STUDY ON THE RADIATION FROM SMARTMETERS

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Abstract—**This paper briefly introduces how and where SmartMeters are commonly installed, the FCC regulations on SmartMeters. The calculation of MPE is presented. The co-located SmartMeters installation and respective public concern are discussed.**

Keywords – SmartMeters; FCC; MPE; RF Exposure, Radiation

I. INTRODUCTION

SmartMeters are widely used by energy companies in household and business locations for the metering of energy consumption.

All SmartMeters have an internal antenna that communicates electricity consumption data via telecommunication network to a local power company. In some instances, an external antenna may need to be attached to or near the meter box to improve signals over longer network distances to ensure reliable transmission of data.

The SmartMeter uses low power radiofrequency (RF) transmitters to communicate meter readings. Two different types of SmartMeters are commonly used in US. One type is the cell relay that provides the normal function of an end point meter but also allows for data connectivity with the electric utility company via a WWAN the functions in the cellular or PCS bands. Another type of SmartMeter is the end point meter with typical frequencies of ISM band such as 900MHz and 2.4GHz bands. SmartMeter's transmission is not continuous. According to EPRI's research result, 99.5% of the SmartMeter sample was operating at a duty cycle of about 0.22% or less. SmartMeters should have RF radiations less than FCC regulated specifications, however, the co-located installation of SmartMeters cause some public concern on the RF exposure risk if they're not installed per FCC grant requirement.

Smartmeter uses at least two internal RF antennas. One is used for the mesh network system and the other is for the Hom Area network (HAN). Take PG&E's SmartMeters™ as example, it operates in the 902-928MHz for electricity-usage communication and 450-470MHz for gas-usage communication.

This paper discusses the RF exposure evaluation of SmartMeters and the concern of their co-located installation which shall be strictly follow the separation distance used for the evaluation.

II. FCC RULES AND REGULATIONS ON DIGITAL AND RADIOFREQUENCY DEVICES

In order to prevent interference to the reception of radio and TV broadcasts, and to protect other sensitive radio services, the FCC, in 1975, established Part 15, Part 22 and Part 24. These rules are directed at equipment that does not deliberately generate RF energy, low power radio transmitters that do not require individual licensing as well as licensed public mobile and personal communication service3. FCC Rules are located in Title 47 of the Code of Federal Regulations. Although the Office of Engineering and Technology (OET) is responsible for the maintenance of FCC rules located in Parts 2, 4, 5, 15, and 18 of the Title, the official rules are published and maintained in the Federal Register. In 1998, the FCC streamlined its rules by eliminating the categories of 'notification' and 'type acceptance' (FCC 98-58). It folded these categories into 'Declaration of Conformity' and 'Certification' procedures. Many parts of 47 CFR are affected including Part 15, Part 22 and Part 24.

The basic requirement in different FCC rules includes two parts.The first part is the radio characteristic requirement on transmitter output power, hopping channel number, dwell time, the bandwidth utilized, power spectral density and the conducted spurious emission, etc. Smartmeters shall be tested and demonstrated to be compliant before being sold into the market. All these measurements are based on conducted measurement methods and won't be affected by the installation method of end units.

The second part is about the radiated spurious emission and the RF exposure to the public environment.

FCC requires that systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines. See §1.1310 of FCC regulation.

The FCC rules on the radio frequency energy levels were adopted from two previous guidelines, one NCRP Report No.

86 in 1986, and the other is IEEE C95.1 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.

In 1996, the FCC adopted a Report and Order in ET Docket 93-62 amending its rules for evaluating the environmental effects of radiofrequency (RF) electromagnetic fields. FCC also adopted the guideline, OET Bulletin 65, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", which differentiates between portable and mobile devices according to their proximity to exposed persons. For portable devices (47 CFR §2.1093), RF evaluation must be based on specific absorption rate (SAR) limits. Human exposure to RF emissions from mobile devices (47 CFR §2.1091) can be evaluated with respect to Maximum Permissible Exposure (MPE) limits for field strength or power density or with respect to SAR limits, whichever is most appropriate.

III. MPE CALCULATION AND MULTIPLE SOURCES AT DIFFERENT FREQUENCIES

Human health impacts from RF exposure vary depending on the frequency and power of the fields. Typically two kinds of effects may be produced by the RF exposure absorbed by the human body, which includes thermal and non-thermal effects. The thermal effect is a phenomenon when body temperature of human tissue can increase during the absorption of RF exposure. The non-thermal effects cover the medical and biological fields caused by the RF exposure absorption. It's been reported that there are complaints of health impacts from "electromagnetic stress" with symptoms including fatigue, headache and irritability.

According to the definition on portable and mobile devices, Smartmeters belong to mobile devices since it's generally used in such a way that a separation distance of at least 20 cm is normally maintained between the transmitter's radiating structures and the body of the user or nearby persons, so compliance with MPE limits may be determined at such distance from the transmitter.

As described in Bulletin 65, calculations can be made to predict RF field strength and power density levels around typical RF sources. For example, in the case of a non-directional antenna, a prediction for power density in the far-field of the antenna can be made by use of the general equation.

$$S = \frac{PG}{4\pi R^2}$$

where:
S = power density (in appropriate units, e.g. mW/cm^2)
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 (dBi)
R = distance to the center of radiation of the antenna (appropriate units, e.g., cm).

OET 65 also provides the MPE limit under different environment condition related to the radio operating frequencies.The limit tables for Occupational / Controlled Exposure and for General Population / Uncontrolled Exposure can be found in Table 1(A) and (B). The limit for Occupational / Controlled Exposure is higher since people in this environment are working with exposure more frequently and closely.

A minimum separation distance of 20 cm for performing reliable field measurements was used to determine adherence to MPE limits. The typical MPE calculation for a cell relay type SmartMeter under General condition / Uncontrolled environment is presented in Table 2: MPE Calculation of Cell relay type SmartMeter.

From the table we can see that there're 3 types of radio being installed in this SmartMeter, which are 900MHz Radio, 2.4GHz Zigbee, and GSM850 (GPRS). By providing the radio power and antenna gain of each radio operating frequencies, with 20 cm separation distance for calculation, we can get the calculated power density easily from the general equation. The result looks good which is well under limit set for respective working environment.

For the compliance assessment of this kind of multiple source devices at different frequencies, we should not get the result by a simple sum of power densities from different sources. Each one shall be weighted according to frequency dependent FCC limit, as shown on Table 3.

Actually when calculating the MPE for SmartMeter, there're 3 other aspects we should consider, which are Spatial Averaging of Exposure, Time Averaging Exposure and Reflections. The Time Averaging Exposure concept has most impact on evaluating the RF exposure for SmartMeter since it's "source-based" category of emitter. It's stated in OET Bulletin 65 that, "source-based" time-averaging based on an inherent property or duty-cycle of a device is allowed. Due to the fact that SmartMeter operates at a duty cycle of under 5% or even much lower of 0.22% only for 99.5% of the SmartMeter samples. Then the averaged RF exposure from SmartMeter shall be only 5% or more typically less than 0.22% of the peak RF exposure calculation value, which will be pretty low.

So we can conclude that generally the RF exposure from SmartMeter won't be harmful due to its low duty cycle operation and based on the MPE calculation with 20cm separation.

IV. SAR (SPECIFIC ABOSORPTION RATE) MEASUREMENT FOR PORTABLE DEVICE

The RF evaluation for portable device is based on SAR limit. The definition for portable device is that it's a transmitting device designed to be used with any part of its radiating structure in direct contact with the user's body or with 20 cm of the body.

Specific Absorption Rate is defined as the time derivative (rate) of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given density (ρ).

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dV}\right)$$

SAR is expressed in units of watts per kilogram (W/kg). SAR can be related to the electric field at a point by

where:

$$SAR = \frac{\sigma \mid E \mid^2}{\rho}$$

σ = conductivity of the tissue (S/m)

ρ = mass density of the tissue (kg/m3)

E = rms electric field strength (V/m)

The SAR measurements are normally performed with an automated near-field scanning system. This kind of system is based on a high precision robot, which positions the probes with a positional repeatability of better than ± 0.02 mm. Special E- and H-field probes are used for measurement close to material discontinuity.

SAR measurement is not applicable to SmartMeter since it's not portable device.

V. CONCERN WITH INSTALLATION OF SMARTMETERS

In many cases, SmartMeters are installed through co-location, i.e. multiple SmartMeters are installed in one single location. The SmartMeter will not be collocated or operating in conjunction with any other antenna. But "Smart" Meters are being co-located with close proximity to each other wherever there are multiple units- in apartment buildings, condos, etc. Co-locations result in more frequent and more powerful RF exposures, which is probably why the FCC required that the antennae not be clustered together.

During the application for FCC equipment authorization, all the measurements and MPE calculation are based on one signal unit with test setup configuration that assumes they're independent and not being affected by any other surrounding units.

On the grant note for one SmartMeter for example (FCC ID: SK9AMI-2A), it says:

Power listed is conducted. This device must transmit with a source-based time-averaging duty factor not exceeding 1.4 %. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter, except as evaluated in this composite filing with FCCID: MIVGSM0108. End-users and installers must be provided with antenna installation and transmitter operating conditions for satisfying RF exposure compliance.

Many Smart Meters are installed within 20 cm of public access. There isn't any warning that the 20 cm separation distance need to be kept for the public access. In some cases the meters are installed inside homes and businesses which are easily accessible to the public.

SmartMeters are widely co-located among multiple SmartMeters. Figure 2 shows typical collocation issues of the installation of multiple SmartMeters.

Utility company who provide the SmartMeter shall disclose or provide the information to end-user that transmitter operating conditions for satisfying RF exposure compliance, it seems that most of the end-user even don't know they need to keep 20 cm separation distance away from the SmartMeters.

VI. CONCLUSION

This paper concludes that individual SmartMeters may have been tested and demonstrated in compliance with FCC rules and regulations, and the RF exposure level from single SmartMeter is low due to its low output power and the low operating duty cycle. But the collocated SmartMeters installation exists and may not meet the FCC regulation requirement, thus raising the concern of potential high RF exposure concern since it's not installed within the safe separation distance that is used during the compliance evaluation. SmartMeter is just one among many other radio devices installation which may cause similar concerns if the installation guide is not being followed and end-users are not notified.

The purpose of this research is to raise public awareness of safety concerns due to the co-located installation of SmartMeters and suggests that the utility company should review its policy on the SmartMeters installation, information disclosure to end-users and warning for public access.

APPENDIX: FIGURES AND TABLES

FIGURE 1: SMARTMETERS

FIGURE 2: CO-LOCATED SMARTMETERS

TABLE 1: MPE LIMIT IN OET65C

(A) Limits for Maximum Permissible Exposure (MPE) - from §1.1310

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Averaging Time (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

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm2)	Averaging Time (minutes)
0.3-3.0	614	1.63	100 †	30
3.0-30	842/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 (see note)
Note: Equivalent far field strength that would have the E-field or H-field components calculated or measured.
Equivalent far field density for near and far fields can be calculated using
Power Density = $|E_{total}|^2/3770\ mW/cm^2$ *or* *Power Density* = $|H_{total}|^2/37.7\ mW/cm^2$

TABLE 2: MPE CALCULATION OF CELL RELAY TYPE SMARTMETER

MPE Calculator for Mobile Equipment Limits for General Population/Uncontrolled Exposure*							
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	21.92	0.60	155.60	3	1.995	20	0.062
2405	18.71	1.00	74.30	1	1.259	20	0.019
2480	-14	1.00	0.04	4	2.512	20	0.000
824	32.4	0.55	1737.80	0	1.000	20	0.346
1850	30	1.00	1000.00	3	1.995	20	0.397

TABLE 3: FRACTION OF FCC LIMIT FOR MULTIPLE SOURCES AT DIFFERENT FREQUENCIES

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

REFERENCES

[1] SIEMIC, Inc, "Global Certification > United States of America", URL: www.siemic.com,

[2] EPRI, "EPRI Comment: Sage Report on Radio-Frequency (RF) Exposures from Smart Meters", pp. 1~14, 2011.

[3] EPRI, "Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model", pp. 4~5, 2011.

[4] ACS, Inc, "Certification Exhibit: RF exposure Info fro FCC ID: SK9AMI-2A", pp. 2, 2007

[5] FCC, OET Bulletin 65C, "Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", pp. 2 ~ 13, 2001

[6] GPO (U.S. Government Printing Office), "Part 2 - FREQUENCY ALLOCATIONS AND RADIO TREATY MATTERS; GENERAL RULES AND REGULATIONS"., URL, http://ecfr.gpoaccess.gov/

[7] GPO (U.S. Government Printing Office), "PART 15--RADIO FREQUENCY DEVICES"., URL, http://ecfr.gpoaccess.gov/