Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E SmartMeter Program Upgrade System

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NOTE

This supplemental report extends the findings contained in an earlier report for PG&E "Analysis of RF Fields Associated with Operation of PG&E Automatic Meter Reading Systems" prepared April 6, 2005. In that report, radiofrequency (RF) fields that could be produced by several different automatic meter reading (AMR) systems were evaluated relative to applicable human exposure limits. This report addresses similar RF fields that could be associated with operation of an additional system that would provide AMR capability for PG&E customers as well as more advanced features that could allow customers to monitor their own electricity usage and program various electric power consuming devices in their homes to operate only during certain times, depending, for example, on electric energy cost at different times of day. The previous report should be consulted for more detail on terminology, methods of evaluation, human exposure limits and specific terminology.

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Summary

Use of new SmartMeter Program Upgrade technology by Pacific Gas and Electric will make use of low power radiofrequency (RF) transmitters for automatic electric power meter reading. The SmartMeter Program Upgrade technology will also allow customers the possibility of controlling their own use of electricity based on energy rates during the day. A study of RF fields produced by the transmitting components of the system shows that potential exposure of individuals will comply with applicable Federal Communications Commission human exposure regulations by a very wide margin. For example, immediately adjacent to a power meter, the RF field power density will be 8.8 $\mu W/cm^2$ compared to the exposure limit of 601 $\mu W/cm^2$ appropriate to the 902-928 MHz band. Typical exposure to access points that are mounted 25 feet above ground will be even lower, more than 15,000 times less than the exposure limit. Exposure to RF emissions associated with the 2.45 GHz signals from a home area network feature of the system will also be similarly small fractions of the allowable human exposure limit. The absolute greatest power density found in the analysis is 24.4 $\mu W/cm^2$ for the rare situation of a person located immediately adjacent to an access point antenna. When compared with RF fields produced by many devices found in our everyday environment, such as radio and television broadcast stations, cellular telephones, and microwave ovens, RF exposures resulting from the SmartMeter Program Upgrade will very much weaker.

RF transmitting components of the system include 1 watt, or less, transmitters contained within the glass envelope of a power meter, in repeater units, and within access points. The system constitutes a sophisticated mesh network wherein each meter can act as a repeater for assisting in delivering outgoing data to access points or other nearby meters from whence the data is further relayed.

Based on this analysis for the system as proposed by PG&E, SmartMeter Program Upgrade related RF exposure of individuals who live and/or work in or around structures that are equipped with the SmartMeter Program Upgrade system will be compliant with existing standards and regulations for safe exposure.

Introduction and Background

Automatic Meter Reading (AMR) technology is being adopted by the Pacific Gas & Electric Company (PG&E). This technology allows for remote reading of electricity usage by customers without the traditional deployment of field personnel for obtaining monthly readings from individual meters. Beyond the capability that AMR technology brings to the company, PG&E is implementing advanced features that will allow individual customers to monitor their own usage of electric energy and even control devices within their homes based on dynamic electric energy charges during the day by programming such appliances as hotwater heaters, furnaces and air conditioning systems to operate only when electric energy rates are less costly. This program is referred to as the SmartMeter Program Upgrade by PG&E and the equipment that will be used makes use of radiofrequency signals for communicating the data associated with meter readings and making electricity rates available to customers. This supplemental report addresses the RF fields that may be produced by the system's operation in relation to the potential for exposure of individuals in the vicinity of the various transmitting portions of the system. Maximum permissible exposure (MPE) values have been adopted by the Federal Communications Commission (FCC) or recommended in various standards that specify maximum safe levels of exposure.

The system which would be implemented by PG&E is provided by Silver Spring Networks[1] and consists of a number of different components, each that make use of RF signals from low power transmitters. Figure 1 provides a simplified illustration of how the SmartMeter Program Upgrade will be configured with the Silver Spring Networks equipment. In this system, so-called endpoint devices consist of the electric power meters which contain two low power transmitters.

One of the two transmitters is used for connectivity for the AMR function, sending meter reading data to an access point from where the data is transmitted back to the company via a wireless wide area network (WAN) (somewhat similar to using a cell phone for voice communications). The AMR transmitter is rated at one watt maximum power output, operates within the license free frequency band 902 to 928 MHz, and uses an internal antenna inside the meter with a nominal gain of 0 dBi (decibels relative to an isotropic radiator). Also contained with the glass envelope of the meter is a second transmitter that operates in the license free 2.40-2.4835 GHz frequency band (hereafter referred to as the 2.4 GHz band) and is used to provide potential communications with a home area network that the customer may elect to install for purposes of monitoring power consumption. This second transmitter is rated at a power of approximately 0.1 watt and also uses an internal antenna having a nominal gain of 0 dBi. The 1 watt transmitter is configured to transmit data approximately once every four hours back to the company so its duty cycle is very small (the actual data transmission duration during any four hour period will vary, however, depending on how often a particular meter transmitter acts as a repeater for other nearby meters). The lower power 2.4 GHz transmitter is designed to transmit only when instructed to by the customer's home area network.

The Silver Spring Networks equipment is configured as a mesh network. This means that the AMR transmitter inside each power meter is designed to communicate with each other meter transmitter within its range if necessary to get the data signal back

[1] Silver Spring Networks, 575 Broadway Street, Redwood City, CA 94063.

to an access point. In essence, each meter transmitter can also act as a repeater. In the event that a given power meter can't directly reach the nearest access point, the data can be handled by a closer meter and relayed to the access point or to yet another meter or a specific relay transmitter for ultimate communication with the access point. Thus, the grouping of a large number of meters with their internal transmitters forms the mesh network, the various meters simulating the interconnection points (or nodes) similar to a screen mesh. Through the mesh approach, more distant meters can still communicate with an access point through the help of its neighbors and an access point can communicate with the more distant meters that may be out of direct range of the access point. Actual dedicated relay transmitters are used in some locations to faciliate the communications and these transmitters also operate with one watt of power but use more efficient antennas with gains of about 2 dBi (approximately the gain of a dipole antenna). While the meter transmitters are constrained to where the power meters are located, repeaters will typically be mounted outdoors and elevated approximately 25 feet above ground[2]. The duty cycle of repeaters is also small since they will only operate when necessary to relay signals on to an access point. The duty cycle of a dedicated repeater may be greater than that of a given individual meter, however, since it may be required to relay data from more meters during any four hour period than a power meter installed on a house.

The data from each power meter must eventually get back to the PG&E management system and this requires that the signal from each power meter ultimately reaches an access point. Each access point has a similar one watt transmitter inside it that communicates in the 902 to 928 MHz band with the power meters or intermediary repeaters but it also contains another transmitter similar to an AirCard used with laptop computers for wireless connection to the Internet. The AirCard transmitter will operate in the band used by the particular company providing the wireless wide area network (WAN) service. This will typically be in the 800-900 MHz range or in the 1.9 GHz range. For purposes of this analysis, the lower frequency range has been assumed since it has the more stringent MPE associated with it.

In the deployed system, the goal is for one access point to handle data transmissions from as many as approximately 5,000 meters. Hence, the duty cycle of an access point will be greater than typical electric power meter transmitters. Access points will typically be mounted at approximately 25 foot above ground level but may, on occasion, be installed on building rooftops. The AirCard transmitters operate with a power in the range of 250 milliwatts to no greater than one watt.

Radiofrequency Exposure Limits

Several guidelines or standards exist that recommend safe upper limits for human exposure to RF fields. These include limits developed by the Institute of Electrical and Electronics Engineers (IEEE, 1999), guidelines published by the International

[2] Approximately 95% of access points and relays within the SmartMeter Program Upgrade system will be mounted high above ground. The remaining 5% may be mounted on building rooftops.

Commission on Non-ionizing Radiation Protection (ICNIRP, 1998) and those promulgated by the Federal Communications Commission (FCC, 1997) relative to human exposure to RF fields[3]. The exposure guidelines of the FCC are most relevant to the evaluation of potential exposure because the AMR system equipment is regulated by the FCC in their rules and regulations[4]. The FCC maximum permissible exposure (MPE) values are expressed in terms of the plane wave equivalent power density of the RF field or the strength of the electric and/or magnetic field components of the RF field. Power density is expressed as power per unit area and is most commonly given in units of milliwatts per square centimeter (mW/cm^2) or microwatts per square centimeter ($\mu W/cm^2$). The FCC exposure limits are, strictly, applied to FCC licensees such as operators of radio and television broadcast stations, two-way radio communications systems, cellular telephone base stations, etc.

Although the Silver Spring Networks AMR transmitters operate in the "license free" band of 902-928 MHz, and while these low power devices are not directly affected by the FCC rules on human exposure, the FCC MPEs for the general public are well recognized by most RF operators and these exposure limits are among the most stringent of those that exist. It is, therefore, relevant to use the FCC MPEs as bench marks for evaluating potential human exposure to the AMR system to be deployed by PG&E. For purposes of this evaluation, the MPE values established for members of the general public have been applied. For emissions at 902 MHz, the FCC MPE for the general public is equivalent to 601 $\mu W/cm^2$. The MPE at 2.45 GHz, for example, is equal to 1,000 $\mu W/cm^2$. The smaller figure of 601 $\mu W/cm^2$ has been used as the benchmark for evaluating potential RF field exposure due to the operation of the PG&E SmartMeter Program Upgrade system for the AMR function and the AirCard transmissions from access points within the mesh network. The larger figure of 1,000 $\mu W/cm^2$ was used for evaluating the internal meter transmitter designed for connectivity to a home area network. It is relevant to note that the MPE values described above contain safety factors of 50; this means that the MPE is not set at the exact demarcation between hazard and no hazard but a factor of 50 times less than the presumed hazardous exposure level.

Maximum Likely RF Fields from System

RF fields that might be associated with emissions from the various transmitting components of the SmartMeter Program Upgrade system were calculated following the methodology outlined in a prior technical report.[5] That method includes the conservative approach of accounting for the possibility of ground reflections that can enhance the local RF field strength at any given location. The principal difference between the results of the earlier analysis and the present one is caused by the implementation of a mesh

[3] Safe exposure limits are specified by the FCC in terms of Maximum Permissible Exposure (MPE) limits that vary with frequency. MPE limits for the general public include at safety factor of 50.
[4] 47 CFR 15.247, Federal Communications Commission.
[5] *Analysis of RF Fields Associated with Operation of PG&E Automatic Meter Reading Systems* prepared for Pacific Gas and Electric by Richard A. Tell, Richard Tell Associates, Inc., and J. Michael Silva, Enertech Consultants, April 6, 2005.

network that will increase duty cycles of transmitters used in the system. Figure 2 illustrates the results of this analysis showing the maximum expected power density from the 902-928 MHz emissions that might exist in the vicinity of one of the power meters and in the vicinity of an access point or relay and the power density of the internal 2.4 GHz meter transmitter for home area network applications. Immediately adjacent to a power meter, for example, the power density is calculated to be 8.8 $\mu W/cm^2$.

The values of power density shown in Figure 2 are based on the expected duty cycles for the various units. Arriving at exact values for these duty cycles is a complex task for mesh networks of the type to be implemented by PG&E. For example, the transmitter in the power meter will transmit data approximately once in each four hour period. The duration of this data transmission is extremely short, approximately 50 milliseconds (0.050 seconds). This means that the fraction of the time that the transmitter is actually active during any four hour period, for transmitting its data, is only about 0.00000347. To obtain values of power density that are relevant to human exposure limits, the signal level from the transmitter at any distance must be multiplied by this duty cycle value. However, since the meter transmitters are a part of the mesh network and will, from time to time, relay data from other meters, the transmitters will actually be active for more than just 50 milliseconds as they handle the traffic for some of the other meters as may be necessary. The actual duty cycle of the meter transmitters will only be known once the system is in place and statistics can be obtained on its operation but based on communications with Silver Spring Networks, a conservative assumption is that the maximum duty cycle of a meter transmitter could be approximately 4% for a heavily loaded meter due to its use in relaying data between other meters and access points (more typically, a duty cycle of approximately 2% is expected during normal operation). Hence, a meter transmitter four-hour duty cycle of 0.040 (4%) has been applied in this analysis. The duty cycle associated with operation of the 2.4 GHz home area network transmitter internal to the meter has been assumed to be 100 times the basic duty cycle of the meter AMR transmitter (0.000347), though this may be an overstatement of actual usage.

For an access point, both the AMR metering transmitter and the AirCard transmitter will produce RF fields. Based on information provided by Silver Spring Networks, an access point that is communicating with up to 5,000 meters could be expected to exhibit a long-term duty cycle of about 5.3%. The AirCard, which provides the RF connection with a WAN, will be a significant contributor to the average RF field found near access points since it will be transmitting aggregated data from as many as 5,000 meters every four hours. With a nominal transmission time of 50 milliseconds for each meter, this represents a total transmission time of approximately 250 seconds during each four-hour period. This represents a duty cycle of 0.0174 or 1.74%. This value has been used in calculating the time-averaged power density of the AirCard emissions from the access point. The maximum power density immediately adjacent to an access point, although access to this location may be impossible due to its high mounting point on a light pole, for example, is calculated to be 24.4 $\mu W/cm^2$.

Dedicated relay units[6] will produce RF fields similar to that of a power meter since the transmitters are the same but use somewhat more effective antennas. The RF fields produced by these relay units will fall between the values shown for a power meter and an access point in Figure 2.

The distance scale of Figure 2 represents the straight line distance from the electric power meter or the access point locations. Generally, relay transmitters and access points will be located on poles at a distance of approximately 25 feet above ground. Hence, the indicated values of power density are, generally, highly conservative since most exposure situations will result in a minimum distance of closest approach of 25 feet and the power densities shown for closer distances will not be relevant to most conditions.

Figure 2 also shows the estimated RF field power density associated with the 2.4 GHz transmitter contained within the meter for use in connecting to a possible home area network in the customer's home or business. The figure shows that the power density from this transmitter will be substantially less than that of the AMR meter transmitter.

Perspective on RF Fields

The RF field power densities that will be produced by the SmartMeter Progarm Upgrade system operated by PG&E will be very weak, even very close to the various RF transmitting components of the system. When compared to limits established for safe human exposure, Figure 2 indicates that the resulting RF fields will be substantially less than the MPEs set for the general public. For example, in the area immediately adjacent to a power meter, the power density will be at least 68 times less than the public MPE. At greater distances, the power density becomes even less with an increasing margin between the RF field and the exposure limit.

While the RF fields near an access point will be greater due to the AirCard transmitter on-time, even in this case, the fields are small in comparison to the limits. For typical exposure distances associated with access points mounted on poles at 25 feet above ground, the power density will be approximately 15,000 times less than the public exposure limit. For the more rare case of an access point being installed on a building rooftop or other location where individuals may have access, the field will still be substantially less than the public limit, being approximately 25 times less than the limit for the case of a person being immediately proximate to the access point.

These power densities can be put in some perspective by comparing them to those fields that are produced by operation of conventional microwave ovens used in residential kitchens. All microwave ovens leak small amounts of RF energy during their normal operation (a tiny fraction of the allowable leakage set by the Food and Drug Administration of 5,000 μW/cm)^2. Most microwave ovens produce RF fields within

[6] Each power meter will function as a relay device for other nearby meters but, in addition, dedicated relay units will exist in the geographic vicinity of the network, as seen in Figure 1, for the purpose of providing relay service for data transmissions.

several meters of the oven in the range of a few to several microwatts per square centimeter at the microwave oven frequency of 2.45 GHz, similar to the frequency band used by parts of the SmartMeter Program Upgrade system.

WI-FI systems, commonly found today at so-called hotspots, for wireless access to the Internet, produce RF fields in the range of 1-2 $\mu W/cm^2$.[7,8] Similar values of power density are found near wireless routers that are commonly used in homes for distributing Internet connectivity to personal computers. All of these values are orders of magnitude less than the limits set for safe human exposure.

Should a customer elect to install a home area network for communication with the SmartMeter Program Upgrade equipment at their home, RF exposure of the customer or other individuals within the home would likely be dominated by the wireless router being used by the customer, not the RF transmission components inside the power meter. Such exposure would be principally driven by distance between the customer and their in-home home area network equipment rather than proximity to the power meter.

This study focused on the SmartMeter Program Upgrade system proposed by PG&E including the potential installation of devices that a customer may elect to install on various electrical appliances that would allow communication between these devices and the SmartMeter system via a home area network. However, the study does not take into account the potential for RF fields that may be produced by the many other devices or systems that are not a part of the SmartMeter Program Upgrade. Such devices or systems include the cellular telephones, cellular telephone base stations, broadcast radio and television stations, microwave ovens used in the home or any other source of RF energy.

Conclusions

An analysis of RF fields that may be produced during operation of different components of the PG&E SmartMeter Program Upgrade system shows that the intensities of these fields are small fractions of the present RF exposure limits established for the general public. Weak RF fields in the frequency range of 902-928 MHz and near 2.4 GHz will be produced on an intermittent basis during its normal operation. These fields may have power densities that, for the most part, range from as great as 8.8 $\mu W/cm^2$ to levels thousands of times less. The present exposure limits for members of the public to the 902-928 MHz and 2.45 GHz bands are 601 $\mu W/cm^2$ and 1,000 $\mu W/cm^2$ respectively. In a worst case scenario of a person able to get immediately next to an access point, despite the difficulty, the maximum power density expected would be 24.4 $\mu W/cm^2$.

[7] Foster, K.R. (2007). Radiofrequency exposure from wireless LANS utilizing WI-FFI technology. *Health Physics*, Vol. 92, No. 3, March, pp. 280-282.
[8] 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.

Based on this analysis for the system as proposed by PG&E, SmartMeter Program Upgrade related RF exposure of individuals who live and/or work in or around structures that are equipped with the SmartMeter Program Upgrade system will be compliant with existing standards and regulations for safe exposure by a wide margin.

Interference due to operation of the mesh network system is unlikely to occur because all units use very low power and operate in radio frequency bands reserved by the FCC for devices of this type.

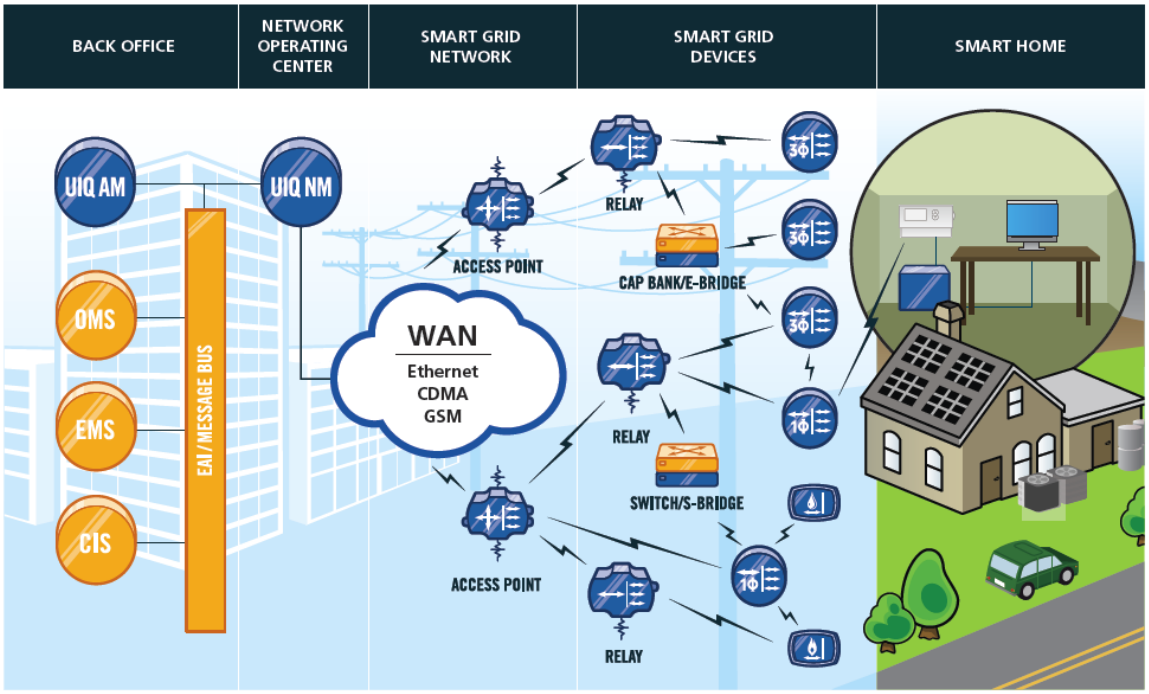

Figure 1. Illustration of components of the PG&E SmartMeter Program Upgrade showing the use of radiofrequency (RF) signals for communications among electric power meters, relays, access points and, ultimately, the company's enterprise management systems. (From Silver Spring Network sales literature).

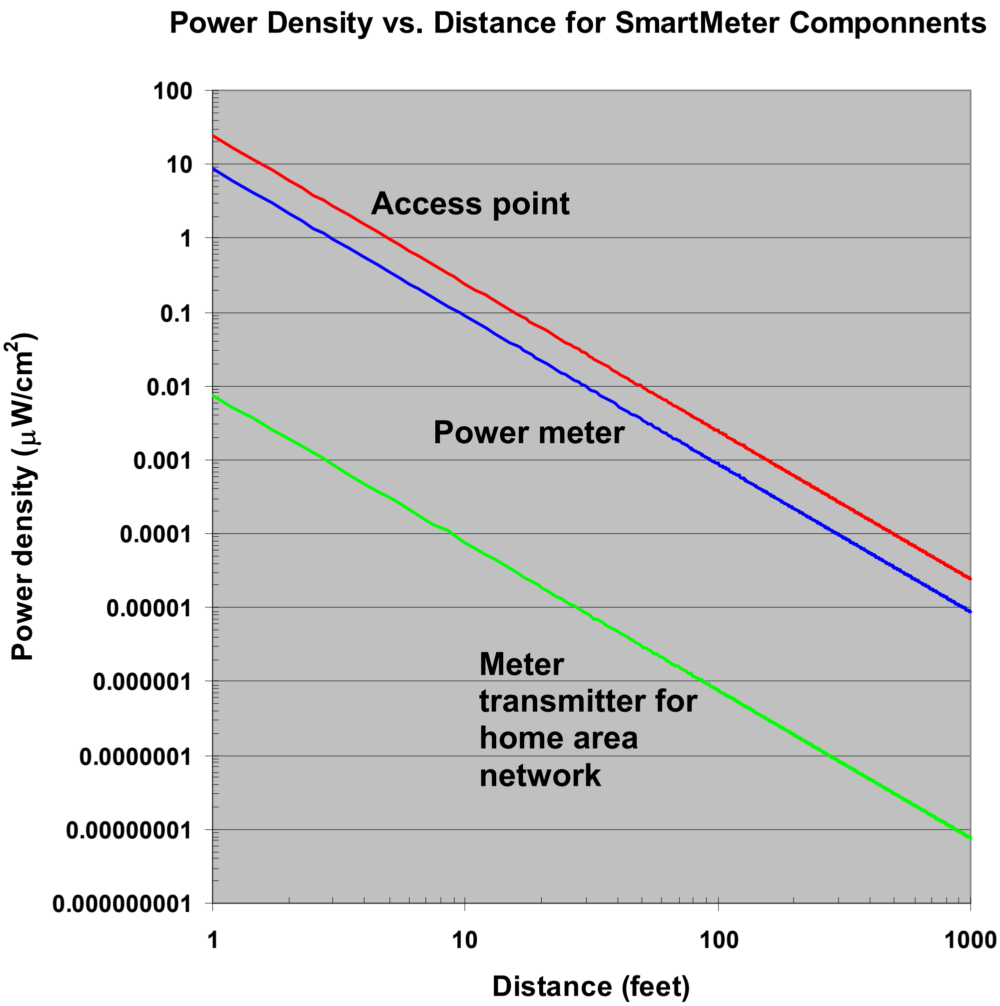

Figure 2. Calculated RF power density vs. distance for the SmartMeter Program Upgrade meters, access points, and internal meter home area network transmitter. Repeater units would produced RF fields greater than the power meter curve and less than the access point curve.