White Paper **WP100006EN**

COOPER POWER SERIES

Smart meters: understanding radio frequency emissions and health impacts

Introduction

The purpose of this paper is to address concerns raised by Eaton's energy consumers regarding the possible health effects of smart meter radio communication and other wireless technology. Eaton takes the customer concerns of our Automated Meter Infrastructure (AMI) users seriously and, after analysis of the issue, would like to affirm that decades of scientific evidence, reinforced by recent specific radio frequency (RF) exposure evaluations, conclude that RF transmissions of the type associated with smart meters is highly unlikely to cause adverse health effects.

Evidence

According to the U.S. Federal Communications Commission (FCC), the organization with oversight responsibility for RF safety guidelines, devices that emit radio energy must be certified to meet maximum permissible exposure (MPE) requirements, as specified in FCC 1.1310. The limits specified by the FCC vary based on frequency, and the power density limits are specified as an average value over a 6-minute time period. The power density limit for the 902–928 MHz band in which the Eaton RF AMI products operate (defined as the 915 MHz Industrial, Scientific, and Medical band) is 0.6 mW/cm^2. The FCC validates a device using a calculation distance of 20 cm (7.9 in) and notes RF exposure drops rapidly with distance.

Note: The FCC limits for exposure are based on the effects of tissue heating in behavioral studies in animal subjects and afford the public a margin of safety 50-fold lower than the adverse effect exposure threshold[1].

Note: Other organizations that recommend exposure limits, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE®), have also adopted guidelines consistent with the FCC's.

The California Council on Science and Technology (CCST), an independent organization, sponsored in part by the state's major universities and federal laboratories, conducted a data analysis review, titled "Health Impacts of Radio Frequency from Smart Meters" to assess the potential health effects of smart meter operation. Upon completion of the study, CCST published **Table 1** below outlining what the organization believes are the key factors when evaluating exposure to radio frequency from smart meters.

Table 1. Key factors when evaluating exposure to radio-frequency 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 (μW/cm^2)	Meter signal strength is 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 μW/cm^2 3 ft–1.0 μW/cm^2 10 ft–0.1 μW/cm^2
4. Signal duration	Extremely short amount of time (2–5%, 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" limit is 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.

Source: California Council on Science and Technology, "Health Impacts of Radio Frequency from Smart Meters," April 2011.

In relation to other commonly used devices, such as cell phones, microwaves, and laptops, the relative power density of smart meters is minimal and much lower than the FCC standard. Furthermore, in most cases the meter is placed outside of the home (providing additional exposure screening) and operates for shorter periods of time (generally for a few seconds at a time with transmissions occurring at different times throughout the day). The very low duty cycle operation of the meters therefore limits potential exposure and decreases the possible threat to the customer's health.

CCST looked at data showing radio frequency levels from various common household items in comparison to smart meters. The findings are shown in **Figure 1**.

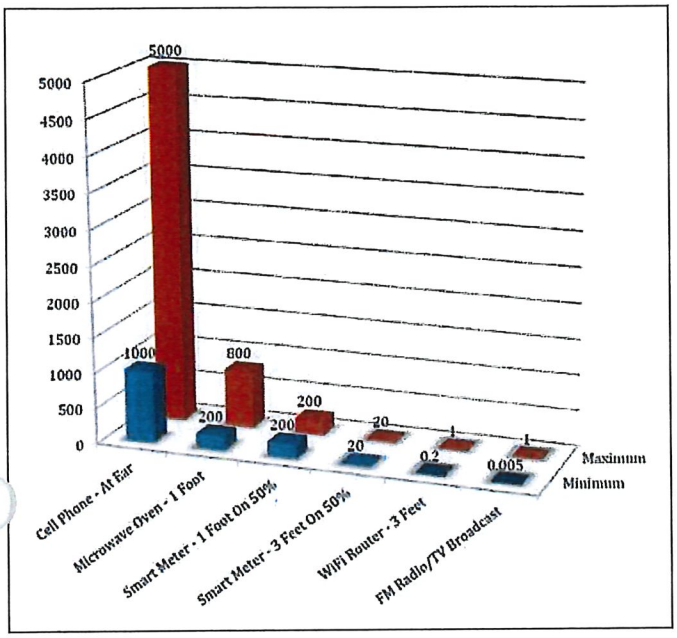

Figure 1. Comparison of radio frequency levels from various sources (in µW/cm²)

Source: California Council on Science and Technology, "Health Impacts of Radio Frequency from Smart Meters," April 2011.

This data shows that the maximum RF exposure effects from a continuously communicating (50% transmit duty cycle) smart meter at 3 feet is one quarter that experienced from a microwave at 2 feet. The maximum possible transmit duty cycle for a normally functioning RF smart meter is 50% where data transmissions and receptions alternate in time. The actual transmit duty cycle is dependent on the meter's location within the network—increasing for devices that are closer to the Gateway collectors if they support a large amount of relay traffic. For currently deployed networks, the average smart meter transmit duty cycle is typically less than 5% and may be as low as 1–2%. The CCST data presented in **Figure 1** thus assumed a worst case scenario of a meter that is continuously sending data. Even under such an extreme assumption, the worst case exposure is still a fraction of that experienced from typical microwave oven usage. A user will also have far more interactions with a microwave at 2 feet than with continuous presence within 3 feet from a smart meter.

A similar study conducted in October 2011 in Australia, for the Department of Primary Industries, and used by the Canadian British Columbia Center for Disease Control (CDC) in their January 2012 testing of 1 W Itron®, smart meters also showed the comparative effects of smart meter transmission relative to other common household RF-transmitting devices. **Figure 2** illustrates the instantaneous RF peak power density of the 1 W smart meter relative to that of other devices when measured at a 30 cm (1 ft) distance (note, that while the measurements are all made at a common 30 cm distance, cell phones used without a wireless headset are typically directly pressed against the user's head).

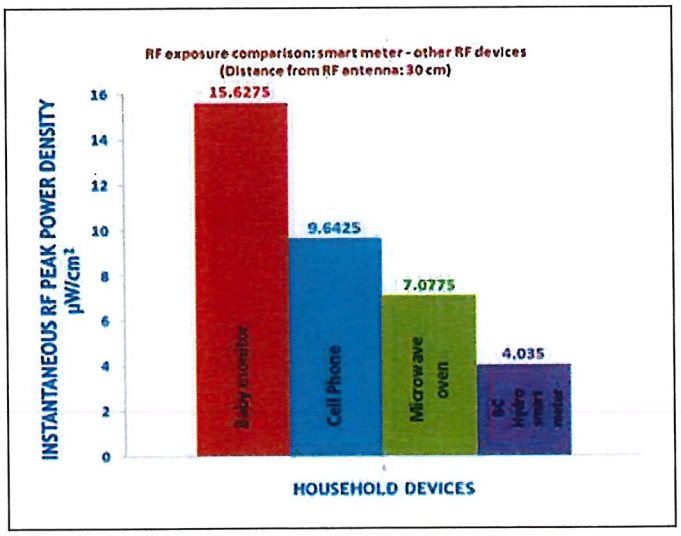

Figure 2. Measured comparative RF exposure at 30 cm (1 ft)

Source: British Columbia CDC "Measurement of Radio Frequency (RF) Emissions from BC Hydro's Itron Smart Meters," January 2012.

In **Figure 3**, to further demonstrate the minimal impact of smart meter RF emissions, the CCST study highlighted the FCC's maximum exposure limits relative to exposure from a typical smart meter. The graph illustrates where smart meter RF exposure stands with regard to the established maximum permissible RF exposure limits against the thermal effects of RF emissions; this notwithstanding the health safety margins that are built into the defined FCC maximum exposure limits.

This data is based on a 1-foot distance from the smart meter operating at a 1 W power level, which is the maximum FCC permitted transmit power for unlicensed operation within the 900 MHz ISM band. The 100% duty cycle is an ultimate worst case in that it is based on an assumed failure scenario in which the meter was stuck continuously transmitting. Because the average meter in an Eaton RF mesh network is likely to be operating with a transmit duty cycle less than 5%, the resulting exposure level, even for a user situated as close as 1 foot, will thus be far below the maximum level permitted by the FCC.

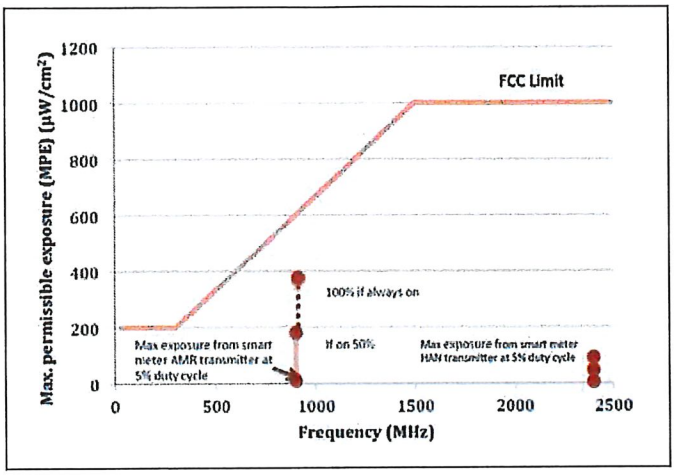

Figure 3. FCC maximum exposure limits and exposure from a 900 MHz, 1 W smart meter 1 foot from the user

Source: California Council on Science and Technology, "Health Impacts of Radio Frequency from Smart Meters," April 2011.

Effect of distance

Distance from a transmitting power source, even without the emission reducing effects of intervening signal blocking structures, can also further significantly reduce potential RF exposure. **Figure 4** provides an illustration of the effects of emission reduction as a function of distance from the smart meter. This drop-off in power density is based on direct line-of-sight, free-space loss where the presence of any intervening structures or surfaces would only lead to further reductions in power density.

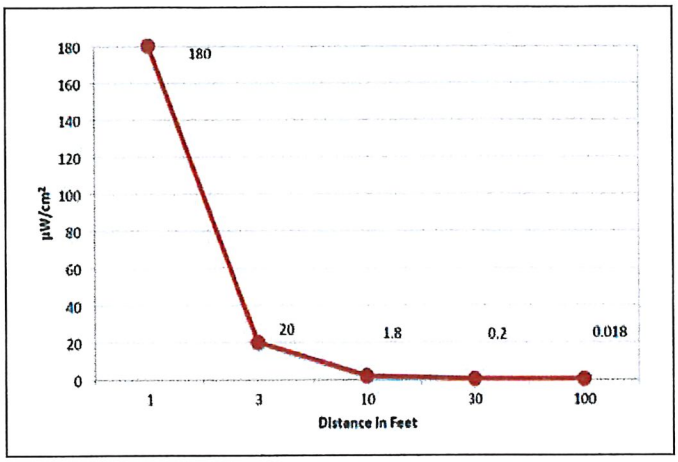

Figure 4. Reduction in power density as a function of distance from source

Source: California Council on Science and Technology, "Health Impacts of Radio Frequency from Smart Meters," April 2011.

An alternative way of visualizing the effect of distance on the potential smart meter RF emission is given in **Figure 5**, which provides a representation of permissible exposure percentage as a function of distance and orientation for a typical residential meter installation based on measured test data. As seen, power density is greatest at the front and closest to the meter with lower exposure levels to the back and further away from the meter.

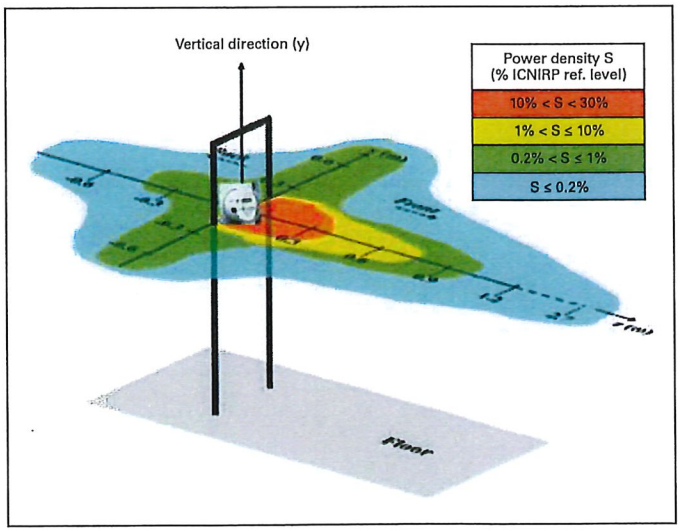

Figure 5. Pictorial representation of maximum RF emission (continuous transmission) from measured test data scenarios

Source: "Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations," EPRI 2014.

Table 2 provides a tabular representation of the results of the RF exposure assessment from smart meters and other common user devices as cited within the California Council on Science and Technology study. The data is based on measurements conducted at a manufacturer's production and test site as part of a study carried out by the Electric Power Research Institute (EPRI). As previous device comparisons illustrated (**Figure 1** and **Figure 2**), together with the effect of distance on radiated RF power, the exposure due to smart meters at 3 or 10 feet is indeed a small fraction of that received from other common user devices such as cell phones and microwave ovens.

Table 2. Radio frequency exposure levels from various sources

Device	Frequency	Exposure level (mW/cm^2)	Distance	Exposure time	Spatial characteristic
Cell phone ①	900 MHz, 1800 MHz	1–5	At ear	During call	Highly localized
Cell phone base station ②	900 MHz, 1800 MHz	0.000005–0.002	10 s to a few thousand feet	Constant	Relatively uniform
Microwave oven ③	2450 MHz	~5 0.05–0.2	2 inches 2 feet	During use	Localized, non-uniform
Local area networks ④	2.4–5 GHz	0.0002–0.001a 0.000005–0.0002b	3 feet	Constant when nearby	Localized, non-uniform
Radio/TV broadcast ⑤	Wide spectrum	0.001 (highest 1% of population) 0.000005 (50% of population)	Far from source (in most cases)	Constant	Localized, non-uniform
Smart meter ⑥	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	Only when in proximity during transmission	Localized, non-uniform

Source: Electric Power Research Institute (EPRI), "Radio Frequency Exposure Levels from Smart Meters," November 2010.

① Based on a 3-inch, 250 mW antenna emitting in a cylindrical wavefront.

② Elliott P, Toledano MB, Bennett J, Beale L, de Hoogh K, Best N, Briggs DJ. 2010. "Mobile phone base stations and early childhood cancers: case-control study. BMJ 340:c3077." ICNIRP. 2009. "Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz)." International Commission on Non-Ionizing Radiation Protection, Oberschleißheim, Germany, page 14. Ramsdale PA, Wiener A. 1999. "Cellular Phone Base Stations: Technology and Exposures." Radiat Prot Dosimetry 83:125-130.

③ ICNIRP. 2009. "Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz)." International Commission on Non-Ionizing Radiation Protection, Oberschleißheim, Germany, page 21. Tell RA. 1978. "Field-strength measurements of microwave-oven leakage at 915 MHz." IEEE Trans Electromagnetic Compatibility 20:341-346. R.A. Tell, personal communication.

④ Wireless router based on 30–100 mW isotropic emitter. Client card based on: Foster KR. 2007. "Radiofrequency exposure from wireless LANs utilizing Wi-Fi technology." Health Phys 92:280-9.

⑤ Tell RA, Mantiply ED. 1980. "Population Exposure to VHF and UHF Broadcast Radiation in the United States." Proc IEEE 68:6-12.

⑥ Based on spatial peak power density with 6 dB (x4) antenna gain.

A 2014 technical study performed by EPRI on the characterization of radio emissions from AMI revenue meters in CPS Energy residential installations in San Antonio, TX, provides a similar summary assessment of the exposure associated with typical household wireless devices. The data, as shown in **Figure 6** provides a qualitative comparison of both the RF emission power (relative to respective maximum permitted exposure limits) and approximated typical estimated exposure times associated with common wireless devices in and around the home.

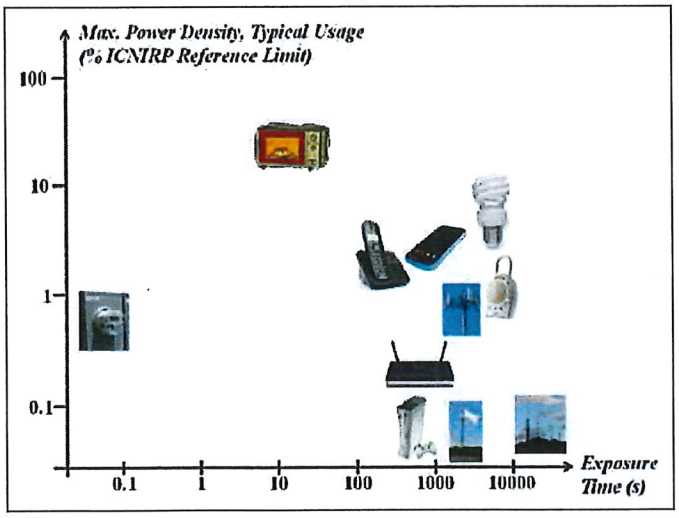

Figure 6. Qualitative comparison of electromagnetic emissions of common household devices vs. approximate uninterrupted exposure times

Source: "Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations," EPRI 2014.

Conclusion

Eaton values our energy customers, their service concerns, and their health. Eaton RF products meet and exceed the FCC certification requirements for operating within the ISM band and are further reassured by recent, continued assessments demonstrating the very limited potential RF exposure caused by smart meters. The exposure analyses confirms the very low impact of smart meter RF transmissions relative even to other more prevalent RF-transmitting household devices that are considered safe. Even under the extreme assumption of close user proximity to a malfunctioning continuous transmitting device, the resulting RF exposure does not rise to a level that creates a human health concern.

U.S. utilities have been installing meters with radios for remote meter reading since the 1980s. There are now over 50 million of these devices installed and operating in the U.S. without a documented health issue. Additionally, due to the fact that smart meters emit radio frequencies intermittently and at much lower levels than many other safe RF-emitting devices, there is currently no demonstrated risk to the user. Eaton is committed to continuing to monitor the technical and health assessments associated with smart meter operation and in adhering to the regulatory requirements and certifications to ensure that our products do not pose a health risk to utility customers.

Experts and public utility commissions concur (see below)—smart meters pose less of a health risk than many other household items and as extensive studies done over decades have concluded, there is no proven or unambiguous biological effects from exposure to low-level radio frequency signals of the type produced by smart meters.

California Council on Science and Technology: "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."

Maine Center for Disease Control: concluded that there is "no consistent or convincing evidence to support a concern for health effects related to the use of radio frequency in the range of frequencies and power used by smart meters."

Public Utility Commission of Texas: based on their survey of existing scientific research and analyses from a number of domestic as well as international studies, including in the UK, Australia, Canada, Norway, and Sweden, concluded that "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."

CPS Energy, San Antonio, TX (EPRI 2014 Technical Report): in their characterization of radio frequency emissions from AMI meters in CPS Energy residential installations.

Additional resources

- CCST's Health Impacts of Radio Frequency Exposure from Smart Meters Report
- Measurement of Radio Frequency (RF) Emissions from BC Hydro's Itron Smart Meters
- No Health Threat from Smart Meters
- DRSG Radio Frequency & Smart Maters Q&A
- Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields
- Electric and Magnetic Fields Associated with the Use of Electric Power Q&A
- FCC Radio Frequency Safety FAQ Website
- Public Utility Commission of Texas
- Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations. EPRI, Palo Alto, CA: 2014

Sources

California Council on Science and Technology, "Health Impacts of Radio Frequency from Smart Meters," January 2011 http://www.ccst.us/publications/2011/2011smartA.pdf

Electric Power Research Institute, "Radio-Frequency Exposure Levels from Smart Meters," November 2010 http://www.marbleheadelectric.com/EMF.pdf

Federal Communications Commission: http://transition.fcc.gov/oet/rfsafety/rf-faqs.html, December 2011

Maine Center for Disease Control, "Executive Summary of Review of Health Issues Related to Smart Meters," November 8, 2010, http://www.maine.gov/dhhs/boh/documents/Smart_Meters_Maine_CDC_Executive_Summary_11_08_10.pdf

Public Utility Commission of Texas, Project No. 40190, Project Relating to Advanced Metering Issues, Report on Health and Radiofrequency Electromagnetic Fields from Advanced Meters, http://www.puc.texas.gov/industry/electric/reports/smartmeter/smartmeter_rf_emf_health_12-14-2012.pdf

Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations. EPRI, Palo Alto, CA: 2014. 3002003262 http://www.cpsenergy.com/files/Smart_Grid/EPRI_Report_RF_Emissions.pdf

References

1. A 2009 review of the radio-frequency health literature conducted by the International Commission on Non-Ionizing Radiation Protection concluded, "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...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..."

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