



Smart Meter – What We Know

Measurement Challenges and Complexities



A Technical Paper to Clarify RF Radiation Emissions and Measurement Methodologies

December 2011

Published by

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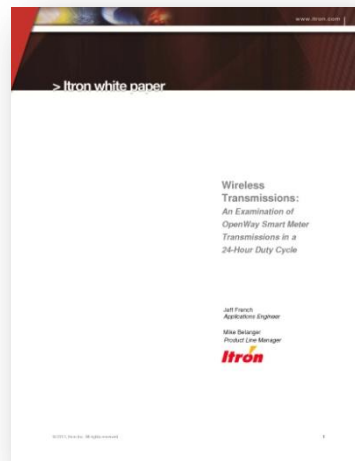
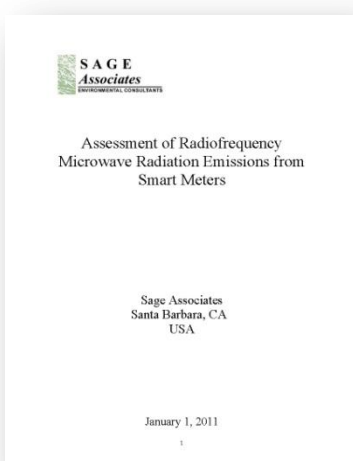
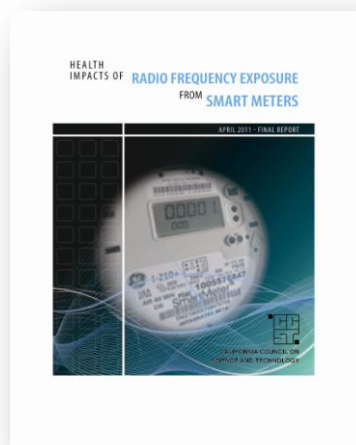
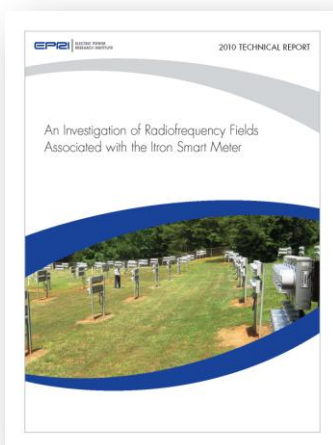
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BACKGROUND INFORMATION

Our office has received a large number of calls from individuals which state that they have experienced significant health problems after the installation of Smart Meters. The installation of Smart Meters at residential buildings has created a public outcry about potential or perceived health effects. We have received numerous calls from the public for the evaluation at their building. To address these requests appropriately we have researched the scientific literature on the technical specifications and measurement methodologies. The issues involved with the evaluation of Smart Meters are very complex. We have summarized our findings in this paper to provide a better understanding of the subject matter and issues involved.

REFERENCE LITERATURE

We have used the following publications as our reference sources. Based on the technology described in these papers, we have conducted some research on our own. The documents are available on the Internet free of charge. Our findings and measurement challenges are summarized in this report.



WHAT ARE SMART METERS?

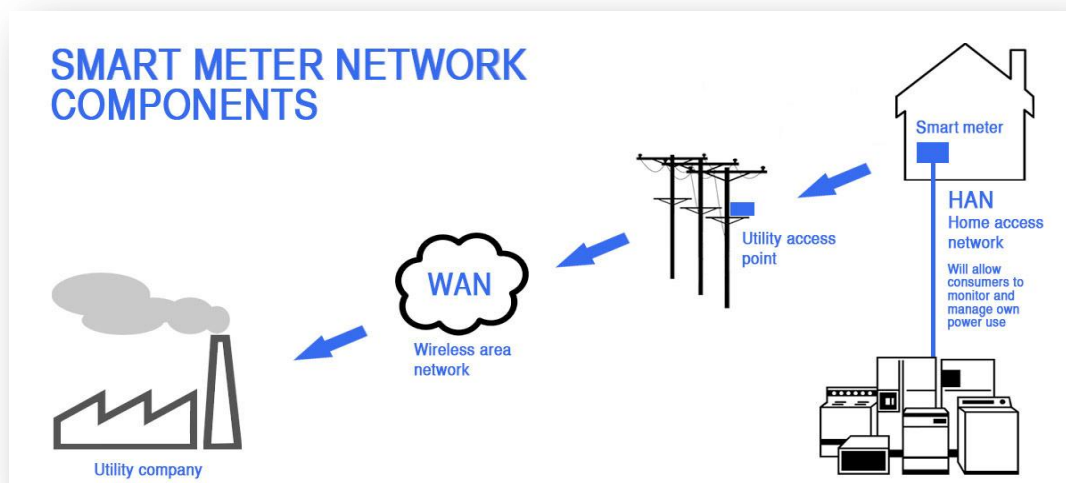
Smart Meters are digital meters which record electrical, gas, and water usage. The data is then transmitted wirelessly to the utility companies. Smart meters are currently installed throughout California, many other states and eventually in all 50 states as well as in Canada.



These Smart Meters are referred to as *access points*. The information from individual meters or *access points* is sent to *utility access points*, which act as data collection points before forwarding the data to the utility company. The *utility access points* are commonly located on power poles and street lights. The entire system is referred to as a *mesh network* allowing for continuous connections around broken or blocked meters or data pathways. Smart Meters provide real-time data to the utility provider and in the future to the consumer in the proposed real-time smart grid.

There are various technologies in use to transmit the data: (A) Wired via cables such as fiber-optic, copper phone lines, or cable; (B) Wired via power lines such as power line communication or broadband over power lines; and (C) Wireless via antennas (e.g. GPRS, GSM, ZigBee, WiMax). In California and many other states a wireless network was chosen.

The installation of Smart Meters is only the first phase. In the second phase, individual appliances will communicate with the Smart Meter. This provides information on when and how much electricity a particular appliance utilizes. The information will then be available to the consumer to make “smart” choices regarding their electrical usage. The communication between appliances and Smart Meters will occur wirelessly. This communication system is referred to as the *home area network* or HAN.



Graphic from Health Impact of Radio Frequency Exposure from Smart Meters report by California Council on Science and Technology

WHY THE CONCERN?

Health, environmental, privacy, and billing concerns have all been voiced over the installation of these meters. Citizen action groups and websites have been formed. Numerous city councils have put a moratorium on the installation of meters until more information is available. This document will summarize these concerns and is focused on the emission from meters and exposure prevention.

Health Concerns

A large number of individuals have reported significant changes in their health and well-being related to the installation of wireless Smart Meters on their property. This has led to community activism against the installation of wireless meters, with websites and appeals to decision makers and politicians. The main symptoms reported by individuals are: sleeping disorders, insomnia, tinnitus (ringing in the ears), fatigue, nausea, dizziness, irritability, listlessness, heart palpitations, and changes in cognitive behavior.

Environmental Concern

With the installation of millions of Smart Meters, their repeaters, and data transfer, the number of cellular transmitters is dramatically increasing and changing our RF exposure and environments. These fields do not occur in nature. In the second phase, when our electrical appliances are talking wirelessly to the Smart Meter, the RF levels and exposure to RF frequencies inside our buildings can be raised. Most Smart Meters are designed to also work in wired mode. Some utilities allow the installation of wired systems.

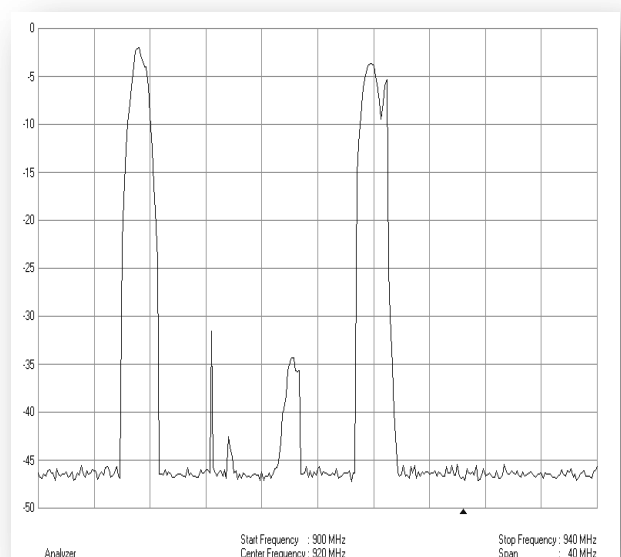
Privacy and Billing

With the remote access to electrical, gas, and water usage in a building, the private lifestyle becomes apparent to the viewer of the data. Hacking into the data transmission is another concern. Are you taking a shower right now or not? Customers have also reported significant increases in billing for utility services. Smart Meters certainly allow monitoring and billing with a tiered-rate system which may significantly increase consumer costs.

WHAT TYPE OF RADIATION?

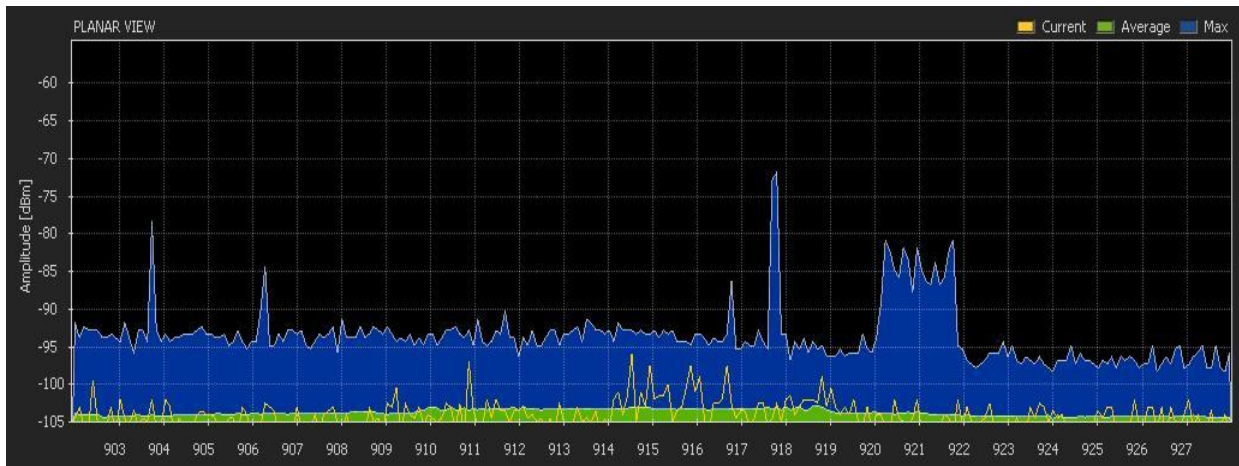
Wireless Smart Meters are able to receive and transmit data using a wireless network. The transmission occurs with a dipole antenna to reach *utility access points* or repeater units. Two or three different frequency bands are being utilized.

- **902-928 MHz** (megahertz) band for transmission to repeater units.
- **1.9 GHz** (gigahertz) band can potentially be used for transmission to repeater units.
- **2.4 GHz** band for future communication of appliance data via ZigBee or Wi-Fi network and in the transmission to the cellular network band.

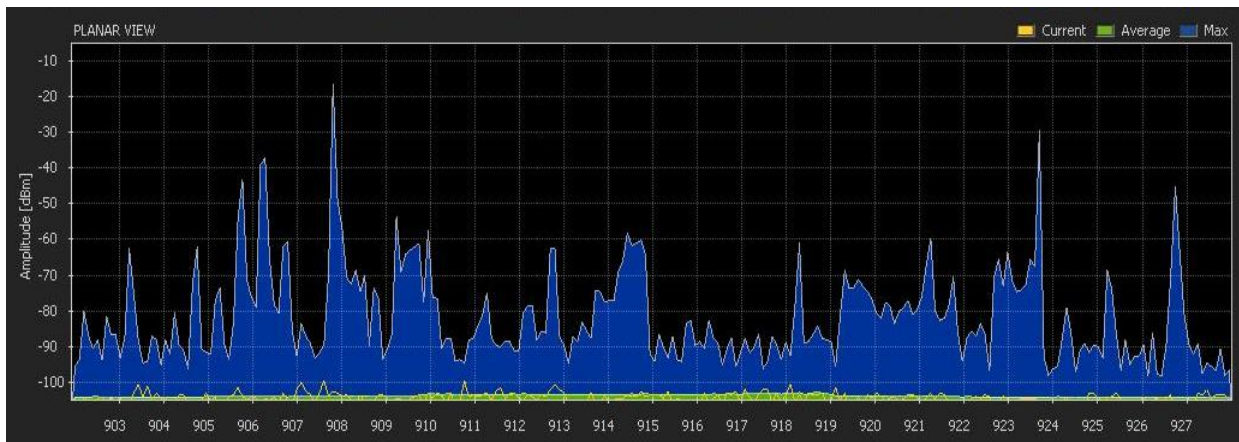


These frequencies are similar to frequencies used in cellular phones, wireless computer networks, DECT cordless phones, baby monitors, Wi-Fi systems, and other wireless networks and devices. The meter uses a technology which is referred to as frequency hopping spread spectrum. That means the transmission frequency will change constantly during a given time period.

The following measurements were performed with a computer software-based system provided by *Metageek*. It shows the frequency range between 902 and 928 MHz on the x-axis (horizontal). The amplitude or field strength of the signal is expressed on the y-axis (vertical).



The graph above depicts the frequencies present in a residential home without a wireless Smart Meter. The peaks show the amplitude (strength) of the signal. The largest peak in the 918 MHz range is emitted from a cordless phone. The amplitude shows maximum signal strength of approximately -70dB.



The graph above depicts measurements conducted outside at a one-foot distance from a Smart Meter. The largest peaks are now in the -20dB range. This constitutes a 100,000 fold increase in the power density (signal strength).

THE DUTY CYCLE

The data from the wireless Smart Meter is sent out in short transmission bursts, which usually last only from 12 to 120 milliseconds (ms) at a time. These transmission times are referred to as duty cycles. A 100% duty cycle corresponds to continuous operation, e.g. 24 hours/day. A 1% duty cycle corresponds to a transmitter operation of 1% per 24 hours, which means 14.4 minutes/day.

The most controversial question in the assessment of wireless Smart Meters is how often is this intermittent burst occurring per day? This short time sequence makes it difficult to detect and measure the signal properly with RF instrumentation. The estimates on how often the pulse or burst occurs range from:

- Once or twice a day
- Once (1) every four (4) hours
- To 750 times/day
- To an almost continuous transmission from utility access points

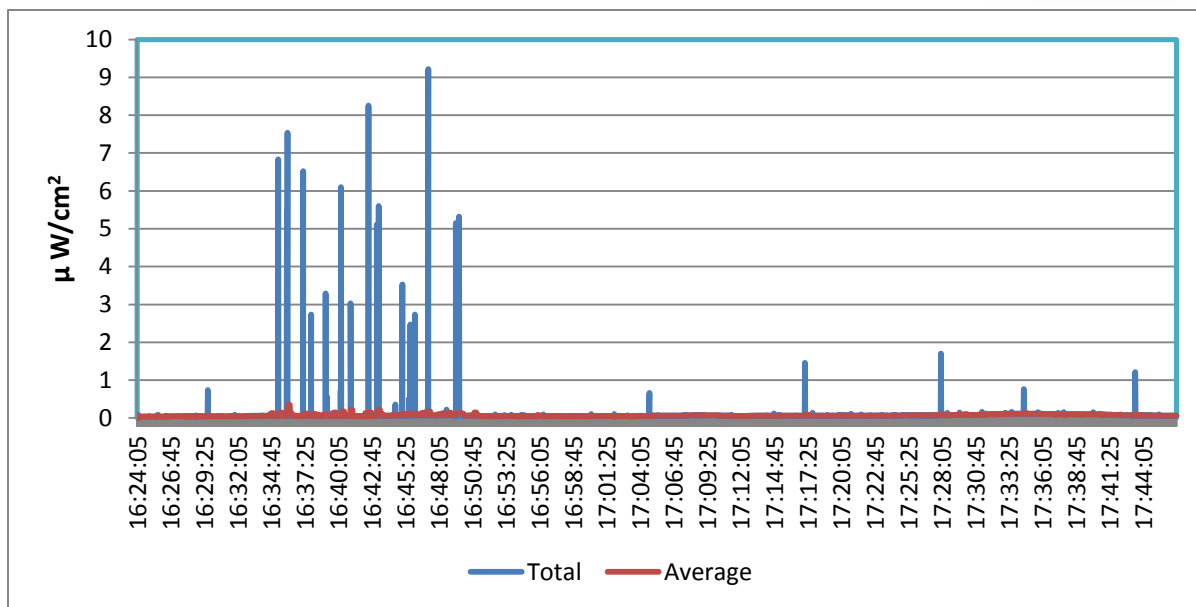
During our measurements at one residential meter, we manually counted the number of bursts for a ten-minute time period. The number of bursts varied significantly over the time period. We used a simple consumer instrument which only provides an audible signal when the field strength increases. We used this tool to audibly and manually count the frequency bursts. The table below shows the result for this meter located in a residential development in San Diego County with the assumption of 50 ms bursts.



Minutes	Counts
1	15
2	0
3	2
4	3
5	5
6	9
7	4
8	5
9	3
10	4
Total counts over 10 minutes	50
Average counts per minute	5
Average transmit time per minute	0.25 seconds
Minutes per 24 hours	1440
Total Transmission Time	6 minutes
Duty Cycle	0.4%

Next, we used a professional broadband meter with an isotropic probe to measure the data burst and amplitude over time. A *Wavecontrol SMP* with a *WPT 8* probe was used at the Smart Meter. The frequency range of the instrumentation with the probe is 100 kHz to 8 GHz. The graph below shows the results of the data logging.

The difficulty most professional instruments have is that they collect the data twice per minute. However, when the short (50-millisecond) burst occurs during the time when the instrument is not recording, it will not be visible. Only if the measurement period and transmission burst coincide in time will the signal be recorded. This is likely to account for the different amplitudes detected. The instrument may measure when the signal is building up or phasing out. This appears to be the reason for the significantly varying amplitude.

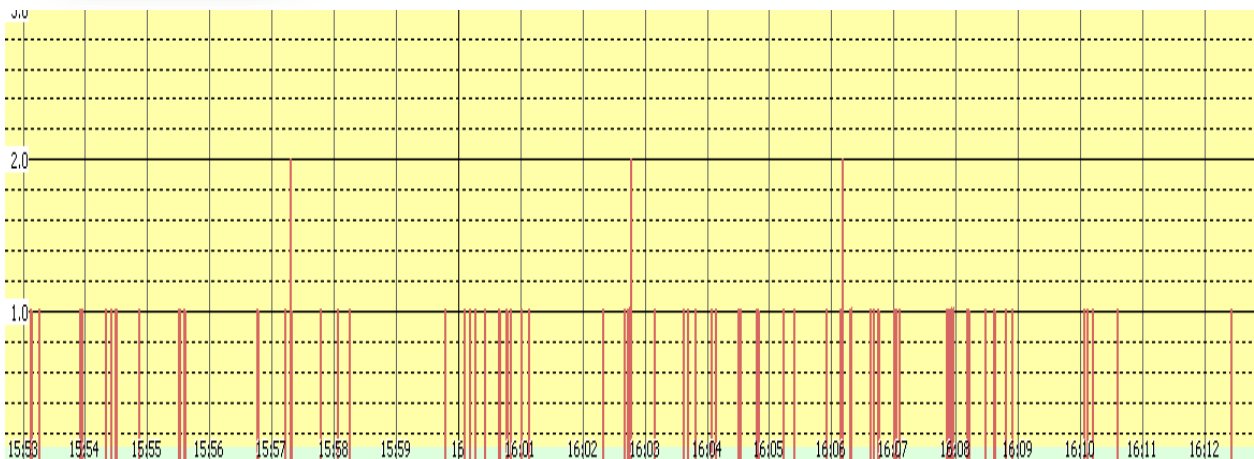


Wavecontrol SMP with WPT8 probe measuring for 20 minutes at one foot distance from the meter

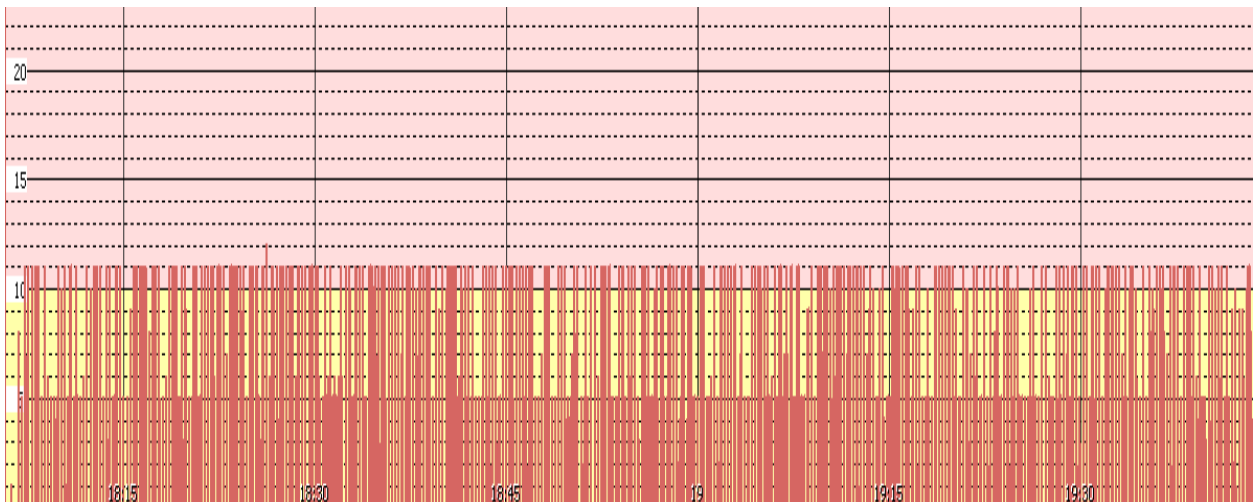
The graph also shows the disadvantage of looking at and reporting the average power levels only because the signal strength disappears as background noise.



Thirdly, we used a *Gigahertz* RF meter with a data logger attached to the instrument to count the transmission bursts over time. The following instrumentation was used: *Gigahertz HF59B* instrument with probe *HF800V2500* and the *NFA 1000* data logger. This set of instrumentation appears to have a higher capture range of the transmission pulses. The graphic below shows a 17-minute time period at one-foot distance from an Itron Smart Meter.



Instrumentation at one-foot distance from smart meter for a 19-minute time period in the afternoon



Instrumentation at one-foot distance from smart meter later that evening for a 90-minute time period

These measurements show a much higher duty cycle than anticipated by most entities. However, the instrument clipped the amplitude levels of at a certain high. Therefore, we could not measure the strength of the signal. It is possible we need to make some adjustments to the recording modes.



POWER DENSITY MEASUREMENT RESULTS

We conducted initial power density measurements and found that it can be difficult to measure these short transmission bursts. A variety of previously mentioned RF Instruments were used at a distance of one (1) foot from the meter. The results varied significantly between the different instruments; therefore, we are only reporting our spectrum analysis results here.

A *Rhode & Schwarz FSH3* spectrum analyzer was used in conjunction with a directional periodic-logarithmic antenna. Measurements were performed at a distance of one (1) foot from the Itron Smart Meter. A max peak detector with max hold function was selected. The peak hold value was recorded.

Frequency Band	Distance in feet	nW/cm ²	μW/cm ²	μW/m ²	V/m
902 - 924 MHz	1 foot	2,100	2.1	21,000	2.8

The California Council on Science and Technology (CCST) used 50% duty cycles in their charts and graphs to extrapolate compliance with the FCC standard. According to CCST the following exposure levels are emitted.

Frequency Band	Distance in feet	nW/cm ²	μW/cm ²
902 - 924 MHz	1 foot	8,800	8.8
	3 feet	1,000	1.0
	10 feet	100	0.1

FCC GUIDELINES

The Federal Communications Commission (FCC) in conjunction with the American National Standards Institute (ANSI) and the National Council on Radiation Protection and Measurements (NCRP) have established rules to protect workers and the general public from known RF hazards. The FCC rules establish limits for emissions from devices and exposures to the population.

These regulations are based on thermal effects to human tissue (heating). The thermal heating effect of radio frequency (RF) radiation on humans has been studied and is well understood. Non-thermal effects were not taken into consideration for the basis of these regulations. Some scientific studies have shown that non-thermal effects due to cumulative or prolonged exposure to lower levels of RF emissions can cause adverse health effects. The lack of a definitive cause with scientific acceptance is being cited as the reason for the exclusion of the non-thermal effects in regulations. The BioInitiative Report provides a good summary on the studies of non-thermal adverse health effects detected¹.

The specific absorption rate (SAR) is related to the power emitted from wireless devices such as cellular phones. The SAR limit is 1.6 Watt of power per kilogram of body weight (W/kg). The amount of radiation an individual can be exposed to is limited by the maximum permissible exposure (MPE). MPE is

¹ BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF), published August 2007



expressed as a percentage of the allowable exposure. The allowable limit varies with the frequency, occupational and general public exposure.

REGULATIONS AND OTHER GUIDELINES AND RECOMMENDATIONS

The following table shows regulatory RF levels, suggestions and recommendations by different entities.

Entity	Power Density
Regulatory - FCC/ANSI – USA – 900 MHz range	610,000 nW/cm ²
Regulatory - Italy, Poland, Hungary, Bulgaria, China, Russia	10,000 nW/cm ²
Regulatory - Switzerland	4,500 nW/cm ²
Recommendation – Ecolog Institute (2000)	300 nW/cm ²
Recommendation – Salzburg Resolution (2000)	100 nW/cm ²
Recommendation – BioInitiative Report (2008)	<100 nW/cm ² outdoor <10 nW/cm ² indoor
Recommendation - STOA – EU Parliament (2001)	10 nW/cm ²
Average range in metropolitan areas	0.5 – 2 nW/cm ²
Background levels in residential areas	0.05 -0.5 nW/cm ²
Necessary for cellular phone reception	0.0001 nW/cm ²

SUMMARY AND RECOMMENDATIONS

Accurate and precise measurements for the power density and duty cycles are not easily performed even with costly professional equipment. Few instruments are able to detect the short transmission bursts properly.

Average power density readings are misleading because they severely underrate the peak power levels. Distance from the meter as well as the number and density of the wall assemblies between the meter and the living and sleeping areas have a significant impact on the RF exposure. The larger the distance is and the greater the wall density is, the lower the RF exposure will be.

- Smart Meters can be installed in a wired mode via phone lines, cable, fiber-optic, or copper wiring. Some utilities allow the installation of wired systems. This would provide the lowest RF exposure levels for occupants.
- If measurements for wireless Smart Meter are conducted, peak amplitude levels and the burst cycle (duty cycle) should be recorded and extrapolated.
- If health problems are experienced with the installation of Smart Meters, a comprehensive EMF and RF survey should be conducted to rule out other sources of elevated electromagnetic fields. We recommend an EMF survey according to the Building Biology Standard SBM 2008. This will provide information on the most appropriate reduction or shielding methodology.
- Research is currently ongoing to evaluate if the Smart Meter's switching mode power supply is creating dirty electricity (signal distortions), which may be carried throughout the building through the electrical circuits.
- The installation of interior wall shielding appears to be the most effective alternative.



- Many RF attenuating (reducing) materials are available such as RF-specific copper wire meshes, shielding drywall, paints, glass films, and fabrics. These are specialty products and are more expensive than regular construction materials.
- The exterior shielding of meters may not be very useful but may impede the operation of the meter and may be counterproductive.
- Shielding kits are already being sold on the Internet. How effective they are should be evaluated by taking before and after installation measurements.
- Consumers should be provided with clearly understandable information about the radiofrequency emissions of all devices that emit RF radiation including smart meters. Such information should include intensity, duration, and frequency of the power output and, in the case of smart meters, the pattern of sending and receiving transmissions to and from all sources².
- Be also aware that any electric meter—be it analog, digital, or smart—is a “hot spot” for elevated magnetic fields, which is why frequent-use rooms such as bedrooms and dining areas should be located away from electrical meters.

APPENDICES

The Appendix tables on the follow pages are provided by Katharina Gustavs with Rainbow Consulting in Canada. She has reviewed the listed reference papers, extracted the measurement information, and compared the data with other entities, standards, guidelines and recommendations on exposure values. In appendix C, she lists a number of resources and references and their websites. Thank you Katharina.

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Appendix A: Emission Levels of Itron OpenWay[®] Smart Meter in nW/cm² (900 MHz Antenna)
Appendix B: RF Emission Level Comparison of Common Household Devices and Smart Meters
Appendix C: Resources and References

² Health Impacts of Radio Frequency Exposure From Smart Meters, April 2011 – Final Report, California Council on Science and Technology (CCST)



APPENDIX A: EMISSION LEVELS OF ITRON OPENWAY[®] SMART METER IN nW/cm² (900 MHz ANTENNA)

Distance	20 cm/8 inches	1 m/3 feet	3 m/10 feet
Common peak exposure levels of a single Itron smart meter			
Smart meter, front		ca. 1000-10,000	outdoor
Smart meter, back		ca. 10-100	indoor
Sage Report—CALCULATED for 90% duty cycle			
1000% reflection	8,904,390	556,520	50,090
100% reflection	1,294,360	18,400	1,660
60% reflection	188,390	11,770	1,060
ACS Compliance Testing Laboratory (RSS-210/FCC15.247)—CALCULATED without reflection factor			
900 MHz LAN	227,000	[9,000]	[1,000]
2.4 GHz ZigBee	31,000		
Electric Power Research Institute—CALCULATED for upper range of possible RF fields			
Peak level	(30 cm/1 foot) 168,360	18,727	1,683
Itron, Inc.—CALCULATED			
Centron	68,000		
Sentinel	81,000		
Richard Tell Associates, Inc.—CALCULATED with ground reflection factor 2.56			
Maximum level	adjacent to meter 10,000	1000	100
BC Centre for Disease Control—MEASURED* (at British Columbia Hydro Laboratory)			
Peak level, front	≤ 20,000	≤ 20,000	
Min. detectable level of RF Probe	≤ 20,000		
Safe Living Technologies (Ontario)—MEASURED a single smart meter at residence			
Peak level, front		≥ 2,000	
Indoor peak level, back		10-90	
Electric Power Research Institute—MEASURED a single smart meter at residence			
Peak level, front	(30 cm/1 foot) 5,337	1,134	
Indoor peak level, back		bedroom1 behind meter 61	In bath and bedroom2 55
ET&T (California)—MEASURED a single smart meter at residence			
Peak level, front	(30 cm/1 foot) 2,100		
British Columbia Hydro—As quoted in its Smart Meter Business Case			
	< 10,000		10
British Columbia Hydro—CALCULATED AVERAGE based on transmit time per day			
0.6% duty cycle (8 min)	2,000	[54]	[6]
0.06% duty cycle (1 min)	160	[6]	[0.7]

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- [] Values in square brackets are not listed in the quoted report, but inferred based on the formulas provided.

APPENDIX B: RF EMISSION LEVEL COMPARISON OF COMMON HOUSEHOLD DEVICES AND SMART METERS

Emission Level in nW/cm ²	Distance	RF Device/RF Guideline	Type	Exposure Duration
> 1,000,000	10 cm*	Cell phone handset	GSM	During phone call, continuous
600,000		Canada Safety Code 6/FCC	900 MHz	
450,000		ICNIRP Guidelines (1998)	900 MHz	
100,000	10 cm*	Cordless phone handset	DECT	During phone call, continuous
20,000	1 m	Leaky microwave oven	2.45 GHz	During use, continuous
1,000-10,000	1 m Outdoor	Itron smart meter, front	Peak 902-928 MHz	Intermittent 1 min/day every 30 min up to 8 min/day every 3-10 s
100-10,000	Varies	Cell phone base station		Continuous exposure
100-10,000	0.5 m	Wi-Fi router, PC card	2.4 GHz	Continuous exposure
4,250		Swiss Ordinance (2000)	900 MHz	Cell towers in sensitive areas
2,400		Ukraine Safety Guidelines	Radio, TV,	Cell towers in sensitive areas
200-2,000	1 m	Cordless phone base station	DECT	Continuous exposure
200-2,000	30 cm	RF baby monitor	DECT	During use, continuous
200-2,000	1 m	New microwave oven	2.45 GHz	During use, continuous
10-100	1 m Indoor	Itron smart meter, back	Peak 902-928 MHz	Intermittent 1 min/day every 30 min up to 8 min/day every 3-10 s
50-100	Varies	Health effects observed in populations near cell towers (Kundi 2009) Cardiac effects, headaches, sleep problems		
100		Salzburg Resolution (2000)		
100	Outdoor	BioInitiative Report (2007)		
> 100	Indoor	“Significant Concern” Building Biology Guidelines for Sleeping Areas (SBM-2008)		
17		Seletun Consensus Statement (2010)		
10	Indoor	BioInitiative Report (2007)		
10		Precautionary reference value for very low radar exposure according to testing specialist Wolfgang Kessel (Germany)		Intermittent exposure Pulse repetition time > 10 s
1-100	Indoor	“Severe Concern” Building Biology Guidelines for Sleeping Areas (SBM-2008)		
up to 2.5		Precautionary reference value for low radar exposure according to Ecolog Institute (Germany)		Intermittent exposure Every ≥ 1 s
1	Outdoor	Salzburg Public Health Department (2002)		
≤ 1	Indoor	Largest number of credit points for indoor environment (TQB 2009)		Green building rating system (Austria)
0.01-1	Indoor	“Slight Concern” Building Biology Guidelines for Sleeping Areas (SBM-2008)		
0.1	Indoor	Salzburg Public Health Department (2002)		
< 0.01	Indoor	“No Concern” Building Biology Guidelines for Sleeping Areas (SBM-2008)		
0.000 001		Natural background (30 MHz-30 GHz): stormy sun		
0.000 000 001		Natural background (30 MHz-30 GHz): quiet sun		

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* Near-field exposure from handsets. All listed exposure guidelines apply to far-field exposure situations.



APPENDIX C: RESOURCES AND REFERENCES

RF Exposure Guidelines for the General Public

USA: FCC Maximum Permissible Exposure at 900 MHz: 6,000,000 $\mu\text{W}/\text{m}^2$ or 600 $\mu\text{W}/\text{cm}^2$
Canada: Safety Code 6 at 900 MHz: 6,000,000 $\mu\text{W}/\text{m}^2$ or 600 $\mu\text{W}/\text{cm}^2$

References

British Columbia Centre for Disease Control (Canada)

Assessment of Radio Frequency (RF) Emissions from BC Hydro Smart Meters (2010)

http://www.bccdc.ca/NR/rdonlyres/43EF885D-8211-4BCF-8FA9-0B34076CE364/0/June92011_BCCDCReport_BCHydroSmartMeters.pdf

BC Hydro (utility of British Columbia, Canada)

Understanding Radio Frequency and BC Hydro's Smart Meters

http://www.bchydro.com/etc/medialib/internet/documents/smi/smi_RadioFrequency_SmartMeters.Par.0001.File.smi-RadioFrequency-SmartMeters.pdf

Smart Metering & Infrastructure Program—Business Case

http://www.bchydro.com/etc/medialib/internet/documents/smi/smi_business_case.Par.0001.File.smi_business_case.pdf

Electric Power Research Institute

An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter (2010)

<http://mydocs.epri.com/docs/CorporateDocuments/Newsletters/ENV/QN-2011-02/07-060c.html>

Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model (2011)

http://www.demandresponsesmartgrid.org/Resources/Documents/Reports-Govt-NFP/EPRI_RF%20Exposure%20from%20Smart%20Meters_Summary%20Report_FEB%202011.pdf

Itron, Inc.

Analysis of Biological Hazards from Exposure to Radio Frequency (RF) Radiation (2007)

Itron White Paper

Wireless Transmissions: An Examination of OpenWay Smart Meter Transmissions in a 24-Hour Duty Cycle (2011)

https://www.itron.com/na/PublishedContent/OpenWay%20Wireless%20Transmissions_24%20Hour%20Duty%20Cycle.pdf

OpenWay[®] Radio Frequency and Safety Compliance

Prepared by Itron, Inc. on behalf of BC Hydro

https://www.itron.com/na/resourcesAndSupport/Documents/OpenWay_Radio_Frequency_and_Safety_Compliance.pdf

Richard Tell Associates, Inc.

An Analysis of Radiofrequency Fields Associated with Operation of the Hydro One Smart Meter System (2010)

http://www.hydroone.com/MyHome/MyAccount/MyMeter/Documents/Smart_Meters_Report_on_RFE.pdf

Sage Associates

Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters (2010)

<http://sagereports.com/smart-meter-rf/>

Precautionary Guidelines

BionInitiative Report (2007)

<http://www.bioinitiative.org/report/index.htm>

Building Biology Evaluation Guidelines for Sleeping Areas (SBM-2008)

http://www.baubiologie.de/downloads/english/richtwerte_2008_englisch.pdf



International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines (1998)

<http://www.icnirp.de/documents/emfgdl.pdf>

Salzburg Public Health Department (Austria 2002)

http://www.salzburg.gv.at/konfliktmanagement_salzburger_modell.pdf

Seletun Consensus Statement (2010)

<http://iemfa.org/index.php/publications/seletun-resolution>

TQB Green Building Rating System (Austria 2009)

<https://www.oegnb.net/tqb.htm>

Wolfgang Kessel: Radar – Eine unterschätzte Gefahr. In Elektromagnetische Verträglichkeit Energieversorgung & Mobilfunk. 3rd EMC Conference of the VDB 2004, p. 195.

http://www.baubiologie.net/uploads/media/2004_3_EMV_Themen_Inhalt.pdf

Ecolog Institute <http://www.ecolog-institut.de/index.php?id=42>

Wolfgang Kessel <http://www.cuprotect-shieldingsystems.eu>

Legally Binding Safety Standards

Canada Safety Code 6

http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct-eng.php

Swiss Ordinance on Protection from Non-Ionizing Radiation (NISV 2000)

<http://www.bafu.admin.ch/elektrosmog/01100/01101/index.html?lang=de> or

<http://www.electric-fields.bris.ac.uk/SwissOrdNIR.pdf>

Ukraine Health and Safety Standard (1996)

<http://zakon.rada.gov.ua/cgi-bin/laws/main.cgi?page=1&nreg=z0488-96>