December 10, 2015 Ronald M. Powell, Ph.D.

FCC Maximum Permissible Exposure Limits for Electromagnetic Radiation, as Applicable to Smart Meters

This document expresses my best understanding, as of the above date, of the FCC Maximum Permissible Exposure (MPE) limits, as applicable to Smart Meters. This understanding has been reached by reading the FCC document in the first footnote below, and by asking the FCC any questions that remained.

History

The FCC's most recent explanation of its current exposure limits was published in 1999 with the title "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields".[1] The current FCC exposure limits are based principally on a 1986 publication of the National Council on Radiation Protection and Measurements (NCRP). That publication is "Report No. 086 - Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields".[2] The NCRP was chartered by the U.S. Congress in 1964, but is not a Government agency and is not subject to oversight by the Congress.[3]

The current FCC exposure limits agree, in part, with those developed jointly in 1992 by the American National Standards Institute (ANSI) and the Institute of Electrical and Electronics Engineers (IEEE). The exceptions are "limits on exposure to power density above 1500 MHz, and limits for exposure to lower frequency magnetic fields." [4] I will not address the ANSI and IEEE limits further here because the FCC limits are the ones applicable to Smart Meters.

The fact that the current exposure limits are based on the NCRP limits published in 1986, now 29 years ago, means that those limits: (1) predated the emergence of the vast majority of devices currently emitting microwave radiation into our environment, including Smart Meters and other digital microwave devices; and (2) cannot be current with the results of biomedical research on the biological effects of electromagnetic radiation, including microwaves, published since.

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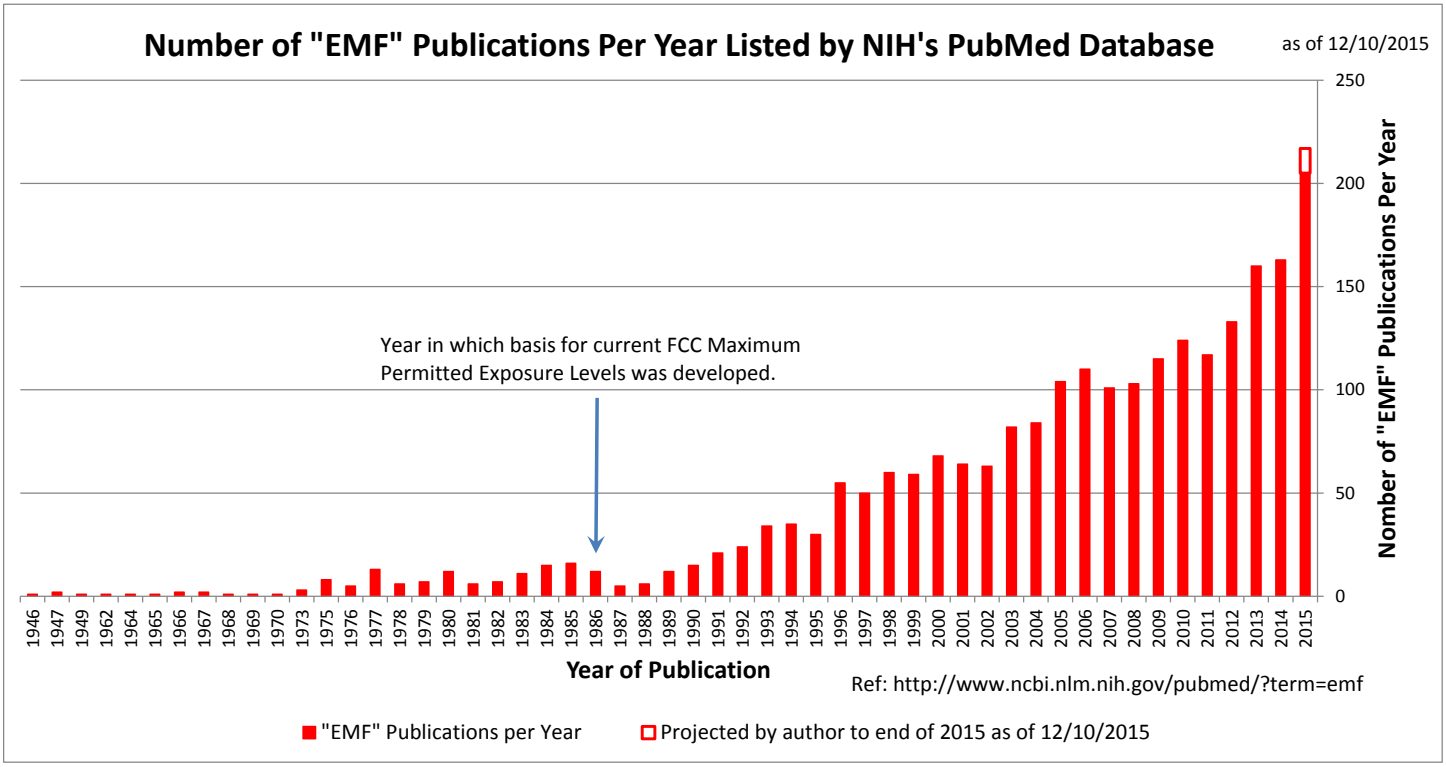
[1] "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields", OET (Office of Engineering and Technology) Bulletin 56, Fourth Edition, Federal Communications Commission, August 1999. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf)

[2] This document is sold by the NCRP for $56 in downloadable PDF form. (http://www.ncrppublications.org/Reports/086)

[3] The National Council on Radiation Protection and Measurements has this history: (1) in 1929, formed as the U.S. Advisory Committee on X-Ray and Radium Protection; (2) in 1946, renamed as the National Committee on Radiation Protection and Measurements; (3) in 1964, chartered by the U.S. Congress and renamed as the National Council on Radiation Protection and Measurements. (https://en.wikipedia.org/wiki/National_Council_on_Radiation_Protection_and_Measurements)

[4] In the document in my footnote 1 above, footnote 9 on page 12 explains: 'The FCC adopted limits for field strength and power density that are based on Sections 17.4.1 and 17.4.2, and the time-averaging provisions of Sections 17.4.1.1 and 17.4.3, of "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, for frequencies between 300 kHz and 100 GHz (Reference 34). With the exception of limits on exposure to power density above 1500 MHz, and limits for exposure to lower frequency magnetic fields, these MPE limits are also based on the guidelines developed by the IEEE and adopted by ANSI. See Section 4.1 of ANSI/IEEE C95.1-1992, "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz".' Further, again in the document in my footnote 1 above, footnote 4 on page 10 describes ANSI and IEEE as follows: "ANSI is a non-profit, privately funded, membership organization that coordinates development of voluntary national standards. The IEEE is a non-profit technical and professional engineering society."

The growth in the biomedical research literature since 1986 has been substantial and is illustrated by the following figure. That figure shows the number of new publications per year addressing "EMF" (electromagnetic fields), as indexed in PubMed.[5] PubMed is the on-line database of the biomedical research literature maintained by the National Institutes of Health. PubMed and is the most comprehensive index to the biomedical research literature in the world. According to PubMed, the cumulative number of publications addressing "EMF" from 1946 to 2015 (as of 12/10/2015) is 2337. Of those, 135 were published from 1946 to 1986, and 2202 were published since 1986. It is reasonable to assume that something useful has been learned from those additional 2202 publications, which represent 94 percent of all of the EMF publications since 1946.



Of course, publications addressing the very broad field of biological effects of exposure to electromagnetic fields may be filed under many headings, not just "EMF", so there will be many publications of relevance not reflected in the above figure.

On March 29, 2013, the FCC issued, for comment, proposed new exposure limits. While there are many changes, the key numbers that are currently applicable to Smart Meters, as described in the next section, appear to be unchanged.[6]

Current FCC Maximum Permissible Exposure Limits

Within the FCC's 1999 publication, "Questions and Answers...", the exposure limits of relevance to Smart

[5] (http://www.ncbi.nlm.nih.gov/PubMed)

[6] Reassessment of Federal Communications Commission Radiofrequency Exposure Limits and Policies (ET Docket No. 13-84), and Proposed Changes in the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields (ET Docket No. 03-137), released March 29, 2013. See Table 1 on pages 98, 110, and 122 of the PDF version.
(http://www.fcc.gov/document/fcc-review-rf-exposure-policies)

meters are contained in Table 1(B), entitled "Limits for General Population/Uncontrolled Exposure", on page 15. Since Smart Meters operate in two principal frequency bands, one at about 900 MHz, and one at about 2400 MHz (which is equivalent to 2.4 GHz),[7] just two lines from Table 1(B) apply to these frequency bands, as shown below.

Extracted from FCC Table 1 (B) Limits for General Population/Uncontrolled Exposure

line	**Frequency Range**	**Power Density**	**Averaging Time**
	MHz	**mW/cm^2**	**minutes**
(a)	300-1500	f/1500	30
(b)	1500-100,000	1.0	30
f is the frequency in MHz			

Line (a) above applies to the 900 MHz frequency band used by Smart Meters. That line indicates that the permitted power density increases as the frequency increases. At 900 MHz, the maximum permitted power density is (900/1500) mW/cm^2, which is 0.6 mW/cm^2. Line (b) applies to the 2400 MHz frequency band of Smart Meters, and the maximum permitted power density is 1 mW/cm^2, independent of frequency. With this understanding, Table 1(B) can be applied to Smart Meters, as shown below. I have added columns that translate mW/cm^2 into mW/m^2 and into W/m^2 for comparison with data from other sources.[8]

Limits for General Population/Uncontrolled Exposure for Smart Meters

Frequency	**Power Density**			**Averaging Time**
MHz	**mW/cm^2**	**mW/m^2**	**W/m^2**	**minutes**
900	0.6	6,000	6	30
2400	1.0	10,000	10	30

Interpretation of the Table

Here is how to interpret the preceding table. For easy reference, call the power-density levels in the table the **absolute levels**, consistent with the terminology that the FCC uses.

(1) A continuous exposure of an individual is considered compliant with the FCC limits if that exposure remains at or below the specified absolute level for that frequency, even if that exposure continues indefinitely.

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[7] The FOCUS AXR-SD and the I-210+c both have FCC-ID OWS-NIC514, which indicates that they send and receive information in two microwave frequency ranges: (1) 902.3 to 926.9 MHz, and (2) 2405.8 to 2480.9 MHz. MHz means millions of hertz. 1 hertz is one cycle per second. The microwave output power in the first frequency range is 0.968 watts. The microwave output power in the second frequency range is 0.147 watt.
(http://stopsmartmeters.org/wp-content/uploads/2012/01/OWS-NIC514-FCC-specifications.pdf)

[8] 1 meter (m) equals 100 centimeters (cm). So 1 square meter (m^2) equals 10,000 square centimeters (cm^2). 1 watt (W) equals 1000 milliwatts (mW).

(2) A discontinuous exposure, such as that produced by a digital signal, is considered compliant with the FCC limits, if the average exposure over a period of 30 minutes is at or below the specified absolute level for that frequency. That is, if the exposure rises above the absolute level for that frequency, even for a moment, then the average level, over a 30 minute period, must be at or below the absolute level. Stated another way, periods of exposure at higher than the absolute level must be accompanied, in any given 30 minute interval, by periods of exposure far enough below the absolute level, and lasting long enough, that the average over 30 minutes does not exceed the absolute level.

Because of (2) above, the level of exposure permitted for short intervals of time may greatly exceed the absolute level. Consider an exposure that is ON for less than 30 minutes and OFF for the rest of the 30 minutes. Here are some specific patterns that would be permitted, no matter how many times the 30 minute pattern is repeated.

Examples of FCC Permitted Exposure Levels at 900 MHz

ON Time	OFF Time	ON Time Fraction	Permitted Power Density During ON Time		
minutes:seconds	minutes:seconds		mW/cm^2	mW/m^2	W/m^2
30:00	00:00	1	0.6	6,000	6
01:00	29:00	1/30	18	180,000	180
00:20	29:40	1/90	54	540,000	540
00:01	29:59	1/1800	1080	10,800,000	10,800

Examples of FCC Permitted Exposure Levels at 2400 MHz

ON Time	OFF Time	ON Time Fraction	Permitted Power Density During ON Time		
minutes:seconds	minutes:seconds		mW/cm^2	mW/m^2	W/m^2
30:00	00:00	1	1	10,000	10
01:00	29:00	1/30	30	300,000	300
00:20	29:40	1/90	90	900,000	900
00:01	29:59	1/1800	1800	18,000,000	18,000

Discussion of Examples of Permitted Exposure Levels

The surface area of an adult human being is about 2 m^2.[9] So the surface area presented to a microwave wave coming from the front or the back is about 1 m^2. Consider the W/m^2 column in the

[9] The surface area of a adult man is about 1.9 m^2. The surface area of an adult woman is about 1.6 m^2. Both according to Wikipedia. (http://en.wikipedia.org/wiki/Body_surface_area)

above table. An oncoming microwave wave will transfer to a human being the number of watts shown in the W/m^2 column. Consider the three examples at 2400 GHz that are contained in the preceding table:

(1) A microwave wave with a power density of 300 W/m^2 will transfer 300 watts of power to a human being. That is the amount of power required to run 3 light bulbs of 100 watts each. Such exposure would be compliant with the FCC exposure limits, if continued for 1 minute or less.

(2) A microwave wave with a power density of 900 W/m^2 will transfer 900 watts of power to a human being. This is somewhat more than the amount of microwave power, 700 watts, generated by the typical consumer microwave oven.[10] So exposure of a human being to a microwave wave with somewhat greater power than a microwave oven would be compliant with the FCC exposure limits, if continued for 20 seconds or less.

(3) A microwave wave with a power density of 18,000 W/m^2 will transfer 18,000 watts of power to a human being. This is between one-third and one-half of the maximum power that the typical home can draw (48,000 watts) without tripping its master circuit breaker (200 amperes AC at 240 volts AC). Such exposure would be compliant with the FCC exposure limits, if continued for 1 second or less.

For each of the three examples given above, the level of exposure cited, with the associated duration, could be repeated once each 30 minutes, indefinitely, and still be in compliance with the FCC exposure limits.
Finally, exposure of a human being at even higher power levels than discussed here is permitted by the FCC exposure limits, if the duration of that exposure is sufficiently short.

These examples indicate that the current FCC exposure limits permit exposure levels to microwave radiation that challenge common sense.

Peak versus Average Exposure Levels

Given the above discussion, the concerns raised by the FCC exposure limits arise not only from high permitted absolute levels, but also from the concept of time averaging, which does, indeed, seem based on thermal thinking only. When the level of microwave radiation exposure is averaged over time, the implicit assumption being made is that the body reacts the same way to each of the following:

(1) a burst of microwave radiation of high intensity but short duration over a given period of time
(2) a hypothetical continuous level of radiation at a lower level but with the same average value over the same period of time

So a real burst exposure event is translated into a hypothetical continuous exposure event, and the effect of that hypothetical continuous exposure event is taken to represent the effect of the real burst event. Yet, everyday life suggests that the body may not react the same way to these two different

[10] The typical consumer microwave oven consumes 1100 watts of electrical power and produces 700 watts of microwave power. (http://en.wikipedia.org/wiki/Microwave_oven)

circumstances. Ask a boxer if the following two events are of equal concern: (1) a series of "average" punches spread out uniformly over the length of a fight, or (2) a single punch, somewhere during the fight, with the energy of the sum of all of those "average" punches.

Thermal versus Non-Thermal Effects on Humans

The FCC developed two sets of exposure limits, one for Occupational/Controlled Exposure and one for the General Population/Uncontrolled Exposure. Only the latter have been discussed here because only they apply to Smart Meters installed on residences. My understanding from the FCC is that the Occupational set were based principally on thermal (heating) effects on the human body; but the existence of possible non-thermal effects was recognized back then. So when the limits for the General Population were developed, a factor of five reduction in permitted levels, relative to the Occupational set, was implemented for the General Population set, for two reasons, again according to the FCC: (1) to allow for non-thermal effects, and (2) to provide a safety margin because exposure levels in the General Population would not usually be known as well as the levels in an occupational setting.

So the FCC exposure limits made some recognition of the existence of non-thermal effects but with a generic adjustment that did not consider those effects in detail. But the knowledge of non-thermal effects, back in 1986, had to be greatly limited compared to today because most of the biomedical research on such effects has been conducted since then. That more recent research indicates the existence of a broad range of non-thermal effects at power density levels many orders of magnitude below current FCC exposure limits.[11]

Applying the FCC Exposure Limits

Additional information on applying the FCC exposure limits is contained in "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", OET Bulletin 65, Edition 97-01, published in August 1997.[12]

Legal Presentation of the FCC Exposure Limits

The current FCC exposure limits are presented, in legal form, in the Code of Federal Regulations in 47 CFR 1.1307[13] and 47 CFR 1.1310.[14] The latter publication is the one that contains Table 1 which also appears in the FCC's 1999 publication "Questions and Answers...", OET Bulletin 56, introduced above.

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[11] Ronald M. Powell, Ph.D., Biological Effects from RF Radiation at Low-Intensity Exposure, Based on the BioInitiative 2012 Report, and the Implications for Smart Meters and Smart Appliances, August 4, 2013. Based on the BioInitiative 2012 Report, December 2012. (http://www.bioinitiative.org)

[12] (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf)

[13] 47 CFR 1.1307
(http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=107f88e2bfc955fa0e55da1ed33ccc76&rgn=div8&view=text&node=47:1.0.1.1.2.9.194.7&idno=47)

[14] 47 CFR 1.1310
(http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=2d225c5f0cac16b94293d1d7270b19e8&rgn=div8&view=text&node=47:1.0.1.1.2.9.194.10&idno=47)