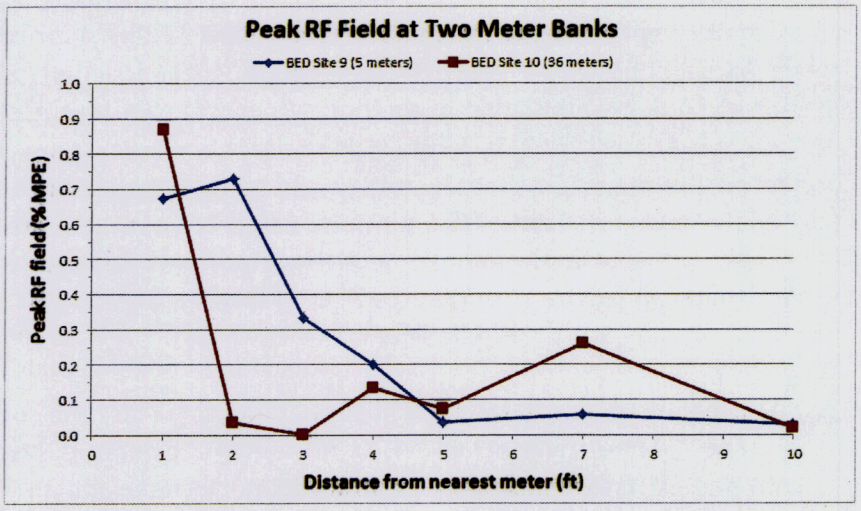

Figure 20. Measured peak RF fields of 900 MHz emissions observed at two meter banks (one with 5 meters and the other with 36 meters) in the BED service territory.

Figure 21. BED site 10 with 36 smart meters inside an electrical room.

Results

Implementation of the HAN radio feature by either GMP or BED for routine customer use had not occurred as of the time that this study was performed. GMP had established approximately 500 residential locations within their Rutland regional service territory as experimental sites to test the capability of the HAN system and explore customer reaction to the in home display (IHD). Whether all of those customers had "paired" the IHD with their smart meter to be able to see their electrical energy consumption was not known at that time. BED had not made any use of the HAN system as of the time of the project field work in Vermont. Despite the fact that the Elster meters used by GMP were not generally "activated" to interact with IHDs, the HAN radios in the smart meters periodically issue a very brief signal lasting approximately 1.75 ms once every 15 seconds plus a group of four closely spaced signals once per minute for a total of eight pulse emissions per minute. These signals are presumably related to the HAN radio searching for IHDs in the vicinity that have been commissioned to wirelessly connect to the meter. This characteristic of the HAN radios in the Elster meters means that one expects to observe periodic pulsed signals from the radio even if there is no IHD in range; in the case of multiple meters located together, as in a meter bank, more pulsed signals should be observed over time simply due to the greater number of meters, each sending out a periodic signal.

The time domain characteristics of the HAN (ZigBee) radio signal are the subject of a later section in this report. Measurements at BED smart meter sites during the project as well as work with the BED test meter in Colville did not reveal any HAN radio transmission activity.

Measured peak values of the RF field of the HAN radio in the vicinity of nine GMP smart meter sites, each composed as the resultant of the three orthogonal polarization components of the detected fields, are tabulated in Table 4. The resultant peak values are displayed graphically in linear and logarithmic format in Figures 22 and 23. Figure 24 illustrates the mean value of the measured peak HAN RF fields at each distance with the associated standard deviation of values obtained at nine GMP sites.

Table 4. Peak 2.4 GHz RF field magnitudes, associated with the HAN (ZigBee) radio, obtained at nine residential smart meter sites in the GMP (Rutland) service territory. These values represent the instantaneous RF field observed at any frequency within the 2.4 to 2.5 GHz band and are expressed as a percentage of the FCC MPE for public exposure. A 'T' designates measurements of the GMP test meter in Colville. Sites not listed here included nonresidential locations or locations where interior measurements were not conducted.

	Distance (ft) from meter face						
Site	1	2	3	4	5	7	10
GMP-2	0.276	0.21	0.05495	0.03912	0.03639	0.01948	0.00524
GMP-4	0.075	0.03836	0.07782	0.05009	0.04596	0.02047	0.01647
GMP-5	0.311	0.078	0.0273	0.0369	0.02981	0.00459	0.0037

Table 4 continued.							
GMP-6	0.311	0.06291	0.074	0.03879	0.02024	0.00848	0.00847
GMP-7	0.545	0.212	0.0867	0.04518	0.01215	0.02555	0.00765
GMP-9	0.254	0.139	0.11	0.04917	0.03597	0.0317	0.01264
GMP-10	0.51685	0.071	0.03448	0.01325	0.01436	0.01418	0.00689
GMP-11	0.317	0.16076	0.04742	0.01115	0.01052	0.00928	
GMP-13	0.18	0.00359	0.011	0.00047	0.00124	0.00192	0.00419
GMP-T	0.255	0.085	0.081	0.043	0.01322	0.01346	0.00936

RF Field Variation vs. Height above Ground

A comprehensive assessment of compliance with the FCC RF exposure rules includes an evaluation of the spatial average value of RF field over the dimensions of the body. The IEEE [7] provides guidance on this process.[13] In accord with this guidance, fields were measured over six-foot vertical lines at a lateral distance of one foot from the front surface of the 900 MHz band GMP and BED smart meters as well as the 2.4 GHz GMP meter with an active HAN radio. Spatially averaged fields, while less than the spatial maximum, more accurately correspond with the limiting energy absorption rates (SARs) of the body upon which the exposure limits are specified by the FCC.

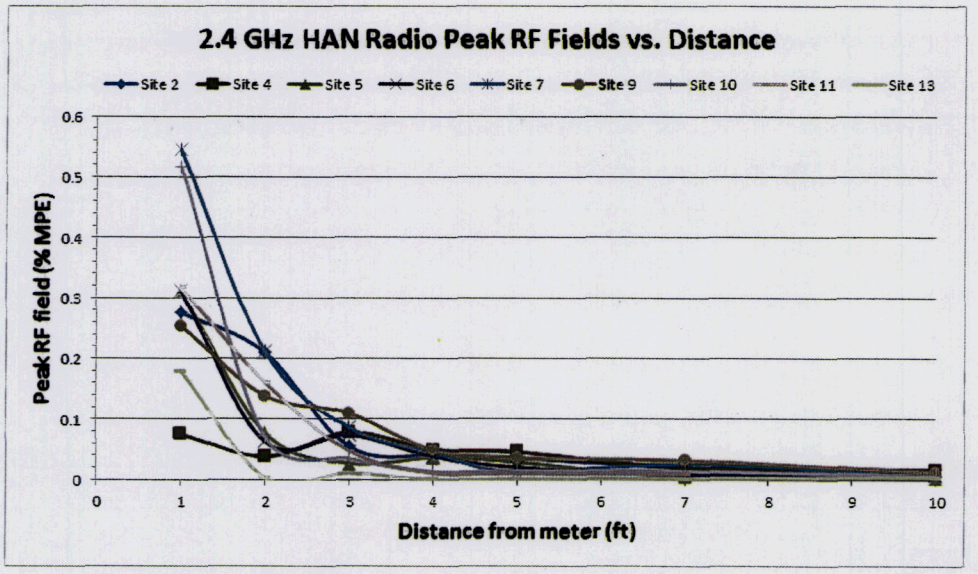

Figure 22. Linear display of measured peak 2.4 GHz RF fields of the HAN radio at GMP smart meters observed at nine individual meter sites.

[13] From IEEE [7]: The spatial average is measured by scanning (with a suitable measurement probe) a planar area equivalent to the area occupied by a standing adult human (projected area). In most instances, a simple vertical, linear scan of the fields over a 2 meter height (approximately 6 feet), through the center of the projected area, will be sufficient for determining compliance with the MPEs.

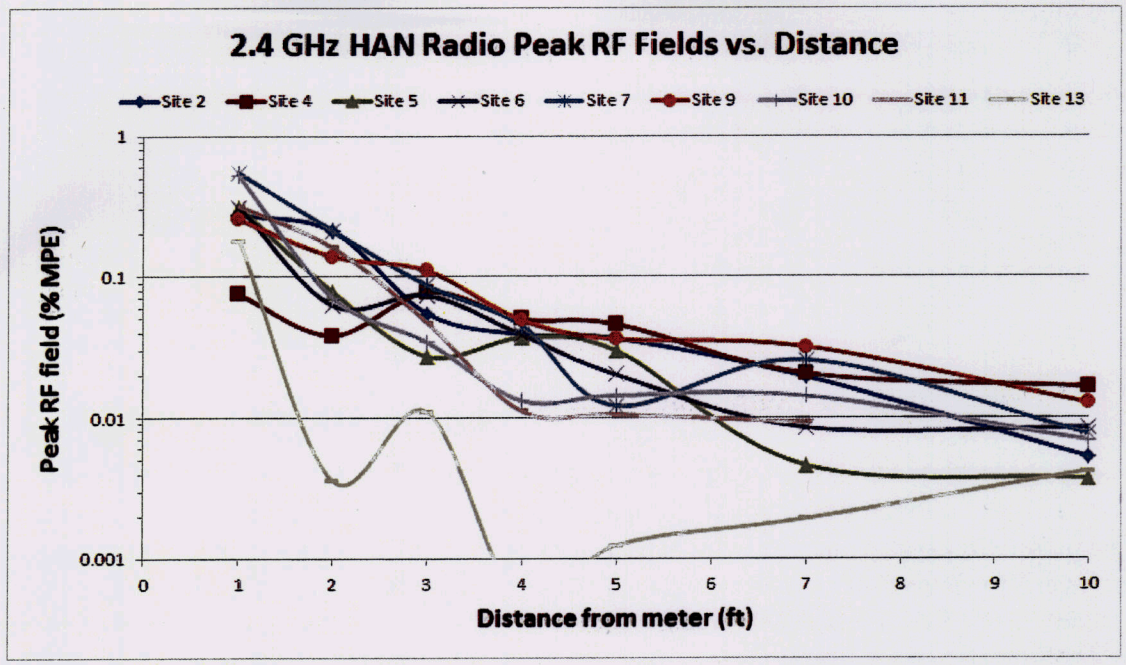

Figure 23. Logarithmic display of measured peak 2.4 GHz RF fields of the HAN radio at GMP smart meters observed at nine individual meter sites.

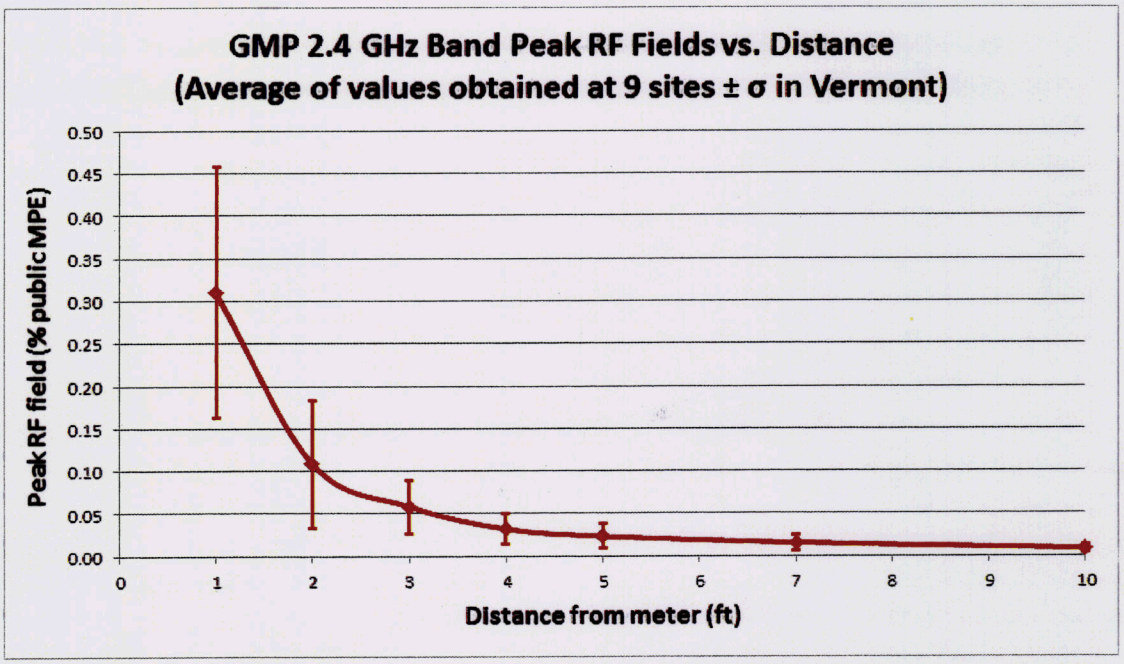

Figure 24. Average of 2.4 GHz band peak RF fields vs. distance ± 1 standard deviation of values obtained at nine individual smart meter sites in the GMP service territory.

Results

Figure 25 displays the 900 MHz band measurement results obtained near a GMP Elster meter for determining the vertical spatial average value of RF fields where the values have been normalized to a value of unity representing the greatest value at any height above ground. Figure 26 shows that the overall spatial average of peak RF field, expressed as a fraction of the FCC MPE, is 30.4% of the spatial maximum.

A similar set of measurement data shown in Figure 26, but for a different meter mounting height for the two test meters in Colville, show a consistent observation of the maximum field being associated with the mounting height of the meter. Spatially averaged RF fields of 36.3% and 48.9% of the spatial maximum values were measured. With both meters mounted at the same height, the results suggest a somewhat different distribution of RF fields in the elevation plane.

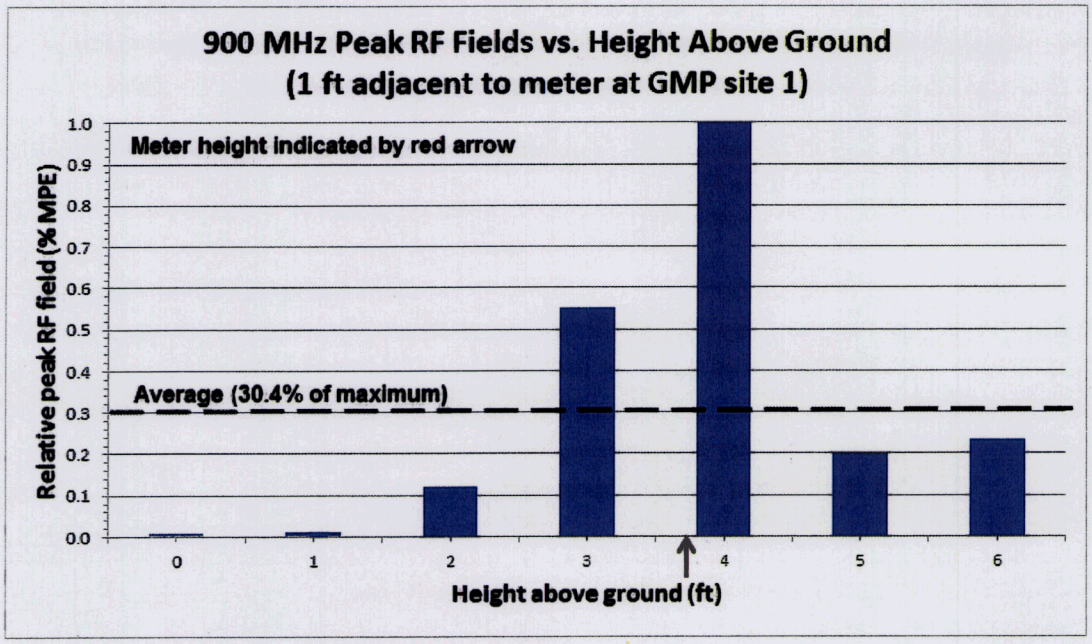

Figure 25. Relative peak RF field (as a percent of the MPE) vs. height above ground at one foot in front of a 900 MHz Elster meter operated by GMP in Vermont. Measured fields were normalized to the greatest value determined from all measurements. Overall, the spatial average was found to be 30.4% of the spatial maximum value. The variation in relative values is due to the fact that the smart meter emissions are mainly directed horizontal to the meter.

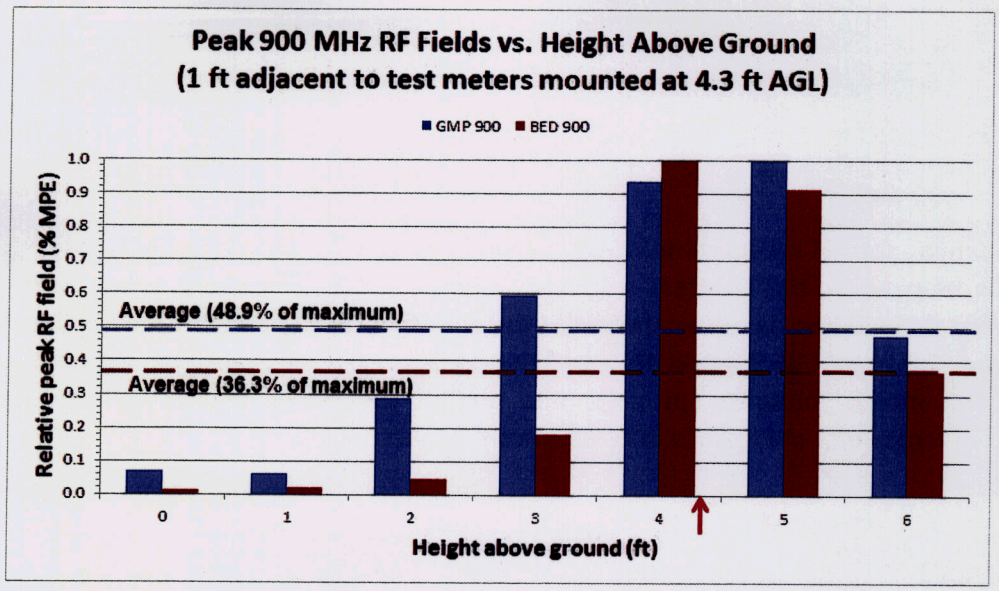

Figure 26. Relative peak 900 MHz band RF field (as a percent of the MPE) vs. height above ground at one foot in front of the Elster and Itron test meters in Colville, WA. Measured fields were normalized to the greatest value determined from all measurements.

The vertical spatial variation of 2.4 GHz peak RF fields of the HAN radio in front of the Elster meter is shown in Figure 27 where the spatially averaged RF field was 34.9% of the spatial maximum observed near the mounting height of the meter.

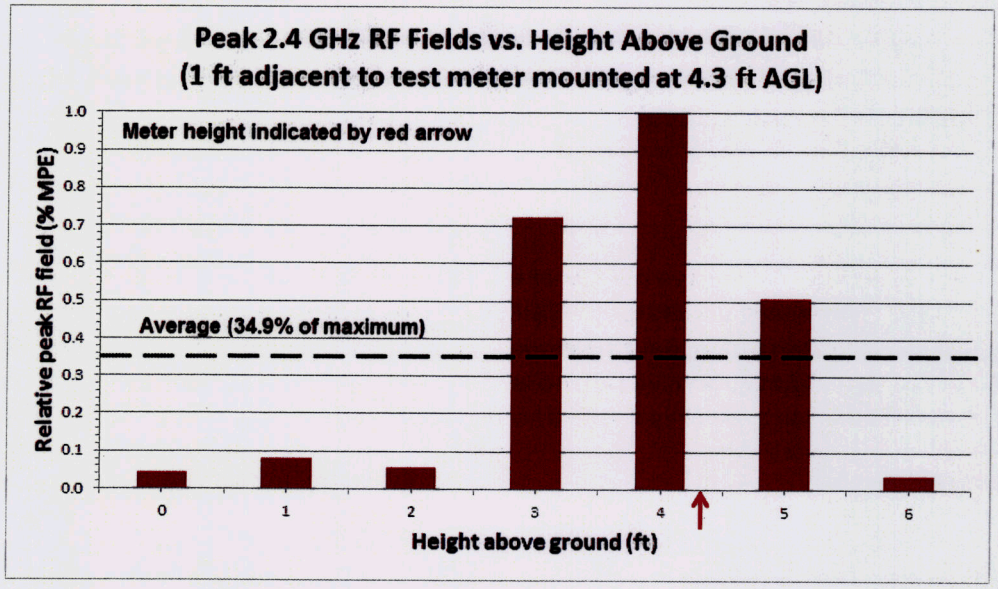

Figure 27. Relative peak 2.4 GHz band RF field (as a percent of the MPE) vs. height above ground at one foot in front of the Elster test meters. Measured field was normalized to the greatest value determined from all measurements.

Results

Azimuthal Directivity

Beyond variation of RF fields in the elevation plane, measurements were also performed to examine the directional properties of the smart meter emissions in the azimuth (horizontal) plane near the smart meters. The meters were installed in a standard electrical meter socket, powered up and, with the SRM-3006 and probe/antenna supported on a tripod, the peak RF fields were measured. The smart meter positioned in four directions: 0° (face of the meter facing the probe/antenna), 90° (smart meter facing to the left), 180° (smart meter facing to the rear and away from the probe/antenna) and 270° (smart meter facing right). These relative pattern data are shown in Figure 28. For both meters, including the 900 MHz and 2.4 GHz bands, the weakest RF fields were found to the rear of the meter, ranging from approximately 6% to 8% of the maximum value. This is the side of the meter that would typically face the exterior wall of a residence. For the 900 MHz emissions, the strongest RF fields were always from the front of the meter with lesser values to the sides and to the rear. RF fields of the 2.4 GHz HAN radio, however, were observed to be as much as 27% stronger off to one side of the meter as directly from the front.

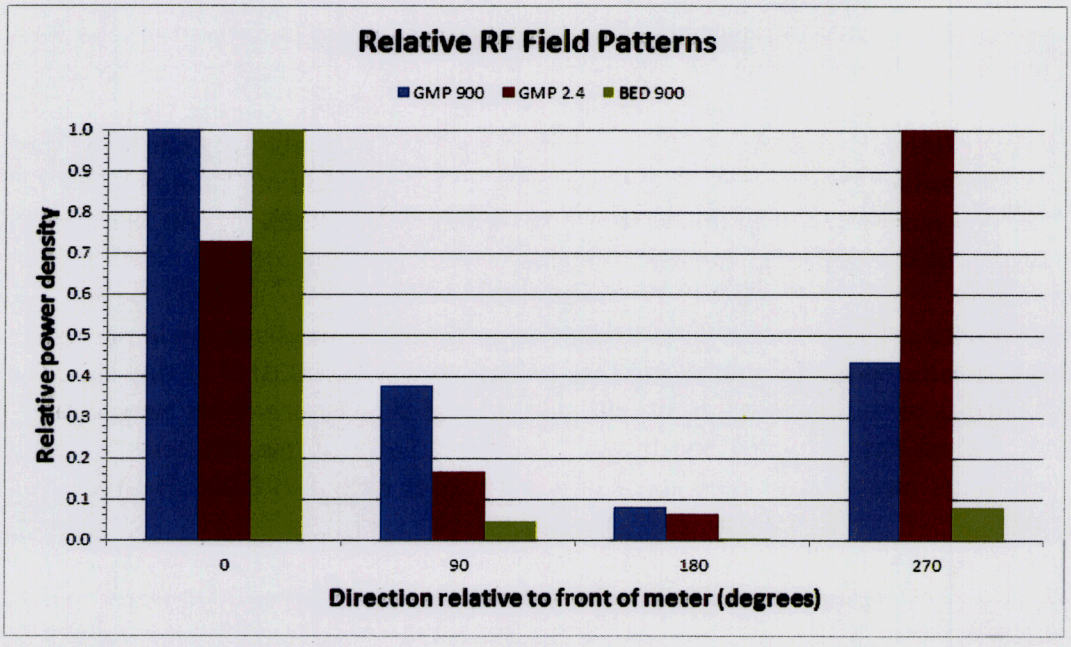

Figure 28. Relative RF field patterns in the azimuth plane for the GMP and BED 900 MHz radios and the GMP 2.4 GHz HAN radio. Generally, RF fields to the rear of the meters are weakest, being between approximately 6% and 8% of the maximum values.

Results

Interior RF Measurement Results

An important aspect of this project was determining the magnitude of smart meter RF fields found inside of residences equipped with smart meters operated by both GMP and BED. This process involved a similar approach as used for the exterior field vs. distance measurements. The respective meters were "pinged", either via the field service unit in the GMP territory or via the network in the BED area, and different rooms within each residence were scanned with the SRM-3006 to acquire a spectrum of the RF emissions. The maximum values were extracted from the saved spectral data as the value representative of potential exposure within the room. For interior measurements of the GMP HAN radio emissions, time domain measurements of the separate X, Y and Z polarization component fields were acquired by standing within the room, toward the center of the room where accessible, and capturing the narrow pulses that were relatively infrequently emitted. In this instance, the room was not spatially scanned since the acquisition of a meaningful measure of the RF field magnitude required the three polarization measurement values to be obtained at the same point in space.

A total of 141 interior RF field measurements (RF LAN and HAN emissions from GMP meters) were made between those in the Rutland area and in Burlington. The 900 MHz band measurement results are tabulated for the GMP and BED service territory homes in Tables 5 and 6 respectively. Interior RF fields associated with the operation of the 2.4 GHz HAN radios of the GMP meters are tabulated in Table 7. Collectively, the interior residential measurements yielded a maximum peak value of RF field of 0.08% of the MPE for public exposure, an average peak value of 0.0033% of the MPE and a minimum value of 0.00001% of the MPE.

Figure 29 shows the results of a cumulative percentile analysis of the interior peak RF field measurements. The median value of peak field was 0.00019% of the MPE. The horizontal axis of this figure represents the percent of all measurements having values equal to or less than the values on the vertical axis. For example, 40 percent of the measurements had values of peak RF field equal to or less than 0.0001% of the FCC MPE.

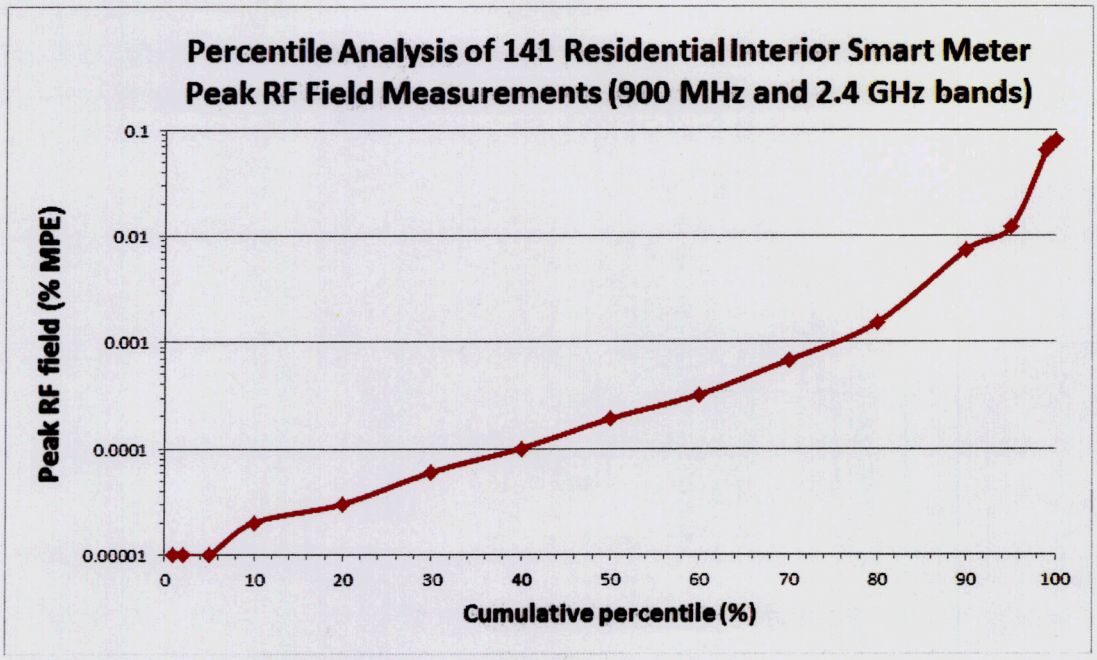

Figure 29. Percentile analysis of 141 residential interior field measurements of the instantaneous peak RF field as a percentage of the FCC MPE for public exposure performed in Rutland and Burlington, VT residences.

Results

Table 5. Summary of interior 900 MHz RF field measurements in residences in the GMP Rutland service territory (values in terms of instantaneous peak RF field as a percent of the FCC MPE for public exposure). Shaded cells represent rooms that were either not present at the site or were unavailable for measurement at the time of the visit.

Location	Site 2	Site 4	Site 5	Site 6	Site 7	Site 9	Site 10	Site 11
Inside Garage	0.00752	0.080	0.00038	0.024	0.00003			
Inside Living Room	0.07	0.00341	0.00935	0.00005	0.00071	0.00005		0.00055
Inside Dining Room			0.00029		0.016		0.00009	
Inside Family Room			0.00156	0.00009	0.00022			0.00003
Inside Kitchen	0.0033	0.00083	0.0001	0.00015	0.00015	0.00553	0.00067	0.00127
Inside Basement						0.00002		
Inside Master BR	0.00735	0.00439	0.00375	0.00315		0.00003	0.00306	0.00007
Inside BR1	0.00009	0.00056	0.00013	0.00025		0.00004		0.00002
Inside BR2	0.00039	0.012	0.00009	0.00025				0.00003
Inside BR3				0.011				
Inside BR4				0.00093				
Inside Office	0.00032	0.055		0.00029			0.00005	
Inside enclosed porch						0.038		
Utility Room							0.011	0.00505

Table 6. Summary of interior 900 MHz RF field measurements in residences in the BED service territory (values in terms of instantaneous peak RF field as a percent of the FCC MPE for public exposure). Shaded cells represent rooms that were either not present at the site or were unavailable for measurement at the time of the visit.

Location	Site 2	Site 3	Site 4	Site 5	Site 7	Site 8	Site 9
Inside Garage		0.00133				0.00067	
Inside Living Room	0.00754				0.00091	0.00006	0.00069
Inside Dining Room	0.00038	0.022		0.00001	0.00004	0.00004	0.00003
Inside Family Room		0.0001					
Inside Kitchen	0.00019	0.0005	0.00034	0.00001	0.00011	0.00028	0.00001
Inside Basement							
Inside Master BR	0.00003	0.00002	0.0007	0.00001	0.00002	0.00002	0.00001
Inside BR1	0.00041	0.00006			0.00012	0.00007	0.00021
Inside BR2	0.00007	0.00042			0.00012	0.00006	
Inside BR3		0.00017					
Inside BR4							
Inside Office	0.00003			0.00003			
Inside enclosed porch							0.00011
Utility Room							

Results

Table 7. Summary of interior 2.4 GHz HAN radio RF field measurements in residences in the GMP Rutland service territory (values in terms of instantaneous peak RF field as a percent of the FCC MPE for public exposure). A * indicates that the home had an active HAN radio that was communicating with an IHD. Shaded cells represent rooms that were either not present at the site or were unavailable for measurement at the time of the visit.

Location	Site 2	Site 4*	Site 5	Site 6	Site 7	Site 9	Site 10	Site 11*
Inside Garage	0.00033	0.00149	0.00001	0.00008	0			
Inside Living Room	0.00078	0.0071	0.00417	0.00002	0.00007	0.00016		0.00152
Inside Dining Room							0.00002	
Inside Family Room			0.0001		0.00002			0.00037
Inside Kitchen		0.00294	0.00007	0.00001	0.00025	0.00008	0.00005	
Inside Basement		0.00142		0.00001		0.00003		
Inside Master BR		0.0003	0.00013	0.00003		0.00002	0.00005	0.00031
Inside BR1	0.00007	0.00055	0.00002	0.00387		0.00001		0.00032
Inside BR2	0.00023	0.00034	0.00002	0.00128				0.00929
Inside BR3				0.00009				
Inside BR4								
Inside Office	0.00017			0.00004			0.00002	
Inside enclosed porch								
Utility Room								

Results

An alternative way of viewing the residential interior field measurement values is provided in Figure 30 where each of the 141 measurements is plotted in order of decreasing value ranging from the overall maximum of 0.08% of the MPE to smaller values. The greatest measured values pertain to approximately 20% of the total number of measurements. After correction for time and spatial averaging, the maximum and average values are equivalent to 0.0014% and 0.000057% of the MPE respectively.

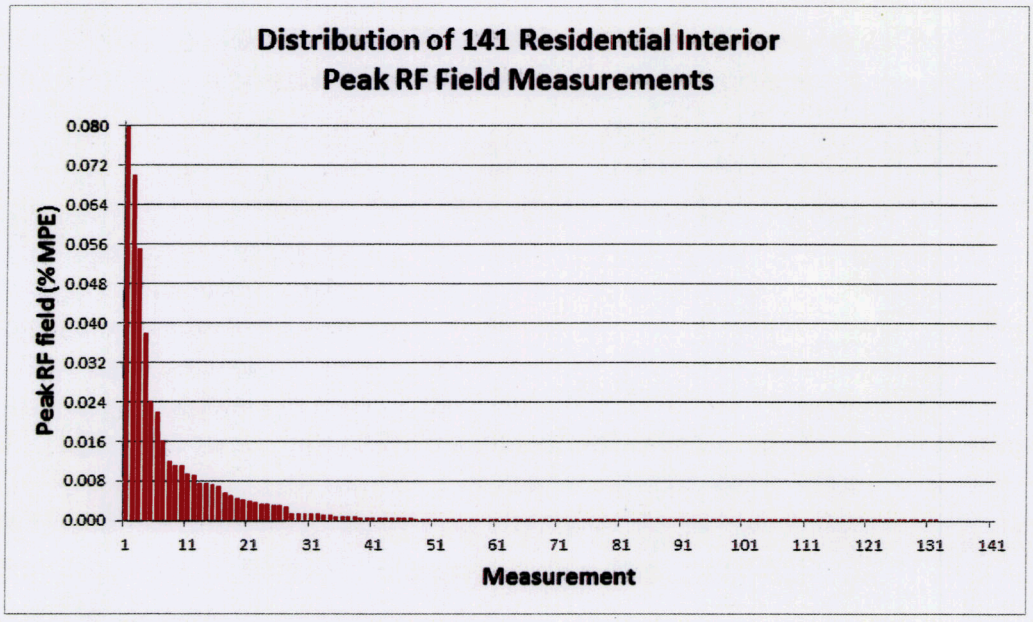

Figure 30. Distribution of 141 residential interior peak RF field measurements in decreasing order.

Assessing Duty Cycles of Smart Meters

The most demanding aspect of characterizing potential exposure of individuals to smart meter RF emissions is determining the duty cycle of operation of the smart meters. This determination is relevant to adjusting measures of instantaneous peak values of RF fields to obtain the actual time-averaged value of field. Time-averaged RF fields, averaged over any 30-minute period, are specified by the FCC for compliance with their exposure regulations. The measured values of RF fields in this report are in terms of instantaneous peak values, relative to a percentage of the MPE. The duty cycle of a smart meter emission is a measure of the ratio of the average power transmitted by the meter to its peak power transmitted over an observation time. For intermittent RF fields that are exactly of the same amplitude, the duty cycle can be defined as the ratio of the "on time" of the field to the total time of observation. As an example, if an intermittent field is on for 1 second once every 10 seconds, then the duty cycle is simply 1/10 or 10%.

In a more general sense, for RF fields that may vary in magnitude during their on-time, duty cycle is defined as the ratio of the overall average of the power, or overall average of percentage of MPE that the signal represents, to the peak value of field, as a percentage of the MPE, during the observation or measurement period. For fields that exhibit the same amplitude each time they exist, these two definitions are the same.

Frequency hopping, spread spectrum smart meters produce only intermittent RF fields (pulses) that last for very short times. The upper range of smart meter signal on-time is in the range of 100 milliseconds (ms) (one tenth of a second) or less with the length of the pulse being related to the information content carried by the transmissions from the smart meter. Previous studies of similar smart meters have indicated typical duty cycles of only a few percent or less [1, 2, 10]. Such small duty cycles result because of the digital nature of the wireless RF LAN, the relatively high speed of data transmission and the small amount of data on electric energy consumption that needs to be transmitted. While each end point meter also serves as a repeater for neighboring meters that need assistance in getting their data to a data collection point, all of this activity only adds up to a relatively small amount which does not require much transmitting time on the part of the smart meter. Taking all of the requirements for the smart meter to actually transmit, including beacon pulses and other network organizational overhead, maximum duty cycles are remarkably small.

How one determines what the duty cycle of a meter is presents considerable challenge. From a measurement perspective, the normal variability in transmission by a smart meter means that measurements performed at any individual meter can take a lot of time and may be fraught with considerable uncertainty. For instance, typical meter activity may vary from moment-to-moment, hour-to-hour and day-to-day. To obtain a good overall picture of transmitting activity of a large number of smart meters could require many days of effort and result in considerable uncertainty from a statistics perspective in the resulting estimate of average activity.

Generally, for exposure assessment purposes, the conservative approach is to determine the maximum duty cycle that may be exhibited by any meter within the network and using this value for adjusting all measured peak values to obtain average levels of potential exposure. It becomes clear that attempting to do this by a direct physical measurement of fields by statistically sampling a large number of smart meters over time can be extremely arduous. Because of this difficulty, past studies have made use of a statistical approach to examining smart meter transmitting activity that has relied on collecting and analyzing data from the utility's smart meter data management software system [1, 2, 10]. If data can be collected from a large portion, or all, of the deployed smart meters in an area on the amount of data transferred wirelessly by the meters, then estimates of the total transmit time can be developed for the associated sampling period. Typical sampling periods have ranged from nominally an hour to as much as a 24 hour period. Thus, average duty cycles can be generated that are

applicable to whatever the sampling period was. The strength of this approach is that the statistical estimates can be based on very large numbers of meters and produce results on duty cycles that have high confidence.

An alternative approach was taken for this project in which direct measurements were performed under conditions that would correspond to the greatest meter transmission activity. For both the GMP and BED measurements, each utility arranged for measurements to be made at specific times during which maximum amounts of data would be transmitted. Rather than performing measurements at a large number of meters, focused measurements could be performed on a selected meter or the RF LAN component of a data collection point to obtain estimates of the maximum likely duty cycle of any of the meters in the system. Hence, through a contrived scenario in which the greatest amount of data that would normally ever be transmitted, duty cycles could be directly measured for the Vermont smart meters in this study.

In this project, a feature of the SRM-3006 that is based on its time-analysis mode of operation was used to directly measure duty cycles. In essence, RF field amplitudes, as a percent of the MPE, were monitored over various time periods but with an emphasis on 30 minutes. The SRM-3006 makes many measurements of the peak and average RF field magnitude that occur within small time increments across the long term monitoring period and directly indicates the measured duty cycle. During these measurements, examples of smart meter pulse characteristics were also collected to examine the duration of the pulses.

Measurements of 900 MHz band RF pulse characteristics during the Vermont field work allowed evaluation of smart meter duty cycles. Measurements were conducted on single end point meters as well as at banks of meters. In the GMP territory, measurements were strategically made at a single end point meter during the scheduled time of day when maximum meter activity would occur. A 30-minute measurement in the time domain was made at GMP site 1 beginning at 9:15 A.M. (one of the four periods during the day that meters report energy consumption data) as shown in Figure 31. During this measurement period, the meter is scheduled to transmit load profile data back to its data collection point (Gatekeeper in GMP terminology)[14]. This particular meter was selected specifically for the measurements because of its location within the mesh network to which it was assigned; because of its hierarchy within the network, this meter would be expected to exhibit transmit activity related to the 554 meters that communicate through it (GMP was able to provide network maps that allowed the identification of this meter). Based on examination of the Rutland service territory, this meter represented the best opportunity for finding maximum transmit activity and, hence, would provide a conservative measure of maximum meter activity across the

[14] Load profile data consists of the historical record of all 15-minute interval data since the last reporting period, normally six hours.

network. During the measurement period of 30 minutes, a duty cycle of 0.0355 (3.55%) was determined. In Figure 31, the recorded instantaneous peak value of RF field was retained for use in preparing this graph of signal activity. The sweep time of the instrument is divided into as many as 4000 time-resolution increments depending on the overall sweep time. The instrument measures the overall peak and average value of all pulses occurring within each time increment and represents this result as a vertical bar. Each bar can, visually, only represent signal values associated with each time resolution increment. Hence although the peak and average signal amplitudes are accurately measured for all pulses, the number of pulses that occurred or precisely when they occur can be obscured by the particular time, and graphical, resolution.

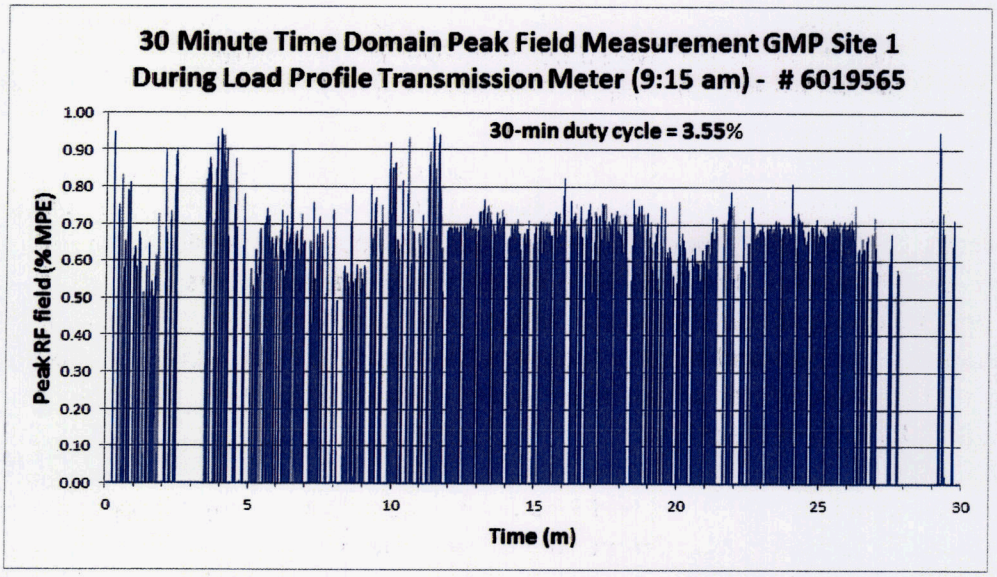

Figure 31. Result of 30-minute time domain measurement of peak RF fields at GMP site 1 during period of maximum expected transmit activity.

The duty cycle result obtained from the measurement shown in Figure 31 represents the greatest 30-minute duty cycle value that was found during any of the project measurements in Vermont.

At the same GMP site (site 1), an additional 30-minute measurement of duty cycle was conducted beginning at 10:15 A.M. This signal sample was captured near the end of the transmission of load profile data but included part of the register reads from meters across the network. Figure 32 illustrates the results of this measurement. The 30-minute duty cycle was measured to be 1.21%.

These values of duty cycle may be interpreted in terms of the how the time-average value of RF field is related to the overall instantaneous peak value of RF field during the 30-minute period in which the measurement was made. From a practical, but

conservative perspective, the greatest duty cycle may be used to adjust all reported peak values of RF fields to equivalent 30-minute time-averaged values.

The waveform of a typical pulsed signal response from the GMP meters, after being pinged by the field service unit, is shown in Figure 33. This time domain display shows that the pulse width is very close to 100 ms.

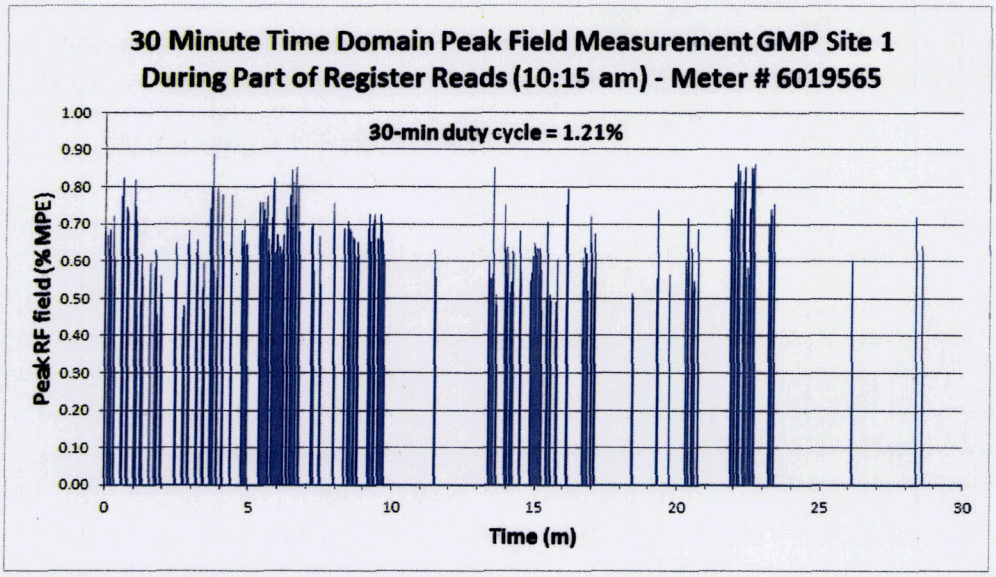

Figure 32. Result of 30-minute time domain measurement of peak RF fields at GMP site 1 during a second period of high expected transmit activity including transmission of register reads from meters.

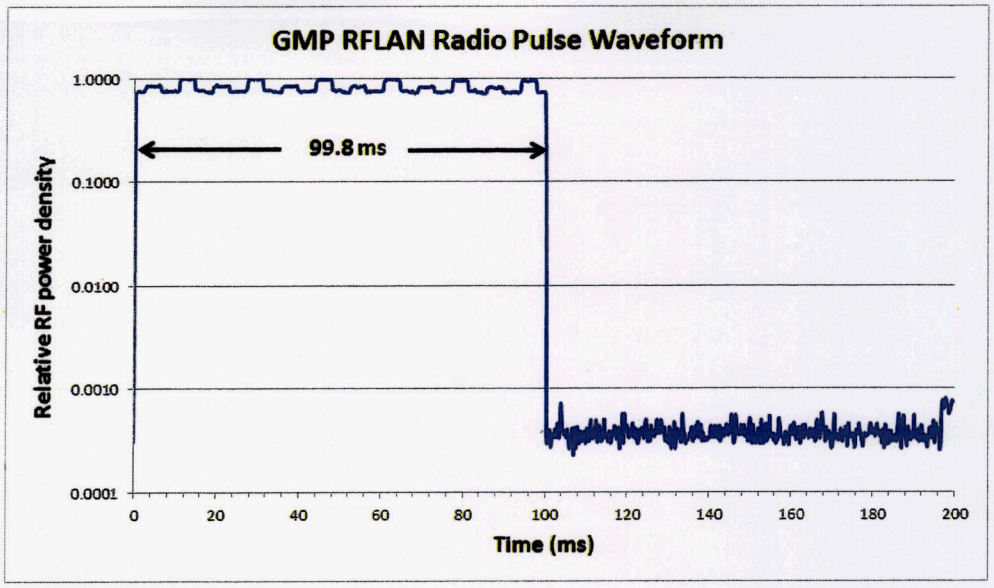

Figure 33. Waveform of GMP end point meter emission when pinged by field service unit.

Additional time-domain measurements were conducted at an end point meter located near the bottom of the network hierarchy (no other end point meters would normally make use of this meter for relaying of data). Three different data transmission scenarios were arranged for these measurements by sending commands from the GMP head end via the wireless network that requested the meter to transmit back the retained 15-minute interval data collected and stored during the past one day, during the past two days and during the entire period (~70 days) since the meter had been initially installed. Figure 34 illustrates these measurement data where the instrumentation was kept active for capturing signal levels as the meter was sequentially instructed to transmit according to the three scenarios. The data collection period existed for approximately 15 minutes. The increased transmit activity is evident, depending on the amount of data being requested from the network head end. In this contrived scenario, the 15 minute duty cycle was found to be 0.141%. The normal duty cycle of this meter would be far less than this value since it would only be transmitting data applicable to the past six hours. Importantly, although the maximum amount of data that could be pulled from this meter was included in the measurement, the process resulted in a very small overall duty cycle when compared to the data acquired at GMP site 1 where historical data from more than 500 meters was involved in the transmission.

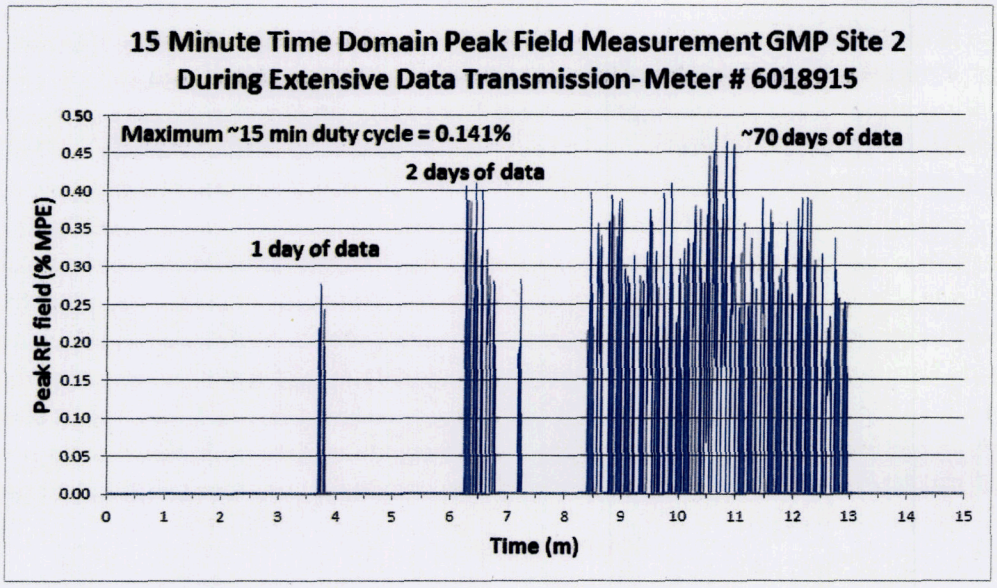

Figure 34. Result of 30-minute time domain measurement of peak RF fields at GMP site 2 during a contrived scenario of three different data transmission requests of the meter (one day's worth of data, two days of data and all of the data stored since the meter had been installed).

Arrangements were made to perform additional measurements of the meter emissions at GMP site 2 during a typical data transmission for comparison with the contrived scenario of maximum data transmission. Figure 35 presents the time domain results for a 30-minute observation. The observed 30-minute duty cycle was found to be 0.022% verifying that the meter transmitting activity is very low under normal operating conditions.

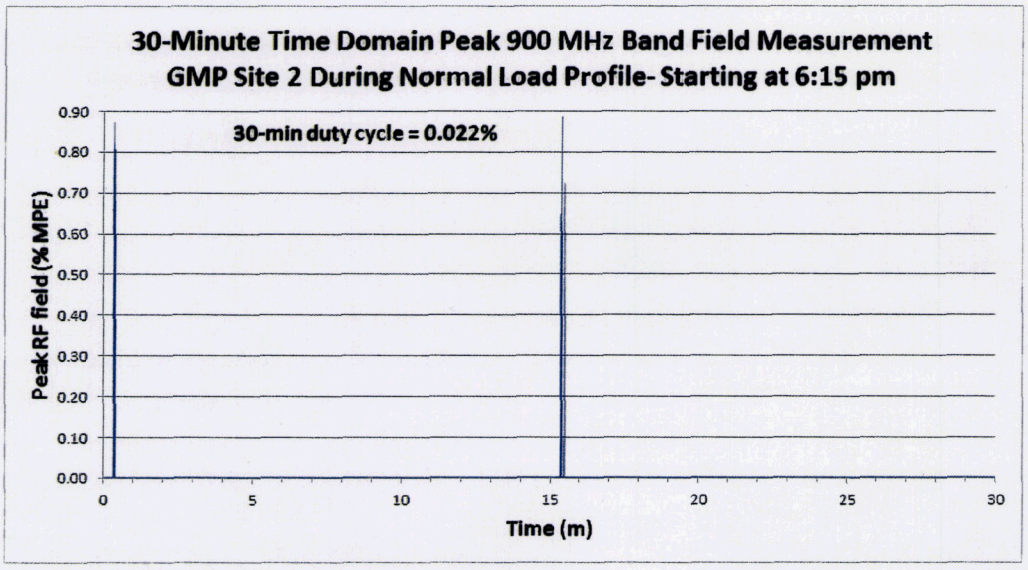

Figure 35. Result of 30-minute time domain measurement of peak 900 MHz band RF fields at GMP site 2 during a normal data transmission request that occurs four times per day.

Results

The 30-minute RF field duty cycle observed at a meter bank of 14 meters (GMP site 3) was measured during the scheduled period for meter transmissions. The SRM-3006 probe/antenna was positioned on a tripod near the center of the bank of meters and signal activity was monitored for 30 minutes. The observed result is shown in Figure 36 for which a 30-minute duty cycle of 0.041% was measured. Although there were 14 meters within this bank, only minimal transmit activity was observed. It is relevant to note that when the request for meters to report interval data is transmitted out to all of the end point meters from the network head end, this does not necessarily mean that the meters within this specific bank of meters will report sequentially in time. While one meter in the bank may report, other meters located physically elsewhere may sequentially report before another one of the meters within the bank becomes active. This likely leads to the relatively sparse amount of signal activity over this period near the bank. Differences among signal peak values are likely related to the different distances between the probe/antenna and various meters within the bank and the transmitting pattern of each meter.

Measurements of meter transmit activity were also performed at a GMP Gatekeeper (site 8). This was accomplished by, first, identifying the cellular WWAN frequency used by the Gatekeeper, using the SRM-3006, in spectrum analysis mode, to observe for the presence of a predominant signal when the probe/antenna was held near the WWAN antenna on the Gatekeeper (a step ladder was used to gain access to

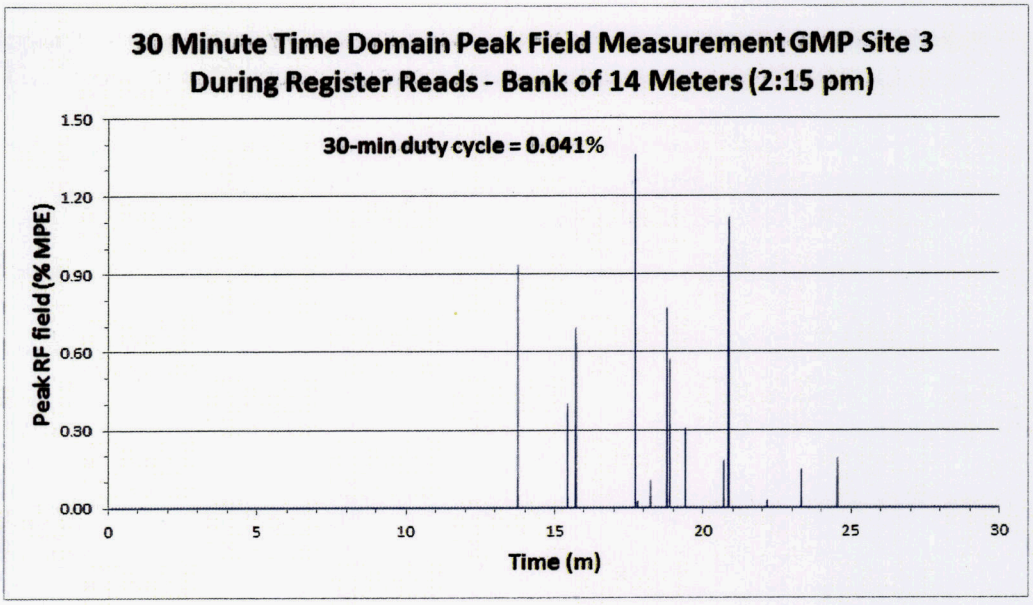

Figure 36. Result of 30-minute time domain measurement of peak RF fields at a bank of 14 meters (GMP site 3) during a normal data transmission period that occurs four times per day.

the elevated Gatekeeper antennas). Once this frequency was identified, approximately 825 MHz, the SRM-3006 was set to time-analysis mode with a center frequency of 825 MHz and a RBW of 5 MHz to capture the time domain waveform of the emitted WWAN signals. This process was accomplished in rapid manner beginning with the expected start of transmission by the Gatekeeper via the WWAN at 10:15 A.M. The subject Gatekeeper at site 8 has 1245 end point meters that report back to it; it is these data that are, then, put on the WWAN back to the GMP data management system. The measurement of duty cycle was performed with the SRM-3006 on a tripod at three feet above ground level. Figure 37 shows the Gatekeeper box mounted on a power pole at GMP site 8 with the measurement instrumentation situated on a tripod.

Figure 38 shows the result of this measurement exercise. Over the 30-minute observation period, a duty cycle of 0.141% was determined. The relatively small duty cycle observed, despite the large amount of data accumulated from all 1245 end point meters, is likely a result of the high data transmission rate associated with the WWAN such that only a very small amount of time is required to convey the large amount of data to the Internet.

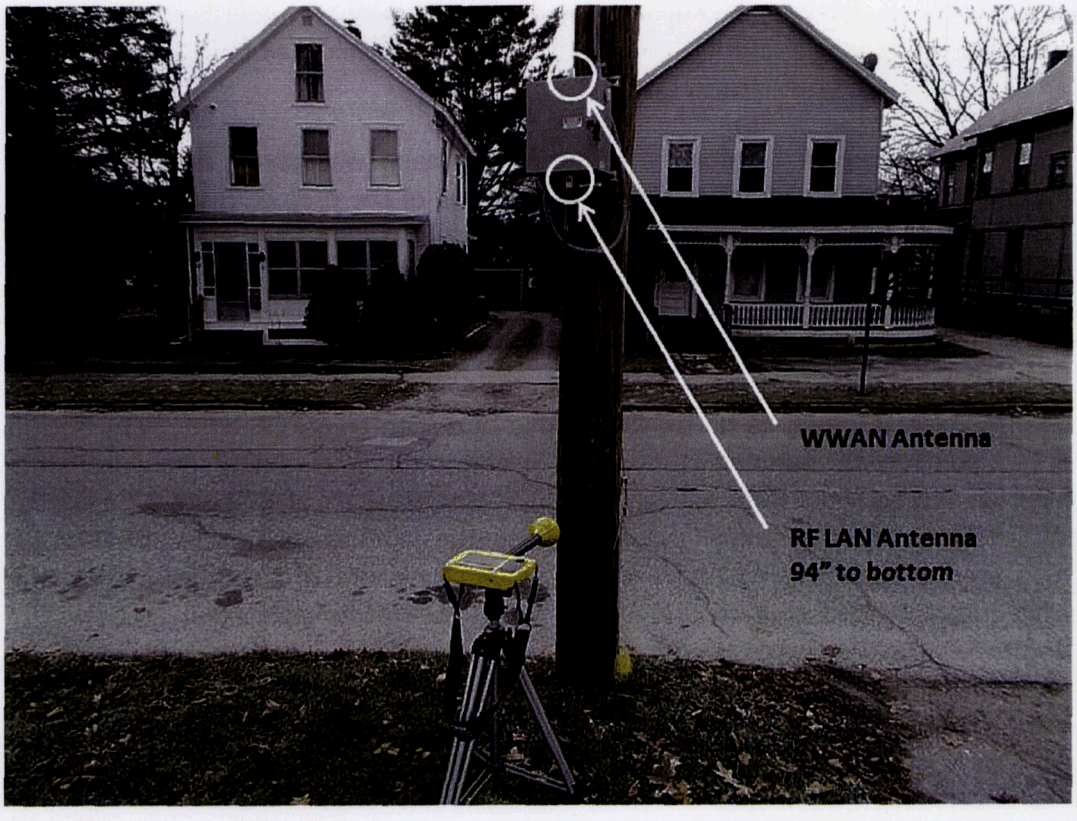

Figure 37. GMP Gatekeeper mounted on a power pole at GMP site 8 with the WWAN antenna on the top and the 900 MHz RF LAN antenna on the bottom.

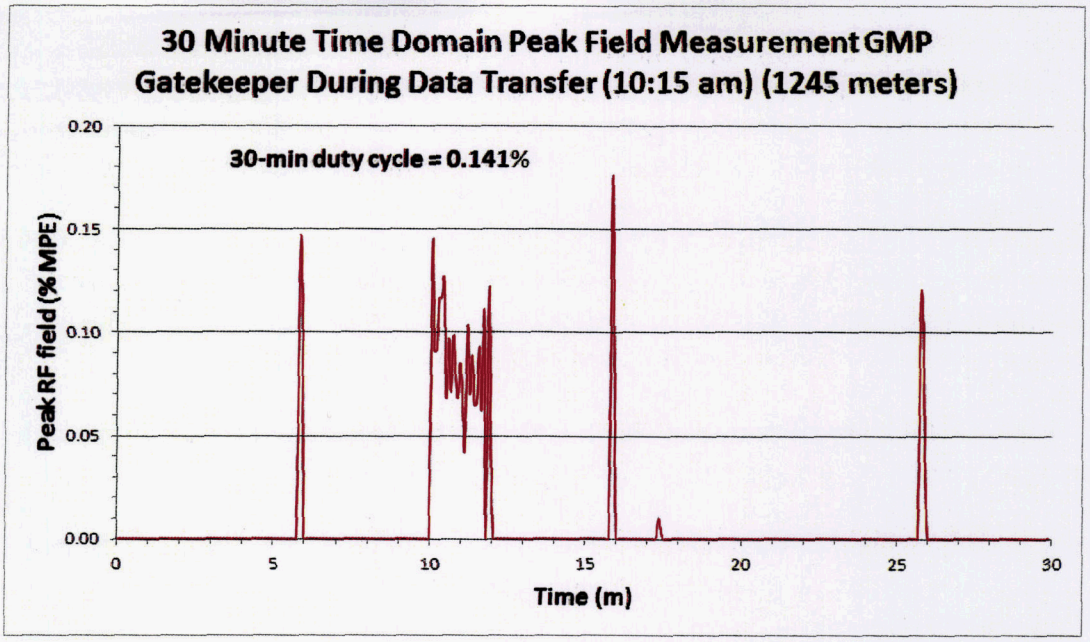

Figure 38. A 30-minute time domain measurement of peak RF fields near the base of a GMP Gatekeeper (site 8) during a scheduled transmission of data accumulated from 1245 end point meters.

In the BED service territory, a different approach was taken to estimate the maximum duty cycle of end point meters. At the time of the project, it was difficult for BED to cause, on command, a prolonged transmission of data from end point meters during which measurements could be made. As an alternative, it was deemed that a suitable substitute could be represented by the transmission activity of the 900 MHz radio within one of the BED Cell Routers during the time that it sends instructions to a mass of end point meters requesting each meter to transmit its data back to the Cell Router. This was assumed to be representative of a high transmission activity from a given end point meter sending stored load profile data. Accordingly, measurements were performed near the base of one of the BED Cell Routers at BED site 1 beginning shortly before a scheduled transmission of instructions via the Cell Router at 8:00 A.M. The measurement began at 7:55 A.M. and continued for a total of 35 minutes, observing the Cell Router 900 MHz emissions. Figure 39 shows the resulting time domain data. The 35 minute duty cycle was measured as 0.041%.

The characteristics of a typical RF pulse observed at one of the BED end point meters is shown in Figure 40. The duration of the pulse is 69.5 ms.

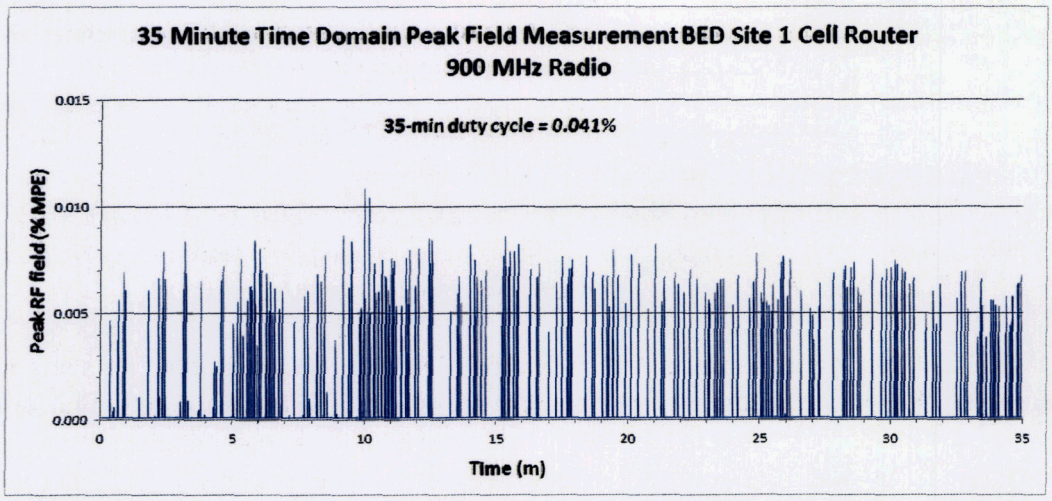

Figure 39. A 35-minute time domain measurement of peak RF fields near the base of a BED Cell Router (BED site 1) during a scheduled transmission of commands to end point meters to respond with data. These data pertain to the 900 MHz band emissions associated with the Cell Router.

Other measurements performed at BED end point meters, while the meter was pinged via the network head end, were used to estimate potential duty cycles during different scenarios consisting of varying amounts of data being transmitted back to a Cell Router. This method was limited in that the software at the head end of the network was difficult to control for specific amounts of data to be transmitted and how often the commands could be repeated. Nonetheless, the greatest observed duty cycle from a single end point meter was measured to be 0.157% over a two minute period.

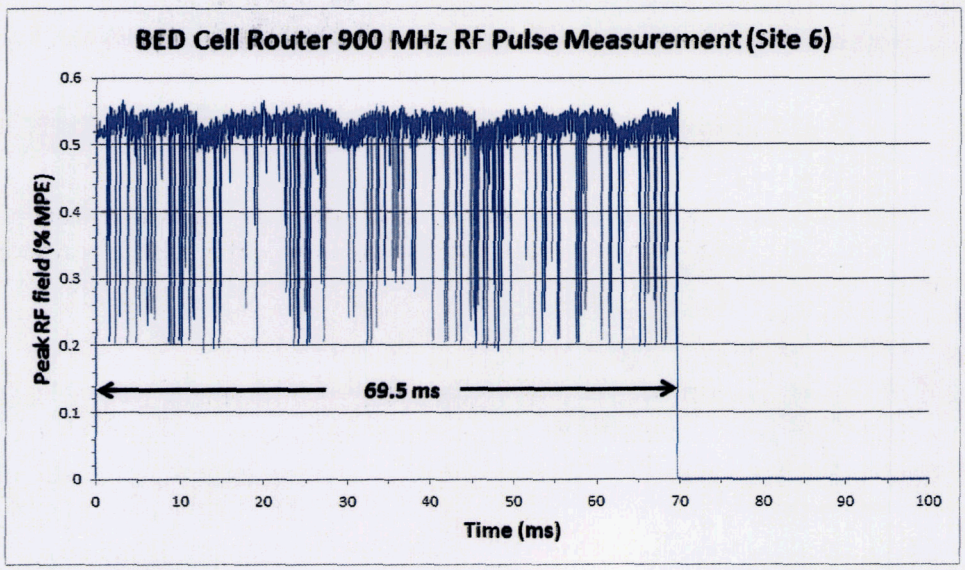

Figure 40. The time domain waveform of a 900 MHz RF pulse emitted by a BED Cell router RF LAN radio (BED site 6). The duration of the pulse was measured to be 69.5 ms.

As a conservative estimate of maximum duty cycle, if one pulse lasting for 69.5 ms were to be emitted once per second (not supported by any of the measurements performed during the project), the corresponding duty cycle, based on a 1 second time analysis of the signal from an end point meter at BED site 8, would be 3.49%. It is not reasonable to assume a continuous stream of such pulses over a 30-minute period but were such to occur, this could represent the maximum possible duty cycle.

HAN radio emissions associated with the GMP end point meters presented considerable challenge because of the rather narrow pulses of RF produced by the HAN transceiver. A time domain waveform of the pulse emitted by the HAN radio is shown in Figure 41. The pulse exists for only 1.79 ms with an even shorter pulse when connected to an IHD.

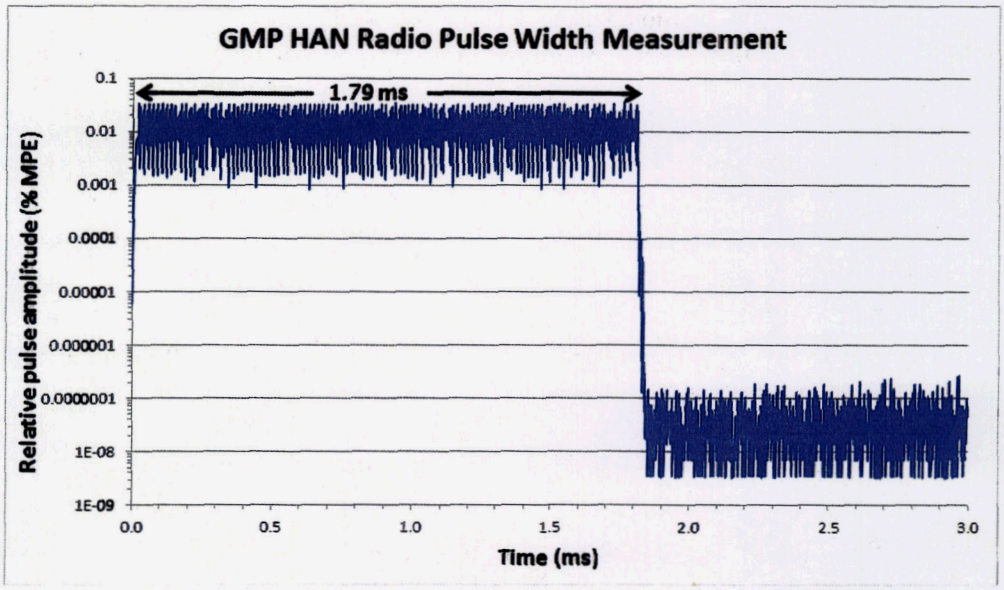

Figure 41. The time domain waveform of an RF pulse emitted by a GMP end point meter HAN radio when there is no IHD to connect with the meter. The duration of the pulse was measured to be 1.79 ms.

Because of the narrow HAN pulse width, the alternative approach of separately measuring the three orthogonal polarization components of the composite RF field was necessary since the settling time of the internal filters within the instrument could not provide a response to the instantaneous peak value of the pulsed field when using the isotropic mode of operation of the instrument. Using the time-analysis mode of the SRM-3006, however, measurements of each field component, corresponding to the X, Y and Z polarizations from the probe/antenna were recorded for each measurement

location. Following the measurements, these three component values were summed to obtain the resultant RF field magnitude expressed as a percentage of the MPE.

Initial investigation of the HAN radio emission characteristics revealed that, when the radio is not paired with an IHD, the time profile of emissions consists of nominally four pulses spaced approximately 15 seconds apart plus a burst of four pulses once approximately each minute for a total of some eight pulses, each 1.79 ms wide, every minute. This is illustrated with the time domain measurement shown in Figure 42. This pattern of radio emission activity describes the normal operation of the majority of HAN radios in the GMP deployed meters as observed in this project.

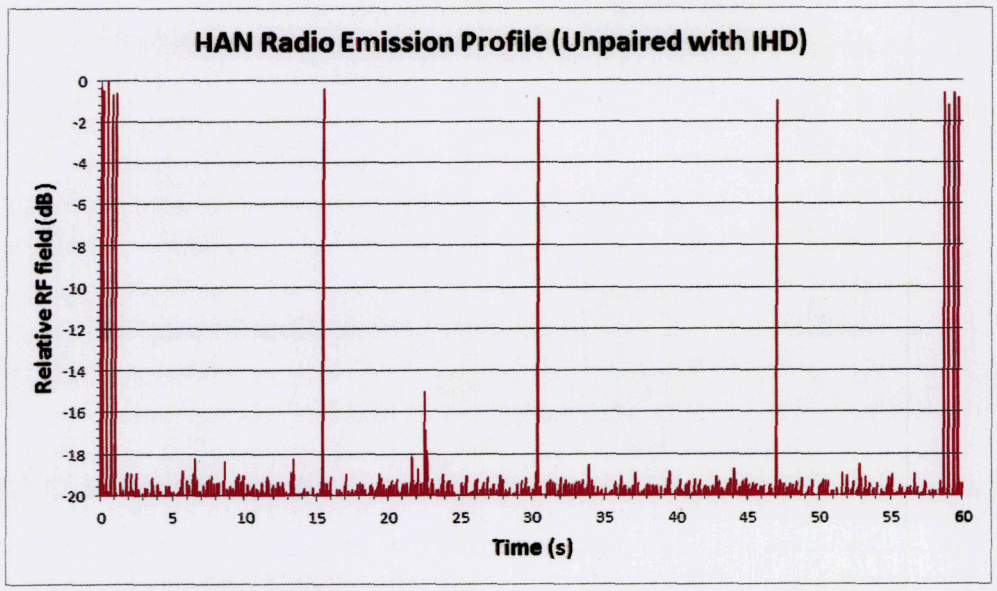

Figure 42. The time domain pattern of RF emissions from a GMP end point meter HAN radio showing a repeating pattern corresponding to nominally eight pulses every minute. The much smaller peak at approximately 23 seconds is unrelated to the operation of the HAN radio.

A different transmit activity exists, however, when a HAN radio becomes linked with an IHD. Interestingly, the pulse emission characteristics of the HAN radio change when it becomes wirelessly connected to an IHD. When connected to an IHD, two things happen; the number of pulses occurring increase and the width of the pulse decreases substantially. This observation is best illustrated in Figures 43 and 44. When the HAN radio is paired with the IHD, the pulse width of the emitted signal is reduced from 1.79 ms to 0.35 ms. However, the IHD signal is approximately the same width as the HAN radio signal when it is not paired with the IHD.

In Figure 44, the amplitude of the IHD signal is substantially greater simply because the IHD was relocated to the top of the smart meter, placing it at the same distance from the instrument probe/antenna as the smart meter and its internal HAN radio.

A 30-minute measurement of the time domain profile of the emissions from the HAN radio obtained at GMP site 2, where the smart meter HAN radio is not paired with an IHD, is shown in Figure 45. The 30-minute duty cycle in this case was measured to be 0.00030%, reflective of the narrow pulses of RF field and relatively long periods between pulses.

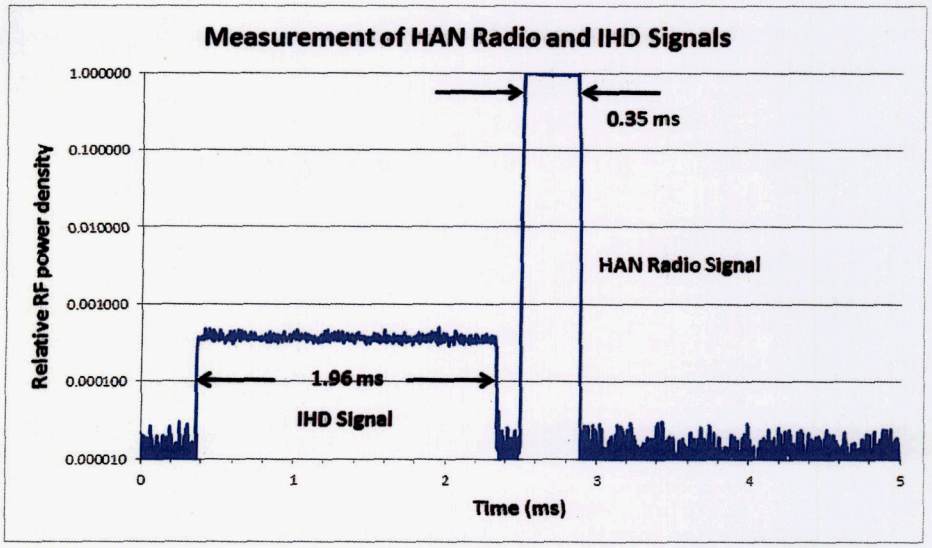

Figure 43. Time domain pattern of RF emissions from the HAN radio and an IHD located approximately 30 feet from the smart meter when the radio is paired with the IHD. Note the narrower pulse width of the HAN radio and the broad signal from the IHD that has the same approximate pulse width of the HAN radio when the HAN radio is not connected to the IHD.

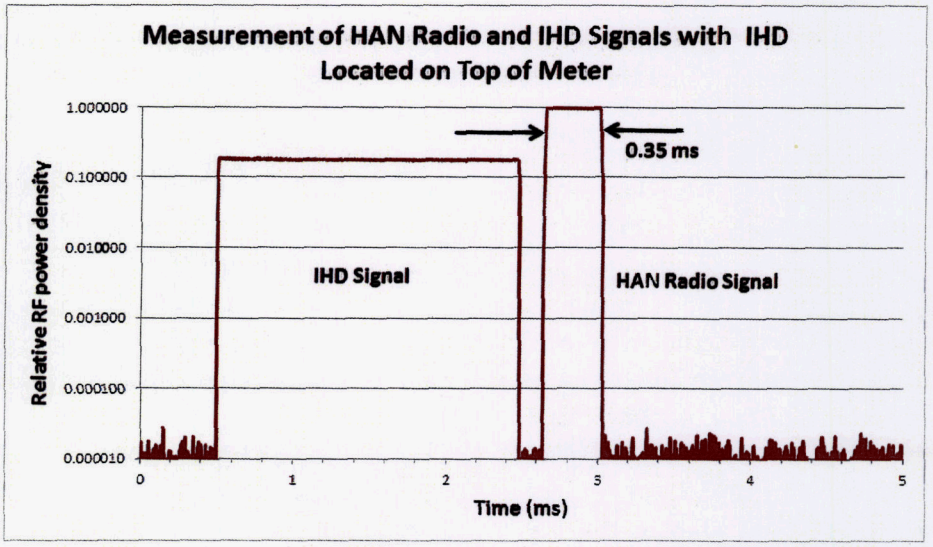

Figure 44. Time domain pattern of RF emissions from the HAN radio and an IHD located on top of the smart meter with the radio paired with the IHD. The amplitude of the IHD signal has increased significantly since it is at the same distance to the measurement probe/antenna.

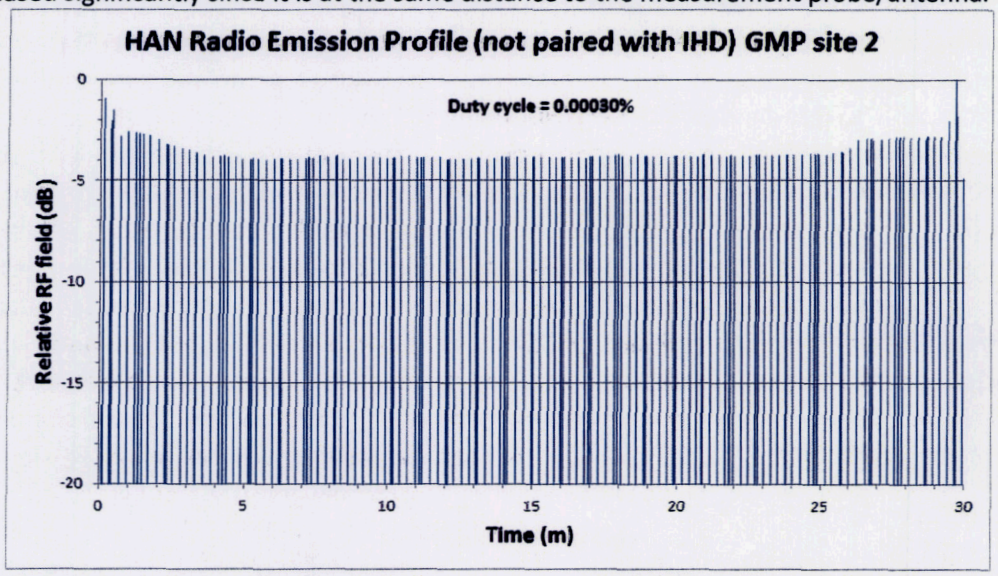

Figure 45. 30-minute time domain pattern of RF emissions from a smart meter HAN radio at GMP site 2 that is not connected with an IHD.

For comparison, another 30-minute measurement performed with the HAN radio that is paired with an accompanying IHD is shown in Figure 46. The result of this measurement was a 30-minute duty cycle of 0.00087%, approximately three times greater than for the unpaired HAN radio.

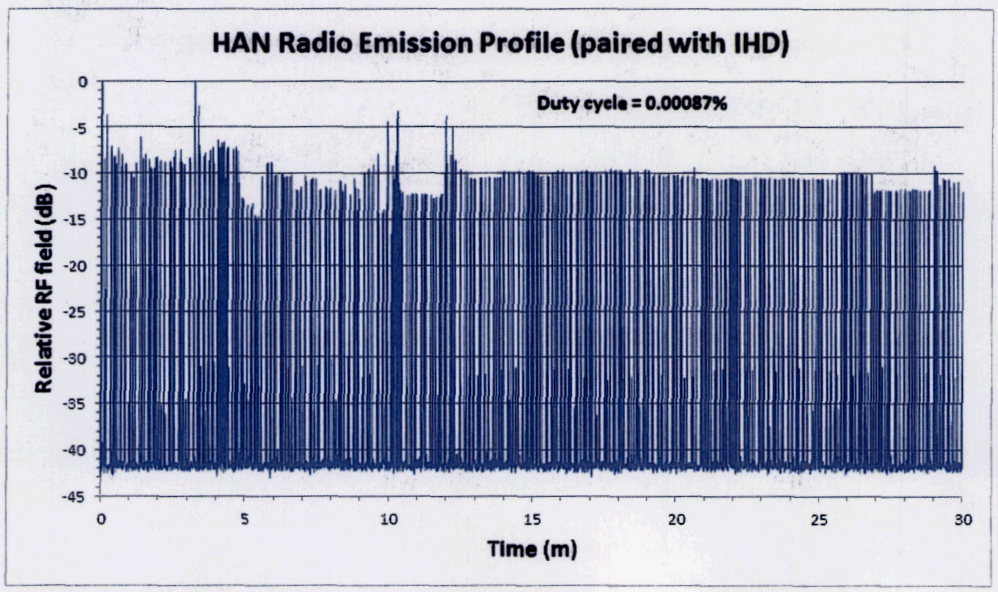

Figure 46. 30-minute time domain pattern of RF emissions from a smart meter HAN radio paired with an IHD.

Further insight to the HAN radio emission characterization is provided in Figure 48 which represents a time domain measurement at a bank of six smart meters (GMP site 13), none of which were paired with an IHD. A long term duty cycle of 0.00034 resulted. In Figure 47, a visual image of varying line density of the vertical bars representing the measured signals is presumably caused by the presence of other HAN radio signals incident on the measurement probe/antenna. At least four different levels of apparent signal strengths are seen. The top level of signal, closest to the 0 dB line, is due to the signal from the smart meter that the probe/antenna was closest to with the other lower level signals being related to emissions of the other smart meters within the bank. Only the closest smart meter will lead to the strongest measured signal; the other meters, due to greater distance between the probe/antenna and meter as well as variations in the emission pattern of the smart meter HAN radios, results in lower measured signal levels.

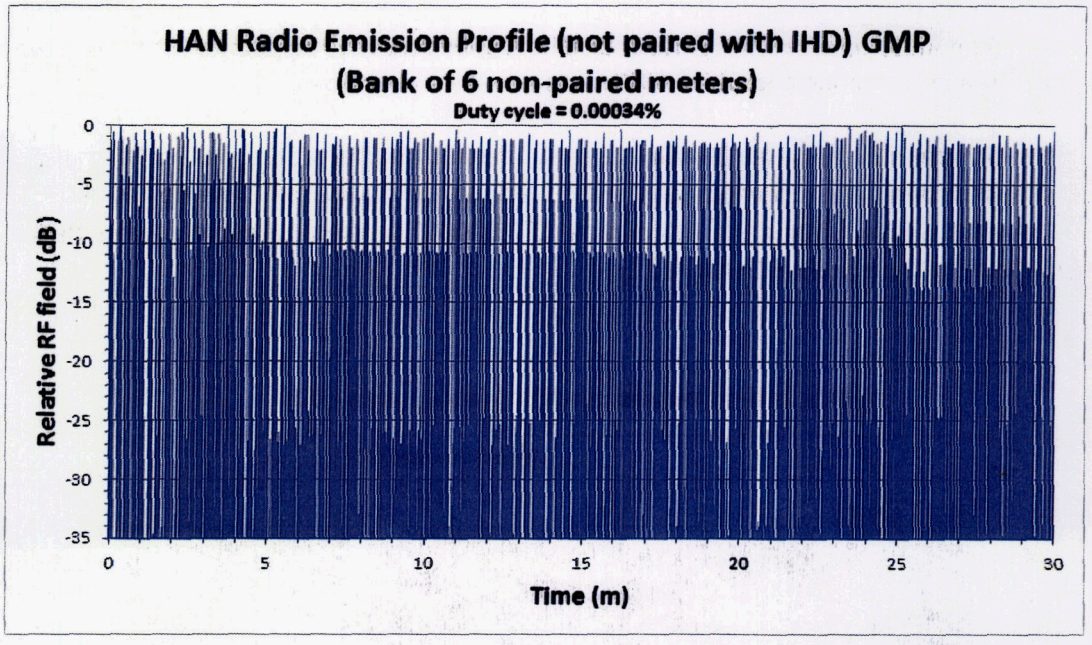

Figure 47. 30-minute time domain pattern of HAN radio emissions from a bank of six meters (GMP site 13) that are not paired with IHDs.

Another 30-minute HAN radio emission profile with the radio paired with an IHD is shown in Figure 48 where the overall duty cycle was found to be 0.00073%.

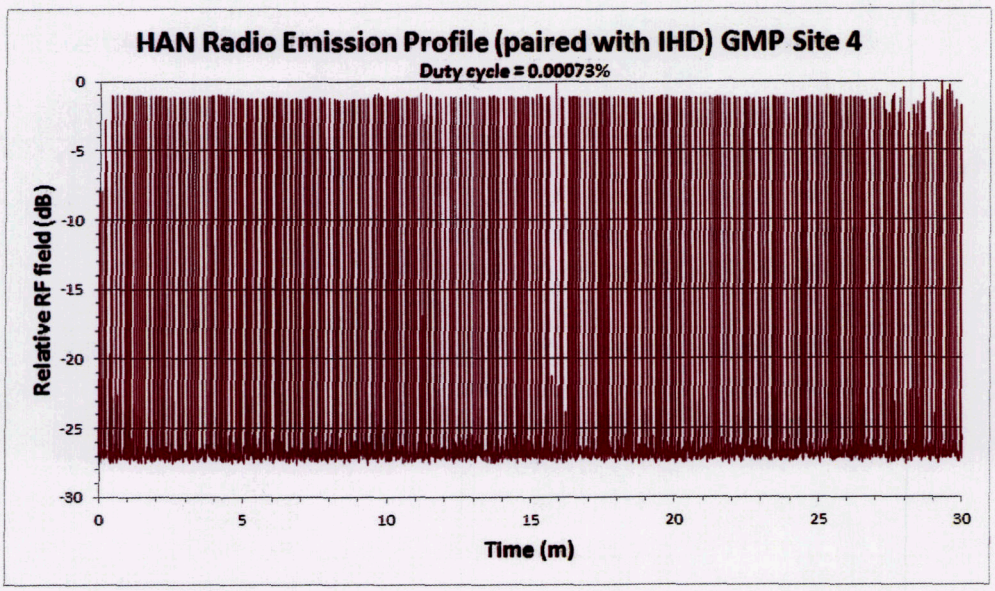

Figure 48. 30-minute HAN radio emission profile at GMP site 4 with radio paired to an IHD.

Table 8 summarizes the duty cycle assessments of the HAN radios obtained under a number of different conditions and at several different sites during this project. These measurements include work done in Vermont at different GMP sites and in Colville. For the measurements in Vermont, the designation Active Meter means that the meter had been activated for use with a specific IHD; an Inactive Meter was not activated for use with an IHD. An additional, third, smart meter was made available for use during the tests in Vermont. During the Colville measurements, two separate GMP smart meters were available designated as SM1 and SM2. SM1 had the HAN radio activated for use with an IHD; SM2 did not.

Table 8. Summary of duty cycle measurements of HAN radios, IHDs and a 2.4 GHz cordless telephone under different conditions and for different measurement durations.

Measurement	Condition	Duration (min)	Duty cycle (%)
1	SM1 on paired with IHD	30	0.087
2	SM1 on with IHD off	30	0.016
3	SM1 and SM2 on, IHD off, observing SM1	30	0.030
4	SM1 and SM2 on, IHD off, observing SM2	30	0.061
5	SM1 and SM2 on, IHD on nearby,	30	0.073

	observing SM2		
6	SM2 on with IHD on, SM1 off	30	0.082
Table 8 continued.			
7	SM1 and SM2 off, IHD on	30	0.106
8	SM2 on and SM1 off, IHD on and close to instrument	30	0.171
9	SM1 on, IHD off	2	0.016
10	Active meter paired with IHD, 2nd active meter paired with separate IHD, 3rd inactive meter on	2	0.062
11	Active meter paired with IHD, second IHD on but not paired with meter, 2nd inactive meter on	2	0.019
12	Active meter paired with IHD, 2nd active meter with IHD off, 3rd inactive meter on	2	0.067
13	2 active meters + 1 inactive meter, all IHDs off	2	0.045
14	2 active meters with paired IHDs both on, 3rd inactive meter on + 2.4 GHz cordless phone on in house	2	0.258
15	2.4 GHz cordless phone	2	1.552
16	Active meter on, non-paired IHD on, 2nd inactive meter on	2	0.024
17	Bank of 6 inactive meters, no IHD	2	0.032
18	Bank of 6 inactive meters, no IHD	30	0.034
19	Inactive meter, no IHD	2	0.003
20	Inactive meter, no IHD	30	0.034
21	Bank of 14 meters, all non-paired, no IHDs	2	0.022
22	Active paired meter with IHD on, measurement near IHD in home	2	0.071
23	Active paired meter with IHD in home, measurement near meter	2	0.087
24	Active paired meter with IHD in home, measurement near meter	30	0.029

Low Frequency Field Measurements

Results

As part of this project, low frequency electric and magnetic fields were measured at one foot in front of the test meters provided by both GMP and BED. The Narda EHP-50D instrument, capable of isotropic measurements (that provide measures of the resultant field magnitude by forming the result of three orthogonal polarization values), was used to acquire background spectra of electric (E) and magnetic (B) fields prior to powering on the smart meters and, subsequently, acquisition of the E and B field spectra upon powering up the meters. Measurements were performed over the frequency spans of nominally 0 to 1 kHz, 0 to 10 kHz and 0 to 100 kHz to provide a broad perspective on any fields within these frequency ranges. Associated with the spectral measurements of field vs. frequency, a value of the wideband RMS value of the field is also provided.[15] Table 9 lists the wideband values of electric field strength and magnetic flux density for each of the three frequency ranges mentioned and for both the GMP Elster meter and the BED Itron meter. No electrical loads were placed on either meter during the measurements that would introduce potentially strong 60 Hz magnetic field components simply due to the current flow through the meter.

Table 9. Summary of low frequency measurement values of wideband (RMS) electric field strength (V/m) and magnetic field flux density (μT) at 1 foot in front of meter.

		Electric field (V/m)		Magnetic flux density (μT)	
	Frequency	Background	Smart Meter	Background	Smart Meter
GMP	0-1 kHz	0.4682	35.126	0.0235	0.0909
GMP	0-10 kHz	0.1775	12.105	0.0107	0.045
GMP	0-100 kHz	0.1866	0.2091	0.019	0.0196
BED	0-1 kHz	0.4682	35.808	0.0235	0.5708
BED	0-10 kHz	0.1775	12.375	0.0107	0.2987
BED	0-100 kHz	0.1866	0.2227	0.019	0.0296

Spectrum analysis results showing the distribution of frequency components across the 0 to 1 kHz, 0 to 10 kHz and 0 to 100 kHz spans are shown in Figures 49, 50 and 51 for electric fields and in Figures 52, 53 and 54 for magnetic fields.

[15] Wideband values of electric and magnetic fields do not include the first 1.2% of any components in the frequency spectrum. This is to eliminate the local oscillator zero feed through associated with any spectrum analyzer at zero frequency.

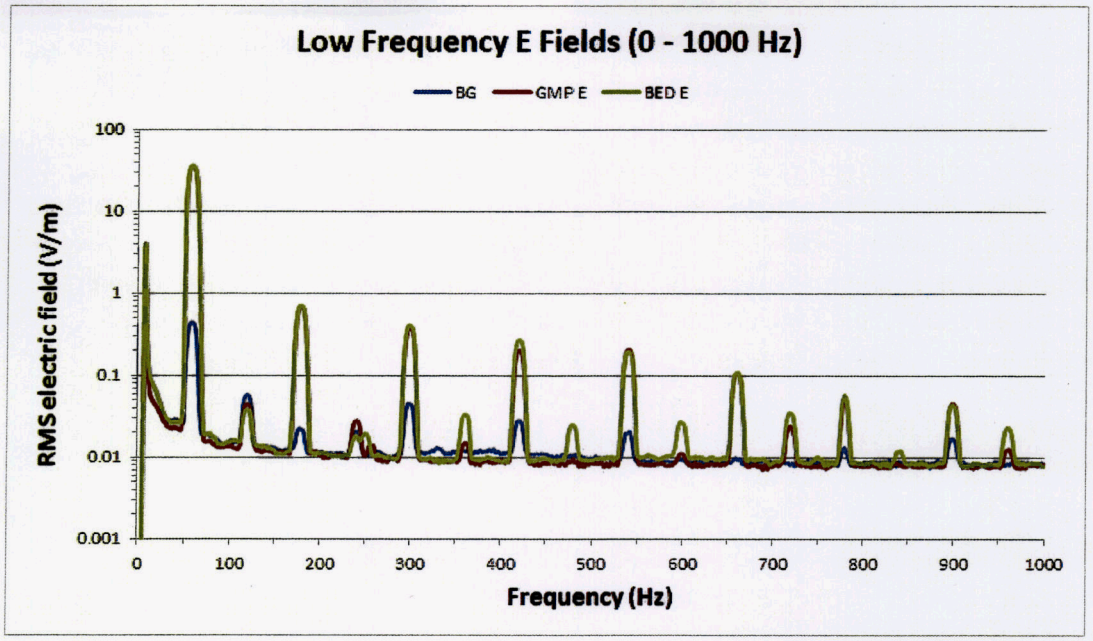

Figure 49. Low frequency electric (E) fields measured in the range of 0 to 1,000 Hz (1 kHz) for the GMP Elster meter, the BED Itron meter and background.

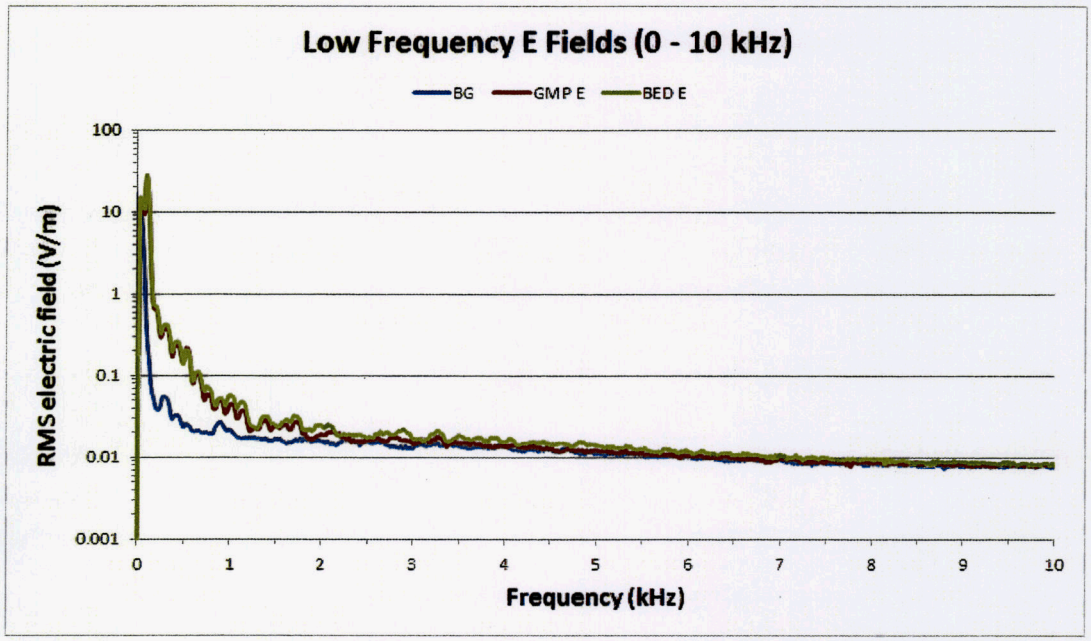

Figure 50. Low frequency electric (E) fields measured in the range of 0 to 10 kHz for the GMP Elster meter, the BED Itron meter and background.

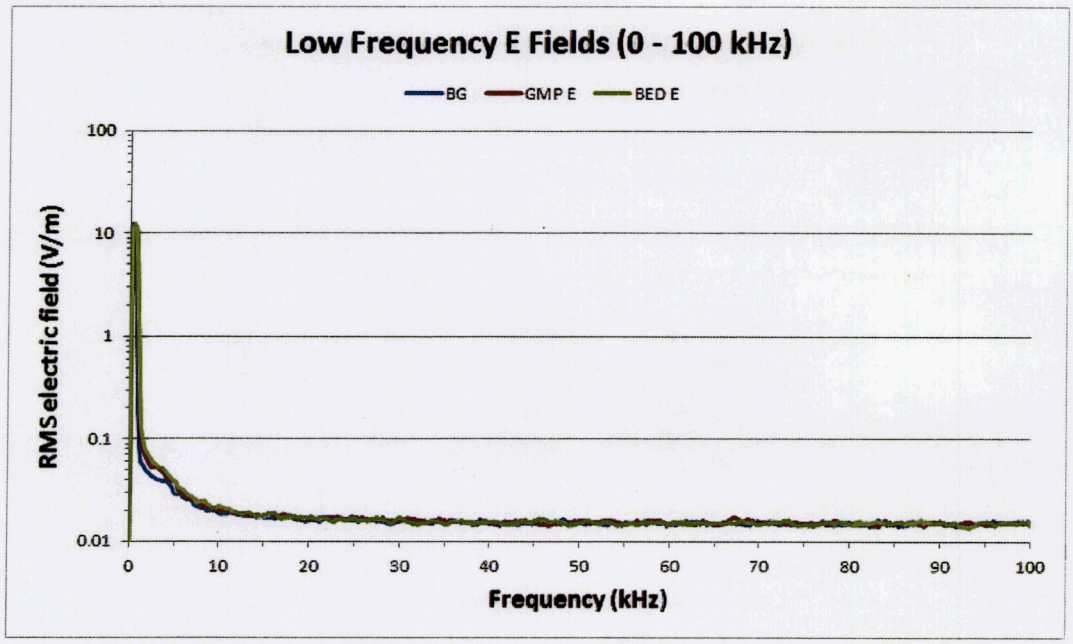

Figure 51. Low frequency electric (E) fields measured in the range of 0 to 100 kHz for the GMP Elster meter, the BED Itron meter and background.

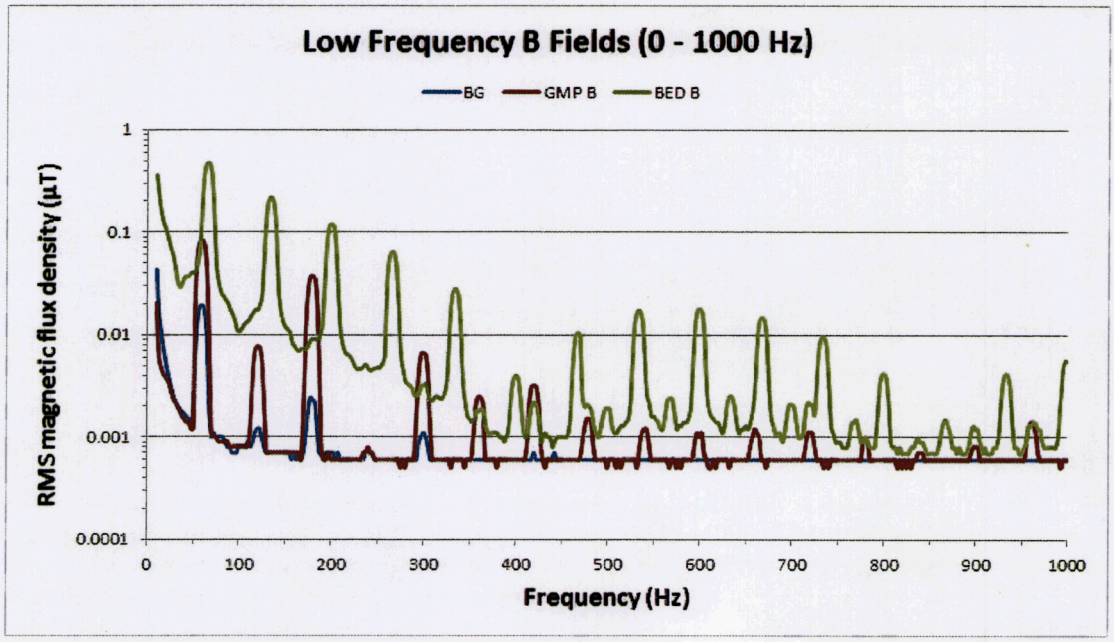

Figure 52. Low frequency magnetic flux density (B) measured in the range of 0 to 1,000 Hz (1 kHz) for the GMP Elster meter, the BED Itron meter and background.

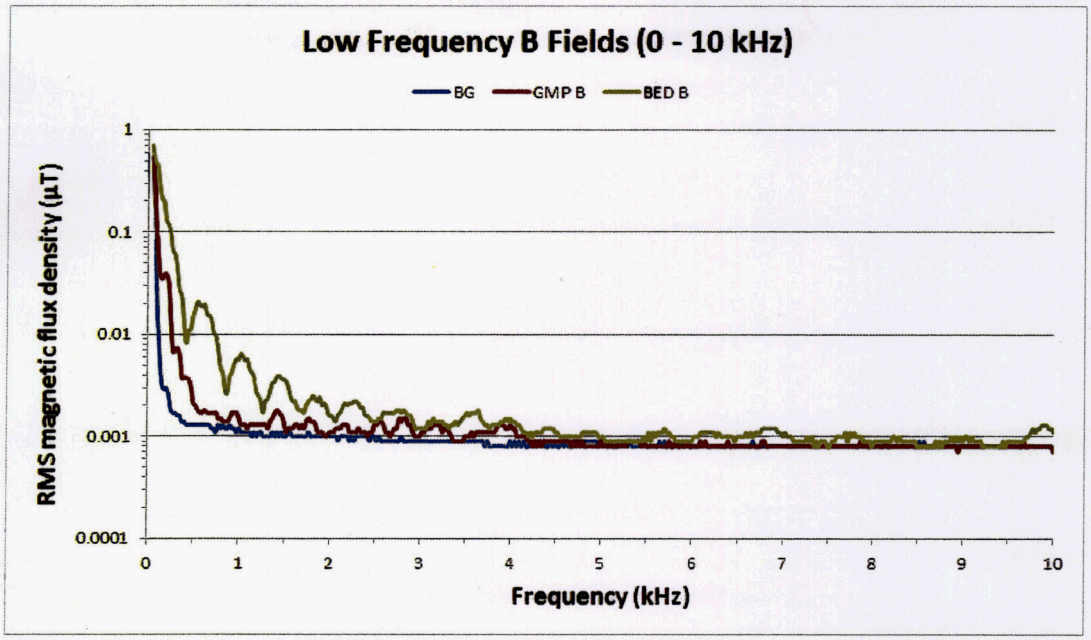

Figure 53. Low frequency magnetic flux density (B) measured in the range of 0 to 10 kHz for the GMP Elster meter, the BED Itron meter and background.

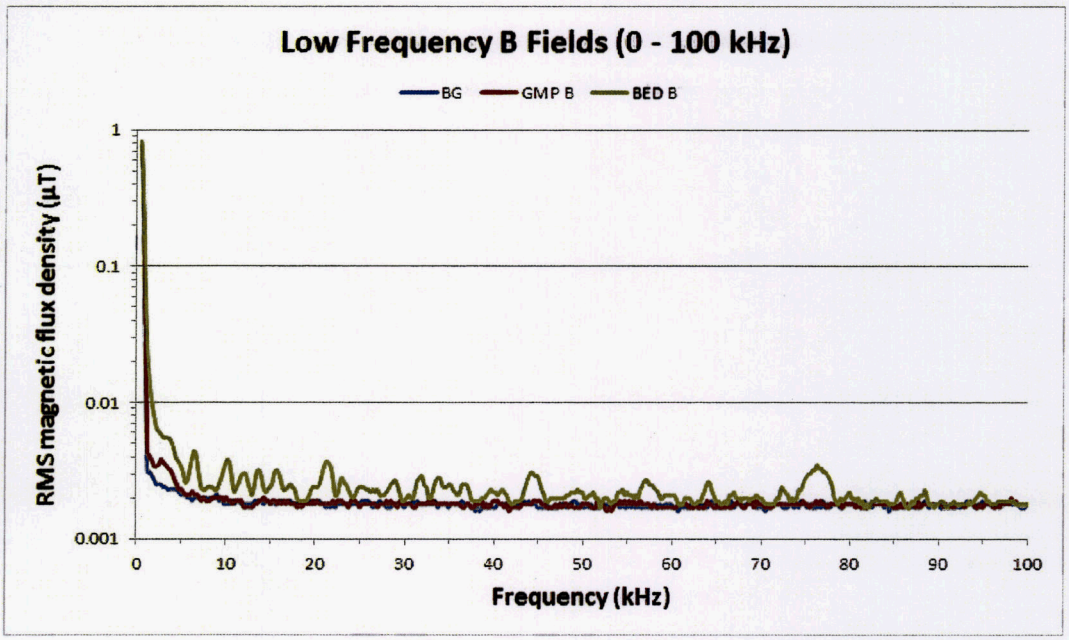

Figure 54. Low frequency magnetic flux density (B) measured in the range of 0 to 100 kHz for the GMP Elster meter, the BED Itron meter and background.

Measurements of Other Sources

While smart meter RF emissions were the principal focus of this study, during the field work in Vermont, measurements of RF fields associated with a number of other types of RF sources were also conducted. Mostly, these measurements were opportunistic in nature when the opportunity presented itself. In some cases, these measurements took place during the measurement of interior smart meter RF fields in homes included in the study. In others, referred to as "environmental" measurements, the measurements were performed outdoors in different parts of the state ranging from Rutland in the South, Montpelier in the East, Saint Albans in the North and Burlington to the West. A total of 14 environmental sites were included at which measurements of radio and television (TV) broadcast signals and wireless base station signals were performed as well as a few instances of investigation of unique signal characteristics. These data help provide a foundation for interpreting the relative magnitude of potential public exposure to RF fields produced by smart meter emissions.

Multiple HAN Radio Emissions

When measuring in the 2.4 GHz license free band, signal activity from a number of different kinds of devices can often be observed. This is illustrated by Figure 55 which shows a measured spectrum at GMP site 3. The measurement was performed inside the building on which the meter bank was mounted, inside a closet located directly behind the meter bank. In this case, the emissions of four HAN radios are clearly seen as well as a wireless router (see labels in figure). Given more time, other HAN radio emissions would be expected to be seen but it is important to note that the display of RF fields is the result of a "maximum hold" mode of the measuring instrument in which the greatest measured RF field at any given instant in time and on any given frequency is retained and displayed. This means that while there may be numerous peaks shown in a spectrum, each associated with a particular HAN radio transmission, they may have not occurred simultaneously nor operate continuously.

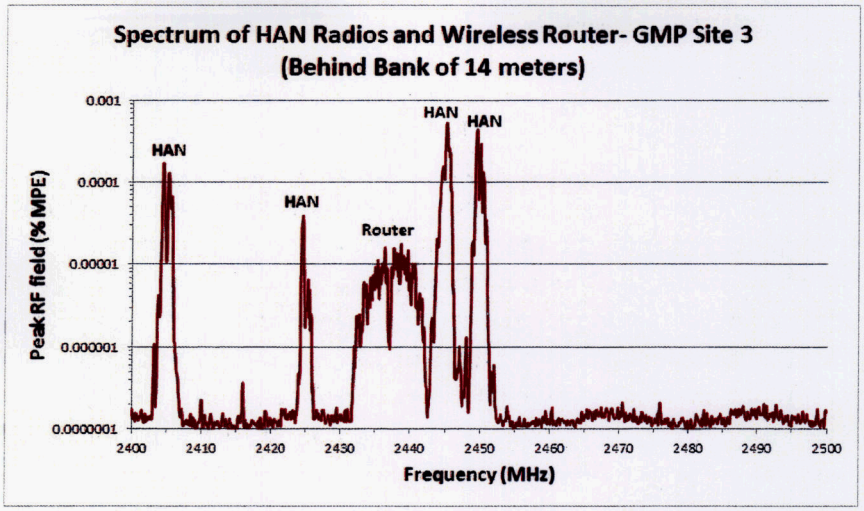

Figure 55. A measured spectrum of RF fields at GMP site 3, behind a bank of 14 smart meters, showing the presence of four HAN radio emissions and a wireless router.

2.4 GHz Cordless Phone

At one of the measurement locations, measurements were made of the RF spectrum produced by a 2.4 GHz cordless telephone (not a cell phone). The phone handset was removed from its base station cradle and turned on as if to make a call while the measurement probe/antenna was placed at one foot from the handset. A broadband display of RF fields resulted from 2400 MHz to approximately 2483 MHz that appeared to be relatively continuous in nature. Figure 56 illustrates this measurement.

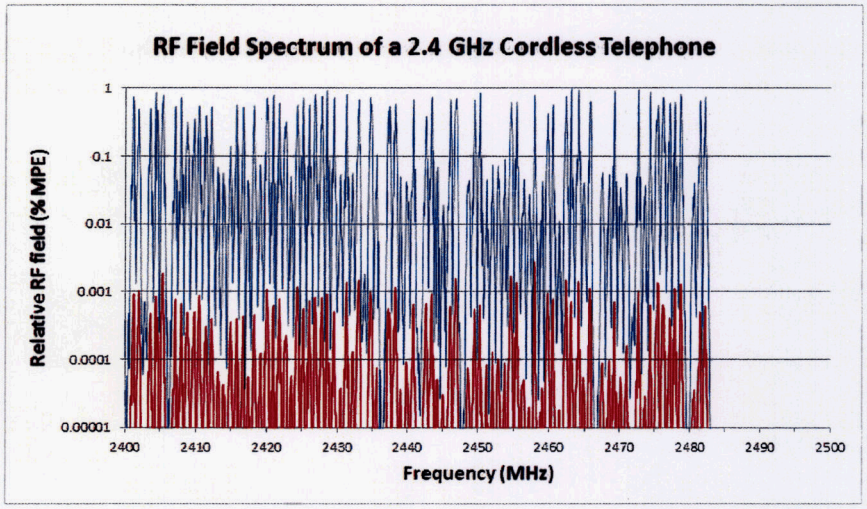

Figure 56. The relative RF field spectrum (blue is peak, red is average) of a 2.4 GHz cordless telephone at one foot from the hand set after it was turned on. RF emissions occur across a large portion of the 2.4 GHz license free band.

Results

Following the spectrum measurement shown in Figure 56, a time domain measurement was made of the cordless phone signal over a two minute period. This measurement resulted in a two-minute duty cycle of 1.6% as shown in Figure 57.

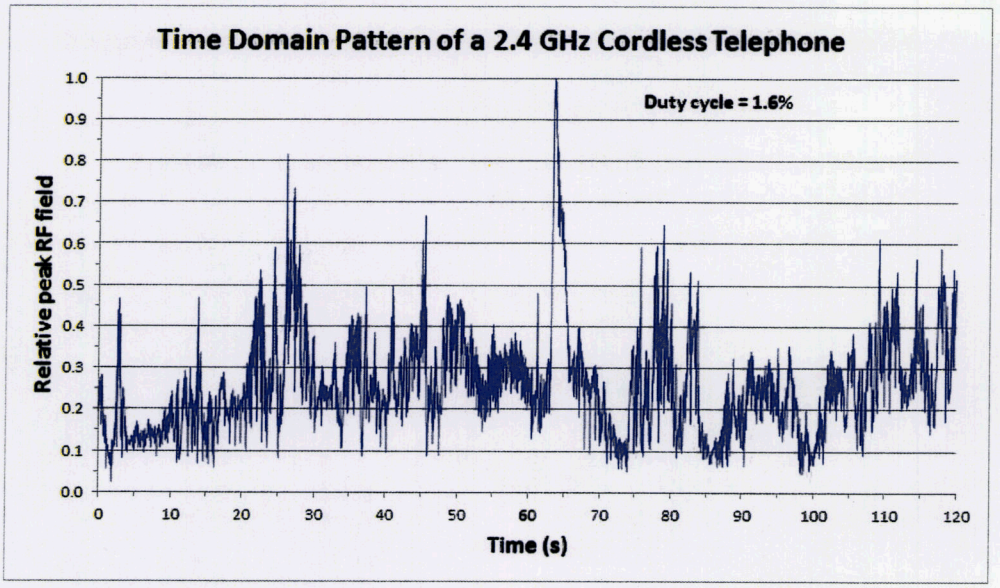

Figure 57. A measured time domain profile of the 2.4 GHz cordless telephone over a two minute (120 second) period. The duty cycle of this two minute capture of signal was 1.6%.

FAA Long Range Air Traffic Control Radar

While in the Saint Albans vicinity, the RF fields associated with an FAA long range air traffic control radar were monitored. While the instantaneous peak RF fields were relatively weak, the measurement illustrates another source in the environment that can result in long term exposure to pulsed fields. The radar site near Saint Albans was taken over full time by the FAA from the Air Force in approximately 1979. Since that time, it has been modified and includes what is now referred to by the FAA as a Common Air Route Surveillance Radar (CARSR). Such radars commonly use an antenna rotation rate, for scanning the skies, of five revolutions per minute (RPM), peak transmitter powers of over a megawatt (1,000,000 watts) and pulse repetition rates of, typically several hundred pulses per second.

Figure 58 shows the results of a one minute time domain profile of the detected signal (at 1,269.5 MHz) from the radar which was located approximately 1.5 miles southeast of the measurement site (environmental site 7). The illumination of the measurement probe/antenna of the SRM-3006 on each revolution of the radar antenna is evident with the maximum peak signals (fields) spaced in time by exactly 12 seconds (equivalent to five RPM). The arrival of main beam emissions of the radar antenna are indicated by the small blue arrows above the peaks. Each time the radar antenna

rotates the signal level significantly increases and repeats its pattern. Other peaks in Figure 58 represent side lobes of the radar antenna. Their relative amplitude, compared with that of the main beam, are also influenced by the terrain between the radar and the measurement location which introduces reflections of the radar signal and alters what would be expected purely on the basis of the antenna transmitting pattern in free space.

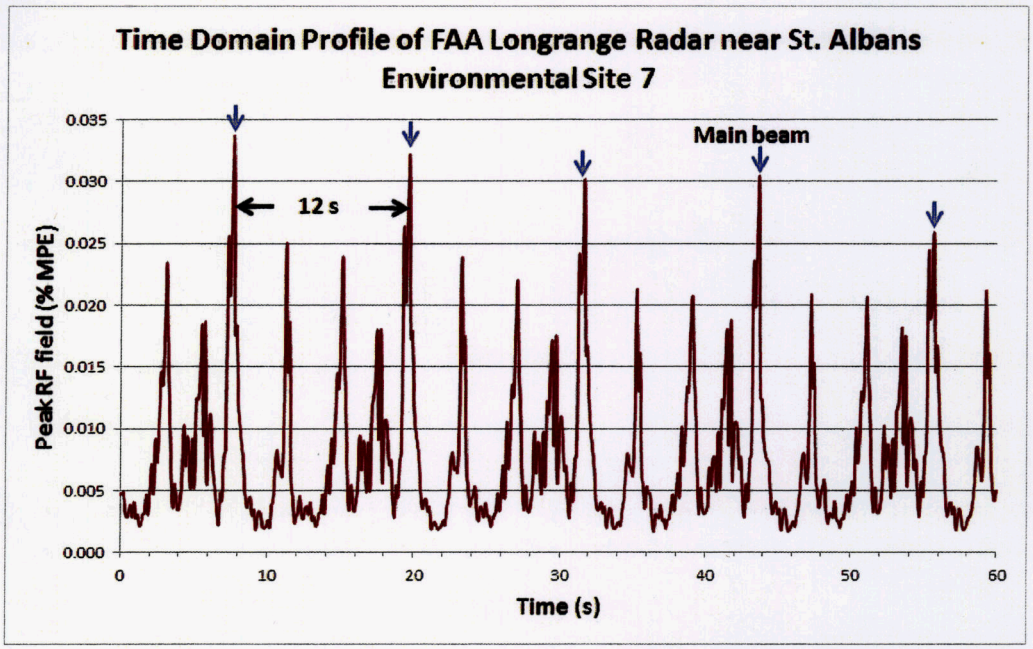

Figure 58. Time domain profile of an FAA long range radar located on a hill east of Saint Albans, VT at environmental site 7. The 5 RPM rotation rate of the antenna is apparent with the major peaks spaced exactly 12 seconds apart. The smaller peaks are side lobes of the antenna and the result of reflections within the environment of the measurement.

Microwave Ovens

Generally, the strongest source of RF fields within a home is a microwave oven. Most microwave ovens operate with powers ranging from about 750 watts to 1200 watts at 2.45 GHz. Despite careful design which reduces any leakage from microwave ovens to very low levels, some microwave energy is always present near ovens while they operate. RF field measurements were performed at distances from one foot to five feet in front of two microwave ovens during the course of this project, one at GMP site 4 and the other at BED site 2. The results of these measurements are plotted in Figure 59 in terms of the average RF field. A cup of water was place in each oven during while it operated and the field measurements were taken. The differences in measured values of RF fields for the two ovens can be related to the possible different operating power levels of the ovens, their physical condition at the time of measurements (which can

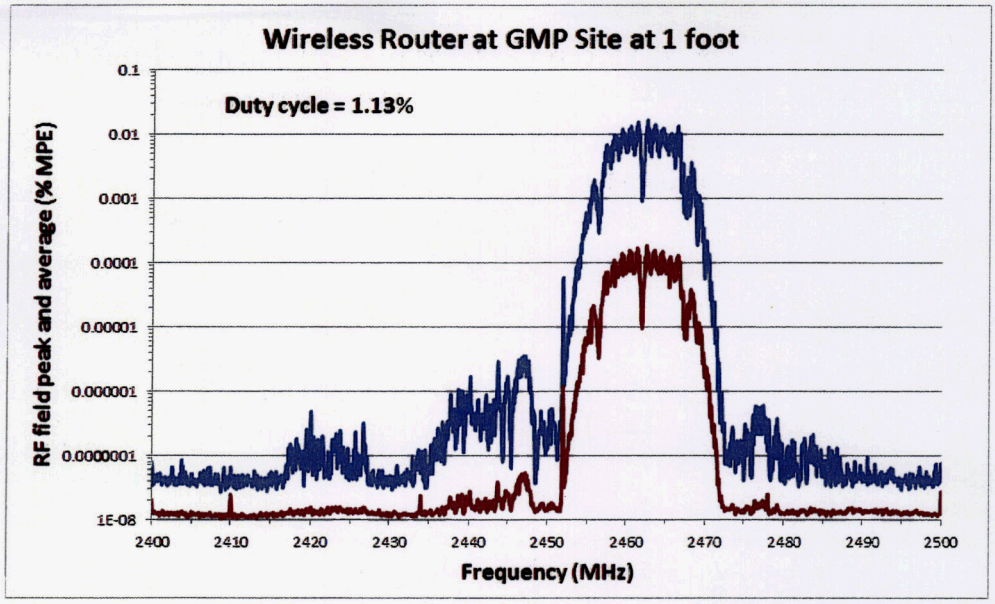

Figure 60. Unique spectral characteristic of 2.4 GHz wireless router at GMP site 5. Based on an integration of the peak (blue) and average (red) RF fields, the apparent duty cycle of the router was determined to be 1.13%.

The continuous peak RF field as a function of distance from six different routers measured during the study is shown in Figure 61. The RF fields are seen to vary widely and this is undoubtedly due to the highly variable nature of the local environments of the routers. In some cases, the routers were in the clear while in other cases they were buried behind monitors, books or other items. Also, the measurements were made with the router in its normal orientation at the site; this may have not been optimum in terms of the antenna for producing the maximum field at the location of the measurement probe/antenna for any particular router. In most cases, accessing the near vicinity of the router was difficult. Since the router is a source of intermittent RF emissions while it is powered on, the intermittent peak RF fields reported are constantly present.

Additional measurements of router duty cycles were performed in Colville. A LinkSys model WRT-54G router was configured for operation on WiFi channel 1, centered at 2412 MHz, and used to wirelessly transfer large amounts of data in different formats to a distant laptop computer. With the router in idle mode, the observed duty cycle was approximately 0.53%, this being roughly comparable with the router simply transmitting its narrow and periodic beacon signals (for network management) at a 10 Hz rate. When transferring binary data, the duty cycle rose to 2.4%. The greatest duty cycles were observed when transferring video files in either .avi or .mov formats when a maximum value of 6.5% could be measured. The issue of duty cycles of routers used

with Wi-Fi technology as it is related to the transmission of data has been addressed previously [11].

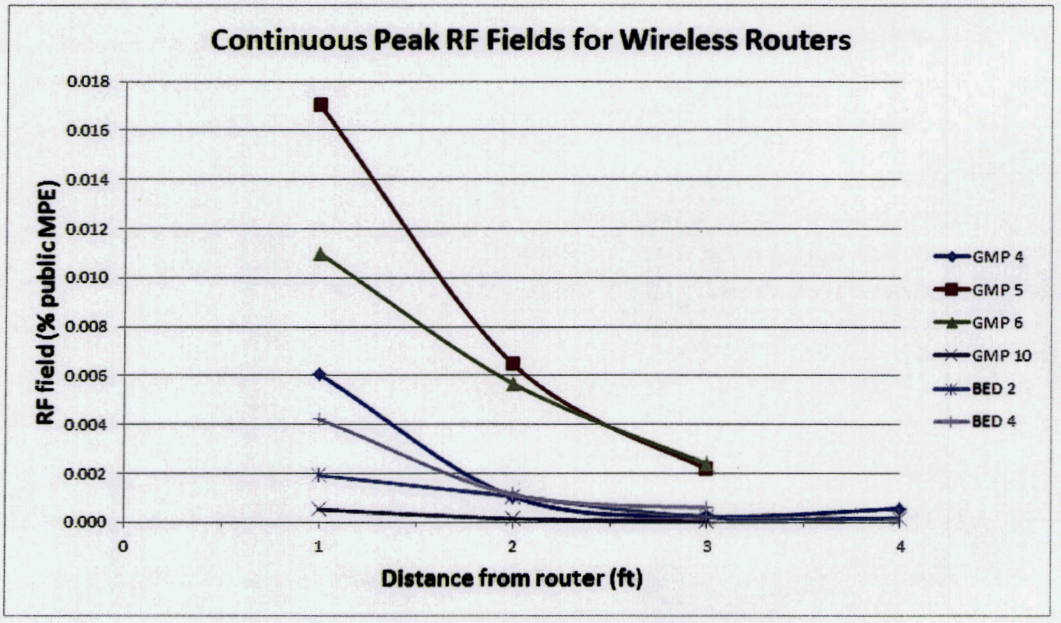

Figure 61. Spatial variation of peak RF fields continuously emitted by six wireless routers measured during this project.

Cell Phones

During the work in Colville, measurements were made of RF fields produced by a mobile phone (Samsung model Blackjack II). Although mobile phones are evaluated for RF exposure on the basis of specific absorption rate (SAR), these measurements were performed to provide perspective on potential exposure to cell phones and smart meters. The measurements consisted of supporting the mobile phone on a dielectric stand at a height of five feet above a concrete floor. The phone was placed into a continuous call during the measurements and the SRM-3006 was used to measure the field starting at floor level and in one foot intervals up to six feet above the floor. At each measurement point, the phone was rotated in three axes while the instrument was in maximum hold mode. This allowed the instrument to record the greatest RF field that might be associated with any particular orientation of the phone and its internal antenna. The phone operated at approximately 840 MHz during the measurements though it was a dual band phone and could operate in the 1.9 GHz band as well.

Figure 62 illustrates the measured peak values of RF field produced by the cell phone at the seven different heights. The greatest field is correlated with the fixed height of the phone. Similar to a smart meter, the spatially averaged value of RF field is substantially less than the spatial peak value near the mounting height of the phone.

The ratio of the spatially averaged field to the spatial peak field is 0.308; i.e., the spatially averaged field is 30.8% of the spatial peak value, similar to the finding for a smart meter. Relative to the MPE, the spatially averaged RF field, derived from instantaneous peak values of field, corresponded to 3.28% of the MPE.

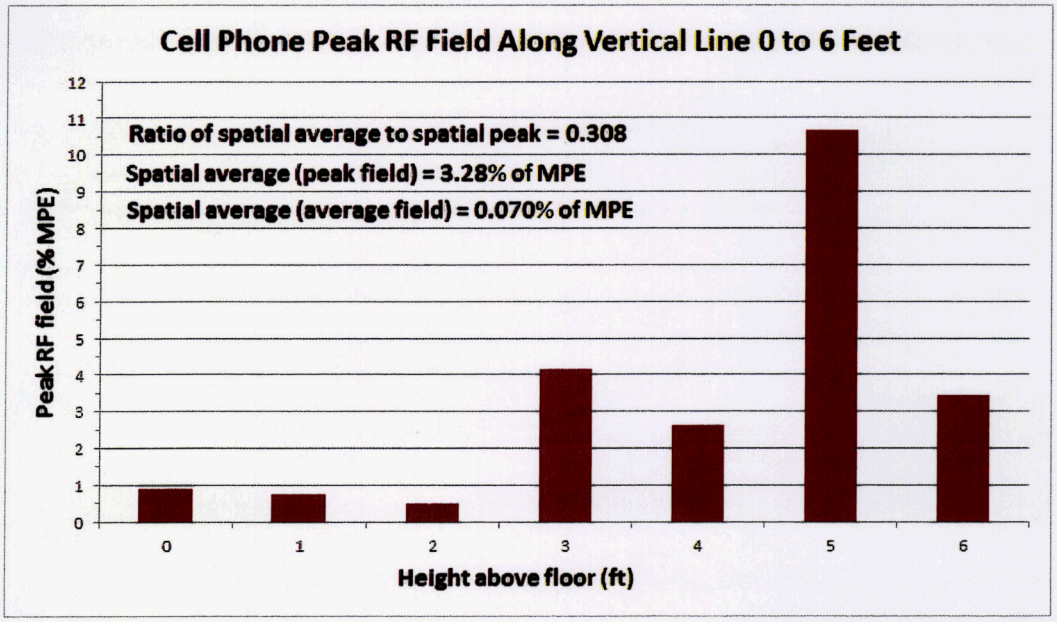

Figure 62. Peak RF fields along a six foot vertical line spaced laterally one foot from an active 840 MHz cell phone fixed at five feet above a concrete floor. The spatially averaged field in terms of time-averaged RF fields (0.070% of MPE) is obtained by multiplying the peak value by the duty cycle (see text below).

To calibrate this peak value of field to an average value, a measurement was made of the duty cycle of a one minute transmission (phone call during which the phone was modulated by a moderate level of speech) by observing the time domain profile of the phone's emission and simultaneously recording the peak and average values of field.[16] Figure 63 illustrates this measured time domain pattern of fields from the phone. It is noted that there are abrupt changes in the signal level (RF field) at different times during the test call suggesting that the phone is dynamically changing its power in response to the mobile phone base station to which it is connected at the time. The observed duty cycle of the phone during this transmission was 2.13% meaning that the average RF field, as a percent of MPE, is nominally 2% of the instantaneous peak field. Using this value of duty cycle, the spatial average of fields shown in Figure 62 (above), when converted to a time-averaged value of field (relative to the MPE) is 0.070% of the MPE.

[16] Note that with a continuously present RF field, this is straightforward with the SRM-3006. However, for intermittent emissions, such as smart meters, this is more difficult to do via a single measurement.

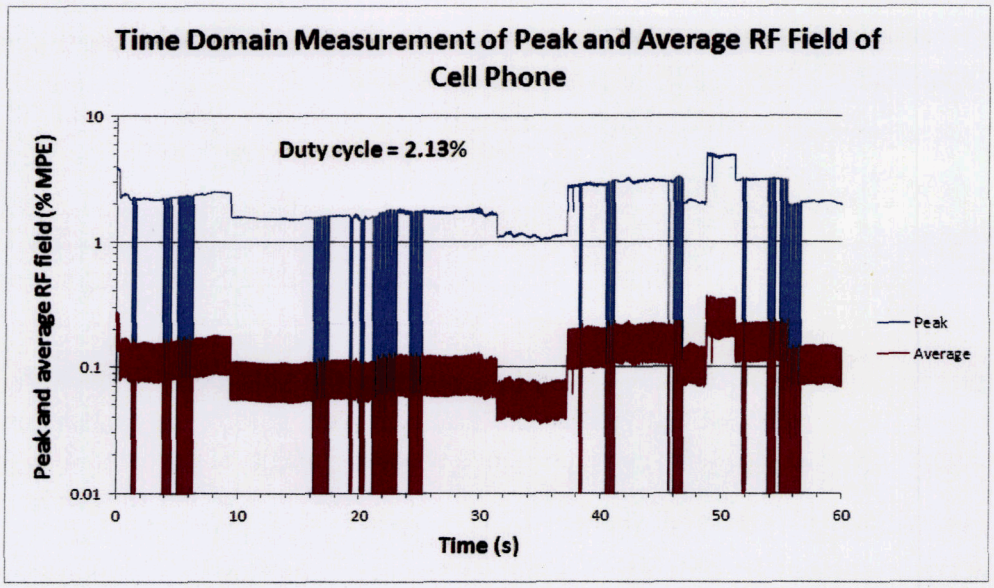

Figure 63. A measurement of the duty cycle of a cell phone across a 60 second phone call during which the phone was modulated with a moderate level of speech. The measured duty cycle was 2.13%.

Broadcast Signals

Broadcast stations provide essentially continuous RF fields of low magnitude that are widespread throughout the environment. The SRM-3006 instrumentation allowed for relatively convenient measurement of both broadcast signals, consisting of signals in the low and high very high frequency (VHF) television (TV) bands, the FM radio broadcast band, and the ultrahigh frequency (UHF) TV band, and the signals produced by wireless communications base stations used for mobile phones. Measurements of these frequency bands were made at 11 of the 14 general environmental sites for this study. Table 10 lists each band measured, the frequency range of the band and the resolution bandwidth (RBW) of the SRM-3006 used for the measurement[17].

[17] Resolution bandwidth is a measure of the ability of the instrument to distinguish signals that are close in frequency. It is similar to the selectivity of a radio receiver.

Results

Table 10. List of frequency bands measured at environmental sites in Vermont, their frequency ranges and the resolution bandwidth (RBW) of the SRM-3006 instrument used during the band measurement.		
Band	Frequency range (MHz)	RBW of SRM-3006 (kHz)
Low VHF TV	54 to 88	100
FM radio	88 to 108	30
High VHF TV	176 to 216	100
UHF TV	470 to 700	500
Cell	700 to 2500	1000

The measurement process consisted of supporting the SRM-3006 probe/antenna above the roof of a vehicle with the use of a 24 inch piece of PVC pipe and a cable allowing connection to the SRM basic unit. Representative spectra of detected average RF fields for the different bands from several different locations within the state are shown in Figures 64, 65, 66, 67, and 68 for the low VHF TV, high VHF TV, FM radio, UHF TV and what will be designated in this report as the cell band (for cellular telephone base stations) respectively.

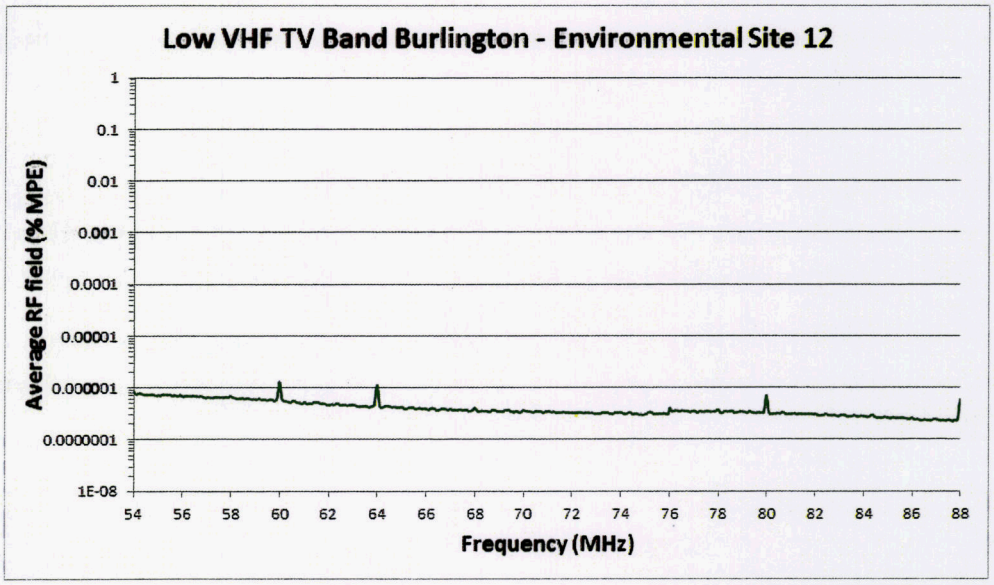

Figure 64. Spectrum measurement of average RF field (% MPE) across the low VHF TV broadcast band at environmental site 12 in Burlington.

Results

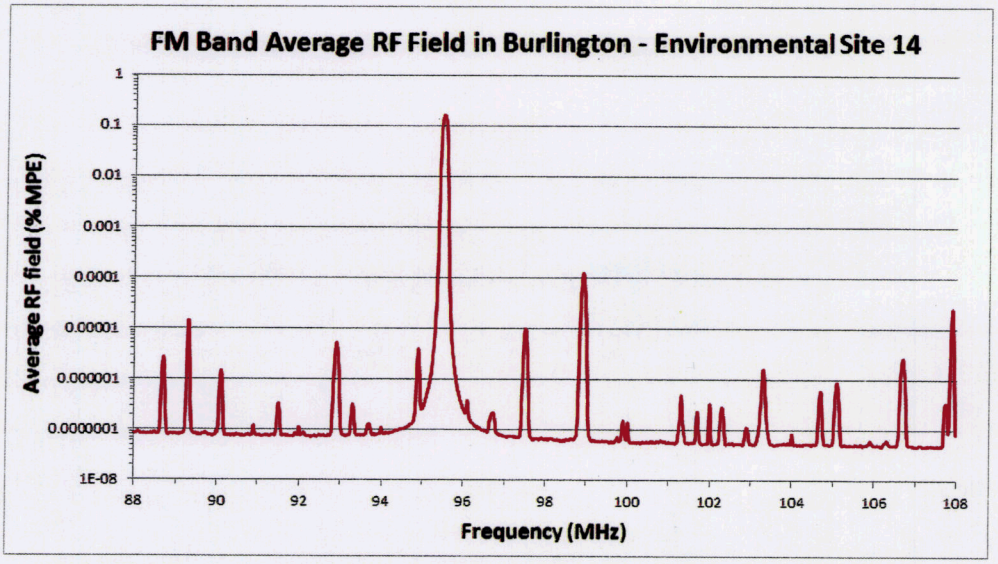

Figure 65. Spectrum measurement of average RF field (% MPE) across the FM radio broadcast band at environmental site 14 in Burlington.

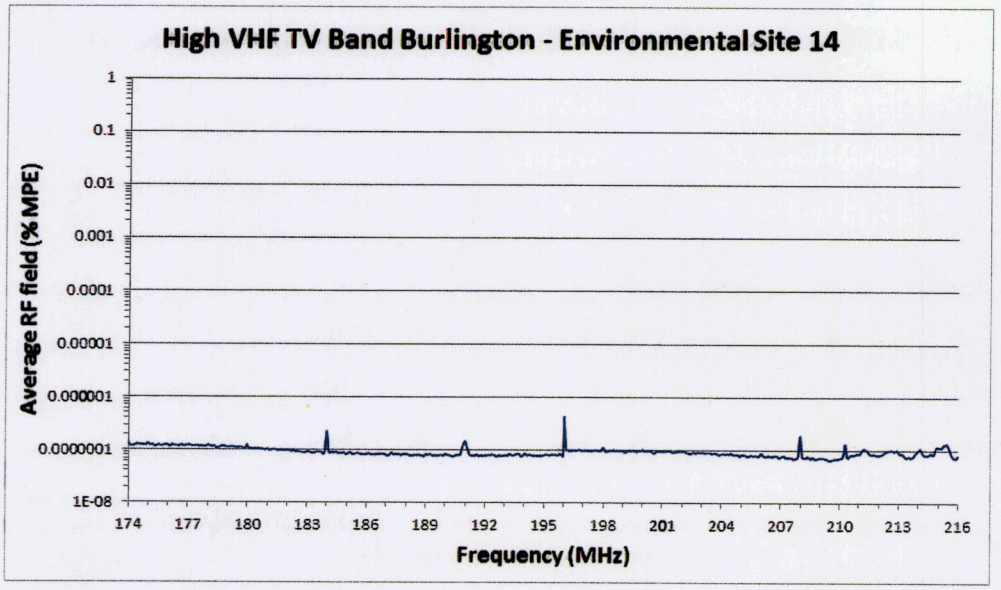

Figure 66. Spectrum measurement of average RF field (% MPE) across the high VHF TV broadcast band at environmental site 14 in Burlington.

The general lack of broadcast signals in the low and high VHF TV broadcast bands is the current result of the transitioning from analog to digital (high definition) TV wherein virtually all VHF TV stations were provided UHF TV spectrum for establishing a digital presence. This has resulted in these two bands becoming relatively vacated.

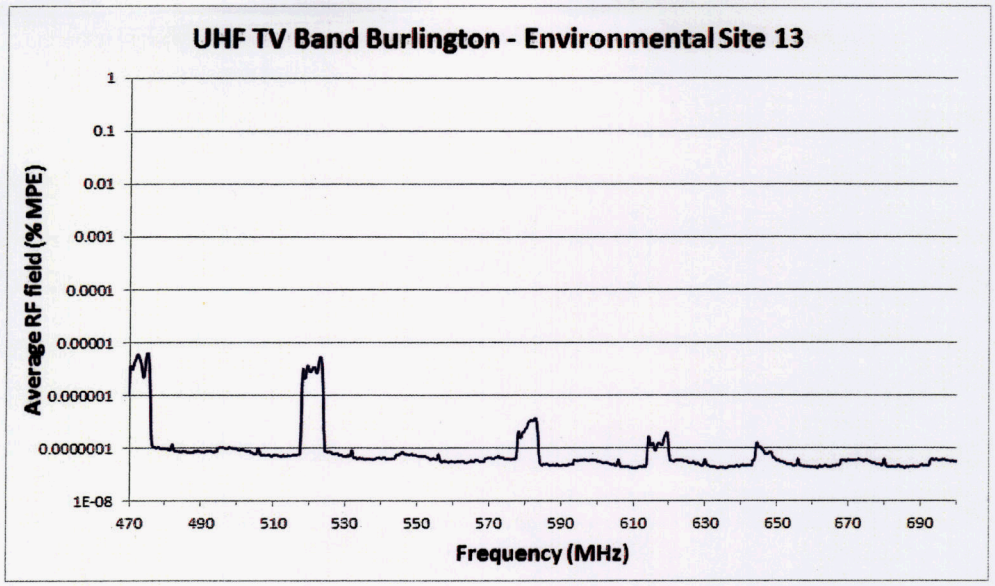

Figure 67. Spectrum measurement of average RF field (% MPE) across the UHF TV broadcast band at environmental site 13 in Burlington.

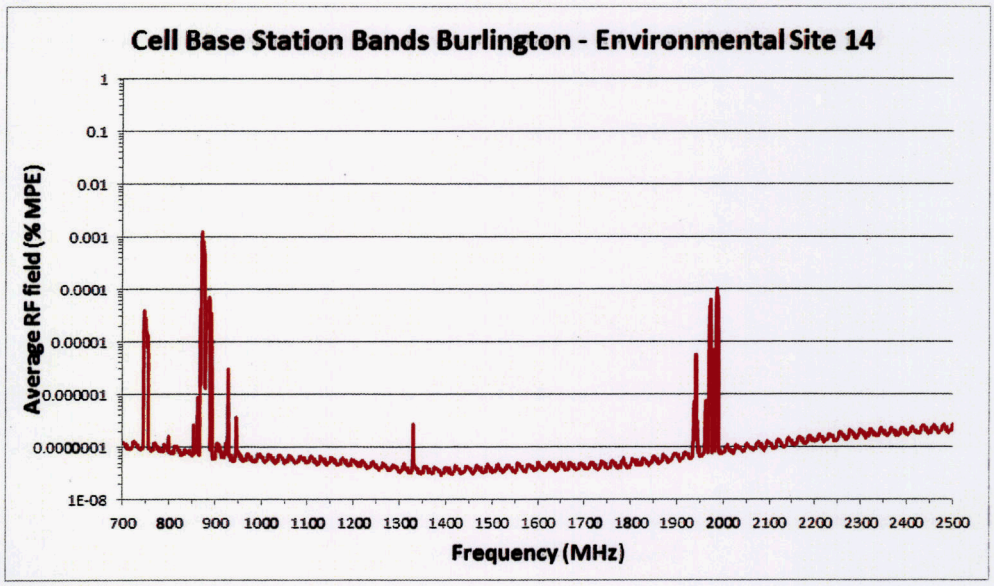

Figure 68. Spectrum measurement of average RF field (% MPE) across the wireless communication (cellular telephone) base station bands at environmental site 14 in Burlington.

For each spectrum measured, the data were retained and subsequently post processed to obtain the aggregate value of RF field from all signals detected within each band. This process consists of integrating the amplitude data obtained from the analyzer using a method specified by Narda. By independently integrating the spectra, using a computer based software tool developed for this purpose, a threshold could be

specified for each band measurement such that only the amplitudes of legitimate signals were included in the integration. In this fashion, there was no impact caused by integration of the noise level of the instrument which can drive integrated results to erroneously high values. The specifics of the integration process are provided in Appendix F.

After integration of each measured spectrum of signals, the overall effective value of RF fields in that band were assessed as a percentage of the FCC MPE and tabulated in Table 11. These results are graphically illustrated in Figure 69. Generally, signals measured in the FM radio broadcast band were strongest and resulted in the greatest integrated values of RF field. In some instances, the fields in the cell (wireless) band were greater. This is consistent with a dated but only nationwide study of broadcast RF fields in metropolitan areas of the US [12].

Table 11. Summary of environmental RF field measurements (non-smart meter) in Vermont. Average RF fields are expressed in terms of a percentage of the MPE for public exposure and were obtained through an integration process described in the text to obtain a composite RF field value that also accounted for the noise floor of the instrument.

	Lo VHF	FM	Hi VHF	UHF	Cell
1	4.99E-06	0.003315	1.71E-05	0.000119	0.000237
2	1.36E-05	9.09E-05	3.69E-05	4.49E-06	0.009462
3	2.53E-05	0.000252	1.5E-05	8.14E-06	0.000171
4	3.22E-05	8.21E-05	5.33E-06	8.4E-06	0.000122
5	7.98E-06	1.58E-05	2.95E-07	2.76E-06	0.001135
6	1.92E-05	7.99E-05	2.57E-07	9.84E-06	4.89E-05
10	3.23E-05	0.006532	3.41E-07	9.43E-06	0.00393
11	3.14E-05	0.00925	6.09E-07	3.14E-05	2.55E-05
12	3.81E-05	0.000657	3.36E-07	5.52E-05	4.97E-05
13	3.66E-05	0.003438	3.24E-07	9.56E-05	0.001101
14	2.93E-05	0.616876	3.27E-07	8.71E-05	0.004996

These data support the conclusion that the total composite field of all of these bands range from 0.00016% to 0.62% of the MPE, depending on the site.

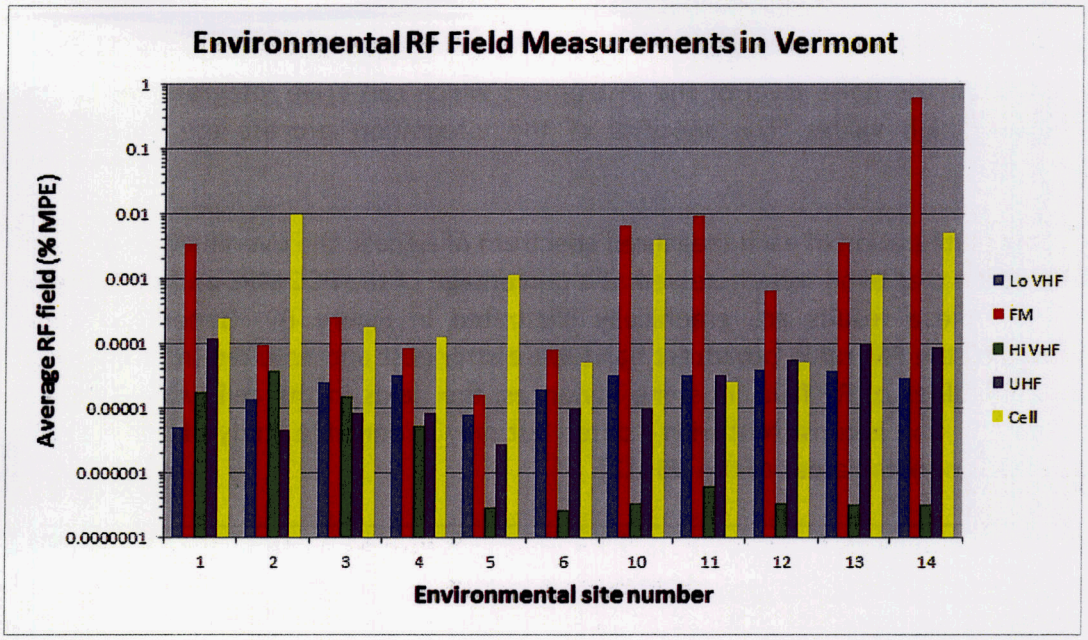

Figure 69. Graphical display of the integrated RF fields across five different frequency bands allocated to broadcast TV and FM radio as well as mobile phone base stations (wireless or cell band).

Water Meter Signals

In the GMP service territory measurements, at some sites, RF signals were observed that were not associated with the smart meters. This was evident since the Elster smart meters only operated in the lower half of the license free 900 MHz band. When extraneous signals appeared, it was very evident. Upon investigation, these signals that occur above 915 MHz but within the 900 MHz band were identified as being emitted by a small box, sometimes located on the home in the same area as the smart meters. This box was found to be related to a wireless remote water meter reading system present on some homes[18]. Figure 70 shows a measurement result in Rutland where the RF signals above 915 MHz are seen. Because the output power of the water meter transmitter is lower than that of the Elster RF LAN radio, it is unlikely that the strength of the water meter generated signals that could exist, from time to time, below 915 MHz would exceed that of the smart meters measured.

[18] Neptune Technology Group, frequency hopping spread spectrum transmitter used for remote water meter reading that operates on 50 hopping frequencies between 910 MHz and 920 MHz with 22 dBm (158 mW) of power and transmits once approximately every 14 seconds.

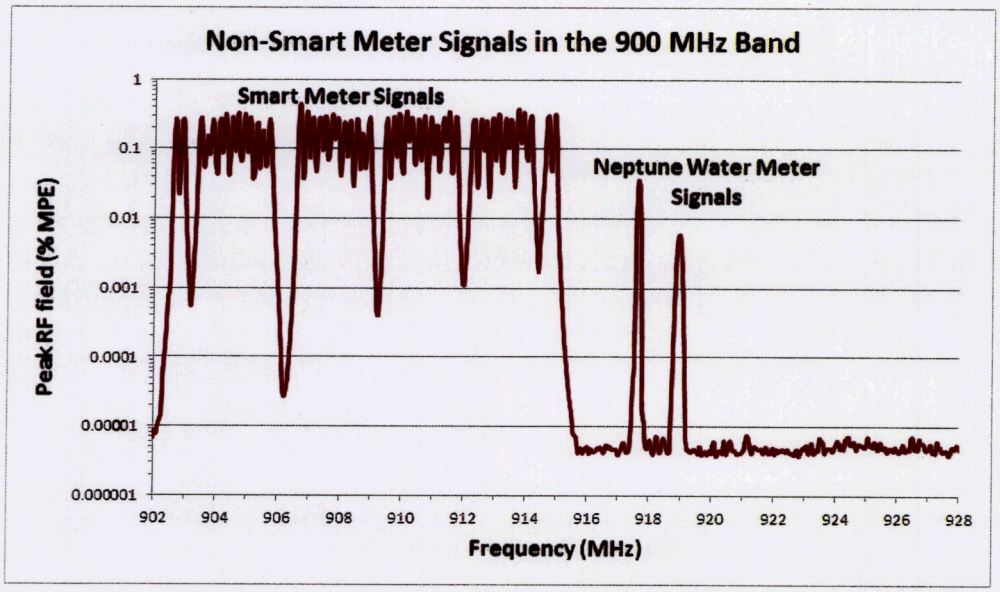

Figure 70. Spectrum measurement result at GMP site 4 where RF fields above the frequency range in which the Elster meter operates are apparent. The signals are intermittent and appear approximately once every 14 seconds.

Discussion

This study is, generally, about low power radio transmitters and how they relate to potential exposure of individuals. An extensive set of measurements of two different types of smart meters being deployed within Vermont determined that the RF emissions produced by them are, in fact, low in value when compared to the applicable limits on human exposure promulgated by the FCC. The field characterization process consisted of measurement of the instantaneous peak value of RF fields during the emitted brief pulses from the meters and a direct determination of the meter duty cycles. Hence, both the peak values of RF fields as well as their time-averaged values, needed for direct comparison to the FCC MPE values, were determined. The frequency hopping, spread spectrum radios in the GMP and BED smart meters operate with very small duty cycles which means that time averaged values of RF fields to which someone may be exposed will be even lower than the measured peak values by typically two orders of magnitude.

The duty cycle may be thought of as a factor that is used to adjust the peak measured value of field to a time averaged value; it is a measure of the ratio of average to peak RF fields, or exposures. An averaging time specified in the FCC RF exposure rules of 30 minutes is required for proper exposure assessment and considerable effort was used to acquire direct measurements of 30-minute duty cycles in the project.

The matter of assessing compliance with the FCC rules can be simplified by the process illustrated in Figure71.

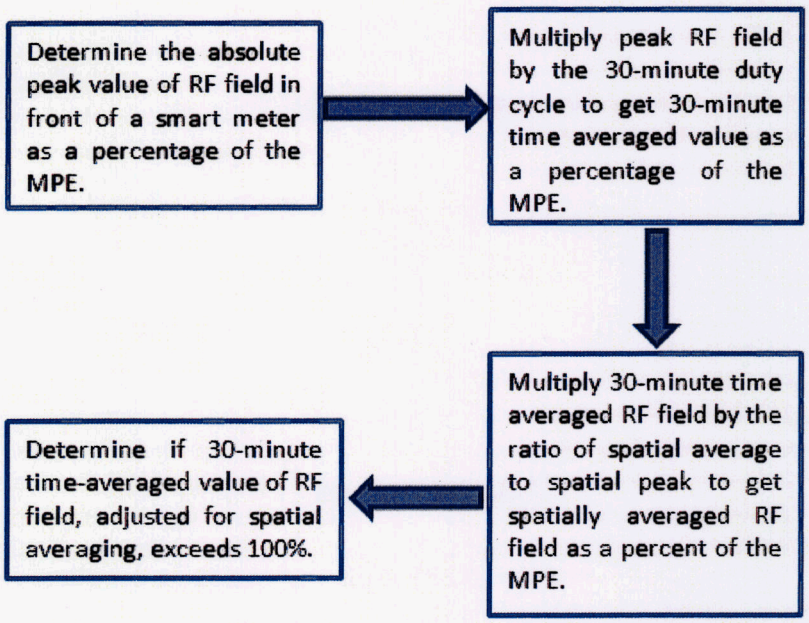

Figure 71. Illustration of steps for assessing compliance with the FCC rules on human exposure used for this study.

Discussion

A simple but conservative observation from all of the presented RF LAN (900 MHz band) data is that the greatest measured peak RF field obtained at a distance of one foot from any smart meter in the GMP service territory corresponded to 3.9% of the MPE and 2.5% of the MPE in the BED service territory. Other measurements resulted in lower values, sometimes considerably lower. In the GMP meter measurements, the maximum duty cycle found under a condition representing the greatest possible amount of data transmission during the measurement, was 3.55% (Figure 31). For the BED area measurements, a maximum duty cycle of 3.49% was deduced on the basis of pulse width measurements and a presumption of such pulses repeating at a rate of once per second. Using these duty cycle values, the 30-minute time averaged RF fields would be 0.14% of the MPE for GMP meters and 0.087% of the MPE for BED meters, both at a distance of one foot directly in front of the meters.

As a strict interpretation of the FCC exposure rules, these time-averaged values are to be adjusted to correspond to spatial averages over the body. Using the values of the ratio of spatial average to spatial peak RF fields over a six foot tall person obtained from direct measurements (0.489 for GMP meters and 0.363 for BED 900 MHz band meters), the overall estimated RF exposure to the RF LAN smart meter emissions at one foot would be 0.068% of the MPE for the GMP meters and 0.032% of the MPE for BED meters.

Associated with the operation of the GMP meters are emissions of the HAN radio that operates in the 2.4 GHz band. A similar exercise with the maximum measured RF field at one foot from the meter, the maximum estimated duty cycle and the spatial variation of field in front of the meter yields a local peak value of field of 0.55% of the MPE, a 30-minute time averaged field equivalent to 0.0014% of the MPE (using a duty cycle of 0.258%) and a resulting, six-foot spatially averaged field equal to 0.00049% of the MPE (spatial ratio of 0.349). The exceptionally low duty cycle for the HAN radios is related to the very narrow pulses that they emit and the relatively large amount of time between pulses.

Hence, using the most conservative results from the measurements performed in this study, a potential maximum exposure of individuals to the RF fields associated with the currently deployed smart meters in the GMP and BED service territories is small when compared to the limits set by the FCC. To provide an alternative perspective on how the anticipated exposure near the smart meters compares to the hazard upon which the present exposure limits are based, it is relevant to know that the FCC limits include a safety factor of 50 fold below the presumed threshold of hazard. In other words, the exposure limit is not set at the boundary of potentially hazardous effects. When the above estimated RF field exposures are considered in this light, this means that the most conservative estimates of potential exposure range between approximately 74,000 and 156,000 times less than the hazard threshold.

Discussion

Using manufacturer's specified values for the peak output powers of the RF LAN transceivers and antenna gains (tabulated in Table 1), the peak RF field power density at one foot from the respective smart meters can be calculated with the following expression.

$$S = \frac{EIRP}{4\pi R^2} \qquad \text{Eq. 1}$$

Where
S is the power density (milliwatts per square centimeter, mW/cm^2)
EIRP is the effective isotropic radiated power (milliwatts)
R is the radial distance from the smart meter (cm)

For the GMP Elster meter, at one foot, the peak power density is calculated to be 0.059 mW/cm^2 and for the BED Itron meter, a value of 0.045 mW/cm^2 is obtained. These values can then be expressed as a percentage of the MPE by dividing by the MPE (nominally 0.61 mW/cm^2 at 915 MHz) and multiplying by 100. This leads to calculated peak RF fields at one foot for the GMP and BED meters of 9.6% and 7.4% of the MPE respectively. These values are greater than the maximum peak values measured in this study, an often typical result of modeling calculations for RF fields when compared to actual measurements. In fact, in the FCC certification report provided by Elster to the FCC in which measured RF fields at a distance of 3 meters are provided, the measured values proved to be approximately 4.5 times less than what the theoretical calculation would suggest.

RF fields found behind the smart meters are considerably lower than those values at the same distance but directly in front of the meters. In this work, rearward directed RF fields were found to range between 6 and 8% of the forward value. This generally has a significant influence on the strength of the RF fields that are found inside homes that have smart meters. Indeed, the interior measurements of RF fields for both the RF LAN and HAN radios of the GMP meters and the RF LAN radios of the BED meters prove this. The greatest value of RF field anywhere within a residence was 0.08% of the MPE with an average value of 0.0033% of the MPE, these values before adjustment for duty cycle or spatial averaging. Arguments that reflections will significantly increase ambient values of smart meter fields are not borne out during measurements. Certainly, reflections can, and will, influence the actual value of field measured at any given point in space. This is partly why the plots of RF field vs. distance in front of the meters do not follow a strict inverse square law. But, based on the extensive measurement data taken inside homes, including areas immediately behind the meters, extraordinary fields were not found.

Discussion

If the maximum and mean interior RF fields, found in homes, are adjusted for duty cycle using the largest duty cycle found in this study, they become equivalent to 0.0028% and 0.00012% of the MPE respectively. When further spatially averaged, these values become 0.0014% and 0.000058% of the MPE respectively.

The task of making smart meter RF field measurements is made more complex because of the non-uniform pattern of emissions from the meters. This is illustrated in Figure 72 where a detailed set of measurements were performed in Colville on both of the test meters provided by GMP and BED. This figure shows the spatial dependence of the measured RF field in relation to the center of the face of the GMP Elster and BED Itron meters. It clearly shows how slight differences in the exact location of the measurement probe/antenna can influence the result and this certainly is a factor in some of the spread of data in measurements taken during this study. The difference between the two meters is related to the location within the meter housing where the radios are installed. All distances are from the surface of the meter face to the center of the SRM probe/antenna.

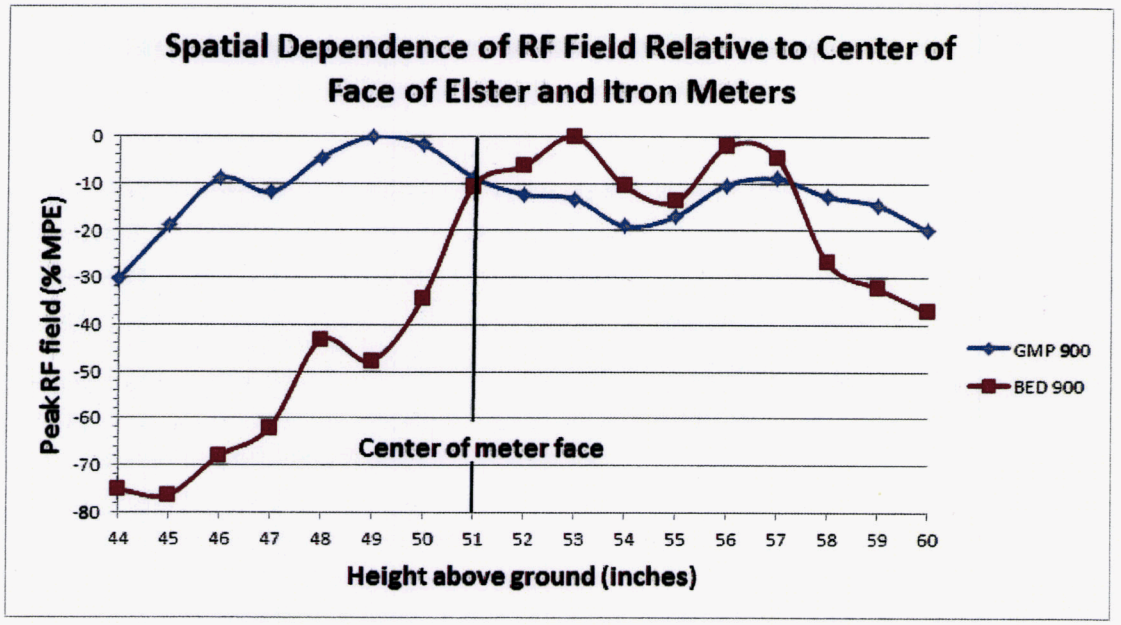

Figure 72. The measured spatial dependence of 900 MHz band RF fields produced at one foot from the GMP Elster and BED Itron smart meters along a vertical line extending from 44 inches to 60 inches above the floor.

Smart meter RF emissions can be put in perspective by comparing their emission levels to RF fields associated with other kinds of sources. A few highlights of such a comparison include:

Discussion

- The likely strongest source of RF exposure in the home is the microwave oven that can result in average RF fields exceeding 6% of the FCC MPE at one foot from the oven and greater than 1% of the MPE at three feet.

- Wireless routers can result in average field levels of as much as 0.0011% of the MPE in the 2.4 GHz band at a distance of one foot (based on a measured peak field of 0.017% of the MPE and a duty cycle of 6.5%).

- The prevalence of FM radio broadcast stations leads to RF field levels that are roughly uniform over the body dimensions, operate with 100% duty cycle and can be in the range of about 1% of the MPE (greatest average value of 0.6% of the MPE was found at environmental site 14 in the Burlington area). This value of field is almost 9 times greater than the time-averaged field at one foot in front of the maximum field smart meter and 400 times the smart meter field at 10 feet from a smart meter.

- The most likely source of personal exposure to RF today is the mobile (cell) phone. Cell phones make use of transceivers that, in terms of power and frequencies used, are not very different from the transceivers in smart meters. Thus, one would not expect that there would be very much difference in exposure between the two devices except for the fact that cell phones are intended to be used against the body while smart meters are not. In a measurement of the spatially averaged RF field over a six-foot vertical dimension, with the phone positioned at five feet above the floor, the field was found to be equivalent to 0.070% of the MPE (Figure 62). Interestingly, this is in quite close agreement with the value obtained for the maximum field smart meter in terms of time-averaged field, including spatial averaging of 0.068% of the MPE. The local energy absorption rate associated with use of the cell phone, however, because of the proximity of the phone to the body during typical use, will result in a far greater local SAR than the smart meter positioned at one foot in front of a person.

Interestingly, when a large group of smart meters are installed together in a bank, such as on an apartment building, the instantaneous peak RF field produced is no different from that of a single meter. However, the time-averaged value of RF field can be greater simply due to the number of meters present. The measurement data collected as part of this study did not, however, reveal any duty cycles of the aggregate RF fields of a meter bank greater than that associated with a single end point meter during its reporting of historical data to the Gatekeeper or Cell Router. The aggregation of smart meters in a bank does not necessarily imply that the long-term time-averaged RF field will be any greater than a high activity end point meter because the smart meters are not interrogated in a physically sequential manner. While one meter in the

bank may respond with data, the next meter queried may be located substantially far from the bank of meters and, consequently, its fields are negligible in comparison to those immediately at the bank.

RF fields found near data collection points in both the GMP and BED service territories were unremarkable other than for the amount of data traffic observed. Because of the elevated height of these Gatekeepers and Cell Routers, RF field emissions are greatly reduced from those found immediately in front of smart meters. As such, the data collection points do not represent any significant increase in potential RF exposure. This is related to the fact that, in the GMP territory, the WWAN connection operates at high speed, thereby allowing for overall low duty cycles when it is transmitting large amounts of data back to the utility company. In the BED region, all data collected by the Cell Router is routed back to the company via a fiber optic network and no additional RF is involved.

Smart meters emit short duration pulses of RF energy in their communication with other meters and data collection points. These emissions generally happen all through the day. Besides the normal three (in the case of BED) or four (in the case of GMP) times a day that electric energy consumption data are reported back to a data collection point for subsequent transmission to the company, smart meters must maintain their organization within the RF LAN to which they belong and this necessitates the transmission of beacon signals from time to time. Additionally, each meter can, when required by the mesh network, assist neighboring smart meters by transmitting the neighbor's data on to another meter or data collection point. Further, the HAN radio can produce pulsed fields in its search for and communication with IHDs. All of this means that most smart meters remain relatively active in terms of brief signals being transmitted. However, the total amount of time that a smart meter transmits during a day is small but non-zero. For instance, the greatest 30-minute duty cycle found for the GMP meters in the` 900 MHz band of 3.55% means that, if this meter were to continue to operate at this rate, the meter would be active for 3.55% of each 30 minute window of time. This corresponds to 63.8 seconds during each half-hour period that it may be active at this level. If this high duty cycle were to be maintained for, say, two hours, four times per day, this would amount to some 17 minutes of transmit time during the day. It is likely that there would be some additional network overhead activity that would increase the total transmit time but, suffice it to say, actual emission of RF fields occurs only for a small fraction of the day. For most meters within the mesh network, the activity will be far less than for those meters that happen to lie within one hop to the data collector since it is these meters that do the most work in transferring RF LAN data.

An evaluation of low frequency electric and magnetic fields of the smart meters that could be a product of switch mode power supplies within the meters showed that the two test meters exhibited different magnitudes of fields but in both cases, all such fields were substantially less than applicable science based guidelines and standards for

exposure. Recommended exposure limits at low frequencies have been recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [13] and the IEEE [14]. Of the two, the more stringent values are those of ICNIRP which are summarized in Table 12 for sinusoidal electric and magnetic fields for general public exposure.

Table 12. Recommended public exposure limits (reference levels) from ICNIRP [13] for sinusoidal low frequency electric and magnetic fields for whole-body exposure.

Frequency range	Electric fields (V/m) RMS	Magnetic fields (μT) RMS
1 Hz – 8 Hz	5000	40,000
8 Hz – 25 Hz	5000	625
25 Hz – 50 Hz	5000	200
50 Hz – 400 Hz	5000	200
400 Hz – 3 kHz	625	200
3 kHz – 10 MHz	83	27

The low frequency measurement data for the two smart meters in the various ICNIRP defined frequency ranges are very substantially less than the recommended values contained in Table 12.

Smart meters emit pulses of RF energy similar to many other everyday sources in the environment. For instance, wireless routers continuously transmit beacon pulses at a rate of 10 pulses per second (10 Hz). Signals from airport and long range air traffic control radars and Doppler weather radar systems produce a constant stream of pulsed RF fields to which individuals may be exposed. For systems such as radars, high pulse repetition frequencies (PRFs) are often used that can range from several hundred Hz to greater than one kilohertz.

Conclusions

A number of field measurement studies conducted by one of the authors address RF emissions from wireless smart meters [1, 2, 3, 9, 15]. All of these studies have demonstrated that the potential exposures that could result from proximity to the subject smart meter emissions comply with the limits set by the FCC. This study is no different.

The RF emissions produced by the smart meters deployed by GMP and BED were found to comply with the public exposure regulations of the FCC by a wide margin, typically by a factor of approximately 1500 times, even at one foot from the meters. The measurement data show that the RF field emissions decrease sharply with increasing distance from the smart meters. At distances more likely associated with common day-to-day exposures to smart meter emissions, the RF fields become even dramatically less. For example, at a distance of 10 feet in front of a meter, the RF field drops to approximately 76,000 times less than the FCC limit. Relative to the actual biological hazard thresholds, not the MPE which contains a safety factor of 50 for the general public, the RF fields at one foot and ten feet from a smart meter are some 75,000 times and 3,800,000 times less respectively.

Detailed measurements of RF fields found inside of smart meter equipped homes showed that the highest fields (typically directly behind the meter but inside the home) were comparable to that found at 10 feet in front of the meter. However, the average of residential indoors smart meter RF fields measured in this study was more than 1.7 million times less than the FCC public exposure limit.

Potential exposure to RF emissions of banks of smart meters was not found to be significantly greater than that of a single meter in terms of the peak value of field but the time-averaged level of RF field can increase simply because of the larger number of meters. However, there is no general correlation between overall higher average RF fields associated with large banks of meters since the greatest duty cycle of any given smart meter appears to be more related to a specific meter's position within the wireless network's hierarchy, i.e., how close it is, from a communications perspective, to its designated data collection point. Hence, a single meter that serves to relay energy consumption data from many other meters to the data collection point can exhibit a greater time-averaged RF field than a large group of meters that are not close, network wise, to a data collection point.

The greatest measured smart meter duty cycles found through this investigation were in the 3-4% range and are comparable to those values determined from statistical analysis of meter transmission activity derived from electric utility data management software systems in earlier studies [1, 2]. Average duty cycles of most meters are substantially less than 1%.

Conclusions

Exposure, in terms of instantaneous peak as well as time-averaged RF fields, caused by deployed smart meters in Vermont is small in comparison to that related to many other sources of RF fields in the environment. For instance, local values of long term, time-averaged RF fields (as a fraction of the MPE) from FM radio broadcasting can, in some areas, be as much as ten to hundreds of times greater than those values found immediately near smart meters. The common use of normal appliances within a home or office, such as microwave ovens and wireless routers, can lead to RF fields that are comparable to or substantially greater than those produced by smart meters. This applies to the use of mobile phones as well; both mobile phones and smart meters operate with roughly the same transmitter peak powers. In this context, however, mobile phones are normally held against the head during use while smart meters are not.

Low frequency electric and magnetic fields produced by the smart meters and their internal switch mode power supplies, at one foot from the meters, were substantially smaller in value than the recommended limits of the ICNIRP guidelines [13].

The communications technology used by smart meters makes use of low power, pulsed RF transmissions that result in weak RF fields by comparison to currently scientifically based human exposure limits. The pulsed nature of smart meter emissions is not very dissimilar to other sources such as wireless routers, mobile phones or air traffic control and weather radars, for example. Pulse repetition rates from 10 Hz for routers sitting idle, 217 Hz for GSM type mobile phones and up to more than a kilohertz for radars characterize many of the signals found in the everyday environment.

The operation of the HAN radios in smart meters produces additional RF emissions for communication with IHDs but the extremely low duty cycle and lower transceiver power levels result in very weak additions to the overall fields that individuals may experience near them.

Applying the highest indicated results from the measurements performed in this study, the RF fields associated with the currently deployed smart meters in the GMP and BED service territories are small when compared to the limits set by the FCC. It is concluded that any potential exposure to the investigated smart meters will comply with the FCC exposure rules by a wide margin.

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Appendix A

RF Exposure Report Prepared for the FCC on Behalf of Elster Solutions, LLC
By
TUV Rheinland North America

Appendix A

TÜVRheinland®
Precisely Right.

RF Exposure Report

EUT Name: Rex2 Power Meters
EUT Model: RX2EA4, RX2EA4-I
FCC ID: QZC-RX2EA4 , QZC-RX2EA4I

FCC Title 47, Part 15.247(i), 1.1307(b), and 1.1310

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Report/Issue Date: 9 February 2010
Report Number: Supplement to 30953899.001 - MPE

Appendix A

1 RF Exposure Measurement (Mobile Device) 15.247(i)

1.1 Test Methodology

In this document, we try to prove the safety of radiation harmfulness to the human body for our product. The limit for Maximum Permissible Exposure (MPE) specified in FCC 1.1310 is followed. The Gain of the antenna used in this product is measured in a Semi-Anechoic Chamber, and also the maximum total power input to the antenna is measured. Through the Friis transmission formula (see section 4.9.6) and the maximum gain of the antenna, we can calculate the distance, away from the product, where the limit of MPE is reached.

Although the Friis transmission formula is a far field assumption, the calculated result of that is an over-prediction for near field power density. We will take that as the worst case to specify the safety range.

1.2 RF Exposure Limit

According to FCC 1.1310 table 1: The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b)

LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Average Time (minutes)
(A)Limits For Occupational / Control Exposures				
300-1500	…	…	F/300	6
1500-100,000	…	…	5	6
(B)Limits For General Population / Uncontrolled Exposure				
300-1500	…	…	f/1500	6
1500-100,000	…	…	1.0	30

f = Frequency in MHz

Appendix A

1.3 EUT Operating condition

The software provided by Manufacturer enabled the EUT to transmit data at lowest, middle and highest channel individually.

1.4 Classification

The antenna of the product, under normal use condition, is at least 20cm away from the body of the user. Warning statement to the user for keeping at least 20cm or more separation distance with the antenna should be included in users manual. Therefore, this device is classified as a **Mobile Device**.

1.5 Test Results

1.5.1 Antenna Gain

The maximum Gain measured in Semi-Anechoic Chamber is 5.64 dBi or 3.66 (numeric).

1.5.2 Output Power into Antenna & RF Exposure value at distance 20cm:

Calculations for this report are based on highest power measurement and the highest gain of the antenna. Limit for MPE (from FCC part 1.1310 table 1) is f (MHz) / 1500 = 927.6 / 1500 = 0.62 mW/cm^2

Highest Pout is 250mW, highest antenna gain (in linear scale) is 3.27, R is 20cm, and f = 927.6 MHz

Pd = (250*3.66) / (1600π) = **0.182 mW/cm^2**, which is 0.438 mW/cm^2 below to the limit.

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

1.6 Sample Calculation

The Friis transmission formula: Pd = (Pout*G) / (4*π*R^2)

Where:

Pd = power density in mW/cm^2
Pout = output power to antenna in mW
G = gain of antenna in linear scale
π = 3.1416
R = distance between observation point and center of the radiator in cm

Ref.: David K. Cheng, *Field and Wave Electromagnetics*, Second Edition, Page 640, Eq. (11-133).

Appendix B

RF Exposure Report Prepared for the FCC on Behalf of Iton
By
Advanced Compliance Solutions (ACS)

Appendix B

ACS
Excellence in Compliance Testing

Certification Exhibit

FCC ID: SK9AMI6
IC: 864G-AMI6

FCC Rule Part: 15.247
IC Radio Standards Specification: RSS-210

ACS Report Number: 10-0158.W06

Manufacturer: Itron Electricity Metering, Inc.
Model: AMI6

RF Exposure

5015 B.U. Bowman Drive Buford, GA 30518 USA Voice: 770-831-8048 Fax: 770-831-8598

Appendix B

General Information:

Applicant:	Itron Electricity Metering, Inc.
ACS Project:	10-0158
Device Category:	Mobile
Environment:	General Population/Uncontrolled Exposure
Simultaneous Transmission:	Yes

Technical Information 900 MHz LAN Radio
Antenna Type: Quarter Wave Embedded Slot Antenna
Antenna Gain: 2.2dBi
Transmitter Conducted Power: 24.83dBm
Maximum System EIRP: 27.03dBm (505mW)

Technical Information 802.15.4 Zigbee Radio
Antenna Type: Quarter Wave Embedded Slot Antenna
Antenna Gain: 3.8dBi
Transmitter Conducted Power: 18.94dBm
Maximum System EIRP: 22.74dBm (188mW)

MPE Calculation
The Power Density (mW/cm^2) is calculated as follows:

$$S = \frac{PG}{4\pi R^2}$$

Where:
S = power density (in appropriate units, e.g. mW/cm2)
P = power input to the antenna (in appropriate units, e.g., mW)
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna (appropriate units, e.g., cm)

MPE Calculator for Mobile Equipment Limits for General Population/Uncontrolled Exposure[a]							
Transmit Frequency (MHz)	**Radio Power (dBm)**	**Power Density Limit (mW/Cm2)**	**Radio Power (mW)**	**Antenna Gain (dBi)**	**Antenna Gain (mW eq.)**	**Distance (cm)**	**Power Density (mW/cm^2)**
902.25	24.83	0.60	304.09	2.2	1.660	20	0.100
2475	18.94	1.00	78.34	3.8	2.399	20	0.037

Summation of Power Densities – Simultaneous Transmissions
This device contains multiple transmitters which can operate simultaneously and therefore the maximum RF exposure is determined by the summation of power densities. The 900 MHz LAN and 2.4GHz Zigbee radio can operate simultaneously there it is appropriate to include both of those power density values in the summation of power densities.

The maximum power density is calculated by a summation of power densities for each simultaneous transmission combination as follows:

900MHz LAN:	0.100 (mW/cm^2)
2.4GHz Zigbee:	0.037 (mW/cm^2)
TOTAL:	**0.137 (mW/cm^2)**

Appendix B

Installation Guidelines
The installation manual should contain text similar to the following advising how to install the equipment to maintain compliance with the FCC RF exposure requirements:

RF Exposure
In accordance with FCC requirements of human exposure to radio frequency fields, the radiating element shall be installed such that a minimum separation distance of 20 centimeters will be maintained.

Conclusion
This device complies with the MPE requirements by providing adequate separation between the device, any radiating structure and the general population.

Appendix C
Calibration Certification of the Narda SRM-3006 Selective Radiation Meter

Appendix C

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Calibration Certificate

Narda Safety Test Solutions hereby certifies that the object referred to in this certificate has been calibrated by qualified personnel using Narda's approved procedures. The calibration was carried out in accordance with a certified quality management system which conforms to ISO 9001

OBJECT	Selective Radiation Meter, Basic Unit, SRM-3006
MANUFACTURER	Narda Safety Test Solutions GmbH
PART NUMBER (P/N)	3006/01
SERIAL NUMBER (S/N)	D-0069
CUSTOMER	
CALIBRATION DATE	2010-10-13
RESULT ASSESSMENT	within specifications
AMBIENT CONDITIONS	Temperature: (23 ± 3)°C Relative humidity: (25 to 75) %
CALIBRATION PROCEDURE	3006-8701-00A

ISSUE DATE: 2010-10-18

MANAGEMENT SYSTEM

CALIBRATED BY:
Paul Geyer

AUTHORIZED SIGNATORY:

Certified by DQS against ISO 9001:2008 (Reg.-No. 099379 QM08)

This calibration certificate may not be reproduced other than in full except with the permission of the issuing laboratory. Calibration certificates without signature are not valid.

Appendix C

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OBJECT

The spectrum analyzer is based on digital signal processing. Small frequency spans were measured at fixed local oscillator (1st LO) settings using discrete Fourier transformation (DFT). The LO was also swept for larger frequency spans.
A memory chip contains correction values for various frequencies and object settings. The stored values were taken into account automatically during the measurement.

METHOD OF MEASUREMENT

Calibration using the reference standard. The output power level of the synthesized CW generator was adjusted and calibrated using power sensors as reference standards.
The frequency of the generator was calibrated using a frequency counter.

The reflection of the object was measured directly using a vector network analyzer (VNA) calibrated by means of a calibration kit. The measuring equipment and the associated uncertainty were verified using a reference standard (verification kit).

CALIBRATION PROCEDURE

The object was connected to the signal source instead of the power sensors in order to calibrate it.

Measurement of the RF frequency response was made with different settings of the measurement range. As a result, the measured values also include the effects due to the "input attenuator" and the "reference level accuracy".
The calibration factor was calculated for various frequencies and settings from a comparison between the "actual level" and the "indicated level".

All the selection filters are digital filters. No calibration of the filters is necessary.

TRACEABILITY

The calibration results are traceable to the International System of Units (SI) in accordance with ISO/IEC 17025. The measuring equipment used for calibration is traceable through the reference standards listed below.

STANDARD	MANUFAC-TURER	MODEL	SERIAL NUMBER	ID	CERTIFICATE	NEXT CAL. DATE	TRACE
HF-MILLIVOLTMETER	R&S	URV 55	100143	913	0116 DKD-K-16101 2010-05	2012-05	DKD
DIODE POWER SENSOR	R&S	NRV Z4	100199	956	0104 DKD-K-16101 2010-05	2012-05	DKD
THERMAL POWER SENSOR	R&S	NRV Z51	101777	1635	0264 DKD-K-16101 2008-11	2010-11	DKD
MISMATCH VSWR 1,2 (f)	Rosenberger	--	01237	552-3	12996 DKD-K-00201 2008-05	#	DKD
FREQUENCY COUNTER	Advantest	R5362B	120700137	923	15137 DKD-K-00201 2009-09	#	DKD

Reference standard; not used for routine calibration

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UNCERTAINTY

The reported expanded uncertainty U is based on a standard uncertainty multiplied by a coverage factor $k = 1.96$, providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with the "Guide to the Expression of Uncertainty in Measurement" (GUM).
The reported measurement uncertainty is derived from the uncertainty of the calibration procedure and the object during calibration, and makes no allowance for drift or operation under other environmental conditions.

MEASURING CONDITIONS

The following results were obtained after adjustment of the object under calibration.
These values are within the setting ranges defined by the manufacturer.

RESULTS

1	FREQUENCY RESPONSE (IF):	passed
2	FREQUENCY RESPONSE (RF):	passed
3	OUT-OF-BAND RESPONSE:	passed
4	FREQUENCY ACCURACY	passed
5	NOISE SIDEBAND (SSB):	passed
6	SPURIOUS (input related)	passed
7	SPURIOUS (residual)	passed
8	NOISE FLOOR:	passed
9	INTERMODULATION REJECTION (2nd and 3rd order):	passed
10	INPUT RETURN LOSS:	passed

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APPENDIX

FREQUENCY RESPONSE (RF)

The generator was set to the *Fgen*. The object settings were *Fspan*, *RBW*, and *Fcent*.
The measurements were made at different settings of the measurement range *MR*. The nominal level of the generator was -32 dBm (for *MR* < -5 dBm) and -7 dBm (for *MR* > -5 dBm), respectively. The frequency response *G* was calculated as the difference of the actual generator level L_{actual} and the indicated level $L_{indicated}$ according to the following equation: $G/\mathrm{dB} = (L_{indicated} - L_{actual})/\mathrm{dBm}$

Frequency in MHz	Fspan in MHz	RBW in kHz	Fcent in MHz	MR												U
				-30	-28	-25	-20	-15	-10	-5	0	5	10	15	20	
0.00901	0.002	0.01	0.01	0	0	0	-0.01	-0.01	0	0	0	0	0	-0.01	-0.01	0.2
0.012	0.006	0.5	0.012	0.01	0.01	0.01	0	0	0.01	0.01	0.01	0	0.01	0	0	0.2
0.02	0.02	2	0.02	0.01	0	0	0	-0.01	0.01	0.01	0	0	0	0	-0.01	0.2
0.04	0.02	2	0.04	0	0	0	-0.01	-0.01	0	0	0	0	0	0	-0.01	0.2
0.1	0.02	2	0.1	0	0	0	-0.01	-0.01	0	0	0	-0.01	-0.01	-0.01	-0.01	0.2
0.5	0.02	2	0.5	0	0	0	-0.01	-0.01	0	0	0	-0.01	-0.01	-0.01	-0.01	0.2
2	0.02	2	2	0	0	0	-0.01	-0.01	0	0.01	0	0	0	0	0	0.2
10	0.02	2	10	0.01	0.01	0	0	0	0.01	0.01	0.01	0	0	0	0	0.2
20	0.02	2	20	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0	0	0.2
30	0.02	2	30	0.01	0.01	0	0	0	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.2
31.233	26.75	30	44.578	-0.11	-0.19	-0.15	-0.18	-0.29	-0.12	-0.14	-0.15	-0.29	0	-0.14	-0.21	0.2
36.1	26.75	30	44.578	-0.03	-0.11	-0.07	-0.13	-0.17	-0.06	-0.08	-0.1	-0.17	-0.02	-0.1	-0.14	0.2
40	0.02	2	40	0.01	0.01	0	0	0	0	0.01	0.01	0	0	-0.01	-0.01	0.2
44.1	26.75	30	44.578	0.04	-0.01	-0.01	-0.03	-0.03	0.01	0	-0.01	-0.02	-0.04	-0.03	-0.06	0.2
50	0.02	2	50	0.01	0	0	0	0	0.02	0.01	0.01	0	0.01	0.01	0.02	0.2
52.1	26.75	30	44.578	0.03	0	-0.01	-0.05	-0.01	0	-0.01	-0.03	0	-0.11	-0.07	-0.07	0.2
57.9948	0.02	2	57.9868	0.01	0	0	-0.01	-0.01	-0.01	0	0	-0.01	-0.01	-0.03	-0.05	0.2
58.344	26.75	30	44.999	-0.02	-0.04	-0.07	-0.12	-0.05	-0.05	-0.06	-0.09	-0.05	-0.18	-0.13	-0.11	0.2
60.1	26.75	30	60.1	0.02	0.01	0.01	0	-0.01	0	0.01	0.01	0.01	0	-0.01	-0.03	0.2
100.1	26.75	30	100.1	0.02	0.01	0.01	0.01	0	0	0.02	0.01	0	0	-0.02	-0.02	0.2
200.1	26.75	30	200.1	0	0	0	-0.01	-0.02	-0.02	0	-0.01	-0.02	-0.02	-0.03	-0.04	0.2
300.1	26.75	30	300.1	0	0	0	0	-0.01	0	0.01	0	0	0	-0.02	-0.02	0.2
400.1	26.75	30	400.1	0	0	-0.01	-0.01	-0.02	-0.02	0	-0.01	-0.01	-0.02	-0.02	-0.05	0.2

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Frequency in MHz	Fspan in MHz	RBW in kHz	Fcent in MHz	MR												U
				-30	-28	-25	-20	-15	-10	-5	0	5	10	15	20	
500.1	26.75	30	500.1	-0.01	-0.01	-0.01	-0.01	-0.02	-0.03	0	-0.01	-0.01	-0.02	-0.03	-0.04	0.2
600.1	26.75	30	600.1	0	0	0	-0.01	-0.01	-0.02	0	-0.01	-0.01	-0.01	-0.02	-0.04	0.2
700.1	26.75	30	700.1	0	0	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	-0.04	-0.04	0.2
800.1	26.75	30	800.1	0	0	-0.01	-0.01	-0.02	-0.03	-0.01	0	-0.01	-0.02	-0.04	-0.05	0.2
900.1	26.75	30	900.1	-0.01	-0.01	-0.02	-0.01	-0.02	-0.03	-0.01	-0.01	-0.01	-0.03	-0.03	-0.05	0.2
1000.1	26.75	30	1000.1	-0.02	-0.03	-0.02	-0.03	-0.04	-0.05	-0.02	-0.03	-0.03	-0.04	-0.05	-0.08	0.2
1100.1	26.75	30	1100.1	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.03	-0.04	-0.06	0.2
1200.1	26.75	30	1200.1	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.03	-0.04	-0.04	-0.06	0.2
1300.1	26.75	30	1300.1	-0.01	-0.01	-0.01	-0.02	-0.03	-0.02	-0.02	-0.02	-0.02	-0.03	-0.04	-0.05	0.2
1400.1	26.75	30	1400.1	0.01	0.02	0.02	0.01	0.01	0	0.01	0.01	0	0	-0.01	-0.03	0.2
1500.1	26.75	30	1500.1	0.03	0.03	0.03	0.02	0.02	0.01	0.03	0.03	0.02	0.01	0	0	0.2
1600.1	26.75	30	1600.1	0.02	0.02	0.01	0.01	0.01	0	0.03	0.02	0.01	0	0	-0.01	0.2
1700.1	26.75	30	1700.1	0.06	0.06	0.06	0.05	0.05	0.04	0.07	0.06	0.04	0.04	0.03	0.02	0.2
1800.1	26.75	30	1800.1	0.02	0.02	0.02	0.01	0	0.01	0.01	0.01	0	0	-0.01	-0.04	0.2
1900.1	26.75	30	1900.1	0.01	0	0	-0.01	-0.02	-0.02	0	0	-0.01	-0.01	-0.02	-0.04	0.2
2000.1	26.75	30	2000.1	0.01	0	0.01	0.01	-0.01	-0.01	0.01	0.01	0	0	-0.02	-0.03	0.2
2100.1	26.75	30	2100.1	0.02	0.01	0.01	0	-0.01	0	0.01	0.01	0.01	0	-0.01	-0.03	0.2
2200.1	26.75	30	2200.1	0.01	0.02	0.01	0.01	-0.01	0	0.02	0.01	0	0	-0.01	-0.03	0.2
2300.1	26.75	30	2300.1	0.02	0.02	0.01	0.01	0	0	0.02	0.02	0.01	0.01	-0.01	-0.01	0.2
2400.1	26.75	30	2400.1	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.03	0.03	0.01	0	-0.03	0.2
2500.1	26.75	30	2500.1	-0.01	-0.01	0	-0.02	-0.02	-0.02	0	0	-0.01	-0.02	-0.03	-0.04	0.2
2600.1	26.75	30	2600.1	0.01	0	0.01	0	-0.01	0	0.02	0.01	0	0	-0.01	-0.03	0.2
2700.1	26.75	30	2700.1	0.04	0.04	0.03	0.02	0.02	0.03	0.04	0.03	0.03	0.02	0.02	-0.01	0.2
2800.1	26.75	30	2800.1	0.05	0.05	0.04	0.03	0.03	0.04	0.05	0.05	0.04	0.03	0.02	0.01	0.2
2900.1	26.75	30	2900.1	0.02	0.02	0.02	0.01	0	0.01	0.04	0.04	0.03	0.03	0.01	0	0.2
2999.9	26.75	30	2999.9	0.01	0.02	0.03	0	0.01	0.02	0.03	0.03	0.01	0.02	0	-0.01	0.2
3002.1	26.75	30	3002.1	-0.04	-0.02	-0.02	-0.01	-0.03	0	0.01	0.01	-0.01	0	-0.02	-0.03	0.2
3100.1	26.75	30	3100.1	-0.02	-0.02	-0.02	-0.02	-0.02	0	0	0.01	-0.01	0	-0.01	-0.03	0.2
3200.1	26.75	30	3200.1	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0.03	0.02	0.02	0.02	0.01	-0.01	0.2
3300.1	26.75	30	3300.1	0	0.01	0.01	0	0	0.02	0.03	0.01	0.03	0.02	0.02	0	0.2
3400.1	26.75	30	3400.1	0	0	-0.01	-0.02	-0.02	0.02	0.03	0.01	0.01	0.01	0	-0.02	0.2
3500.1	26.75	30	3500.1	0.01	0.01	0	0	-0.01	0.02	0.04	0.02	0.03	0.02	0.01	-0.01	0.2

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Frequency in MHz	Fspan in MHz	RBW in kHz	Fcent in MHz	MR												U
				-30	-28	-25	-20	-15	-10	-5	0	5	10	15	20	
3600.1	26.75	30	3600.1	0	0	-0.01	0	-0.02	0.01	0.02	0.02	0.03	0.02	0	-0.02	0.2
3700.1	26.75	30	3700.1	-0.02	-0.02	-0.02	-0.02	-0.03	0	0.03	0.01	0.01	0.01	0	-0.02	0.2
3800.1	26.75	30	3800.1	-0.02	-0.01	-0.02	-0.02	-0.04	0.01	0.02	0.01	0.01	0	-0.01	-0.03	0.2
3900.1	26.75	30	3900.1	-0.01	-0.01	-0.02	-0.02	-0.02	0	0.02	0.02	0.01	0.01	-0.01	-0.02	0.2
4000.1	26.75	30	4000.1	-0.02	-0.01	-0.01	-0.02	-0.03	0.01	0.01	0.01	0	0	-0.02	-0.04	0.2
4100.1	26.75	30	4100.1	0.02	0.01	0.01	0	0	0.04	0.05	0.05	0.04	0.03	0.01	0.02	0.2
4200.1	26.75	30	4200.1	0.03	0.03	0.03	0.03	0.01	0.06	0.07	0.05	0.07	0.04	0.05	0.02	0.2
4300.1	26.75	30	4300.1	0.03	0.04	0.03	0.03	0.01	0.04	0.06	0.06	0.06	0.04	0.03	0.01	0.2
4400.1	26.75	30	4400.1	0	-0.01	-0.01	-0.01	-0.01	0.01	0.03	0.03	0.02	0.01	-0.01	-0.05	0.2
4500.1	26.75	30	4500.1	-0.02	-0.03	-0.04	-0.04	-0.05	-0.02	0.01	0.01	0	-0.02	-0.04	-0.05	0.2
4600.1	26.75	30	4600.1	0	0	0	0	-0.01	0	0.04	0.03	0.01	0	0.01	-0.03	0.2
4700.1	26.75	30	4700.1	0.02	0.01	0.01	0	-0.01	0.01	0.04	0.03	0.03	0.01	0.01	-0.02	0.2
4800.1	26.75	30	4800.1	-0.01	0	-0.02	-0.01	-0.03	-0.02	0.01	0	-0.01	-0.02	-0.06	-0.08	0.2
4900.1	26.75	30	4900.1	-0.04	-0.03	-0.04	-0.06	-0.07	-0.05	-0.02	-0.03	-0.04	-0.06	-0.06	-0.09	0.2
5000.1	26.75	30	5000.1	-0.03	-0.03	-0.04	-0.04	-0.05	-0.04	-0.01	-0.02	-0.04	-0.04	-0.05	-0.07	0.2
5100.1	26.75	30	5100.1	-0.02	-0.02	-0.01	-0.01	-0.04	-0.02	-0.01	-0.01	-0.01	-0.03	-0.04	-0.09	0.2
5200.1	26.75	30	5200.1	0	0	0.01	0	-0.03	0	0	0.01	-0.01	-0.01	-0.03	-0.05	0.2
5300.1	26.75	30	5300.1	0.03	0.02	0.03	0.01	0	0.01	0.02	0.02	0.01	0.01	-0.02	-0.06	0.2
5400.1	26.75	30	5400.1	0.01	0.02	0.01	0.01	-0.01	0	0.02	0	0	0	-0.03	-0.07	0.2
5500.1	26.75	30	5500.1	0.01	0.01	0.02	0.01	0	-0.02	0.02	0.01	0	-0.01	-0.03	-0.05	0.2
5600.1	26.75	30	5600.1	0.03	0.04	0.02	0.03	0.01	-0.02	0.02	0.02	0.02	0.01	-0.02	-0.04	0.2
5700.1	26.75	30	5700.1	0.03	0.03	0.04	0.03	0.03	-0.01	0.03	0.01	0	0.02	0	-0.04	0.2
5800.1	26.75	30	5800.1	0.03	0.04	0.04	0.03	0.02	0	0.02	0.01	0.01	0	-0.02	-0.04	0.2
5900.1	26.75	30	5900.1	0.04	0.04	0.04	0.02	0.01	-0.02	0.01	-0.01	0	-0.02	-0.03	-0.06	0.2
5986.1	26.75	30	5986.625	0.05	0.05	0.05	0.04	0.04	0	0.02	0.02	0.01	0	-0.01	-0.06	0.2

Frequency Response G and Uncertainty U in dB

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Appendix C

Narda Safety Test Solutions GmbH
Sandwiesenstrasse 7 . D-72793 Pfullingen . Germany
Phone: +49-7121-9732-0 . Fax: +49-7121-9732-790

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Calibration Certificate

Narda Safety Test Solutions hereby certifies that the referenced equipment has been calibrated by qualified personnel to Narda's approved procedures. The calibration was carried out within a certified quality management system conforming to ISO 9001.

Object	**Antenna, Three-Axis, E-Field, 27 MHz to 3 GHz**
Part Number (P/N)	**3501/03**
Serial Number (S/N)	**K-0242**
Manufacturer	Narda Safety Test Solutions GmbH
Customer	
Date of Calibration	07-Okt-2010
Results of Calibration	Test results within specifications
Confirmation interval recommended	24 Months
Ambient conditions	Temperature: (23 ± 3) °C Relative humidity: (20 to 60) %
Calibration procedure	3000-8702-00A

Pfullingen, 07-Okt-2010

MANAGEMENT SYSTEM

Person in charge
Geyer

i.A.
Head of Laboratory
J. v. Freeden

Certified by DQS according to ISO 9001:2008
(Reg.-No. 099379 QM08)

This certificate may only be published in full, unless permission for the publication of an approved extract has been obtained in writing from the Managing Director.

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Measurements

The calibration of RF field strength probes involves the generation of a calculable linearly polarized electromagnetic field, approximating to a plane wave, into which the device is placed.
The RSS value of three axis is used.

At each test frequency, the probe is orientated in the analytic angle (54.74 degrees between probe axis and electric field vector) and rotated 360 degrees. The noted indicated output voltage is calculated from the geometric mean of the minimum and maximum readings during rotation. The antenna factor is calculated from the ratio of the applied field strength to the output voltage (nominal impedance 50 Ohm). The minimum and maximum readings during rotation are further used to calculate the ellipse ratio.
A power meter head is connected by means of an ferrite beaded 50 Ohm coaxial cable.

A Crawford TEM cell is used to generate the known field at frequencies up to 100 MHz. The field strength is derived from the TEM cell's properties and from the output power of the cell.
Over the frequency range from 200 MHz to 1.6 GHz, the probe is positioned in front of a double balanced ridge horn antenna. The field strength is set to a known value by means of a calibrated E-field reference probe.
Above 1.7GHz the probe is positioned with the boresight of a linearly polarized horn antenna. The field strength is derived from the mechanical dimensions and the input power of the antenna.

The antenna factor is permanently stored in the antenna connector memory. When combined with the SRM basic unit (BN 3001 series) the frequency response of the antenna is automatically compensated.

Uncertainties

The measurement uncertainty stated in this document is the expanded uncertainty with a coverage factor of 2 (corresponding, in the case of normal distribution, to a confidence probability of 95%).

The uncertainty analysis for this calibration was done in accordance with the ISO-Guide (Guide to the expression of Uncertainty in Measurement). The measurement uncertainties are derived from contributions from the measurement of power, impedance, attenuation, mismatch, length, frequency, stability of instrumentation, repeatability of handling and field uniformity in the field generators (TEM cell and anechoic chamber).

This statement of uncertainty applies to the measured values only and does not make any implementation or include any estimation as to the long-term stability of the calibrated device.

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Traceability of Measuring Equipment

The calibration results are traceable to National Standards, which are consistent with the recommendations of the General Conference on Weights and Measure (CGPM), or to standards derived from natural constants. Physical units, which are not included in the list of accredited measured quantities such as field strength or power density, are traced to the basic units via approved measurement and computational methods.

The equipment used for this calibration is traceable to the reference listed above and the traceability is guaranteed by ISO 9001 Narda internal procedure.

Reference- / Working- Standard	Manu facturer	Model	Serial Number	Certificate Number	Cal Due Date	Trace
Power Sensor	R&S	NRV-Z4	100122	0171 DKD-K-16101 2008-11	2010-11	DKD
RF-Millivoltmeter	R&S	URV55	100213	0224 DKD-K-16101 2010-08	2012-08	DKD
Set-Up "A" (1800 MHz to 3 GHz)						
Calliper	Preisser	0-800mm	310121016	649724 DKD-K-12001 06-05	#	DKD
Power Sensor	agilent	8481A	US37299951	1-2217165994-1	2011-08	UKAS147
Power Sensor	agilent	8481A	US37299952	1-2217214152-1	2011-09	UKAS147
Power Meter	agilent	E4419A	MY40330449	1-2217141092-1A	2011-09	UKAS147
Set-Up "B" (200 MHz to 1600 MHz)						
E-Field Reference Probe	Narda	Type 9.2	V-0017	51200637E	#	SIT08
Power Sensor	agilent	8481A	US37299870	1-2217214643-1	2011-09	UKAS147
Power Sensor	agilent	8481A	2702A57611	1-2217165866-1	2011-09	UKAS147
Power Meter	agilent	E4419B	GB43311917	1-2295928041-1A	2011-11	UKAS147
Set-Up "D" (100 kHz to 100 MHz)						
Calliper	Preisser	0-800mm	310121016	649724 DKD-K-12001 06-05	#	DKD
Power Sensor	agilent	8482A	2652A13544	08D177 DKD-K-02201 2008-06	2010-12	DKD
Power Meter	agilent	438A	2741U00723	1-1321958613-1A	2010-12	UKAS147
Attenuator	Weinschel	49-30-33	KC115	3248 DKD-K-00501 2008-06	2011-06	DKD

Reference standard; not used for routine calibration

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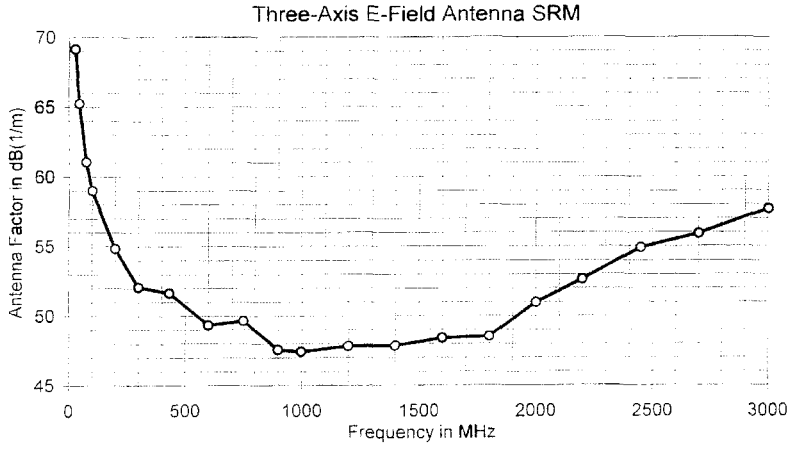
Results

Frequency Response **passed**

Frequency in MHz	E_applied in V/m	Output voltage in dB(µV)	Meas. Uncertainty in dB	Antenna Factor in dB(1/m)
26	10,0	70,85	1,0	69,15
45	10,0	74,76	1,0	65,24
75	10,0	78,95	1,0	61,05
100	10,0	81,00	1,0	59,00
200	10,0	85,17	1,0	54,83
300	10,0	87,92	1,0	52,08
433	10,0	88,36	1,5	51,64
600	10,0	90,66	1,5	49,34
750	10,0	90,35	1,5	49,65
900	10,0	92,45	1,5	47,55
1000	10,0	92,59	1,5	47,41
1200	10,0	92,20	1,5	47,80
1400	10,0	92,15	1,5	47,85
1600	10,0	91,60	1,5	48,40
1800	10,0	91,49	1,0	48,51
2000	10,0	89,04	1,0	50,96
2200	10,0	87,37	1,0	52,63
2450	10,0	85,11	1,0	54,89
2700	10,0	84,11	1,0	55,89
3000	10,0	82,34	1,0	57,66

Frequency Flatness (100 - 3000 MHz): 11,6 dB

The Antenna Factor data is permanently stored in the antenna connector memory.
The SRM basic unit uses this correction data to correct the display.



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Rotational Ellipticity **passed**

Frequency in MHz	Ellipse Ratio in dB
26	+/-0,13
45	+/-0,17
75	+/-0,12
100	+/-0,10
200	+/-0,10
300	+/-0,11
433	+/-0,11
600	+/-0,10
750	+/-0,15
900	+/-0,17
1000	+/-0,24
1200	+/-0,37
1400	+/-0,41
1600	+/-0,63
1800	+/-0,80
2000	+/-1,13
2200	+/-1,55
2450	+/-1,53
2700	+/-1,37
3000	+/-1,69

Output Return Loss **passed**

Appendix D

Calibration Certificate for the Narda EHP-50D Electric and Magnetic Field Analyzer

Appendix D

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Narda Safety Test Solutions S.r.l.
Sales & Support: Via Leonardo da Vinci 21/23
20090 Segrate (MI)
Tel.: +39 02 2699871 Fax: +39 02 26998700
Manufactering Plant: Via Benessea, 29/B
17035 Cisano sul Neva (SV)
Tel.: +39 0182 58641 Fax: +39 02 586489

CERTIFICATE OF CALIBRATION
Certificato di taratura

Number Numero 10510

Item *Oggetto*	Electric and Magnetic field Probe - Analyzer
Manufacturer *Costruttore*	Narda S.T.S. / PMM
Model *Modello*	EHP50D
Serial number *Matricola*	000WX10510
Calibration procedure *Procedura di taratura*	Internal procedure PTP 09-31
Date(s) of measurements *Data(e) delle misure*	23.06.2011
Result of calibration *Risultato della taratura*	Measurements results within specifications

This calibration certificate documents the traceability to national/international standards, which realise the physical units of measurements according to the International System of Units (SI). Verification of traceability is guaranteed by mentioning used equipment included in the measurement chain. This equipment includes reference standard directly traceable to (inter)national standard (accuracy rating A) and working standard calibrated by the calibration laboratory of Narda Safety Test Solutions (accuracy rating B) by means of reference standard A or by other calibration laboratory.
The measurement uncertainties stated in this document are estimated at the level of twice the standard deviation (corresponding, in the case of normal distribution, to a confidence level of about 95%). The uncertainties are calculated in conformity to the ISO Guide (Guide to the expression of uncertainty in measurement).The metrological confirmation system for the measuring equipment used is in compliance with ISO 10012-1. The applied quality system is certified to UNI EN ISO 9001.
Questo certificato di taratura documenta la tracciabilità a campioni primari nazionali o internazionali i quali realizzano la riferibilità alle unità fisiche del Sistema Internazionale delle Unità (SI). La verifica della tracciabilità è garantita elencando gli strumenti presenti nella catena di misura.La catena di riferibilità metrologica fa riferimento a campioni di prima linea direttamente riferiti a standard (inter)nazionali (classe A), di seconda linea, tarati nel laboratorio metrologico della Narda Safety Test Solutions con riferibilità ai campioni di prima linea oppure tarati da Enti esterni accreditati (classe B).
Le incertezze di misura dichiarate in questo documento sono espresse come due volte lo scarto tipo (corrispondente, nel caso di distribuzione normale, a un livello di confidenza di circa 95%). Le incertezze di misura sono calcolate in riferimento alla guida ISO. La conferma metrologica della strumentazione usata è conforme alla ISO 10012-1. Il sistema di qualità è certificato ISO 9001.

COMPANY WITH QUALITY MANAGEMENT SYSTEM CERTIFIED BY DNV
= ISO 9001:2000 =

Date of issue *Data di emissione*	**Measure operator** *Operatore misure*	**Person responsible** *Responsabile*
28.06.2011	F. Ferrari OPERATORE n. 03	G. Basso

This calibration certificate may not be reproduced other than in full. Calibration certificate without signature are not valid. The user is recommended to have the object recalibrated at appropriate intervals.
La riproduzione del presente documento è ammessa in copia conforme integrale. Il certificato non è valido in assenza di firma. All'utente dello strumento è raccomandata la ricalibrazione nell'appropriato intervallo di tempo.

Appendix D

The calibration was carried out at an ambient temperature of (23 ± 3)°C and at a relative humidity of (50 +10/-20)%.

Calibration method

The magnetic calibration was set up with the probe in a region of uniform magnetic field at the centre of a calibrated Helmholtz coil system. The magnetic flux density is calculated from the current flowing in the coil. The current waveform was sinusoidal. The current in the Helmholtz coil system was adjusted to produce a series of indicated magnetic flux densities on the instrument at various frequencies. The calibration procedure agrees with the indication of IEC 61786 "Measurement of low frequency magnetic and electric fields with regard to exposure of human beings- Special requirements for instruments"
The instrument readings were recorded and the actual values of magnetic flux density were calculated from the measured currents.
The magnetic correction factor (CF) is defined as rapport between actual and indicated magnetic flux density.

$$CF = \frac{Bo}{Bmis}$$

where Bo is the applied magnetic flux density and Bmis is the indicated magnetic flux density

For the electric calibration the probe is positioned inside a big TEM cell (section 1.8x1.8 mete For each measurement, the input voltage was adjusted so that the field strength was set to a specified reading on the monitor.
The actual field strength, at the plane of reference of the probe was then determined and the correction factor calculated using the following definition.

$$CF = \frac{Eo}{Emis}$$

where Eo is the applied field strength and Emis is the indicated field strength

The correction factor data are permanently storec in the internal EEPROM.

Calibration equipment and traceability

ID Number	Description	Manufacturer	Model	Trace
PMM 391	Digital multimeter	Agilent	34401A	/SIT
CMR 169	Electric and Magnetic ref. Probe	Narda	EHP50C-REF	/INRIM
CMR 090	Standard resistor	Narda	PMM BSD250	/NPL
CMR 095	Current Trasformer	Frer	AP10-1TAC010	/INRIM
CMR 001	TEM Cell	Narda	1818	/Narda
CMR 020	Helmholtz coil	Narda	HCSS001	/Narda

Uncertainty of measurements

The statement of uncertainty (see first page) does not make any implication or include any estimation as to the long term stablity of the calibrated monitor. The relative expanded uncertainty result are given below

E field	3% at 50 Hz
	7.5% other frequencies
H field	2% at 50 Hz with 100µT range
	3.5% at 50 Hz with 10mT range
	3% other frequencies

Results

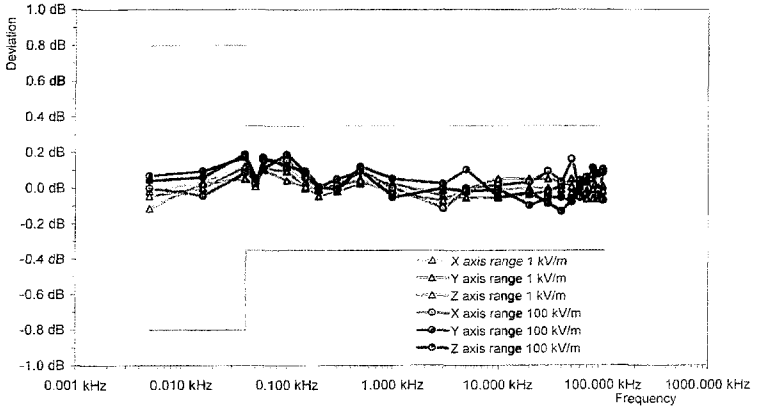
The results of measurements in the following pages were obtained after calibration data storing and indicates the residual of the reciprocal CF.
The results given on the tables were obtained with the axis aligned at the electric vector for electric measurements and with axis concatenated at the magnetic flux density for magnetic mesurements
The shown limits of the EHP50D specification in the diagrams are in orange.

Appendix D

Electric field Frequency response for each axis at nominal field of 100 V/m.
The instrument was set as electric field measure with 100 Hz span up to the frequency of 100 Hz, 200 Hz span up to the frequency of 200 Hz, 500 Hz span up to the frequency of 500 Hz, 1 kHz up to 1000 Hz, 10 kHz up to 10 kHz and 100 kHz span for frequency over 10 kHz

Freq. (kHz)	Deviation with 1kV/m range			Deviation with 100 kV/m range		
	X axis (dB)	Y axis (dB)	Z axis (dB)	X axis (dB)	Y axis (dB)	Z axis (dB)
0.005	-0.02	-0.04	-0.11	0.00	0.07	0.04
0.016	0.03	0.00	0.03	-0.04	0.10	0.06
0.04	0.12	0.12	0.05	0.09	0.17	0.19
0.05	0.03	0.03	0.01	0.04	0.03	0.05
0.06	0.11	0.11	0.10	0.15	0.17	0.11
0.10	0.12	0.10	0.04	0.15	0.12	0.19
0.15	0.03	0.00	0.01	0.06	0.10	0.09
0.20	-0.01	-0.04	0.00	0.00	0.01	0.01
0.30	0.02	-0.02	0.02	0.02	0.05	-0.01
0.50	0.05	0.03	0.04	0.10	0.10	0.12
1.00	-0.01	0.03	-0.03	0.00	-0.05	0.05
3.00	-0.01	-0.04	-0.07	-0.11	0.00	0.03
5.00	-0.02	-0.05	-0.01	0.00	-0.02	0.10
10.00	-0.01	-0.05	0.05	0.02	-0.01	-0.05
20.0	0.00	-0.03	0.05	0.03	-0.10	-0.03
30.0	0.00	-0.02	0.05	0.10	-0.05	-0.09
40.0	-0.01	0.02	0.03	0.03	-0.05	-0.13
50.0	-0.03	0.05	0.01	0.16	-0.08	-0.06
60.0	0.01	0.02	-0.03	-0.05	0.04	0.02
70.0	0.03	-0.02	-0.06	-0.03	0.06	0.03
80.0	-0.01	-0.06	0.03	0.02	0.07	0.11
90.0	-0.06	0.00	-0.03	-0.02	-0.04	0.08
100.0	-0.05	0.01	-0.02	0.10	-0.07	0.09

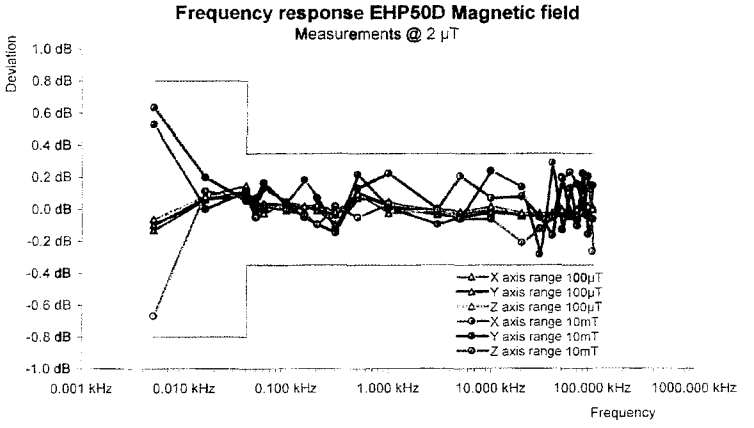
Frequency response EHP50D Electric field
Measurements @ 100 V/m



Appendix D

Magnetic Field Frequency response for each axis at nominal magnetic flux density of 2µT.
The instrument was set as magnetic field measure with 100 Hz span up to the frequency of 100 Hz,
200 Hz span up to the frequency of 200 Hz, 500 Hz span up to the frequency of 500 Hz,
1 kHz up to 1000 Hz, 10 kHz up to 10 kHz and 100 kHz span for frequency over 10 kHz

Freq. (kHz)	Deviation with 100µT range			Deviation with 10mT range		
	X axis (dB)	Y axis (dB)	Z axis (dB)	X axis (dB)	Y axis (dB)	Z axis (dB)
0.005	-0.13	-0.10	-0.06	0.53	0.64	-0.67
0.016	0.06	0.08	0.08	0.00	0.20	0.11
0.04	0.11	0.09	0.15	0.11	0.05	0.07
0.05	-0.02	0.02	-0.03	0.03	0.07	-0.05
0.06	0.02	0.03	-0.03	0.13	0.16	0.03
0.10	-0.01	0.03	0.04	0.04	0.03	-0.01
0.15	0.02	0.02	0.02	0.18	-0.05	-0.03
0.20	-0.01	-0.01	0.03	0.07	-0.10	-0.10
0.30	-0.10	-0.03	-0.02	-0.13	-0.15	0.02
0.50	0.07	0.10	0.10	0.21	0.13	-0.05
1.00	0.04	0.02	-0.03	0.01	0.22	0.03
3.00	-0.03	-0.03	0.00	-0.10	0.00	-0.01
5.00	-0.03	-0.05	-0.02	-0.05	0.21	-0.06
10.00	0.00	-0.02	0.02	0.24	0.07	-0.06
20.0	-0.04	-0.03	-0.03	0.14	0.08	-0.21
30.0	-0.03	-0.04	-0.03	-0.28	-0.05	-0.12
40.0	-0.03	-0.05	-0.03	0.29	-0.17	-0.05
50.0	0.00	-0.03	-0.01	-0.13	0.20	0.19
60.0	-0.01	-0.04	-0.01	0.13	-0.03	0.23
70.0	-0.02	-0.03	0.00	-0.10	-0.07	0.15
80.0	-0.02	0.00	-0.02	0.05	0.22	-0.03
90.0	-0.03	-0.03	0.02	-0.04	-0.16	0.21
100.0	0.02	0.00	0.00	0.15	-0.08	-0.26

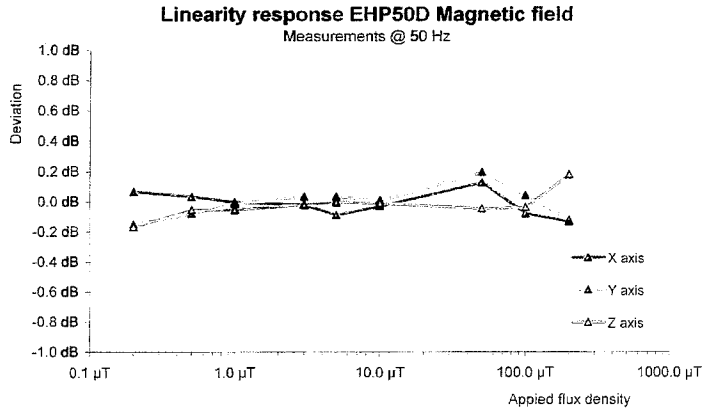


Appendix D

Magnetic Field Linearity response for each axis at applied frequency of 50 Hz and magnetic flux density below
The instrument was set with 100 Hz span.

Applied flux density (µT)	Deviation		
	X axis (dB)	Y axis (dB)	Z axis (dB)
0.2	0.07	-0.15	-0.17
0.5	0.03	-0.08	-0.05
1.0	0.00	-0.01	-0.05
3.0	-0.02	0.03	-0.02
5.0	-0.09	0.03	0.00
10	-0.03	0.01	-0.01
50	0.13	0.20	-0.04
100	-0.08	0.04	-0.03
200	-0.13	-0.12	0.18

X axis linearity 0.13 dB
Y axis linearity 0.17 dB
Z axis linearity 0.17 dB



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Determining the Recalibration Due Date

Determinazione della data di ricalibrazione

The Certificate of Calibration accompanying this product states the date that this unit was calibrated according to Narda Safety Test Solutions procedures. We have determined that the calibration of this product is not affected by storage prior to its initial receipt by the customer.
The recalibration of this unit should be based on the date when the product is put into service, plus the recommended calibration interval.

The Narda Safety Test Solutions recommended calibration interval is 24 months. To determine the date for recalibration, the customer should use the appropriate start date, and apply either the Narda Safety Test Solutions calibration interval, or an interval that satisfies their own organization's internal quality system requirements.

Il certificato di taratura che accompagna questo strumento attesta la data di taratura, quest'ultima eseguita in accordo alle procedure interne. La Narda Safety Test Solutions assicura che la taratura dello strumento non viene alterata da eventuali tempi di attesa prima del ricevimento da parte del cliente.
La ri-taratura di questo strumento dovrebbe essere effettuata adottando appropriati intervalli di taratura, a partire dalla data di messa in servizio.

La Narda Safety Test Solutions raccomanda un massimo intervallo di taratura di 24 mesi. Per determinare la data di ri-taratura, l'utente dovrebbe considerare l'intervallo raccomandato dalla Narda Safety Test Solutions o un intervallo che soddisfa i requisiti interni di qualità della propria organizzazione.

Model *Modello*	EHP 50 D
Serial Number *Matricola*	000WX10510
Put into service date *Data di messa in servizio*	05/15/2012

For additional information please contact
Per informazioni aggiuntive

Narda S.T.S. Calibration Laboratory
Via Benessea, 29/B
17035 Cisano sul Neva (SV) - Italy
Tel.: +39 0182 58641 Fax: +39 0182 586400

Appendix E

Calibration Certificate for the Comparison SRM-3006 Probe/Antenna

Appendix E

Narda Safety Test Solutions GmbH
Sandwiesenstrasse 7 - 72793 Pfullingen - Germany
Phone: +49 7121 9732 0 - Fax: +49 7121 9732 790

narda
Safety Test Solutions

Calibration Certificate

Narda Safety Test Solutions hereby certifies that the object referred to in this certificate has been calibrated by qualified personnel using Narda's approved procedures. The calibration was carried out in accordance with a certified quality management system which conforms to ISO 9001

OBJECT	Three-Axis-Antenna, E-Field, 50 MHz to 3 GHz
MANUFACTURER	Narda Safety Test Solutions GmbH
PART NUMBER (P/N)	P/N 3501/02
SERIAL NUMBER (S/N)	H-0368
CUSTOMER	
CALIBRATION DATE	27-Okt-2011
RESULT ASSESSMENT	within specifications
AMBIENT CONDITIONS	Temperature: (23 ± 3) °C Relative humidity: (20 to 60) %
CALIBRATION PROCEDURE	3000-8702-00A

ISSUE DATE 2011-10-27

MANAGEMENT SYSTEM

CALIBRATED BY
Kretschmann

AUTHORIZED SIGNATORY

Certified by DQS against ISO 9001:2008 (Reg.-No. 000379 QM08)

This calibration certificate may not be reproduced other than in full except with the permission of the issuing laboratory. Calibration certificates without signature are not valid.

Appendix F

Integration of RF Spectra Acquired on the SRM-3006

Appendix F

SRM-3006 Spectrum Signal Integration

The SRM-3006 Selective Radiation Meter is a fast Fourier transform (FFT) type of analyzer. Rather than using traditional analog frequency sweeping technology in which the instrument tunes from a lower frequency to a higher frequency, the SRM samples the RF signal provided to it from the associated probe/antenna subsystem for a short period of time using an ultra-fast analog to digital converter. Upon Fourier transform of the time series data, this process produces a data set of signal amplitudes at frequencies distributed uniformly through the desired analysis band. The number of such frequencies (bins) depends on the overall frequency span and the resolution bandwidth (RBW) of the analyzer. The power associated with a given signal detected by the instrument can be determined through an integration process in which the powers found within all of the frequency bins over the selected frequency range are, effectively, summed.

This integration process, which can be implemented via firmware within the SRM, can also be accomplished manually by processing each stored amplitude value corresponding to a frequency bin. This approach was taken for integrating the composite (equivalent) RF field represented by multiple signals detected in the various frequency bands during the project for environmental measurements in Vermont.

Based on information provided by Narda, the integrated spectral RF field, $F_{integrated}$, derived from the measured spectral amplitude components, F_i, is obtained through the expression:

$$F_{integrated} = M_B \sum_i F_i$$

where M_B are multiplicative factors that depend on the specific frequency span and RBW setting for a given band. For the various settings used with the SRM for different frequency bands, the multiplicative factor values are listed in Table F-1.

A spreadsheet macro was developed that applied this process to the measured spectral data obtained from the SRM; the stored digital data file within the SRM was downloaded to a computer and then inserted into the spreadsheet tool for integration. An important part of the process, however, was the implementation of a threshold to be used with each band's data below which integration did not take place. This feature eliminated the potential of adding in noise floor values to the integration process, thereby increasing the overall integrated value erroneously. The noise thresholds listed in Table F-1 were experimentally determined by observing the displayed spectrum of

detected RF fields across each band and selecting a value that would just slightly exceed the noise level for peak and average signal values.

Table F-1. Parameters used for band integration of the measured RF field spectral signals from the SRM including the multiplicative factors, M_B, and thresholds used for integration of spectra containing the peak values of RF fields (max threshold) and average values of fields (average threshold).

BAND	Multiplicative Factor	Max threshold	Average threshold
Low VHF	0.493680853	0.000003000	0.000000600
FM	0.493680885	0.000000500	0.000000100
High VHF	0.493680853	0.000000700	0.000000200
UHF	0.473933649	0.000000350	0.000000080
Cell	0.473933649	0.000001000	0.000000200

Glossary of Terms Used in this Report

AMI- Advanced metering infrastructure.

antenna- A device designed to efficiently convert conducted electrical energy into radiating electromagnetic waves in free space (or vice versa).

antenna pattern- Typically a graphical plot illustrating the directional nature of radiated fields produced by an antenna. The pattern also shows the directional nature of the antenna when used for receiving signals.

attenuation- The phenomenon by which the amplitude of an RF signal is reduced as it moves from one point in a system to another. It is often given in decibels.

averaging Time (T_{avg})- The appropriate time period over which exposure is averaged for purposes of determining compliance with the maximum permissible exposure (MPE). For exposure durations less than the averaging time, the maximum permissible exposure, MPE', in any time interval, is found from:

$$MPE' = MPE\left(\frac{T_{avg}}{T_{exp}}\right)$$

where T_{exp} is the exposure duration in that interval expressed in the same units as T_{avg}. T_{exp} is limited by restriction on peak power density.

azimuth pattern- Commonly a term referring to an antenna pattern showing the distribution of radiated field from the antenna in the azimuth plane (horizontal plane).

bandwidth- A measure of the frequency range occupied by an electromagnetic signal. It is equal to the difference between the upper frequency and the lower frequency, usually expressed in Hertz.

burst- A wave or waveform composed of a pulse train (group of pulses) or repetitive waveform that starts at a prescribed time and/or amplitude, continues for a relatively short duration and/or number of cycles, and upon completion returns to the starting amplitude.

calibration correction factor- A numerical factor obtained through a calibration process that is used to multiply RF field meter readings by to obtain corrected readings to achieve the maximum accuracy possible.

Glossary

continuous exposure- Exposure for durations exceeding the corresponding averaging time (usually 6 minutes for occupational exposure and 30 minutes for the general public). Exposure for less than the averaging time is called short-term exposure.

dBi- Decibel referenced to an isotropic antenna- a theoretical antenna which transmits (or receives) electromagnetic energy uniformly in all directions (i.e. there is no preferential direction).

dBm- A logarithmic expression for radiofrequency power where 0 dBm is defined as equal to 1 milliwatt (mW). Hence, +10 dBm is 10 mW, +20 dBm is 100 mW, etc., and -10 dBm is 0.1 mW.

decibel (dB)- A dimensionless quantity used to logarithmically compare some value to a reference level. For power levels (watts or watts/m^2), it would be ten times the logarithm (to the base ten) of the given power level divided by a reference power level. For quantities like volts or volts per meter, a decibel is twenty times the logarithm (to the base ten) of the ratio of a level to a reference level.

direct sequence- As used in direct sequence spread spectrum radio transmission, a modulation technique wherein the resulting transmitted bandwidth of a signal is spread over a much wider band and resembles white noise.

duty cycle- A measurement of the percentage or fraction of time that an RF field exists over some observation period.

effective isotropic radiated power (EIRP)- The apparent transmitted power from an isotropic antenna (i.e. a theoretical antenna that transmits uniformly in all possible directions as an expanding sphere). The EIRP can be greater than the actual power radiated because of the ability of the antenna to concentrate the transmitted power in certain directions. See gain.

electric field strength- A field vector (E) describing the force that electrical charges have on other electrical charges, often related to voltage differences, measured in volts per meter (V/m).

electromagnetic field- A composition of both an electric field and a magnetic field that are related in a fixed way that can convey electromagnetic energy. Antennas produce electromagnetic fields when they are used to transmit signals.

electromagnetic spectrum- The range of frequencies associated with electromagnetic fields. The spectrum ranges from extremely low frequencies beginning at zero hertz to the highest frequencies corresponding to cosmic radiation from space.

elevation pattern- Commonly a term referring to an antenna pattern showing the distribution of radiated field from the antenna in the elevation plane (vertical plane).

end point meter- A term used to designate a smart meter that is installed on a home or business to record and transmit electric energy.

exposure- Exposure occurs whenever a person is subjected to electric, magnetic or electromagnetic fields or to contact currents other than those originating from physiological processes in the body and other natural phenomena.

far field- The far field is a term used to denote the region far from an antenna compared to the wavelength corresponding to the frequency of operation. It is a distance from an antenna beyond which the transmitted power densities decrease inversely with the square of the distance.

Federal Communications Commission (FCC)- The Federal Communications Commission (FCC) is an independent agency of the US Federal Government and is directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. The FCC also allocates bands of frequencies for non-government communications services (the NTIA allocates government frequencies). The guidelines for human exposure to radio frequency electromagnetic fields as set by the FCC are contained in the Office of Engineering and Technology (OET) Bulletin 65, Edition 97-01 (August 1997). Additional information is contained in OET Bulletin 65 Supplement A (radio and television broadcast stations), Supplement B (amateur radio stations), and Supplement C (mobile and portable devices).

FFT- Fast Fourier Transform, a mathematical method for transforming data acquired in the time domain into the frequency domain. Some modern spectrum analyzers use high speed analog to digital converters (ADCs) to sample an input signal in the time domain and electronically implement the FFT to calculate and display the frequency spectrum of the sampled signal(s).

free space- A term used to denote an environment free of objects that can reflect, scatter or absorb RF energy. Anechoic chambers can provide free space environments that eliminate most reflections when testing antennas.

frequency hopping- A term describing the transmission frequency of a spread spectrum transmitter or transceiver that jumps (hops) instantaneously to different frequencies within a certain band of frequencies.

gain, antenna- A measure of the ability of an antenna to concentrate the power delivered to it from a transmitter into a directional beam of energy. A search light

exhibits a large gain since it can concentrate light energy into a very narrow beam while not radiating very much light in other directions. It is common for cellular antennas to exhibit gains of 10 dB or more in the elevation plane, i.e., concentrate the power delivered to the antenna from the transmitter by a factor of 10 times in the direction of the main beam giving rise to an effective radiated power greater than the actual transmitter output power. In other directions, for example, behind the antenna, the antenna will greatly decrease the emitted signals. Gain is often referenced to an isotropic antenna (given as dBi) where the isotropic antenna has unity gain (unity gain is equivalent to 0 dBi). At regions out of the main beam of an antenna, such as behind the antenna in a smart meter, the gain of the antenna may be so small that it is less than that of an isotropic antenna and has a gain specified as a negative dBi.

gigahertz (GHz)- One billion hertz.

ground reflection factor- A factor commonly used in calculations of RF field power densities that expresses the power reflection coefficient of the ground over which the RF field is being computed. The purpose of the factor is to account for the fact that ground reflected RF fields can add constructively in an enhanced (stronger) resultant RF field. The ground reflection factor becomes significantly less important for near-field exposures very close to an RF source, such as a smart meter.

HAN- See home area network

hertz- The unit for expressing frequency, one hertz (Hz) equals one cycle per second.

Home Area Network- A term that refers to residential local area network for communication between digital devices typically deployed in the home, commonly implemented by way of a ZigBee radio.

IEEE- Institute of Electrical and Electronics Engineers.

inverted F antenna- The name given to an antenna design typically implemented on printed circuit cards in which the conductive part of the antenna resembles an inverted letter F. The antenna is typically approximately a quarter wavelength long and is fed from the attached transmitter near the end of the antenna that has a short conductive lead that extends from the longer part of the 'F' to the ground plane of the circuit. The antenna is vertically polarized when the long aspect of the 'F' is horizontal.

isotropic antenna- A theoretical antenna which transmits (or receives) electromagnetic energy uniformly in all directions (i.e. there is no preferential direction). The radiated wavefront is assumed to be an expanding sphere.

isotropic probe- Similar to isotropic antenna but normally related to RF measurement instruments designed to evaluate the magnitude of RF fields from a safety perspective. The isotopic character of the probe results in a measurement of the resultant RF field produced by all polarization components.

"license free"- A phrase meaning that an RF transmitter is operated at such low power and within an authorized frequency band that no formal license to operate is required by the FCC. There are restrictions placed on these devices, however, such as they shall not produce interference and/or may not create RF fields exceeding particular field strengths.

lobe, antenna- The name given to regions of an antenna transmitting pattern in which local maxima of the radiated field exist. See main lobe.

local oscillator zero feed through- A characteristic of mixer circuits, typically used in spectrum analyzers, wherein the local oscillator signal is coupled into the intermediate frequency (IF) path due to its limited isolation. As an example, if very low frequency input signals are converted by the mixer, the first IF can be very nearly zero Hz and with relatively large resolution bandwidth, the local oscillator signal is sent to the detector and displayed at zero Hz. This is an extraneous signal that is not related to the actual amplitude of the very low frequency input signal.

Main beam- see main lobe.

main lobe- A region of the transmitting pattern of an antenna in which the greatest intensity exists, also called the main beam of the antenna.

max hold spectrum- A feature often present on instruments such as spectrum analyzers in which the instantaneous peak values of measured signals are captured and continuously displayed so that, over time, the absolute maximum signal values can be determined even if they were only present for a short period.

maximum permissible exposure (MPE)- The rms and peak electric and magnetic field strength, their squares, or the plane wave equivalent power densities associated with these fields and the induced and contact currents to which a person may be exposed without harmful effect and with an acceptable safety factor.

megahertz (MHz)- One million hertz.

mesh network- A term describing a network, typically wireless, in which multiple nodes communicate among themselves and data can be relayed via various nodes to some access point. Mesh networks are self healing in that should a particular pathway become nonfunctional for some reason, alternative paths are automatically configured

to carry the data. Mesh networks can expand beyond the normal range of any single node (smart meter) by relaying of data among the different meters.

microwatts- One-millionth of a watt, a microwatt (μW) or 10^{-6} watts.

modulation- Refers to the variation of either the frequency or amplitude of an electromagnetic field for purposes of conveying information such as voice, data or video programming.

near field- A region very near antennas in which the relationship between the electric and magnetic fields is complex and not fixed as in the far field, and in which the power density does not necessarily decrease inversely with the square of the distance. This region is sometimes defined as closer than about one-sixth of the wavelength. In the near field region the electric and magnetic fields can be determined, independently of each other, from the free-charge distribution and the free-current distribution respectively. The spatial variability of the near field can be large. The near field predominately contains reactive energy that enters space but returns to the antenna (this is different from energy that is radiated away from the antenna and propagates through space).

nearfield coupling- A phenomenon that can occur when an RF measurement probe is placed within the reactive near field of an RF source such that the probe interacts strongly with the source in a way that typically draws power from the source than would not occur at greater distances. When nearfield coupling occurs, field probe readings are typically erroneously greater than the actual RF field magnitude. For this reason, an IEEE measurement standard (C95.3) recommends a minimum spacing between source and sensor of 20 cm.

planar scan- In the context of this study, a spatial scan over a plane in front of a smart meter or a group of smart meters at a fixed distance from the smart meters.

plane wave- Wave with parallel planar (flat) surfaces of constant phase (See also Spherical wave). Note: The cover of this report shows an idealized spherical wave that expands outward- in an appropriate region that this spherical wave can be considered as a plane (flat) wave.

polarization- The orientation of the electric field component of an electromagnetic field relative to the earth's surface. Vertical polarization refers to the condition in which the electric field component is vertical, or perpendicular, with respect to the ground, horizontal polarization refers to the condition in which the electric field component is parallel to the ground.

power density- Power density (S, sometimes called the Poynting vector) is the power per unit area normal to the direction of propagation, usually expressed in units of watts per square meter (W/m^2) or, for convenience, milliwatts per square centimeter (mw/cm^2) or microwatts per square centimeter ($\mu w/cm^2$). For plane waves, power density, electric field strength, E, and magnetic field strength, H. are related by the impedance of free space, i.e. 120π (377) ohms. In particular, $S = E^2/120\pi = 120\pi H^2$ (Where E and H are expressed in units of V/m and A/m, respectively, S is in units of $W/m^{2)}$. Although many RF survey instruments indicate power density units, the actual quantities measured are E or E^2 or H or H^2.

pulse- A brief presence of an RF signal (field).

radiation pattern- A description of the spatial distribution of RF energy emitted from an antenna sometimes referred to as transmitting pattern. Two radiation patterns are required to completely describe the transmitting performance of an antenna, one for the azimuth plane and another for the elevation plane.

radio- A term used loosely to describe a radio transmitter or transceiver.

radio frequency (RF)- Although the RF spectrum is formally defined in terms of frequency as extending from 0 to 3000 GHz, the frequency range of interest is 3 kHz to 300 GHz.

radio spectrum- The portion of the electromagnetic spectrum with wavelengths above the infrared region in which coherent waves can be generated and modulated to convey information- generally about 3 kHz to 300 GHz.

RBW- see resolution bandwidth.

reflection- An electromagnetic wave (the "reflected" wave) caused by a change in the electrical properties of the environment in which an "incident" wave is propagating. This wave usually travels in a different direction than the incident wave. Generally, the larger and more abrupt the change in the electrical properties of the environment, the larger the reflected wave

resolution bandwidth- A specification for spectrum analyzers that denotes the ability of the analyzer to identify two signals on different frequencies, a measure of the frequency selectivity of the analyzer.

resultant field- The combined result of all polarization components of an electromagnetic field found by determining the sum of three orthogonal components of power density or the root sum squared of three orthogonal components of electric or magnetic field strength.

Glossary

RF - Radiofrequency.

RF LAN- A term representing a local area network formed by wireless nodes. In the case of smart meters, the 900 MHz band radios communicate with one another forming an RF LAN.

root-mean-square (RMS)- The effective value of, or the value associated with joule heating, of a periodic electromagnetic wave, current or voltage. The RMS value of a wave is obtained by taking the square root of the mean of the squared value of the wave amplitude.

shielding effectiveness- A measure of the ability of a material or structure to attenuate RF fields, typically specified in decibels.

spatial average- For RF exposure limits, a determination of the average value of power density over the projected cross section area of the body. In practice, an average along a vertical line representing the height of a person.

specific absorption rate (SAR)- The time derivative of the incremental energy absorbed by (dissipated in) an incremental mass contained in a volume) of a given density. SAR is expressed in units of watts per kilogram (W/kg) or milliwatts per gram (mW/g). Guidelines for human exposure to radio frequency fields are based on SAR thresholds where adverse biological effects may occur. When the human body is exposed to a radio frequency field, the SAR experienced is proportional to the squared value of the electric field strength induced in the body. Compliance with RF exposure limits for devices that are intended to be placed, in normal use, closer than 20 cm of the body surface, are evaluated by a direct measurement of the local SAR within the body at the point of maximum exposure. In the case of cell phones, this is usually at the side of the head and is accomplished through the use of a phantom model that simulates the size and shape of the human body and contains a liquid that has electrical properties comparable to human body tissues.

spectrum analyzer- An electronic instrument, similar to a receiver, that sweeps across a part of the RF spectrum and displays detected signals as peaks on a visual display screen. Spectrum analyzers normally continuously sweep repetitively over a given frequency band at a relatively high rate thereby allowing for the observation of intermittent signals.

spread spectrum- Refers to a method by which an RF signal that is generated in a particular bandwidth is deliberately spread in the frequency domain resulting in a signal with a wider bandwidth. Such a technique is used to enhance secure communications, to reduce interference and to prevent detection.

sweep time- In an oscilloscope or spectrum analyzer, the time spent to sweep across either the time or frequency axis in the measurement of signals. Typically, the amount of time it takes to perform a defined measurement before starting the next measurement. Commonly, the instrument is set to continuously and repetitively update the measurement according to its sweep time.

switch mode power supply (SMPS)- A power supply design that incorporates solid state switching elements that significantly increase power conversion efficiency when converting AC to DC. In an SMPS, the input line voltage is typically rectified and applied to the switching element in the supply that chops or switches the DC current at a high frequency. This process, which effectively increases the frequency of input voltage of the supply, results in much smaller component sizes needed for a transformer and associated capacitors for filtering of the output DC voltage. Typically, a feedback signal from the SMPS output is also used to generate a pulse width modulated signal for regulating the supply output voltage.

time-averaged exposure- In the context of RF exposure limits, an average of the exposure value over a specified time period. Commonly, for occupational exposures, the averaging time is six-minutes and for members of the general public 30-minutes. All scientifically based RF exposure limits are in terms of time-averaged values.

time resolution- In a display of signal amplitude vs. time, the incremental time interval (window) within which an instrument samples the instantaneous peak and average values of signals prior to display. The smaller the time resolution, the better the instrument can indicate the time at which signals occurred. Larger time resolutions do not mean that the instrument necessarily does not detect narrow signal pulses, only that it may not indicate the exact time of occurrence during the time resolution window.

transceiver- A radio device that has both transmitting and receiving capability. Strictly, the radio devices in Smart Meters are transceivers since they can both transmit data and receive data. Commonly, in the context of evaluating RF fields, the term transmitter or radio is used to refer to the transmitting feature of the transceiver.

ZigBee radio- A radio transceiver inside some smart meters that allows communications with an in-home-device (IHD) for displaying electric energy consumption data. The radio operates in the 2.4-2.5 GHz license free band often used by wireless routers, some cordless telephones and other devices and can be used in a home area network (HAN). The term ZigBee refers to a set of high level digital communication protocols based on an IEEE 802 standard for personal area networks.

ATTACHMENT F -

EPRI COMMENTS

EMF AND RF HEALTH ASSESSMENT AND SAFETY

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

EPRI Comments: A Perspective on Two Smart Meter Memoranda

EMF and RF Health Assessment and Safety

Introduction

In January 2012, two separate memoranda – one from the Santa Cruz (CA) County Health Officer[1] and another from the American Academy of Environmental Medicine (AAEM)[2] – were issued indicating views that the radio-frequency (RF) electromagnetic fields emitted from smart meters pose a health risk. The purpose of these EPRI Comments is to offer additional perspectives on the issues raised in these two memoranda.

The two memoranda assert that the Federal Communications Commission (FCC) rule issued in 1997 (see FCC OET Bulletin 65[3] and Code of Federal Regulations 47 CFR § 1.1310) that sets enforceable limits on human RF exposure is protective of only adverse thermal effects, and does not address non-thermal effects. Neither the Santa Cruz nor the AAEM documents took into account the vast wealth of research on RF conducted over nearly half a century, as well as the "weight-of-evidence" approach taken by any number of expert groups and panels convened over the years to evaluate the RF health science literature.

Background

By way of historical perspective, the 1997 FCC rule was adopted from two previous guidelines, one published by the National Council on Radiation Protection and Measurements (NCRP Report No. 86) in 1986, and the other by the Institute for Electrical and Electronic Engineers (IEEE C95.1) in 1991. Both had extensively reviewed the biological and health literature, regardless of whether or not the research had been conducted at non-thermal levels of exposure. NCRP and IEEE both concluded that the only established effects were associated with tissue heating, and that there were no confirmed adverse effects from RF exposure levels below an exposure threshold associated with an elevation in body temperature of about 1 degree centigrade (1.8 degrees Fahrenheit).

Prior to its publication, the FCC rule received endorsements from the U.S. Environmental Protection Agency (EPA), the U.S. Food and Drug Administration (FDA), and the U.S. Occupational Safety and Health Administration (OSHA). The EPA reaffirmed its opinion in letters written in 1999 and 2002. The expanding body of scientific evidence concerning potential health effects from RF exposure has been re-visited since the FCC rulemaking, but the basic conclusions have remained consistent with the position taken by the FCC in 1997. The International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998 reaffirmed in 2009) and the IEEE (2005) published exposure limits very similar to the FCC's following a comprehensive review of the scientific literature.

References to reviews and comments about RF health by a variety of scientific and governmental institutions are included at the end of this commentary. They reflect a consensus that adverse effects from RF exposure have not been established below the thresholds that serve as the basis for published exposure limits.

Concerns about RF exposures received significant visibility in Spring 2011 when the International Agency for Research on Cancer (IARC) released the results of its expert panel's evaluation of potential cancer risks from radiofrequency exposures.[4] Based on "limited"[5] epidemiologic evidence in studies of cell phones and "limited"[6] evidence from a small

[1] http://sccounty01.co.santa-cruz.ca.us/bds/Govstream/BDSvData/non_legacy/agendas/2012/20120124/PDF/041.pdf

[2] http://aaemonline.org/images/CaliforniaPublicUtilitiesCommission.pdf

[3] http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf

[4] http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf

[5] "A positive association has been observed between exposure to the agent and cancer for which a causal interpretation is considered by the Working Group to be credible, but chance, bias or confounding could not be ruled out with reasonable confidence." (from: IARC)

[6] "The data suggest a carcinogenic effect but are limited for making a definitive evaluation because, e.g. (a) the evidence of carcinogenicity is restricted to a single experiment; (b) there are unresolved questions regarding the adequacy of the design, conduct or interpretation of the studies; (c) the agent increases the incidence only of benign neoplasms or lesions of uncertain neoplastic potential; or (d) the evidence of carcinogenicity is

fraction of all reported animal experiments, IARC classified radiofrequency electromagnetic fields as a "possible" or a Group 2B carcinogen. The hierarchy of IARC categories consists of: Group 1, Carcinogenic to humans (i.e., sufficient evidence); Group 2A, Probably carcinogenic (less than sufficient evidence); Group 2B, Possibly carcinogenic (limited evidence, less supportive evidence than 2A); and Group 3, Not classifiable (inadequate and/or insufficient evidence for classification).[7] With reference to Group 2, IARC states,

> The terms probably carcinogenic and possibly carcinogenic have no quantitative significance and are used simply as descriptors of different levels of evidence of human carcinogenicity, with probably carcinogenic signifying a higher level of evidence than possibly carcinogenic.

Thus, the IARC 2B classification provides for a range of qualitative interpretations concerning potential carcinogenicity of radiofrequency electromagnetic fields. This classification carries an indication that more research information would be required for a more definitive statement in either direction, but as of the present the weight of evidence does not provide a basis for concluding that RF can be considered even "probably" carcinogenic. IARC is a part of the World Health Organization (WHO), which is planning in the near term to evaluate the potential effects of RF on all health endpoints, including cancer.

In light of the scientific uncertainties with respect to cancer and all other potential health effects from RF fields, similar to those emitted by smart meters and other technologies, the Electric Power Research Institute (EPRI) held two workshops in 2011. The first of these was designed to more specifically identify emerging technologies within the electric utility industry whose operation would result in electromagnetic field emissions. Such emissions may occur by design for communication purposes or may be a by-product of a technology, such as emissions from appliances powered with variable speed drives. The second workshop was a meeting of internationally-convened health scientists to review the state of knowledge with respect to potential health effects of RF. The workshop covered all aspects of RF science including epidemiology, exposure assessment, laboratory studies (humans and animals), and biophysical mechanisms. A report describing both workshops is available to the public.[8]

Specific Comments

The AAEM includes the statement that "the US NIEHS National Toxicology Program in 1999 cited radiofrequency radiation as a potential carcinogen." In 1999, RF was nominated to the National Toxicology Program (NTP) by the FDA's Center for Devices and Radiological Health (CDRH) as an exposure to be tested in a long-term cancer study in animals, an experiment that's termed a bioassay. The CDRH did not offer a conclusion regarding RF carcinogenicity, and a nomination is based on many factors that include scientific uncertainty among other considerations. The nomination's executive summary concluded, "[t]here is currently insufficient scientific basis for concluding either that wireless communication technologies are safe or that they pose a risk to millions of users. A significant research effort, involving large well-planned animal experiments is needed to provide the basis to assess the risk to human health of wireless communications devices." After a delay of several years, the experiment is presently in progress with results expected in the 2014 time frame.

The AAEM also stated that "[e]xisting safety limits for pulsed RF were termed 'not protective of public health' by the Radiofrequency Interagency Working Group [RFIAWG] (a federal interagency working group including the FDA, FCC, OSHA, the EPA and others)". On a formal basis the agencies named had endorsed the FCC rule (see above). However, the RFIAWG's purpose was to raise critical issues with respect to RF exposure limits. The group transmitted a list of 14 questions to the chair of the IEEE Risk Assessment Work Group in June 1999, with the qualification that, "[t]he views expressed in this correspondence are those of the members of the Radiofrequency Interagency Work Group and do not represent the official policy or position of the respective agencies." The exact quote from the AAEM memorandum could not be found or verified, but one of the group's questions concerned pulsed fields (and may have formed the basis for the AAEM statement), as follows:

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restricted to studies that demonstrate only promoting activity in a narrow range of tissues or organs." (from: IARC)

[7] The parenthetical descriptions are encapsulated thumbnails for quick reference only. The full IARC methodology is at http://monographs.iarc.fr/ENG/Preamble/CurrentPreamble.pdf

[8] Visit http://www.epri.com and type "1024737" in the search box to retrieve the workshop summary.

> These studies have resulted in concern that exposure guidelines based on thermal effects, and using information and concepts (time-averaged dosimetry, uncertainty factors) that mask any differences between intensity-modulated RF radiation exposure and CW [continuous wave] exposure, do not directly address public exposures, and therefore *may not adequately protect the public*." (emphasis added)

The IEEE Work Group transmitted a response to all of the RFIAWG's questions and with reference to pulsed fields stated,

> There are no reliable studies that provide convincing evidence of adverse, nonthermal effects, occurring at exposure levels below the current guidelines. To be convincing and reliable, claims of adverse, non-thermal effects must be repeatable by other capable and interested laboratories. Potentially significant in vitro studies demonstrating low level RF induced effects have not been substantiated, and either found upon review after publication to have technical problems, and/or are overwhelmed by a body of evidence which demonstrates a consistent absence of the initial reported effect.

Thus, the RFIAWG was not asserting that the FCC's limits were not protective, but was asking the IEEE Work Group to give its questions serious consideration (which it did).

The transmittal from the Santa Cruz County health officer reflected a misunderstanding of several terms and concepts, including some of the basic principles of how smart meters work. For example, the piece identified sunlight as a source of extremely-low-frequency (ELF) electromagnetic fields. In fact, sun's emissions span the spectrum from ultra-violet to infrared. The frequencies of the sun's emissions are at least 12 orders of magnitude (a thousand billion) times greater than the power frequency, which is 60 Hz and located within the ELF range. As another example, the author identifies x- and gamma-rays as "extremely high frequency," or EHF, which is a label reserved for the frequency band from 30 gigahertz (GHz) to 300 GHz. A GHz is a thousand million Hz and the EHF band is a part of the spectrum that is "non-ionizing," in other words, EHF exposure (unlike x- and gamma-rays) does not directly damage genes. Emissions from smart meters are at frequencies ten or more times lower than EHF, and therefore, also do not directly break molecules (such as DNA) or damage genes.

With respect to smart meter operation, the Santa Cruz memorandum stated,

> It has been aptly demonstrated by computer modeling and real measurement of existing meters that SmartMeters emit frequencies almost continuously, day and night, seven days a week. Furthermore, it is not possible to program them to not operate at 100% of a duty cycle (continuously) and therefore it should not be possible to state that SmartMeters do not exceed the time-averaged exposure limit.

In fact, smart meters transmit for a very small fraction of the time (the fraction of time transmitting is called the duty cycle), usually 1% or much less, with a handful of exceptions that are higher. For example, a recent analysis of data from 88,296 meters in the Pacific Gas and Electric service territory reported that 0.2% of the meters transmitted for 1% or more of the time (EPRI Technical Report 1021829). The results were similar in a study of the Southern California Edison and San Diego Gas and Electric service territories in which, respectively, 0.1% and 0.0% of meters sampled had duty cycles greater than 1% (EPRI Technical Report 1021126).

Though we live in a digital age with a proliferation of wireless technologies, exposure to RF has been ever present indoors and outdoors since the 1920s with the advent of the AM radio broadcast industry (~1 MHz), the 1930s with the introduction of FM radio (~100 MHz), and the 1940s and 1950s with, respectively, the great expansion of VHF TV (~50 to 200 MHz) and UHF TV (~400 to 900 MHz). The range of exposure levels from these broadcast technologies is not much different from those in the near vicinity (~10 feet) of smart meters (see EPRI White Paper, 1022270). The exposure levels from smart meters are very small because they transmit at power levels no greater than about 1 watt, about the same power used by a small flashlight bulb. Although they transmit in all directions, the research to date indicates that the exposure levels are relatively lower behind the meter than in front (EPRI Technical Reports 1021829 and 1021126), a factor that becomes relevant to concerns about exposure in a room directly behind the meter.

Finally, the Santa Cruz memo refers to the following point apparently sourced from another article,

> ...most research carried out by independent non-government or non-industry affiliated researchers suggests potentially serious effects from many non-ionizing radiation exposures [, and] research funded by industry and some governments seems to cast doubt on the potential for harm.

With regard to this statement two points are appropriate to mention. First, the gold standard for including a piece of research in a formal risk evaluation is whether it has been published in the peer-reviewed literature, not who the source of funding happened to be. Second, government institutions and industry have a responsibility to address environmental health issues that may touch either or both the general public or occupational groups. One could justifiably point to a lack of support from public institutions or industry as an abrogation of their responsibility to the common good. The Santa Cruz memo refers to a very limited segment of published research instead of citing the *full record of published science that forms the basis for* formal risk assessments.

Conclusion

In conclusion, smart meters offer consumers the means with which to economically optimize and plan their use of electricity, while providing the electric utility the information to more efficiently operate the system, pinpointing issues with local service in real time. Smart meters deployed in California and many other states across the U.S. communicate wirelessly, meaning that they both receive and emit RF electromagnetic fields. The smart meters studied in California operate at a power of 1 watt or less, producing fields that are very small compared to the exposure limits published by the FCC, ICNIRP and IEEE, even at very close distances to the meter face. The data collected to date indicate that, with very few exceptions, the meters transmit with a duty cycle of one percent or less (about 14 minutes or less per day). For purposes of assessing compliance, the measured field is multiplied by the duty cycle to derive an average exposure level, which would usually lower the total exposure value by a hundred-fold or more. The exposure limits published by the FCC, ICNIRP and IEEE were the product of careful and thorough evaluations of the scientific literature at all levels of exposure (above and below thermal thresholds). All of these limits are based on a consensus that there is no evidence for adverse effects of RF exposure below the level documented in laboratory experiments that caused tissue heating accompanied by behavioral disruption. To remain conservative, the three organizations added safety factors of 10 to the behavioral threshold for occupational groups (i.e., trained personnel), and 50 for the general public. On the basis largely of studies addressing RF exposures from cellular telephones, IARC classified RF electromagnetic fields a "possible" (Group 2B) carcinogen, meaning the existing research information is "limited" leaving uncertainties that further study could lessen. However, the designation fell below the threshold for IARC to conclude that RF is "probably" carcinogenic (Group 2A). For 30-plus years, the Electric Power Research Institute has taken an active role in characterizing electromagnetic environments associated with power frequency transmission and distribution systems, and more recently with RF from smart meters. The results of these recent RF investigations have been shared with the regulatory/policy and industry communities as well as with the general public in the interest of fostering a common understanding of these environments.

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ATTACHMENT G -

EPRI COMMENT

SAGE REPORT ON RF EXPOSURES

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

EPRI Comment: Sage Report on Radio-Frequency (RF) Exposures from Smart Meters

Electric Power Research Institute (EPRI)

Summary

A report by Sage Associates dated January 1, 2011 and entitled, "Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters" was posted on the internet. The "Sage Report" uses various approaches to characterize radio-frequency (RF) field levels and to compare them to the exposure limits published by the Federal Communications Commission (FCC) in FCC OET Bulletin 65, Edition 97-01, dated August 1997. The report concludes that, "FCC compliance violations are likely to occur under normal conditions of installation and operation of smart meters and collector meters in California." The report also compares field levels from smart meters to those from studies reporting biological and health effects. However, the research findings referred to in the Sage Report have not been replicated or are inconsistent with the results of other studies. Furthermore, virtually every recent mainstream expert scientific review of the RF health literature conducted in North America and Europe has not recognized the effects cited by the Sage Report as confirmed or definitive. This commentary deals with the engineering and source characterization aspects of the Sage Report.

The Sage Report misapplies the specifications in the FCC rule as follows:

Time averaging exposure: Exposures from smart meters may be time-averaged according to the FCC statement in OET Bulletin 65 that, "'source-based' time-averaging based on an inherent property or duty-cycle of a device is allowed." Clearly, smart meters fall into the "source-based" category of emitters. An extensive analysis of smart meter transmissions for almost 47,000 units in southern California was conducted for EPRI ("An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter" EPRI Report 1021126 December 2010; available to the public at www.epri.com). The report estimated that 99.5% of the sample was operating at a duty cycle of about 0.22% or less, a value that translates to 3 minutes and 10 seconds of transmitting over a day; the maximum duty cycle in any residence did not exceed 5%. The duty cycle for cell relays (referred to as "collectors" in the Sage Report) within the same sample did not exceed 1%. The Sage Report defaults to compute exposures based on a 100% duty cycle, thus over-estimating exposure in the sample cited above by no less than 20-fold and more typically more than 400-fold.

Spatial averaging of exposure: The FCC states that to characterize a person's exposure properly, the RF power density should be averaged across the entire volume of an exposed body. An example in the EPRI Report indicates that power density averaged over the body of a 6-foot person situated one foot in front of a meter is less than approximately one-quarter of the emission at the point of the wavefront's peak at that distance. The Sage Report assumes a uniform field across the body that is equal to the peak power density within a body's cross-section, thus overestimating an individual's exposure.

Reflections: Radio frequencies "bounce" or reflect off of surfaces exactly the way light is reflected off the surface of a mirror. The level of a reflected wave that is present at any point is expressed as a percent of the electric field of the incident wave, which is the free-space wave in the absence of any reflection. The power density at that point is the incident power density multiplied by $[1+(\text{percent of reflection}/100)]^2$. The FCC's worst-case scenario is a 100% reflection (4-fold increase in power density), with a less conservative though more realistic value of 60% (2.56-fold increase in power density) used in many cases as an upper bound (*e.g., see* EPRI White Paper 1020798, "A Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading Technology"). A key element to factoring reflections into an exposure calculation is that, for RF emitters like smart meters in real-world residential environments, the percent reflection diminishes as one approaches the meter. Thus, at the distance at which incident power density is maximal, the contributions of reflections to total power density are minimal. The Sage Report assumes that incident power density is enhanced by reflections uniformly throughout the space surrounding the

meter. Furthermore, in adopting reflection values from one particular study (Hondou et al., 2006), it uses reflection factors that, in terms of power density, are between 30 and 110 times greater than the worst-case power density enhancement due to reflections identified by the FCC.

In addition, this commentary points out several other pertinent issues:

- The Sage report, in discussing exposure with relation to specific anatomic sites that include eyes and testes, referred to stipulations in an outdated 1999 IEEE standard. The current IEEE standard, published in 2005, with extensive documentation on the topic, removed any exceptions for such anatomic sites.
- In comparing field calculations to the FCC limits, the Sage Report did not frequency weight the contributions from the end-point meter (~900 MHz), the Home Area Network (HAN) antenna (~2,400 MHz) and the cell relay (~850 MHz). Because the FCC exposure limits are frequency dependent, a simple arithmetic addition of contributions from various sources is an inappropriate approach to compliance assessment.

Therefore, the Sage Report, for the reasons enumerated in this commentary, has over-estimated exposures from smart meters using assumptions and calculations that are inconsistent with the FCC's rule and that do not recognize the basic physical characteristics of RF emissions.

Section I: Background

A report by Sage Associates dated January 1, 2011 and entitled, "Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters" was posted on the internet; it will be referred to here as the Sage Report for short. The report's authorship was not specifically identified. The proprietor of Sage Associates, Ms. Cindy Sage, also coordinated the BioInitiative Working Group (BWG) report that was published in 2007. That report included chapters by about a dozen scientists known in the EMF research field. Ms. Sage and Dr. David Carpenter the report's other signatory concluded that health effects of various kinds result from low-level radio-frequency exposure, and:

> There may be no lower limit at which exposures do not affect us. Until we know if there is a lower limit below which bioeffects and adverse health impacts do not occur, it is unwise from a public health perspective to continue "business-as-usual" deploying new technologies that increase ELF [extremely-low-frequency] and RF exposures, particularly involuntary exposures.

The BWG report, which covered RF as emitted from various sources (cell phones, base stations) suggested that safety standards for RF exposures, as specified by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the U.S. Federal Communication Commission (**FCC**[1]), are not sufficiently conservative. EPRI's commentary (EPRI publication #1016233) on the BWG Report can be found at www.epri.com.

The recently issued Sage Report takes a two-fold approach. First, it uses a number of engineering assumptions to calculate presumed exposure levels from one or more smart meters with or with out a **cell relay** (referred to as "collectors" in the Sage Report) also present, and to then identify "violations" of FCC exposure limits for the general public. The Sage Report concludes that:

> FCC compliance violations are likely to occur under normal conditions of installation and operation of smart meters and collector meters in California. Violations of FCC safety limits for uncontrolled public access are identified at distances within 6" of the meter. Exposure to the face is possible at this distance, in violation of the time-weighted average safety limits. FCC violations are predicted to occur at 60% reflection (OET Equation 10 and 100% reflection (OET Equation 6) factors, both used in FCC OET 65 formulas for such calculations for time-weighted average limits. Peak power limits are not violated at the 6" distance (looking at the meter) but can be at 3" from the meter, if it is touched.

Secondly, it compares these exposure levels with those in selected studies that have reported biological or health effects resulting from RF exposures that are considered adverse. However, the research findings referred to in the Sage Report have not been replicated or are inconsistent with the results of other studies. Furthermore, virtually every recent mainstream expert scientific review of the RF health literature conducted in North America and Europe has not recognized the effects cited by the Sage Report as confirmed or definitive.

This commentary will not deal any further with the health aspect of the report, and will focus primarily on its technical assumptions, treatment of engineering factors, and source characterization. This commentary will also draw from

[1] Bolded terms are defined in the Glossary

measurement and modeling data published in an Electric Power Research Institute (**EPRI**) study of smart meters ("An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter" EPRI Report 1021126, December 2010; available to the public at www.epri.com). In the commentary that follows, Section II deals with the Sage Report's understanding of the FCC rule governing RF exposures. Section III comments on how the FCC formula for computing RF field levels was used in the Sage Report, and Section IV provides conclusions.

Section II: Sage Report's Interpretation of the FCC Rule Specifying Exposure Limits for Radio-Frequency Electromagnetic Fields

The Federal Communications Commission established limits for exposure to radio-frequency electromagnetic fields, which are published in FCC OET Bulletin 65 (August 1997), and codified in the Code of Federal Regulations (47 CFR § 1.1310). The FCC rule was adopted from two previous guidelines, one published by the National Council on Radiation Protection and Measurements (NCRP Report No. 86) in 1986, and the other by the Institute for Electrical and Electronic Engineers (IEEE C95.1 1991) in 1991. Both had extensively reviewed the biological and health literature, concluding that the only established effects were associated with tissue heating and no confirmed effects below heating thresholds were identified. The effects associated with heating, so-called "thermal effects", concerned diminished response rates in food-motivated behavioral experiments in laboratory animal subjects (rhesus monkeys and rats) and were accompanied by a rise in body core temperature of about 1° C. Such behavioral changes are considered amongst the most sensitive indicators of potentially adverse effects. In the absence of heating, there have been no consistently demonstrated "non-thermal" mechanisms that could lead to adverse biological or health effects either acutely or chronically. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the IEEE have since developed guidelines very similar to the FCC's based on the same behavioral effects following for each a comprehensive review of the scientific literature. Prior to its publication, the FCC rule received endorsements from the U.S. Environmental Protection Agency (EPA), the U.S. Food and Drug Administration (FDA), and the U.S. Occupational Safety and Health Administration (OSHA). The EPA reaffirmed its opinion in letters written in 1999 and 2002.

There are four aspects of the Sage Report that are examined in the ensuing discussions within this section. The first three relate to the basis for the FCC rule, as follows: (1) averaging exposure over time (2) averaging exposure across space, and (3) **reflections**. The 4th item concerns the Sage Report's understanding of the most recent exposure standards as published by IEEE, as they relate to specific anatomic sites, namely the eyes and testes.

Time Averaging

FCC OET Bulletin 65 states:

> ...exposures, in terms of **power density**...may be averaged over certain periods of time with the average not to exceed the limit for continuous exposure...the averaging time for occupational/controlled exposures is 6 minutes, while the averaging time for general population/uncontrolled exposures is 30 minutes. (page 10)

The OET further states:

> Time-averaging provisions may not be used in determining typical exposure levels for devices intended for use by consumers in general population/uncontrolled environments. However, "source-based" time-averaging based on an inherent property or duty-cycle of a device is allowed. (page 74)

In this context, smart meters fall into the "source-based" category, and time averaging is completely appropriate. The Sage Report claims that time averaging does not apply to assessing exposures from smart meters, and continuous operation should be assumed for compliance assessment, which represents a misinterpretation of the FCC rule. The applicability of time averaging to smart meters was reaffirmed in a letter dated August 6, 2010 to Ms. Sage from the FCC's Julius Knapp, Chief, Office of Engineering and Technology, stating:

> For exposure evaluations, however, the average power is relevant, which is determined by taking into account how often these devices [smart meters] will transmit.

To illustrate the amount of time a meter may actually transmit, data were collected from the transmitting records from almost 47,000 meters over a nearly three month period, amounting to more than four million readings in all. The capability to accomplish this was enabled by special software developed by the smart meter manufacturer (Itron) to acquire transmit data. The analysis enumerated the data

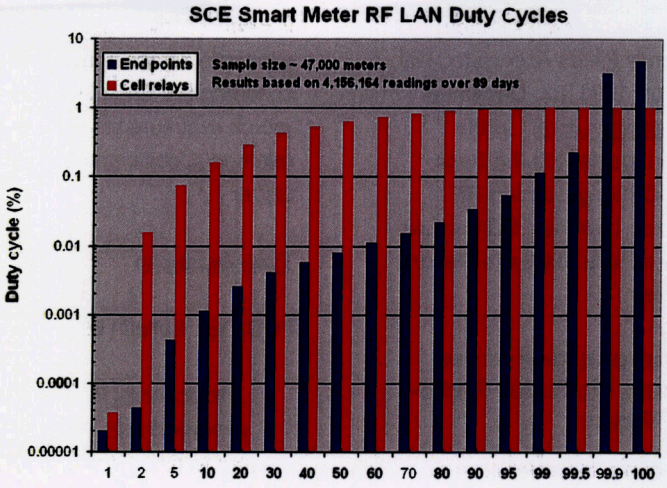

Figure 1

Analysis of SCE daily average duty cycle distribution for different percentiles based on 4,156,164 readings of transmitter activity from an average of 46,698 Itron Smart Meters over a period of 89 consecutive days. Analysis based on estimated transmitter activity during a day. (From EPRI Technical Report 1021126, December 2010)

"packets" associated with uplink and downlink communication to and from end-point and cell relay meters to serve as surrogates for transmission time. The study estimated (Figure 1) a maximum duty cycle of under 5%, with 99.5% of the sample operating at a duty cycle of about 0.22% or less, a value that translates to 3 minutes and 10 seconds of transmitting over a day (a 5% duty cycle, worst case in this study, translates to 72 minutes of transmitting). The duty cycle for cell relays within the same sample did not exceed 1%. Assuming these data are representative of smart meter function in general, the Sage Report using a 100% duty cycle, over-estimates exposure by no less than 20-fold and more typically more than 400-fold. In a smaller study of over 6,800 meters, end-point and cell relay meters were monitored for the number of bytes of data transmitted over an observation period of one day. This method provided a direct (exact) measure of time, and reported duty cycles even lower than those in the larger sample, with no one-day average duty cycle exceeding 1%.

Thus, as an example of examining smart meter duty cycle from the compliance perspective, the EPRI study estimated a nominal exposure of about 12 microwatts per square centimeter ($\mu W/cm^2$) for a person a foot from a 250-mW **end-point meter** while the meter is transmitting. Assuming the worst case duty cycle of 5% for that meter, the "source-based" time-averaged exposure would be 0.6 $\mu W/cm^2$, which is 0.1% of the FCC's **MPE** (maximum permissible exposure); for a 1% duty cycle, the average exposure would be 0.02% of the FCC limit. This value does not yet account for the FCC's stipulation for spatial averaging dealt with in the next discussion.[2]

Spatial Averaging

FCC OET Bulletin 65 states:

> Limits for General Population/Uncontrolled exposure: 0.08 W/kg as averaged over the whole-body and spatial peak **SAR** not exceeding 1.6 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). (page 75)

Exceptions are made for the extremities that have higher SAR permitted. Earlier in the document, FCC states as a general principle:

> A fundamental aspect of the exposure guidelines is that they apply to power densities or the squares of the electric and magnetic field strengths that are spatially averaged over the body dimensions. Spatially averaged RF field levels most accurately relate to estimating the

[2] The FCC rule is not specified to account for the fraction of transmitting time over the course of a day that a person would actually traverse the area within a given distance to the meter. Using the example in the text, a person doing yardwork for 2 hours and 24 minutes (one-tenth of a day) close, say a foot (30 centimeters) from a single meter operating with a 5% duty cycle mounted on the external wall of a residence, would nominally receive an exposure equivalent to 0.01% of the FCC exposure limit for the general public (one-ten thousandth of the exposure limit).

whole body averaged SAR that will result from the exposure and the MPEs ... (page 10)

The Sage Report presumes a uniform exposure level across the volume of an exposed person that corresponds to the maximum level in the wavefront at a given distance. However, in fact, the exposure level varies across the dimensions of a body. Figure 2 depicts the general idea of averaging across a body's volume in which 10 or more measurements along the body's axis are averaged in terms of their power density (often measured as the electric field, which is then squared to represent power density).

According to measurements reported in the EPRI study, power densities vary across the measurements' angle of elevation. Figure 3 illustrates how the power density varies along a circular trajectory from above to below the meter. The color coded graphic on the right-hand panel of the figure indicates that, in the case of the meter characterized, power density may be lower at the top by roughly a factor of 3 (~5 dB), and at the bottom by up to a factor of about 10 (~10 dB). In a crude fashion, one could liken the variation of power to the beam from a flashlight, which is maximal head on and diminishes as one moves further from the center of the beam (Figure 4). Qualitatively, it is fairly apparent that the power density in the center of the beam can significantly overestimate the power density averaged over one's body dimensions. An example of a vertical profile measured 1 foot in front of a continuously transmitting 900-MHz, 250-mW end-point smart meter (i.e., transmitting to the **LAN**), as reported in the EPRI study cited above, is shown in Figure 5. Note that at its peak the emission is just below 2% of the FCC's MPE for 900 MHz, but the vertical average, which is the basis for the FCC rule is 0.44% of the FCC MPE, more than 4 times less than the peak.

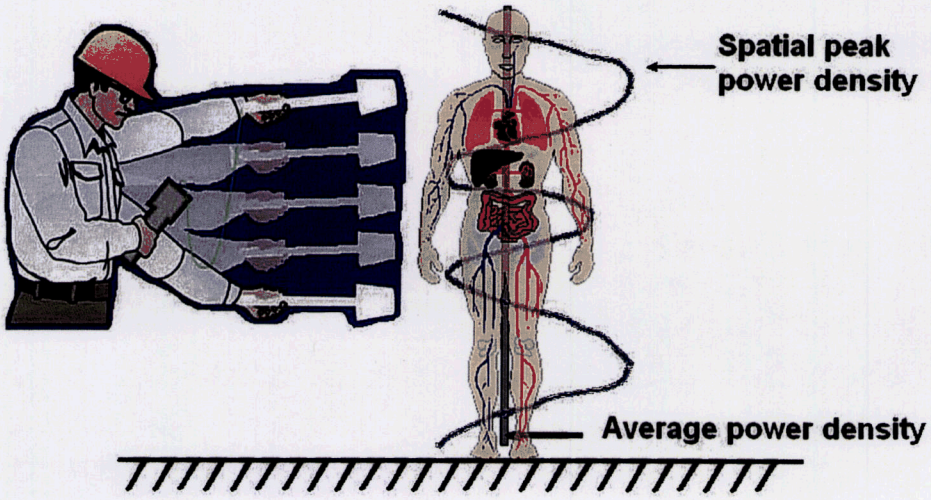

Figure 2
Estimating whole-body SAR with measurements of the power density along the axis of a person in the location to be occupied. (adapted from EPRI Resource paper 1014950, December 2007)

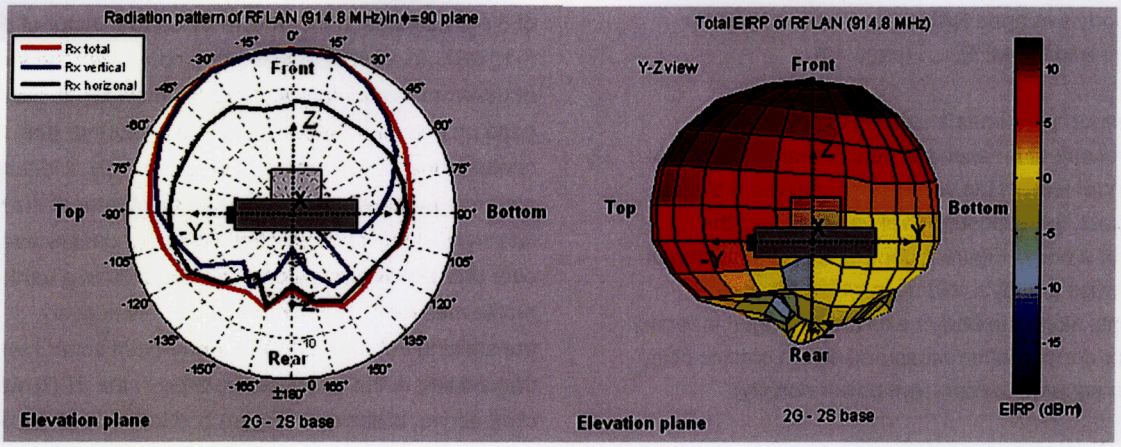

Figure 3

Left: Elevation plane pattern of the 900 MHz RF LAN transmitter in an end point meter showing the horizontal, vertical and total pattern. The scale is in dB with the maximum field at the outer edge of the pattern circle. Right: Elevation plane view of the total EIRP of the 900 MHz RF LAN transmitter in an end point meter. (From EPRI Technical Report 1021126, December 2010)

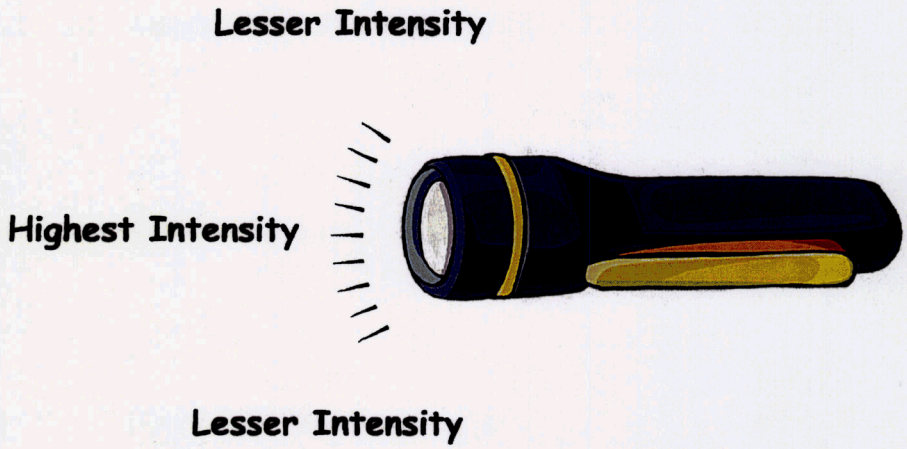

Figure 4

Depiction of beam from a flashlight as a crude analogy of the vertical gradient of the power density from a smart meter

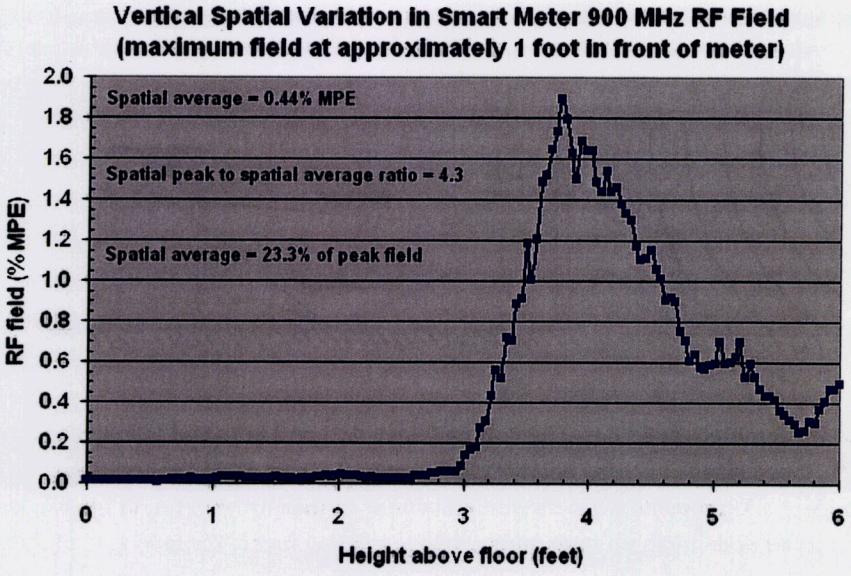

Figure 5
Vertical spatial variation in Smart Meter 900 MHz RF LAN field from 0 to 6 feet above the floor at a lateral distance from the Smart Meter of approximately 1 foot. (From EPRI Technical Report 1021126, December 2010)

Reflections

Electromagnetic waves may reflect off surfaces (Figure 6), which enables us to use rear- and side-view mirrors, which are highly reflective surfaces, to observe traffic traveling behind us. Though visible light is electromagnetic energy that propagates at frequencies 5 to 6 orders of magnitude greater than RF emissions from smart meters, the latter may likewise be reflected to some extent from floors, ceilings and walls depending on their reflective properties. However, most of the environments inhabited by people consist largely of indoor surfaces (wood or carpeted floors, plaster walls and ceilings, windows) and outdoor surfaces (exterior walls, lawns, sidewalks) of moderate reflectivity that may also absorb (and thus attenuate) or pass electromagnetic energy much as light passes through glass. Further, given that smart meters are very frequently on building exteriors facing open space (Figure 7), reflections in those cases would be very small contributors to overall exposure.

The extent of an added exposure due to reflection depends on the reflectivity of the surface (e.g., metallic surfaces are highly reflective; carpeted and wood floors are more absorptive and less reflective), the antenna's beam characteristics (e.g., its angular width and direction) the angle of reflection, and the distance traveled by the wave to an exposed person. For an analysis of RF fields that will result in a conservative estimate of the actual field, the FCC OET 65 Bulletin states:

> For a truly worst-case prediction of power density at or near a surface, such as at ground level or on a rooftop, 100% reflection of incoming radiation can be assumed, resulting in a potential doubling of predicted field strength and a four-fold increase in (far-field equivalent) power density. (Page 20)[3]

The Sage Report interpreted several studies to justify that a worst-case analysis would require increasing the power density of the free-space emissions to account for reflections. This approach was based primarily on a paper by Hondou et al. (J Phys Soc Jap 75:084801, 2006), which reported power density levels for an enclosure made entirely of perfectly reflective surfaces, as depicted in Figure 8 (right). Using the light analogy, this would be equivalent to an enclosed space whose walls, floor and ceiling were made entirely of mirrors. The Hondou et al. (2006) result adapted by the Sage Report is shown in Figure 8 (left), which shows the power density along a path leading away from the antenna.

[3] Reflection values are expressed in terms of the electric field. Thus, as power density is proportional to the electric field squared, a 100% reflection at a particular point in space corresponds to an enhancement of the power density by a factor of $(1+100/100)^2 = 4$. A more common upper bound estimate of 60% for reflection results in a power density enhancement of $(1+60/100)^2 = 2.56$.

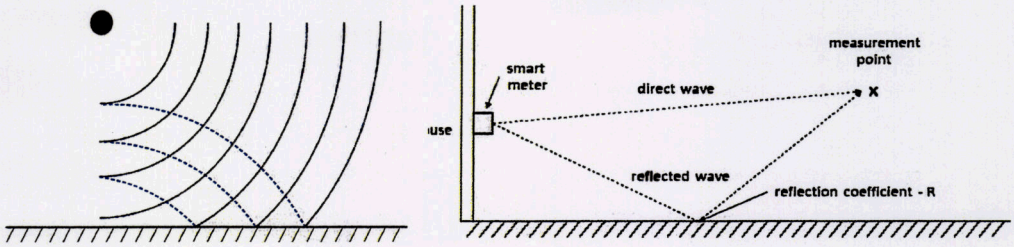

Figure 6

RF Reflections. Left: Wavefronts emitted (solid lines) by source (black dot) and reflected (dashed lines) from the ground. Far from the source (far field), these waves become nearly "plane waves." (From EPRI Technical Report 1014950, Dec 2007); Right: Exposure to incident and reflected wave as would occur at a measurement point; the two contributions may reinforce or cancel one another depending on their mutual phase relationships (Compliments of R.G. Olsen and R.A. Tell)

Figure 7

Measuring RF power densities in front of an outdoor bank of smart meters

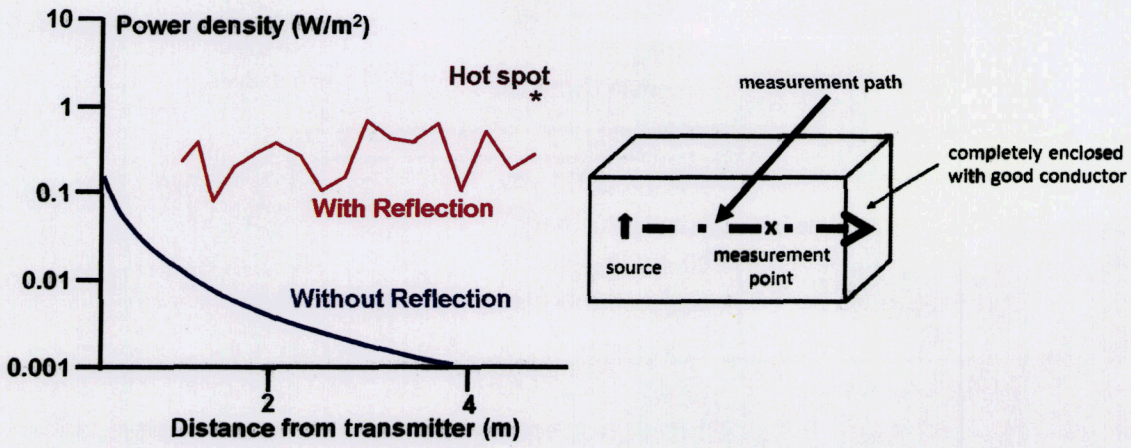

Figure 8

Right: Conceptualization of measurements conducted by Hondou et al. (Compliments of R.G. Olsen and R.A. Tell); Left: Measured power density in the conductive enclosure (red), and calculated free-space value (adapted from Hondou et al., 2006)

At a distance of about 4 meters the power density in this enclosure is between 100 to 1,000 times greater than would be the calculated free space value (blue curve), with a "hot-spot" noted with a power density about 2,000 times greater than the free space scenario. Also note in Figure 8 that as the distance to the antenna decreases, the discrepancy between the reflected and free-space values also decreases (see below for further discussion of reflections versus distance from an antenna). The Sage Report introduced enhancement factors of 1,000% and 2,000%, which translate to, respectively, 121- and 441-fold enhancements of the incident power density (see footnote 3). Despite the claim of adopting "conservative" reflection values based on Hondou et al., the Sage Report, nonetheless used power density enhancements roughly 30 to 110 times greater than the FCC's worst-case scenario, and, moreover, applied the enhancements uniformly to every point in space, which violates the laws of physics. In addition, there are no practical scenarios that simulate the conditions of the enclosure tested by Hondou et al. whereby an individual would be in a space occupied by a smart meter that was also entirely enclosed by conductive surfaces on all sides (floor, walls and ceiling).

Looking further at a realistic indoor case, one might consider rooms in the home (such as a bedroom) to be nearly fully enclosed; doors and windows do represent openings in the enclosure. But, even if this is said, there are two fundamental problems (see Figure 9). First, the source (i.e., the smart meter) is not within the room. It is possible for some of the RF electromagnetic waves to "leak" into the room, but only if the wall is partially transparent to electromagnetic waves from the meter on the exterior of the residence or in the garage. The leakage is small because a smart meter does not radiate much in the direction of the house; its radiation is intentionally directed away from the house. As an added note, though the HAN "Zigbee" antennas are designed to communicate to devices within a residence's interior, their transmission pattern measured in the EPRI study was also more heavily weighted outward much like the end-point meter's pattern. In addition, as the RF passes through the wall it is attenuated. The second problem is since the room is not completely enclosed and the enclosure is not a perfect (or nearly perfect) conductor, it will not behave nearly like the resonant cavity used by Hondou et. al. As a final note, if the wall is more transparent to RF so that attenuation of the RF into the room is small, then the room will look even less like a resonant cavity because its walls are more "leaky."[4]

Although the power density values in the Hondou paper in all likelihood correctly represent the experimental conditions they describe, the results were not utilized appropriately in the Sage Report. The Sage Report calculates the field at

[4] It is worth noting that Hondou et al. reported another scenario simulating an elevator with a mounted antenna. The "elevator" enclosure used by Hondou et. al. also has metallic sides floor and ceiling. It does have an open door, but given the orientation of the source antenna, only smaller fields are radiated towards the door opening. Thus the door does not degrade the properties of the elevator as a resonant cavity as much as it could if the source was oriented in a different direction.

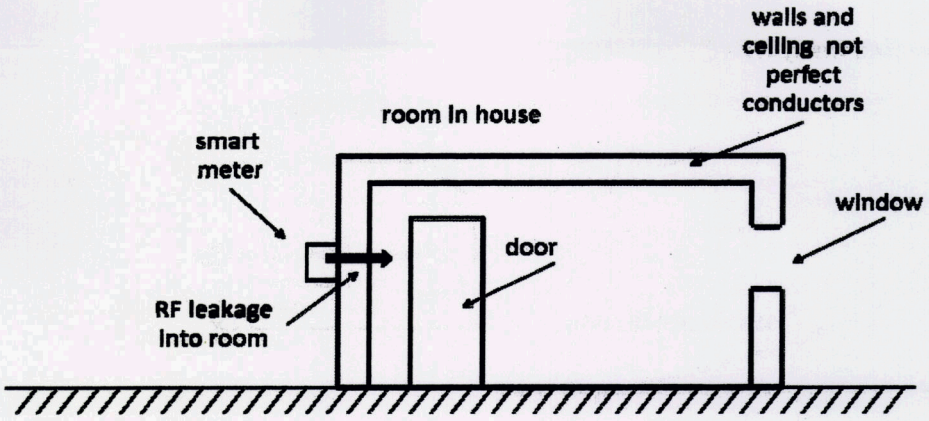

Figure 9
RF leakage into a room in a house which is not a good resonant cavity due both to openings in the walls and the imperfectly conducting enclosure. (Compliments of R.G. Olsen and R.A. Tell)

(for example) 0.15 meters (i.e., 6 inches) from the source and then increases the field by 1000% or 2000% to calculate an "actual" power density at that point. This is not a correct use of Hondou's data. The author of the Sage report incorrectly assumes that the factor of 1,000% or 2000% (10 or 20 fold enhancement of the electric field) may apply at every point in space as a multiplier to the "free space" value of the field. Based on fundamental laws of physics, it can be unequivocally stated that the closer the field point is to the source, the smaller any increase in the field due to reflections. In fact, this ratio approaches 1.0 as the field point becomes arbitrarily close to the source.

This aspect of exposure regarding reflections close to a source, included in the EPRI Technical Report, is illustrated in Figure 10 (left), which represents a calculated power density one foot from a smart meter placed at a height of 5 feet with and without a reflection. The values with reflections present (wavy blue curve) were calculated with a technique called "method of moments" that utilizes realistic characteristics of a ground surface to calculate reflected power density. With a reflection present in this model, the average power density over the vertical axis of a six-foot person standing one foot from the meter was 3.2% greater than the average with no reflections. Also, note how much smaller the exposure levels would be for a person shorter than 4-5 feet. Figure 10 (right) charts the contribution of reflections to the free space power density as distance from the meter increases. Though the relative contribution of reflection is shown to increase with distance from the meter, the total incident power density is simultaneously falling by a greater relative amount with increasing distance from a source. A key finding from this analysis of reflections is that for the distance range modeled, from 1 foot to 20 feet from the meter, the greatest enhancement in power density caused by reflections was only 65%, far smaller than the 256% value provided by FCC for conservatively estimating RF fields when reflections occur. Furthermore, these higher enhancements occurred for points furthest from the source for which the incident field is already smaller. A previous EPRI White Paper, "A Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading Technology" (1020798), described 60% as a realistic upper bound reflection.

The Sage Report cites another paper (Vermeeren et al., Phys Med Biol 55:5541, 2010) in the context of supporting its enhancement factors which, in fact, it does not. This study models SAR resulting from a rooftop exposure to a base station antenna in the presence of a reflective rooftop (or ground plane) and wall. It reports that at 900 MHz – close to the frequency of the RF LAN (915 MHz) in the wireless smart meter under discussion here – the SAR (proportional to power density at any given frequency) could increase by as much as a factor of about 3.6 (5.5 dB) on a localized basis in 10 grams of tissue, and by a factor of about 2.8 (4.5dB) on a whole body basis, both of these values being consistent with the FCC OET 65 cited above (Figure 11, vertical blue bars). At the same time, reflections modeled at 900 MHz may also result in a reduction of SAR compared to the free-space scenario. At lower frequencies (300 and 450 MHz) reflections were slightly greater, and at higher frequencies, including 2,100 MHz, roughly a home area network's **(HAN)** operating frequency, the reflections were lower (vertical red bars).

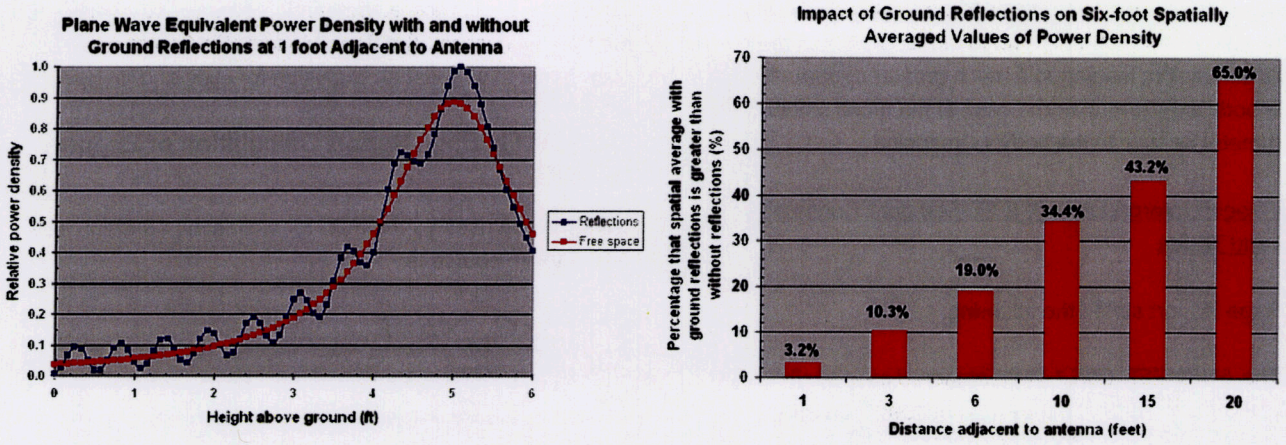

Figure 10

Left: Relative calculated plane wave equivalent power density along a six-foot vertical path, one foot adjacent from a 900 MHz half-wave dipole positioned at five feet above the ground. Power density values are compared with and without ground reflections. Right: Impact of ground reflections on six-foot spatial average of power density for different distances lateral to a 900 MHz dipole antenna mounted at five feet above ground. Vertical axis represents the percentage that the spatially averaged power density that includes any ground reflected fields is greater than the spatially averaged power density in free space (without any ground reflected fields). Ground reflection estimated by method of moments as described in the EPRI Report. (From EPRI Technical Report 1021126, December 2010)

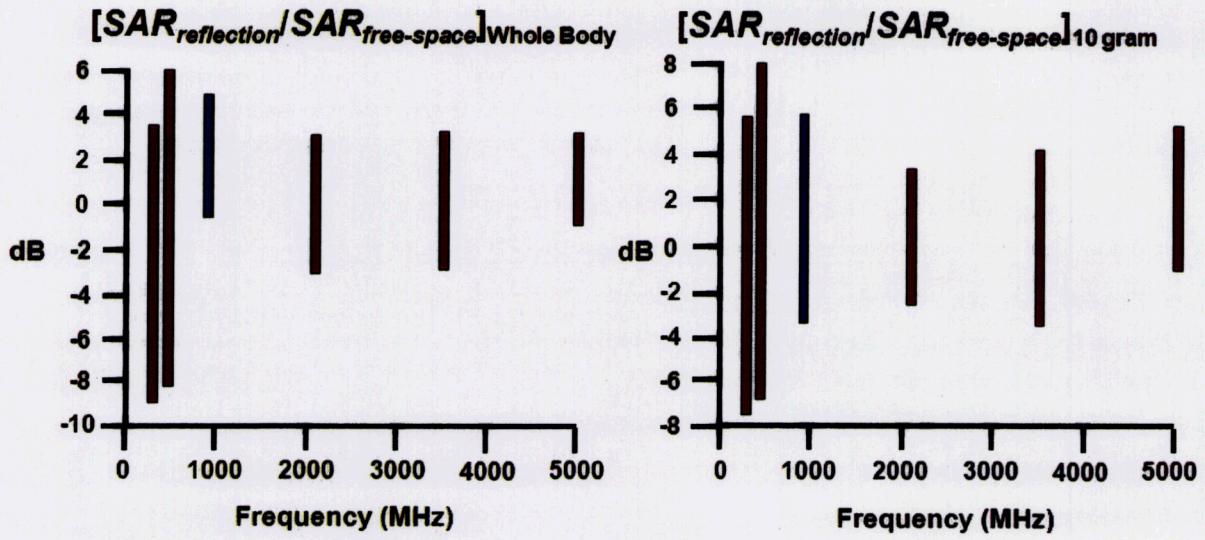

Figure 11

The range of whole-body and 10-gram SAR in the rooftop scenario with reflective ground and wall. Each frequency includes combinations of distance and reflective surface (ground, wall, ground + wall). The blue vertical bar corresponds to the power density range for 900 MHz. (adapted from Vermereen et al., 2010)

Worthy of note was that the Vermeeren et al. study modeled a vertical panel antenna that would intercept much of the body's dimension, leading to a much greater opportunity for whole body exposure than the case of the much smaller smart meter relative to the body's dimension.

Sage Report Interpretation of IEEE Standard Concerning Eyes and Testes

The Sage Report states the following:

> The ANSI/IEEE C95.1-1999 standard specifically excludes exposure of the eyes and testes from the peak power limit of 4000 uW/cm2* [asterisk is a reference to a footnote]. However, nowhere in the ANSI/IEEE nor the FCC OET 65 documents is there a lower, more protective peak power limit given for the eyes and testes.

However, in 2005, IEEE published a revised standard covering RF electromagnetic fields, "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz (IEEE Std C95.1™-2005). The 2005 revision, working with additional research results available after the 1999 standard was published, removed the language and the intent of language in the 1999 standard regarding an exclusion for eyes and testes. IEEE Std C95.1™-2005 remains the current IEEE standard for RF exposures. The basis for the removal of the 1999 language regarding eyes and testes was extensively documented in the 2005 standard, with brief excerpts as follows:

> ...localized exposure at the upper limit (10 W/kg averaged over 10 g of tissue) is protective against all adverse effects including those occurring in the fetus and testes, the two targets identified as most sensitive to thermal damage. (p. 86)

> In summary, adverse effects of RF exposure of the eye, i.e., cataracts, are associated with significant temperature increases due to the absorption of RF energy. The maximal permissible RF exposures in this standard are therefore protective against the significant temperature increases that can result in adverse effects on the eye, such as cataracts. There is no evidence of other significant ocular effects, including cancer, which would support a change in the adverse effect threshold of 4 W/kg. (p 60)

Thus, given that revised standards are designed to override their predecessors, the Sage Report relied on an outdated document to suggest an exclusion for eyes and testes.

Section III: Sage Report Calculation of Exposure Levels

The formula used by the FCC for estimating emission levels from an RF source is:

$$S = \frac{P_t \times G_{\max} \times \delta \times R}{4\pi r^2}$$

Where,

S is plane wave equivalent power density (W/m^2)
P_t is maximum transmitter output power (W)
G_{max} is the maximum possible antenna power gain (a dimensionless factor); this means that the transmission has directionality with maximum power transmitted in one particular direction.[5]
δ is the duty cycle of the transmitter (dimensionless)
r is the radial distance between the transmitter and the point of interest (meters)
R is a dimensionless factor that accounts for possible ground reflections that could enhance the resultant field. For a 60% reflection of the electric field, a value typically used for assessing compliance, the power density, S, would increase of $(1.6)^2$ or 2.56 in the power density since it is proportional to the square of the electric field.[6]

The Sage Report used this formula to calculate RF power density levels as they compare to the FCC general public compliance levels under the assumptions that:

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[5] The power density transmitted in this direction at a given distance is greater – by a factor, G_{max} - than the power density at the same distance were it transmitted symmetrically in all directions (or omnidirectionally) in a spherical pattern as from an isotropic source. This also means that there are areas near the antenna with transmitted power density lower than the power density from an omnidirectional source.

[6] The inclusion of the ground reflection factor of 2.56 makes this formula conservative since it assumes that the meter's signal emitted by a power meter is also reflected from the ground causing an enhancement of the resultant RF field due to what is called phase addition of the direct and reflected signals. If this occurs, it will only happen at very specific points above the ground while at other points, the signals will add destructively, reducing the signal intensity. Hence, when considering the body as a whole, the ground reflection will generally not affect the body's average exposure. Nonetheless, it is common when performing FCC compliance analyses to include the possibility of ground reflections.

1. Duty cycle need not be taken into account, and that continuous exposure should be assumed.

2. Implicitly, space averaging across the volume of an individual is unnecessary, with a uniform exposure at the maximum value occurring across all exposure space.

3. Reflections that may range from 60% to 2000% are uniform across the entire exposure volume.

4. Power densities from multiple meters can be added to calculate a cumulative power density, which can then be compared to the FCC limit.

Taking these in sequence:
(1) The discussion above clarified that as a source-based exposure, incorporating the duty cycle into the estimate of average power density (and average SAR) is appropriate.

(2) Furthermore, the FCC OET 65 indicates that exposure levels should be averaged over the volume of a person presumed to occupy the space where exposure occurs.

(3) In estimating the potential effect reflections may play, 60% is a highly conservative estimate for smart meters, with 100% a worst-case estimate. The reflective enclosure case modeled by Hondou et al. (2006) does not apply to any practical real world situations yet identified (see footnote 3 above concerning Hondou et al.'s elevator model). Uniform enhancement cannot be assumed because close to and in front of an emitter, where the emission is maximum, is exactly where the effect of reflections is at a minimum.

(4) When one is very close to a bank of meters (the Sage Report uses exposure to four meters), one cannot be in the direct path of the maximum emission for each, because (again using the crude flashlight model), the power density decreases to some degree with the azimuthal angle from the center of a propagated field. At the very closest distance in front of one emitter, the azimuthal angle from other emitters predicts lower exposures than derived from simple addition. With respect to this point, it should be pointed out that the exposure level in the 4-meter scenario in the Sage Report was unexplainedly not the 4-fold value expected; rather it was less (for example, see Sage Report, Tables 2 & 3). In Sage Report, Table 1, upper panel, the author reports values at 9 inches, rather than the stated 6 inches, such that the 4-meter scenario in the bottom pane is over 7 times the 1-meter scenario, which is clearly not possible even under the report's assumptions.

In terms of compliance assessment, when more than one source is present, each is weighted according to its frequency dependent FCC limit, as shown below Table 1 on the following page Thus, the Sage Report's approach of reporting a simple sum of power densities from sources at different frequencies is inappropriate in terms of assessing compliance.

In fact, the RF field levels from smart meters, even when grouped together, are not expected to exceed FCC limits. The graph in Figure 12 shows expected exposure levels, in terms of the fraction of the FCC limits appropriately weighted by relative contributions from each source. The specifications for the meters in these calculations, shown here in Table 1, correspond to those used in the Sage Report. The graph considers four end-point meters and three end-point meters combined with a cell relay for 60% and 100% reflections. The smart meters include both the end-point LAN emitter, and the HAN transmitting at 2,405 MHz. The Cell Relay includes these two transmitters, as well as a third transmitter for communicating over a wireless wide area network (**WWAN**) back to the utility company. The calculation assumes a duty cycle of 1%, which was applicable to over 99.5% of the readings from the data shown in Figure 1. Furthermore, the graph is extremely conservative in applying the reflection factor at every distance, and assuming that the peak power density in the wavefront is uniform in space (neither of these applies in actuality). These factors more than compensate for the fact that a small fraction of meters may operate at duty cycles up to 5%. Even at a distance of 8 cm (~3 inches) the power density is well below the FCC MPE.

Section IV: Conclusion

In assessing potential RF exposure levels from smart meters, the Sage Report misapplied the practices prescribed by the FCC in "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields" (OET Bulletin 65, Edition 97-01, August 1997). Both space and time-averaging are appropriate and reflections of 60% or even 100% may be included to provide conservative estimates. In addition, the Sage Report's author did not evaluate cumulative exposure weighted by MPE at the frequency of each source as instructed by the FCC. A more realistic estimate, even allowing for assumptions that overestimate exposure levels

Table 1
Antenna Values for Figure 12

Antenna	*TPO* (dBm)	*G* (dBi)	*EIRP* (dBm)	*EIRP* (mW)	*f* (MHz)	*MPE* (mW/cm^2)
RF LAN	24.27	2.2	26.47	443.6	915	0.610
Zigbee	18.71	1	19.71	93.5	2405	1.0
Cell Relay	31.8	-1	30.8	1202.3	850	0.567

Fraction of FCC Limit = $n_1 S_{LAN}/0.610 + n_2 S_{Zig}/1.0 + n_3 S_{CR}/0.567$
Within a residence:
n_1=number of LAN meters; n_2=number of Zigbee meters; n_3=1=number of cell relays

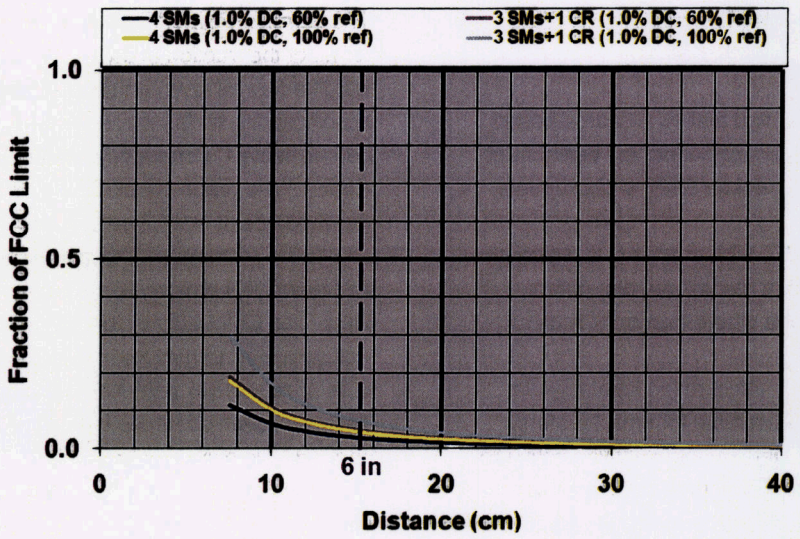

Figure 12
Calculated exposure levels from combinations of meters operating at 1% duty cycle with reflection values of 60% and 100% (see text)

by ignoring space averaging and declining RF levels at positions lateral to the center of a wavefront, reveals that FCC MPEs are very unlikely to be exceeded, even at distances very close to the source. This conclusion also applies to regions behind a meter bank owing to lower emissions in that direction and the attenuating properties of wall materials. These points were supported by measurements described in the EPRI Report, in which power density was measured in front of a rack of 10 ¼ watt (nominal power) continuously operating (i.e., 100% duty cycle) smart meters starting at a distance of 1 foot[7]. Under these circumstances, the frequency-weighted power density was 8% of the FCC MPE for the general public. For a realistic duty cycle of 1%, this would translate to 0.08% of the FCC MPE. For measurements taken immediately behind the rack, the field level for continuous transmission was 0.6% of the FCC MPE at a distance of 8 inches. It should also be pointed out that while the testing was conducted with end-point meters rated nominally at ¼-watt (~250 mW), the manufacturer's data illustrated in the EPRI Report allow one to estimate that, based on a sample of 200,000 meters, 99.9% operate at powers between 150 and 475 mW, with a possible maximum of 500 mW for no more than 0.05% of units. However, were all 10 meters rated at 1 W with the same spatial transmission pattern as the quarter-watt meters actually measured, the exposure at 1 foot would still be less than the FCC limit by a factor of three. Therefore, the Sage Report, for the reasons enumerated in this commentary, has over-estimated

[7] The meters were specially programmed to operate continuously for the measurement study. They do not operate in this manner when actually deployed, transmitting intermittently for very brief periods, as explained in the text.

exposures from smart meters using assumptions and calculations that are inconsistent with the FCC's rule and that do not recognize the basic physical characteristics of RF emissions.

Glossary

Cell relay: A form of Smart Meter that provides the normal function of an end point meter but also allows for data connectivity with the electric utility company via a wireless wide area network that functions in the cellular telephone or personal communications service (PCS) bands.

Duty Cycle: a measured of the percentage or fraction of time that an RF device is in operation. A duty cycle of 1.0, or 100%, corresponds to continuous operation. Also called duty factor. A duty cycle of 0.01 or 1% corresponds to a transmitter operating on average only 1% of the time.

End point meter: A term used to designate a Smart Meter that is installed on a home or business to record and transmit electric energy consumption but that does not provide access point features such as those provided by a cell relay.

EPRI, Electric Power Research Institute, Inc.: EPRI conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent more than 90 percent of the electricity generated and delivered in the United States, and international participation extends to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

FCC, Federal Communications Commission: the Federal Communications Commission (FCC) is an independent agency of the US Federal Government and is directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. The FCC also allocates bands of frequencies for non-government communications services (the NTIA allocates government frequencies). The guidelines for human exposure to radio frequency electromagnetic fields as set by the FCC are contained in the Office of Engineering and Technology (OET) Bulletin 65, Edition 97-01 (August 1997). Additional information is contained in OET Bulletin 65 Supplement A (radio and television broadcast stations), Supplement B (amateur radio stations), and Supplement C (mobile and portable devices).

Gain, antenna: a measure of the ability of an antenna to concentrate the power delivered to it from a transmitter into a directional beam of energy. A search light exhibits a large gain since it can concentrate light energy into a very narrow beam while not radiating very much light in other directions. It is common for cellular antennas to exhibit gains of 10 dB (dB is a form of expressing power density on a logarithmic scale) or more in the elevation plane, i.e., concentrate the power delivered to the antenna from the transmitter by a factor of 10 times (10 dB = 10x; 20 dB = 100x) in the direction of the main beam giving rise to an effective radiated power greater than the actual transmitter output power. In other directions, for example, behind the antenna, the antenna will greatly decrease the emitted signals. Gain is often referenced to an isotropic antenna, that is one that transmits uniformly in all directions (spherical wavefront).

HAN, Home Area Network: In the context of Smart Meters, a local area network for communication between a personal computer and various electrical appliances, equipment or systems to accomplish optimized electric energy consumption at the home. Small sensors with low power radio transmitters are attached to the various electrical appliances for communication in the HAN.

LAN, Local Area Network: The wireless mesh (see below) network that interconnects end-point meters, which transmit data to the cell relay (collection point) for transmittal to the local utility. (**Mesh Network**: A term describing a network, typically wireless, in which multiple nodes communicate among themselves and data can be relayed via various nodes to some access point. Mesh networks are self healing in that should a particular pathway become nonfunctional for some reason, alternative paths are automatically configured to carry the data. Mesh networks can expand beyond the normal range of any single node (Smart Meter) by relaying of data among the different meters.)

MPE, Maximum Permissible Exposure: The value of an exposure that should not be exceeded. These include the electromagnetic field, expressed in terms of power density, or as either the electric or magnetic field, and induced or contact currents.

Power Density: The power per unit area, denoted by the symbol *S*, of an RF electromagnetic field normal (perpendicular) to its direction of propagation, usually expressed in units of watts per square meter (W/m^2) or, for convenience, milliwatts per square centimeter (mw/cm^2) or microwatts per square centimeter ($\mu w/cm^2$). For plane waves (i.e., those beyond the immediate proximity of an antenna operating in the frequency range of a smart meter), power density, electric field strength, *E*, and magnetic field strength, *H*, are related by the impedance of free space, whose value is 120π (377) ohms. In particular, the power density, $S = E^2/120\pi = 120\pi H^2$ (where *E* and *H* are expressed in units of V/m and A/m, respectively).

Reflection: An electromagnetic wave (the "reflected" wave) caused by a change in the electrical properties of the environment in which an "incident" wave is propagating. This wave usually travels in a different direction than the incident wave. Generally, the larger and more abrupt the change in the electrical properties of the environment, the larger the reflected wave.

SAR, Specific Absorption Rate: The time derivative of the incremental energy absorbed by (dissipated in) an incremental mass contained in a volume of a given density. SAR is expressed in units of watts per kilogram, W/kg (or milliwatts per gram, mW/g). Guidelines for human exposure to radio frequency fields are based on SAR thresholds for potential adverse biological effects. When the human body is exposed to a radio frequency field, the SAR experienced is proportional to the squared value of the electric (or magnetic) field strength induced in the body.

WWAN, Wireless Wide Area Network: WWANs are provided by several cellular telephone companies for wireless connectivity directly to the Internet for data transmission. WWANs are different from so-called wireless "hot spots" such as found in cyber cafés and operate in either the 850 MHz cellular or 1900 MHz PCS bands.

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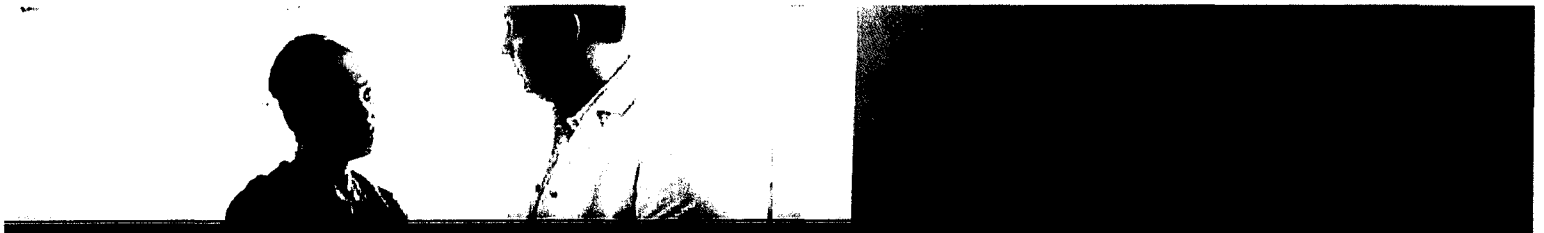

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Smart Meters

Text Size

What are smart meters?

A meter is any device that measures the use of a product such as electricity, natural gas, or water. A smart meter is a meter that has the added feature of being able to send usage information back to the product supplier on a regular basis, often many times a day. Suppliers have promoted the use of smart meters as a way for them to operate more efficiently and cheaply, as well as a way to provide consumers with real-time information about their product use.

meters have been used for a number of years in some developed countries, especially in parts of Europe. They have been installed in some areas of the United States in recent years as well.

Concerns have been raised about the safety of smart meters, mainly because they give off the same kinds of radiofrequency (RF) waves as cell phones and Wi-Fi devices.

How do smart meters work?

Smart meters record the amount of the product (electricity, water, etc.) consumed over time. They differ from traditional utility meters in that they are electronic and can talk to a central computer system.

Smart meters talk to their central systems using RF transmissions, based on either cell phone, pager, satellite, radio, power line (PLC), Wi-Fi or Internet (TCP/IP) communication methods. Internet and cell phone applications have become the preferred options because of their flexibility and ease of deployment.

How are people exposed?

Smart meters are typically installed outside the home, either in place of or as part of existing meters. The level of exposure to RF energy depends on the distance from the smart meter antenna and the communications protocol used in the smart meter. The frequency and power of the RF waves given off by a smart meter are similar to that of a typical cell phone, cordless phone, or residential Wi-Fi router. However, smart meters are typically only in operation a small portion of the time because they only send and receive short messages at set intervals throughout the day (often several times an hour).

Because smart meter antennas typically are located outside the home, people are much farther away from the source of RF waves than with personal cell phones, cordless phones, or Wi-Fi routers. In addition, walls between the person and the smart meter's antenna further reduce the amount of RF energy exposure. For these reasons, the exposure to RF energy from smart meters is estimated to be much less than the typical exposure people receive through cell phones, cordless phones, and/or home Wi-Fi routers.

n smart meters cause cancer?

Smart meters emit RF waves, which are a type of electromagnetic radiation, so there is the potential for them to cause harm. The actual risk of harm, if it exists, is likely to be extremely low, for a number of reasons.

Learn About Cancer Topics

- Cancer Basics
- What Causes Cancer?
- Breast Cancer
- Colon/Rectum Cancer
- Lung Cancer
- Prostate Cancer
- Skin Cancer
- Show All Cancer Types
- News and Features
- Cancer Glossary
- ACS Bookstore

If there is any increased risk, it is likely to be extremely small – even smaller than any possible increased risk from cell phones. Although it's not clear if cell phones cause any health problems, some experts recommend that people concerned about possible health effects keep the device at least 3 to 4 inches from the head to lower exposure to RF waves, just to be safe. In ase of smart meters, people are already much farther from these devices, and an added degree of safety is provided by e or more walls between the person and the smart meter antenna.

Some people may still have health or other concerns (such as privacy) related to the use of smart meters on their homes. In some places where smart meters are being installed, people have the choice to opt in or opt out of having them. Contact your local utility provider to find out what the options are in your area.

Additional resources

More information from your American Cancer Society

The following related information may also be helpful to you. These materials may be read on our web site or ordered from our toll-free number, at 1-800-227-2345.

Cellular Phones

Does This Cause Cancer?

Known and Probable Human Carcinogens

National organizations and Web sites

In addition to the American Cancer Society, other sources of information include*:

Federal Communications Commission (FCC)
Radio Frequency Safety: http://fcc.gov/oet/rfsafety/rf-faqs.html

**Inclusion on this list does not imply endorsement by the American Cancer Society.*

No matter who you are, we can help. Contact us anytime, day or night, for information and support. Call us at 1-800-227-2345 or visit www.cancer.org.

References

Centers for Disease Control and Prevention. Frequently asked questions about cell phones and your health. Accessed at www.cdc.gov/nceh/radiation/cell_phones_FAQ.html on September 19, 2012.

Federal Communications Commission, Office of Engineering & Technology. Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields. OET Bulletin 56, August, 1999. Accessed at http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf on September 19, 2012.

World Health Organization. Electromagnetic fields and public health: Mobile phones. Accessed at www.who.int/mediacentre/factsheets/fs193/en on September 19, 2012.

Last Medical Review: 10/05/2012
Last Revised: 10/05/2012

ATTACHMENT I -

FCC LETTER

Federal Communications Commission
Washington, D.C. 20554

August 6, 2010

Ms. Cindy Sage
Sage Associates Environmental Consultants
1396 Danielson Road
Montecito, CA 93108-2857

Dear Ms. Sage:

Thank you for your letter of March 15, 2010, in which you request that we review compliance with FCC radiofrequency (RF) exposure limits for the "Smart Meter" technology being implemented by utilities across the country. In particular, you expressed concern about multiple adjacent Smart Meter installations used to service multiple dwellings such as condominiums, and the effect of increased data traffic on exposure from collector or controller units.

The FCC Equipment Authorization (EA) program in the Office of Engineering and Technology has taken a very conservative approach to RF exposure compliance for low-power network devices such as Wi-Fi base stations and Smart Meter transceivers. For such devices that are not expected to be used close to the body, it is generally unnecessary to perform routine specific absorption rate (SAR) evaluations as field strength or power density is a sufficient and appropriate measure of exposure. The maximum field strength at a distance can be derived from the effective radiated power (ERP). Also, FCC field strength limits, like the SAR limits, are time-averaged. Accordingly, for devices that will not be used within 20 centimeters of the body, we rely on the "source-based" time-averaged ERP and require that it be less than our specified values of 1.5 or 3 watts, depending on frequency,[1] in order to ensure compliance with our exposure limits. This does not imply that FCC exposure limits will be exceeded at distances less than 20 cm, but only that detailed evaluation of the SAR is not required if the 20 cm separation distance can be maintained.

It is useful in considering this issue to recognize that the power level specified on the Grants of Equipment Authorization issued by the EA program is the peak power as this is the power relevant to interference concerns. For exposure evaluations, however, the average power is relevant, which is determined by taking into account how often these devices will transmit. Since the purpose of these devices is to provide very infrequent information they transmit in occasional bursts. Thus, for exposure purposes the relevant power is maximum time-averaged power that takes into account the burst nature of transmission, and based on the typical maximum time-averaged transmitter power for many of these devices, they would generally be compliant with the local SAR limit even if held directly against the body.

With respect to multiple adjacent Smart Meter installations, since the antennas for each device are mounted individually on each utility meter, the separation distance from people for most of the transmitting antennas is relatively large compared to 20 cm and the

[1] See Section 2.1091(c) of the FCC rules.

meters' contributions to the total potential exposure at any location are small, as only the nearest few transmitters can add meaningfully to the total. Further, as a practical design matter, when several of these meters are placed in a cluster, they have to communicate with a single controller. In order to ensure that the controller receives the information properly, only one transmitter can communicate with the controller at a time, eliminating the potential for exposure to multiple signals at the same time.

The general issue of cumulative exposure from an arbitrary group of transmitter installations or from all transmitters distributed in the environment can appear to be complex, but as discussed, the need for orderly communications requires that a few sources normally dominate. In addition, the exponential decrease in signal strength over distance and additional signal losses due to non line-of-sight conditions for distant sources ensures that only the contributions of nearby transmitters are significant.

In summary, compliance for Smart Meters is determined according to the operating and installation requirements of each type of meter during equipment certification, and is based on the maximum transmission duty cycle for the device, including relay functions. Necessary installation requirements to maintain compliance for each meter are specified in the Grant. Irrespective of duty cycle, based on the practical separation distance and the need for orderly communications among several devices, even multiple units or "banks" of meters in the same location will be compliant with the public exposure limits. These conditions for compliance are required to be met before a Grant can be issued from the EA program and auditing and review of Grants is a routine function of the FCC laboratory.

With respect to interference to medical devices, which you also raise in your letter, Smart Meters typically operate under Part 15 of the FCC Rules. Those rules specify power limitations to avoid interference. The Smart Meter wireless technologies used today are not significantly different from Wi-Fi devices, cell phones and other typical consumer products. Certain medical devices may need specific precautions in many other environments; these are generally considered during FDA approval of the individual medical device.

I hope that this information will be helpful. In addition, some technical information on the subject has been developed by the Electric Power Research Institute (EPRI) and we have enclosed that information for reference.

Please know that the FCC is continually monitoring the issue of RF exposure and related health and safety concerns, both in the general terms of the continuing propriety of its regulations, and in individual cases where substantive concerns are raised.

Sincerely,

Julius P. Knapp
Chief
Office of Engineering and Technology

ATTACHMENT J –

MARYLAND PUBLIC SERVICE COMMISSION

ORDER NO. 85294

ORDER NO. 85294

IN THE MATTER OF POTOMAC ELECTRIC POWER COMPANY AND DELMARVA POWER AND LIGHT COMPANY REQUEST FOR THE DEPLOYMENT OF ADVANCED METER INFRASTRUCTURE	*	BEFORE THE PUBLIC SERVICE COMMISSION OF MARYLAND
	*	CASE NO. 9207
IN THE MATTER OF BALTIMORE GAS AND ELECTRIC COMPANY REQUEST FOR AUTHORIZATION TO DEPLOY A SMART GRID INITIATIVE AND TO ESTABLISH A SURCHARGE MECHANISM FOR THE RECOVERY OF COST	*	CASE NO. 9208
IN THE MATTER OF THE REQUEST OF SOUTHERN MARYLAND ELECTRIC COOPERATIVE, INC. FOR AUTHORIZATION TO PROCEED WITH IMPLEMENTATION OF AN ADVANCED METERING INFRASTRUCTURE SYSTEM	*	CASE NO. 9294

Issue Date: January 7, 2013

In this Order, the Maryland Public Service Commission (the "Commission") concludes that the public interest requires that we provide ratepayers of Potomac Electric Power Company ("Pepco"), Baltimore Gas and Electric Company ("BGE") and Southern Maryland Electric Cooperative, Inc. ("SMECO") (collectively "the Companies") with an additional option related to the installation of smart meters in their homes.[1] We will conduct additional proceedings to determine whether the preferred course is either a) to allow customers the option of retaining their current analog meter, or b) to require all customers to

[1] Chairman Nazarian and Commissioner Speakes-Backman have jointly filed a dissent in this case. We understand and agree with many of the concerns raised by the dissent, and may ultimately determine that their proposed outcome is the better path to take. However, we do not believe the current record adequately establishes that allowing customers to retain an analog meter would so increase costs either to the Companies or to individual customers that we should remove this option from consideration at this time.

response, the Companies and Staff provided detailed testimony and comments that establish the RF emissions from smart meters to be lower than that emitted by microwaves, cell phones and several other common household appliances.[45] The Companies also presented expert testimony that distinguished between "ionizing" radiation, which has the ability to damage human molecules, and "non-ionizing" radiation, which does not.[46] Smart meters emit "non-ionizing" radiation, which scientists have studied extensively for several decades and found no evidence of harmful effects on human beings.[47] Although we have not found convincing evidence that smart meters pose any health risks to the public at large, we acknowledge a good-faith belief on the part of some ratepayers to the contrary. If we ultimately decide to allow customers to retain their analog meter, this option will address any health concerns raised by the use of smart meters. However, if that option proves not to be feasible, we will provide customers with the option to require their utility to install their smart meter so as to minimize or eliminate RF emissions, such as by using an alternative data communications path or by locating the meter farther from the customer's home. We received evidence from the Companies regarding several available options,[48] and our future proceedings will include a review of the costs associated with such options and how best to allow the Companies to recover those costs.

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utilities allege). BGE cites the same Council's 2011 study that concluded smart meter emissions to be lower than microwaves and far lower than cell phones. BGE April 6, 2012 Comments at 5.

[45] May 22, 2012 Tr. at 50-53 (Staff); May 22, 2012 Tr. at 96-100 (BGE).

[46] Testimony of Dr. Peter Valberg, BGE April 6, 2012 Comments, Exhibit 1 at 4; May 22, 2012 Tr. at 104-116 (Valberg).

[47] *Id.* at 7.

[48] Case No. 9207, Item No. 210 (Pepco and Delmarva); Case No. 9208, Item No. 151 (BGE).

(2) That we shall determine the associated costs and procedures for exercising either option following those additional proceedings;

(3) That, on or before July 1, 2013, the Companies shall submit to the Commission their proposals regarding a) the overall additional costs associated with allowing customers to retain their current analog meter, b) their proposals regarding cost recovery of these additional costs from customers, and c) their proposals for recovery of costs related to offering customers different RF-free or RF-minimizing options related to the installation of their smart meters. Additionally, we ask the Companies to provide this information scaled for different levels of customer participation; and

(4) That all requests for relief inconsistent with this Order are hereby DENIED.

/s/ Harold D. Williams

/s/ Lawrence Brenner

/s/ W. Kevin Hughes

Commissioners

ATTACHMENT K –

IDAHO PUBLIC UTILITIES COMMISSION

ORDER NO. 32500

Office of the Secretary
Service Date
March 27, 2012

BEFORE THE IDAHO PUBLIC UTILITIES COMMISSION

BONNIE MENTH AND VICKY DAVIS,	)	
	)	**CASE NO. IPC-E-12-04**
COMPLAINANTS,	)	
	)	
v.	)	
	)	
IDAHO POWER COMPANY,	)	**ORDER NO. 32500**
	)	
RESPONDENT.	)	

On January 4, 2012, the Commission received two formal complaints filed by Bonnie Menth and Vicky Davis against Idaho Power Company. Ms. Menth and Ms. Davis object to the installation of Advanced Metering Infrastructure (AMI), or Smart Meters, at their residences. Both complainants request that the Commission require the Company to create an opt-out opportunity for customers who do not want a Smart Meter, and to order Idaho Power to remove the Smart Meters and replace them with analogue meters. On January 19, 2012, the Commission issued a Summons directing the Company to file an answer to the complaints within 21 days of issuance of the Summons. Idaho Power filed its answer on February 9, 2012. Ms. Menth and Ms. Davis filed responses to the Company's answer on February 22, 2012.

Ms. Menth and Ms. Davis raise similar issues in their complaints. They believe that Smart Meters do not simply measure energy usage, but that they have "the capacity to track minute by minute household activity, control household devices, and as stated on one of its software provider websites, it can generate profiles to target customers for other programs and services based on whatever information is available about them, including the rate class, usage patterns, location, and energy profile that may have been collected from the customer." Accordingly, the complainants regard the meters as surveillance devices. The complainants also believe the Smart Meters produce "dirty power" that can be a health risk. Although the complainants understand the Smart Meters used by Idaho Power do not communicate wirelessly, they nonetheless believe the transmission of a pulse over the house wiring "produces high frequency voltage transients."

Ms. Menth is concerned that Idaho Power's meters "have the capability to be remotely reprogrammed by the utility to enable functions which are currently disabled or

and (4) if an opt-out alternative is available, the cost of using estimated and actual meter readings to calculate bills. The Company estimates it will cost approximately $110.80 to remove the standard AMI meter and replace it with a non-standard meter, and estimates it will cost approximately $75 to re-establish AMI service at the residence if the non-standard meter is later removed. In addition, Idaho Power estimates it will cost approximately $54.58 a month in added billing expense if it cannot use a Smart Meter to remotely obtain usage data. The Company notes that analog and electromechanical meters have not been manufactured since 2007 and they cannot be cost-effectively maintained by the Company. The AMI meter is now the standard equipment used by more than 99% of the Company's customers.

Each complainant "requests an independent investigation of the regulatory monopoly of the Idaho Public Utilities Commission to determine if they are fulfilling their mandate to serve the interest of the public," and also requests "an undetermined amount for attorneys fees to initiate an independent investigation of the regulatory monopoly of the Idaho Public Utilities Commission." This request is for relief that the Commission is not authorized to approve or implement. Instead, this request is more appropriately presented to the Idaho Legislature.

The Commission finds that the meters Idaho Power installed do not have the capability to control appliances or other devices, nor initiate surveillance of electrical usage at individual customer residences. The Commission finds that complainants have not provided sufficient demonstrable, credible factual evidence to support a finding that the meters present legitimate safety or potentially inappropriate communication concerns. The Commission therefore dismisses the complaints.

ORDER

IT IS HEREBY ORDERED that the complaints filed by Bonnie Menth and Vicky Davis are dismissed.

THIS IS A FINAL ORDER. Any person interested in this Order (or in issues finally decided by this Order) or in interlocutory Orders previously issued in this case may petition for reconsideration within twenty-one (21) days of the service date of this Order with regard to any matter decided in this Order or in interlocutory Orders previously issued in this case. Within seven (7) days after any person has petitioned for reconsideration, any other person may cross-petition for reconsideration. See *Idaho Code* § 61-626.

DONE by Order of the Idaho Public Utilities Commission at Boise, Idaho this 27th day of March 2012.

PAUL KJELLANDER, PRESIDENT

MACK A. REDFORD, COMMISSIONER

MARSHA H. SMITH, COMMISSIONER

ATTEST:

Jean D. Jewell
Commission Secretary

O:IPC-E-12-04_ws

ATTACHMENT L –

MICHIGAN PUBLIC SERVICE COMMISSION

CASE NO. U-17000

STATE OF MICHIGAN

BEFORE THE MICHIGAN PUBLIC SERVICE COMMISSION

* * * * *

In the matter, on the Commission's own motion, to review issues bearing on the deployment of smart meters by regulated electric utilities in Michigan.	))))	Case No. U-17000

At the September 11, 2012 meeting of the Michigan Public Service Commission in Lansing, Michigan.

PRESENT: Hon. John D. Quackenbush, Chairman
Hon. Orjiakor N. Isiogu, Commissioner
Hon. Greg R. White, Commissioner

ORDER

On January 12, 2012, the Commission issued an order opening this docket for the purpose of addressing concerns raised by some individuals and local governments regarding the deployment of Advanced Metering Infrastructure (AMI) by electric utilities operating in Michigan.

In its January 12, 2012 order, the Commission directed all regulated electric utilities to submit information in this docket regarding AMI deployment plans, costs, and sources of funding; estimates of monetary savings and other benefits expected to be achieved by the deployment of AMI; scientific information concerning the safety of smart meters; an explanation of the type of information that will be gathered through the use of AMI; the steps that the electric utility intends to take to safeguard the privacy of the customer information; and whether the electric utility intends to allow customers to "opt out" of having a smart meter and if so, how the electric utility intends to recover the cost of an opt-out program.

The Staff's Report on Advanced Metering Infrastructure and Smart Grid

As an initial matter, the Commission expresses its appreciation to the electric providers, the members of the public and various professional organizations that took the time and effort to provide comments, and to the Staff for presenting a comprehensive review of the issues surrounding the widespread deployment of AMI in Michigan.

In its report, the Staff summarized the information on AMI provided by the utilities and noted that the public comments filed could generally be classified as: (1) involving issues of possible adverse health effects of AMI; (2) customer privacy concerns; (3) data protection and cyber security issues; and (4) cost implications of AMI implementation.

The Staff concluded that AMI is rapidly becoming the primary replacement meter to existing electromechanical meters because the new meters are more accurate, they provide enhanced outage response, and AMI offers opportunities for customer energy management. Furthermore, the electromechanical meter is obsolete and no longer in production. Nevertheless, the Staff recognized that investments in AMI and other smart grid components should be subject to ongoing review in contested rate case proceedings. The Staff added that some customers will continue to have concerns about AMI and therefore recommended that the utilities make available a cost-based, opt-out option for these customers.

The Staff also reported that "after careful review of the available literature and studies, the Staff has determined that the health risk from the installation and operation of metering systems using radio transmitters is insignificant. In addition, the appropriate federal health and safety regulations provide assurance that smart meters represent a safe technology." Staff Report, p. 2.

The Staff stated that customer data privacy and cyber security are, and will continue to be, priorities for customers, providers, and the Commission. The Staff observed that data protection

PROOF OF SERVICE

STATE OF MICHIGAN)

Case No. U-17000

County of Ingham)

Lisa Felice being duly sworn, deposes and says that on September 11, 2012 A.D. she served a copy of the attached **Commission Order (Commission's Own Motion) via e-mail transmission**, to the persons as shown on the attached service list (Listserv Distribution List).

Lisa Felice

Lisa Felice

Subscribed and sworn to before me
this 11th day of September 2012

Gloria Pearl Jones

Gloria Pearl Jones
Notary Public, Ingham County, MI
As acting in Eaton County
My Commission Expires June 5, 2016

ATTACHMENT M –

NEW HAMPSHIRE PUBLIC UTILITIES COMMISSION

ORDER NO. 25,409

STATE OF NEW HAMPSHIRE
PUBLIC UTILITIES COMMISSION

DE 12-245

NEW HAMPSHIRE ELECTRIC COOPERATIVE

Joan Wirth Request for Hearing on Installation of Smart Meters

Order Denying Hearing Request

ORDER NO. 25,409

September 6, 2012

I. PROCEDURAL HISTORY

On March 7, 2012, Joan Wirth, a residential electric customer residing in Bristol, New Hampshire and served by the New Hampshire Electric Cooperative (NHEC), filed a letter with the Commission requesting a meeting with the Commission's Executive Director concerning NHEC's proposed installation of new electric meters. Ms. Wirth claimed that, if installed, the new meters would pose serious health problems. On March 16, 2012, the Commission's Director of Consumer Affairs sent a letter to Ms. Wirth informing her that because there was a lawsuit pending in the Grafton County Superior Court concerning NHEC's installation of the new meters, the Commission Staff would wait to meet with her until the lawsuit was concluded. *See Grafton County Superior Court, Nelson, et al. v. New Hampshire Electric Cooperative*, Case No. 215-2012-CV-00046. The lawsuit was brought by Ms. Wirth and several other NHEC customers seeking to enjoin NHEC from installing the new meters in their homes. On March 22, 2012, the Grafton County Superior Court denied the parties' request for preliminary injunction. Following withdrawal of the case by the moving parties, including Ms. Wirth, the Superior Court dismissed the matter without prejudice.

conflicts with the federal regulation. *Id.* at 125, *see, e.g. Buckman*, 531 U.S. 341, 348 (2000). Because the *Farina* court found that the FCC regulations required a balance between safety and the rapid development of an efficient communications system, the court held that allowing states to rebalance that policy decision would conflict with the federal scheme. *Farina* at 125.

> Here, the FCC has weighed the competing interests relevant to RF regulations – safety and efficiency. It has reached an unambiguous conclusion by adopting the hybrid ANSE/IEEE-NCRP set of standards, *see* 47 C.F.R. §2.1093(d), and it has implemented that conclusion via a specific mandate, requiring every cell phone sold in the United States to comply with those standards, *see* 47 C.F.R. §§ 2.803(a)(1); 24.51-.52....Because the intensity of RF emission levels and the strength and range of cell phone signals are positively correlated, allowing additional state-law restrictions on these levels could impair the efficiency of the wireless market. But given the current state of the science, the FCC considers all phones in compliance with its standard to be safe. *See FCC First Order*, 11 F.C.C.R. at 15184 ("We believe that the regulations ...represent the best scientific thought and are sufficient to protect the public health.") These standards represent a "consensus view" of the agencies with jurisdiction over RF emissions and incorporate the views of numerous expert organizations and interested parties. *Id* at 15124. As an agency engaged in rulemaking, the FCC is well positioned to solicit expert opinions and marshal the scientific data to ensure its standards both protect the public and provide for an efficient wireless network. Allowing juries to perform their own risk-utility analysis and second-guess the FCC's conclusion would disrupt the expert balancing underlying the federal scheme. *See Buckman*, 531 U.S. at 348, *Id.* at 125-126.

Having determined that NHEC's meters meet the FCC RF emissions limits, we will not explore a separate state standard for RF emissions because we find that the FCC limits pre-empt a separate and potentially conflicting state standard.

C. RSA 374:62 (Senate Bill 266)

Ms. Wirth contends that the basic, or standard, smart meters NHEC is installing throughout its service territory are "smart meter gateway devices" as defined by newly enacted RSA 374:62, and as a result, NHEC must obtain a signed opt-in form from the customer before installing the smart meter gateway device at the customer premises. Further, Ms. Wirth has

Based upon the foregoing, it is hereby

ORDERED, Ms. Wirth's request for a hearing is DENIED.

By order of the Public Utilities Commission of New Hampshire this sixth day of September, 2012.

Amy L. Ignatius Chairman	Michael D. Harrington (KNS) Commissioner	Robert R. Scott Commissioner

Attested by:

Debra A. Howland
Executive Director

ATTACHMENT N –

NEVADA PUBLIC UTILITIES COMMISSION

DOCKET NO. 11-10007

BEFORE THE PUBLIC UTILITIES COMMISSION OF NEVADA

Investigation regarding NV Energy's Advanced Service Delivery Meter Program a/k/a Smart Meter and its implementation.	))))	Docket No. 11-10007

At a special session of the Public Utilities Commission of Nevada, held at its offices on February 29, 2012.

PRESENT: Chairman Alaina Burtenshaw
Commissioner Rebecca D. Wagner
Commissioner David Noble
Assistant Commission Secretary Breanne Potter

ORDER

The Public Utilities Commission of Nevada ("Commission") makes the following findings and conclusions:

I. INTRODUCTION

The Commission opened an investigation regarding Nevada Power Company's d/b/a NV Energy and Sierra Pacific Power Company's d/b/a NV Energy (collectively, "NV Energy") Advanced Service Delivery Meter Program a/k/a Smart Meter ("smart meter") and its implementation.

II. SUMMARY

The Commission approves the Report on NV Energy's Advanced Service Delivery Meter Program in Attachment 1 as outlined in this Order.

III. PROCEDURAL HISTORY

- On October 25, 2011, the Commission opened an investigation regarding NV Energy's smart meter program and its implementation. This matter has been designated as Docket No. 11-10007.

- The investigation is conducted by the Commission pursuant to the Nevada Revised Statutes ("NRS") and the Nevada Administrative Code ("NAC") Chapters 233B, 703, and 704, including but not limited to, NRS 704.120.

- On November 2, 2011, the Commission issued a Notice of Investigation Regarding NV Energy's Advanced Service Delivery Program a/k/a Smart Meter and Its Implementation, Notice of Request for Comments, and Notice of Workshop ("Notice").

DOCUMENT REVIEW AND APPROVAL ROUTING		
DRAFTED BY: Margaret Lenzi		
FINAL DRAFT ON 2/29/12 AT 2:00 PM		
REVIEWED & APPROVED BY:		DATE
☐ ADMIN / ASST. ( )		/ /
☒ COMM / COUNSEL	AP for SP	2/29/12
☐ SECRETARY / ASST. SEC.		/ /
☐ OTHER ( )		/ /

- On or before November 18, 2011, the Commission received written comments from interested persons regarding smart meter concerns in the following areas: health and safety; privacy and security; accuracy and reliability; and customer service as it specifically relates to notification, installation, and NV Energy call backs regarding smart meters.

- On December 2, 2011, NV Energy filed reply comments responding to the issues raised in initial comments and addressing specific questions in the notice.

- On December 6, 2011, the Commission conducted a workshop to discuss written comments and reply comments filed with the Commission in order to identify the issues and concerns related to smart meter implementation.

- On December 12, 2011, the Commission issued a Notice of Second Request for Comments and Notice of Workshop.

- On December 28, 2011, NV Energy filed comments regarding proposals for ratepayers to opt-out of installation of a smart meter and addressing specific questions in the notice.

- On January 12, 2012, the Commission issued an Interim Order on customer service issues related to smart meter implementation.

- On or before January 13, 2012, the Commission received written reply comments from interested persons regarding the opt-out proposals provided by NV Energy.

- On January 17, 2012, the Commission received the Response of NV Energy pursuant to the direction provided by the Hearing Officer at the December 6, 2011 workshop.

- On January 18, 2012, the Commission conducted a workshop to discuss written comments and reply comments filed with the Commission regarding NV Energy's opt-out proposals.

- On January 23, 2012, NV Energy made a Compliance Filing with the Commission pursuant to the Interim Order.

- On February 14, 2012, the Regulatory Operations Staff ("Staff") of the Commission filed a memorandum regarding NV Energy's Compliance Filing.

IV. COMMISSION DISCUSSION AND FINDINGS

1. The Hearing Officer issued a Report on NV Energy's Advanced Service Delivery Meter Program ("Report"), attached hereto and incorporated herein as Attachment 1. The Report provides an overview of the Commission's approval of NV Energy's smart meter program; smart meter concerns in the areas of health and safety, privacy and security, accuracy and reliability and customer service; and proposals for ratepayers to opt-out of installation of a smart meter.

2. The Commission agrees with the findings and conclusions of the Report and finds that it is in the public interest to approve the Report.

THEREFORE, it is ORDERED that:

1. The Report on NV Energy's Advanced Service Delivery Meter Program in Attachment 1 is APPROVED.

Directives:

2. Within sixty days of the issuance of this Order, NV Energy shall file a Trial Opt-out Tariff with the Commission consistent with the recommendations in the Report.

3. Failure to conform to the directives in this Order may subject NV Energy to administrative fines pursuant to NRS 703.380.

4. The Commission may correct errors that may have occurred in the drafting or issuance of this Order.

By the Commission,

ALAINA BURTENSHAW, Chairman

REBECCA D. WAGNER, Commissioner

DAVID NOBLE, Commissioner
(Concurring in part and dissenting in part)

Attest:
BREANNE POTTER,
Assistant Commission Secretary

Dated: Carson City, Nevada

3-2-12

(SEAL)

PUBLIC UTILITIES COMMISSION OF NEVADA PUC

BEFORE THE PUBLIC UTILITIES COMMISSION OF NEVADA

Investigation regarding NV Energy's Advance Service Delivery Meter Program a/k/a Smart Meter and its implementation	))))	Docket No. 11-10007

REPORT ON NV ENERGY'S ADVANCE SERVICE DELIVERY METER PROGRAM

I. INTRODUCTION

The Public Utilities Commission of Nevada ("Commission") opened an investigation regarding Nevada Power Company's d/b/a NV Energy and Sierra Pacific Power Company's d/b/a NV Energy (collectively "NV Energy") Advanced Service Delivery ("ASD") Meter Program a/k/a Smart Meters and its implementation.

In the first Request for Comments, the Commission asked for comments from interested persons and reply comments from NV Energy regarding smart meter concerns in the following areas: (1) Health and Safety; (2) Privacy and Security; (3) Accuracy and Reliability; and (4) Customer Service.[1] In the second Request for Comments, the Commission asked NV Energy to provide a proposal for ratepayers to opt-out of installation of a smart meter and reply comments from interested persons.

II. SUMMARY

NV Energy should offer to customers who demand a non-standard meter a digital meter capable of drive-by reading.

III. BACKGROUND

The Commission authorized NV Energy to proceed with its ASD program after a thorough and complete investigation of the program. In February 2010, Nevada Power Company filed its 2010-2029 Triennial Integrated Resource Plan ("IRP") in Docket No. 10-02009. In March 2010, Sierra Pacific Power Company filed an Amendment to its 2008-2027 IRP in Docket No. 10-03023. These dockets were consolidated with Docket No. 10-03022. The filings requested approval of NV Energy's ASD program pursuant to Nevada Revised Statutes ("NRS") 704.741 and Nevada Administrative Code ("NAC") 704.925. The Regulatory Operations Staff ("Staff") of the Commission, the Attorney General's Bureau of Consumer Protection ("BCP") and several other parties completed a thorough and complete review of NV Energy's ASD program and the Commission held a full evidentiary hearing regarding the program.[2] The Commission also held two consumer sessions on May 10, 2010, in order to receive public comments.

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[1] On January 12, 2012, the Commission issued an Interim Order addressing customer service issues related to smart meter implementation ("Interim Order").

[2] December 2, 2011, Comments of NV Energy at 6.

advice and observe the same precautions with respect to a smart meter that they would take with respect to many other common RF emitting devices such as cell phones and other typical consumer products.[34]

Smart meters do not violate the ADA or the Fair Housing Act. Both the ADA and the Fair Housing Act require reasonable accommodations for disabled individuals under certain circumstances. A disability is one that substantially limits one or more of the individual's major life functions.[35] EHS is not a medical diagnosis, nor is it clear that the symptoms represent a single medical problem. Moreover, in 2005, the WHO indicated that "no scientific basis currently exists for a connection between" EHS symptoms and exposure to EMF.[36] The accommodations suggested by several individuals including a moratorium on the installation of smart meters, a rule proscribing the installations of smart meters in public facilities, and an opt-out provision, are not reasonable accommodations.[37]

In reply to comments that the smart meters are not being safely installed, the fact is that the individuals who install the smart meters are required to have the same training and possess the same qualifications as individuals who install analog meters. NV Energy's installation contractor, Scope Services, employs two categories of personnel to install smart meters. The first category, Installer/Class 1, does not require the personnel to possess Journeyman Electrician certification. The second category, Senior Installer/Class 2, is required to possess a Journeyman Electrician, Inside Wireman, or Lineman certificate. Personnel employed by Scope Services are referrals from the International Brotherhood of Electrical Workers ("IBEW") Local 396.[38] Additionally, the installers' technical skills, safety, and qualification requirements are extensive.[39]

NV Energy states that UL has developed safety standards and testing procedures for certain products, materials, components, assemblies, tools and equipment. UL has not developed standards for electrical meters.[40]

Commission Analysis of Health and Safety Issues

A number of individuals raised various health concern issues related to RF exposure from smart meters. These health concern issues are beyond the regulatory authority of this Commission. The FCC, not this Commission, establishes standards for the exposure of humans to RF fields.[41] Smart meters meet the FCC emission standards and the RF emissions from smart meters are far lower than the FCC guidelines. Each element of the NV Energy AMI Network must comply with the exposure limitations established by the FCC. The FCC has taken a very conservative approach to RF exposure compliance for low-power network devices such as smart meters. The FCC "is continually monitoring the issue of RF exposure and related health and

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[34] December 2, 2011, Comments of NV Energy at 36-37.
[35] December 2, 2011, Comments of NV Energy at 37-38.
[36] December 2, 2011, Comments of NV Energy Attachment 2.
[37] December 2, 2011, Comments of NV Energy at 39.
[38] December 2, 2011, Comments of NV Energy at 40-41.
[39] December 2, 2011, Comments of NV Energy Attachment 11.
[40] December 2, 2011, Comments of NV Energy at 13 n.42.
[41] Tr. at 61-62.

safety concerns, both in general terms of the continuing propriety of its regulations, and in individual cases where substantive concerns are raised."[42] While this Commission will ensure that NV Energy's smart meters are compliant with FCC standards, any individual substantive health concerns regarding NV Energy's smart meters should be addressed to the FCC.

There were concerns about the impact of higher temperatures on older adults and whether these customers have access to affordable home energy without mandates to follow rate structures. It is important emphasize again that NV Energy's DR programs and time-of use rates are completely voluntary.[43] Additionally, NRS 704.1835 requires the following of the Commission:

> For the purposes of protecting the health of residential customers who receive gas, water or electricity from public utilities, the Commission shall adopt or amend regulations that:
>
> (a) Establish the criteria that will be used to determine when a public utility is required to postpone its termination of utility service to the residence of a residential customer who has failed to pay for such service. Such criteria may be based in part upon the residential customer's ability to pay.
>
> (b) Require a public utility to postpone its termination of utility service to the residence of a residential customer who has failed to pay for such service if the residential customer satisfies the criteria established by the Commission and termination of the utility service is reasonably likely to threaten the health of an occupant of the residence of the residential customer.

In Docket No. 10-07024, the Commission amended its Consumer Bill of Rights to provide additional protections to vulnerable populations from remote disconnection of electric service. First, the Commission codified lower temperature thresholds for disconnecting vulnerable customers for non-payment. Second, the Commission required that vulnerable customers who have identified themselves as vulnerable would receive an "in person" notification before service was disconnected.[44]

The concern that smart meters were not being safely installed because the installers are not licensed electricians is not supported. NV Energy provided a document outlining the extensive skill sets and qualifications required to be possessed by an installer and the safety requirements they must follow. Furthermore, personnel installing smart meters are required to have the same training and possess the same qualifications as individuals who install analog meters. Based on the supporting documentation provided by NV Energy, the Commission has no basis to find that smart meters are not being safely installed.

The concern that smart meters pose a fire and electrical safety risk because they are not UL approved is also not supported because smart meters meet all applicable safety standards. If a customer has older electronic equipment in the home, when the power is disengaged and

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[42] December 2, 2011, Comments of NV Energy at Attachment 1.
[43] Tr. at 84.
[44] October 12, 2011, Order in Docket No. 10-07024.