IEEE COMMITTEE ON MAN AND RADIATION—COMAR TECHNICAL INFORMATION STATEMENT RADIOFREQUENCY SAFETY AND UTILITY SMART METERS

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Abstract—**This Technical Information Statement describes Smart Meter technology as used with modern electric power metering systems and focuses on the radio frequency (RF) emissions associated with their operation relative to human RF exposure limits. Smart Meters typically employ low power (−1 W or less) transmitters that wirelessly send electric energy usage data to the utility company several times per day in the form of brief, pulsed emissions in the unlicensed frequency bands of 902–928 MHz and 2.4–2.48 GHz or on other nearby frequencies. Most Smart Meters operate as wireless mesh networks where each Smart Meter can communicate with other neighboring meters to relay data to a data collection point in the region. This communication process includes RF emissions from Smart Meters representing energy usage as well as the relaying of data from other meters and emissions associated with maintaining the meter's hierarchy within the wireless network. As a consequence, most Smart Meters emit RF pulses throughout the day, more at certain times and less at others. However, the duty cycle associated with all of these emissions is very small, typically less than 1%, and most of the time far less than 1%, meaning that most Smart Meters actually transmit RF fields for only a few minutes per day at most. The low peak power of Smart Meters and the very low duty cycles lead to the fact that accessible RF fields near Smart Meters are far below both U.S. and international RF safety limits whether judged on the basis of instantaneous peak power densities or time-averaged exposures. This conclusion holds for Smart Meters alone or installed in large banks of meters.**
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INTRODUCTION

The institute of Electrical and Electronics Engineers—Engineering in Medicine and Biology Society (IEEE EMBS) Committee on Man and Radiation (COMAR) acknowledges public concern about the safety of exposure to radio frequency (RF) energy from Smart Meters, which are new-generation electric utility meters that are being installed in many parts of the world.

This Technical Information Statement describes the Smart Meter technology and the levels of RF emissions from the meters in relation to U.S. and international RF safety limits and in comparison to RF signal levels from other sources.

BACKGROUND

Smart Meters (a term used both by industry and the public) are electric utility meters that have advanced communication capabilities that allow periodic collection of usage data by the utility. In comparison to a slightly earlier generation of wireless-enabled meters that can be read remotely by technicians driving through a neighborhood, Smart Meters engage in two-way communication with the utility, allowing frequent (hourly or better) reading of the meters and other functions. Eventually the technology could be extended to other utility meters as well, but at present it is mainly limited to electric meters.

Electric utilities have installed Smart Meters and their associated Advanced Metering Infrastructure (AMI) in many places around the world, partly in response to government incentives to adopt time-of-use pricing as an economic tool to improve the efficiency of the electric power grid by smoothing out the peaks and valleys of electricity demand throughout the day. AMI systems can also provide consumers with detailed data about household power consumption and promote energy conservation.

While they vary considerably in design with different vendors, most Smart Meter systems rely on wireless transmission of data using standard wireless networking technologies. (A few systems send data over power lines or use some other means of communication not involving wireless transmissions.) Because of the resulting potential for exposure to RF energy, some citizens have raised concerns about possible health risks from the use of Smart Meters. This Technical Information Statement addresses those concerns.

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Smart Meters and the AMI vary considerably in their design with different vendors. However, most AMI systems rely on wireless communications to link meters to utilities and sometimes also to household appliances. Communication in AMI can occur at three levels, each by means of low-powered RF transmitters:

1. Between Houses in a Neighborhood Area Network (NAN). Most AMI systems link meters in a neighborhood in a wireless network, the NAN. This provides a communications structure that can adapt, for example, to momentary disruptions in a wireless link by a passing truck;
2. Within a single home in a Home Area Network (HAN). This network will eventually link the meter and household appliances. The HAN will allow the homeowner to monitor and control household appliances; for example, scheduling the defrosting of refrigerators to times of low utility demand. Because few appliances are presently equipped with the necessary wireless interfaces, few Smart Meter systems have Home Area Networks, although some utilities are presently installing meters with inactive modules for Home Area Networks pending the arrival of wireless-enabled appliances; and
3. Between a neighborhood and the utility via RF transmission links. Most AMI systems use separate wireless links to collect data from the NAN and transmit them to the utility. Communications devices called collectors are mounted on utility or light poles scattered throughout the city. These collectors, which are typically similar to ordinary mobile phones, communicate between the Neighborhood Area Networks and the utility via the commercial wireless telephone system. Alternatively, some collectors might be mounted on consumers' homes near the meters. A typical collector might aggregate data from a hundred or more meters in a neighborhood.

Because of the normal operation of wireless networks, Smart Meters frequently transmit and receive signals throughout the day, even though the utility might read a meter on a given house only a few times a day. These transmissions, which consist of streams of brief RF pulses, might represent data from the meter itself, data relayed through the network from other meters, or pulses needed for the operation of the network itself. The pulses themselves are brief, and the cumulative transmission time is typically only a few minutes per day.

RADIOFREQUENCY EXPOSURE LEVELS FROM SMART METERS

Smart Meters use RF communications technologies that are variants of those used in many other RF-enabled devices on the consumer market. In many meters, the RF modules are versions of those incorporated in other consumer products (Foster 2013).

Most Smart Meter systems transmit at or near 915 or 2,450 MHz, the same frequency ranges as employed by Wi-Fi, many cordless telephones, remote controlled light switches, some baby monitors, and other wireless-enabled appliances, and a few Smart Meter systems operate in nearby frequency ranges. The meters transmit streams of data in a fashion similar to that from Wi-Fi and other communications devices. Household microwave ovens also operate in the 2,450 MHz band.

All of these devices are strictly limited in their transmitted power by government regulations. In the U.S., the Federal Communications Commission (FCC) limits the output of digital communications devices such as are employed in Smart Meters to approximately 1 W, measured as the peak power during a pulse that is applied to the antenna of the device (Foster 2013). Limits in Canada are the same as in the U.S., while European limits are considerably lower. Most Smart Meters, however, operate at power levels that are considerably below the maximum allowed by government regulations.

Most countries throughout the world have limits for human exposure to RF energy. Three sets of limits form the basis of RF safety limits in effect in most countries around the world. These are the limits set by the IEEE (its International Committee on Electromagnetic Safety or ICES) (IEEE 2005), the International Commission on Nonionizing Radiation Protection (ICNIRP) (Ahlbom et al. 1998), and in the United States, the National Council on Radiation Protection and Measurements (NCRP). For example, in the U.S., the relevant legal limits are those of the FCC (USFCC 1997), which are based on the recommendations from the NCRP and IEEE and are generally similar to the ICNIRP recommendations.

While all of these limits are generally the same, they differ in details. The limits are expressed in terms of the power density (intensity) of an RF signal that impinges on the body, in the unit watts per square meter (W m^{-2}), averaged over an appropriate time (30 min for the general public in FCC and IEEE limits or 6 min in the ICNIRP limits).

Both simple calculations and actual measurements show that RF exposures from Smart Meters fall far below those safety limits. At 1,000 MHz (similar to the frequency at which most Smart Meters operate), the FCC and ICNIRP limits are, respectively, 6.7 and 5 W m^{-2} for exposures that are spatially averaged over the whole body and averaged over 30 or 6 min, respectively.

Consider a hypothetical meter transmitting at a power of 1 W using a simple dipole antenna. This meter will produce a signal intensity of less than 0.5 W m^{-2} at a distance of 0.5 m. This exposure is one-tenth or less of the most widely adopted international (ICNIRP) and U.S. (FCC) exposure limits.

A second consideration is the fact that the meters operate by transmitting streams of pulses and not transmitting

signals between pulses. Only a small fraction of the total time is spent actually transmitting signals. This fraction of time, called the duty cycle, is typically below 1% (Tell et al. 2012, 2013; Foster and Tell 2013). This will reduce the time-averaged exposure by an additional factor of 100 or more. These two factors, the low operating power of the meter and the low duty cycle, mean that the RF exposure to an individual from a typical Smart Meter will be a tiny fraction of FCC and ICNIRP safety limits.

The RF exposures that are produced by Smart Meters have been determined both from analysis of data on file with the FCC (Foster 2013) and measured experimentally with actual meters (Tell et al. 2012, 2013; Foster and Tell 2013). A conservative exposure scenario (that was described by the authors as "beyond the worst case") was considered recently, corresponding to an individual placing his or her head directly against the meter. Assuming that the duty cycle of transmission of the meter was 0.1%, the exposure to the subject even in this extreme scenario was less than 1% of FCC limits (Zhou and Schneider 2012).

The actual RF exposure levels to an individual from a Smart Meter will vary depending on its design, the individual's location in relation to the meter, and other factors. However, under any plausible exposure scenario, the RF exposures from Smart Meters are a tiny fraction (much less than 1%) of U.S. and international exposure limits. Claims to the contrary in some Internet postings are based on incorrect methods for determining exposure levels.

EXPOSURES FROM MULTIPLE SMART METERS

Some members of the public have expressed concerns about RF exposure from multiple Smart Meters. Engineering considerations, as well as direct measurements (Tell et al. 2012) show that RF exposures in such cases will always be far below exposure limits even if many meters are present. This is because (a) the intensity of RF fields falls off rapidly with increasing distance from the meter, and (b) the design of wireless digital networks ensures that only one device can transmit at a time to avoid communication interference between different devices. There is no plausible exposure scenario involving multiple meters that will lead to RF exposures to an individual above FCC or ICNIRP limits.

COMPARISON WITH OTHER SOURCES OF RF EXPOSURE

Many other devices found in the home transmit pulsed RF energy at frequencies in the same or nearby frequency ranges as those used by Smart Meters. Examples include Wi-Fi access points, tablet and laptop computers, cordless telephones, many wireless remote control devices, some baby monitors, as well as some household appliances and wireless-equipped toys. Whereas these devices are typically used inside the home, while Smart Meters are typically mounted on metal utility cabinets on the exterior of houses and direct their signals away from the house, the RF signals inside a home from a Smart Meter on its exterior are typically far lower than signals from other RF-emitting devices in the home.

A variety of experimental evidence supports this conclusion:

- A recent study found that the level of RF energy in homes from a Smart Meter transmitting at 2,450 MHz was below the background level from operation of a laptop computer, energy leaking from the door seals of an operating microwave oven, and a Wi-Fi controlled power outlet and home thermostat (Foster and Tell 2013); and
- An extensive survey of RF exposures in homes in European cities found that the highest time-average RF exposure to the residents of a house was likely to be from the use of mobile phones by individuals in the home (the survey did not measure the exposures to the user of the phone itself, which would be far higher than to nearby individuals) (Veil et al. 2009).

In both of the above cases, all RF exposures measured in the homes were a tiny fraction of relevant safety limits.

MEASUREMENTS OF SMART METER EMISSIONS BY CONSUMERS

Videos can be found on the Internet (e.g., YouTube) of people measuring RF pulses near Smart Meters using inexpensive but highly sensitive instruments that generate audible "clicks" every time a Smart Meter emits a pulse. The individuals seen making the measurements in the videos evidently find the "clicks" to be disquieting. However, the ability to detect frequent pulses of RF energy using a sensitive RF detector in no way disagrees with the present conclusions that exposures to the emissions from the meters are far below U.S. and international limits. To provide useful information about RF exposures from the Smart Meters (or other RF emitting appliances) would require different equipment and methods than used in the videos.

CONCLUSION

The RF exposure levels from Smart Meters are far below U.S. and major international limits. Such exposures are typically below levels of RF exposure from a multitude of RF-emitting appliances found in modern homes.

Smart Meters have provoked public controversy in part because of health concerns about their RF emissions. There have been few if any bioeffects studies specifically involving Smart Meters. However, numerous expert reviews of the large body of scientific literature related to biological effects of RF energy have consistently failed to find clear evidence

of adverse health effects from RF exposures below international exposure limits.

For example, in 2012, Verschaeve summarized 33 expert group reports on this topic that were published since 2009 (Verschaeve 2012). "[T]he vast majority [of these reviews] did not consider that there is a demonstrated health risk from RF-exposure from mobile telephones and other wireless communication devices," he concluded, although the group reports usually noted "remaining uncertainties, especially with respect to long-term exposures."

A similar view was expressed by the World Health Organization in 2006 in a fact sheet (that the WHO still supports) (WHO 2006) that said, "There is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects." This would apply to Smart Meters as well, whose emissions are typical of those of devices in wireless networks of other kinds. Among other national health agencies, Health Canada has concluded that "exposure to RF energy from smart meters does not pose a public health risk" (Health Canada 2013).

Based on these opinions, and considering the small RF exposure relative to national and international safety limits, COMAR concludes that RF emissions from Smart Meters should be considered to be safe. Health agencies and standards-setting bodies will continue to follow closely the developing scientific literature in this area.

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