Longmire, Brandi (CDC/ONDIEH/NCEH) (CTR)

From: Ken Foster (b)(6)
Sent: Tuesday, May 19, 2015 4:56 PM
To: Donovan, John (CDC/ONDIEH/NCEH); Ansari, Armin (CDC/ONDIEH/NCEH)
Subject: draft of document on wireless devices
Attachments: networks_KRF_05_19_15.docx

Follow Up Flag: Follow up
Flag Status: Completed

here is a draft. This touches on smart meters, Wi-Fi - all very controversial at the moment. Will need to be reviewed carefully regards Ken Foster

according to the SciMetrics contract, this period ends on June 6. I will request that they extend it with a no cost extension through the summer to allow a few rounds of revision of this and the next few I will send

regards Ken Foster

--
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Wireless Networks and Exposure to Radiofrequency Energy

What are wireless networks and wireless-enabled devices?

Since the early 2000's, there has been a rapid growth in the number of digital wireless devices that transmit information and link to other devices using radiofrequency (RF) energy. Many of these devices are designed to be used in networks (linked groups of devices) that provide communications over areas that may range from a single household to an entire neighborhood, by transferring information from one device to another throughout the network. Examples include Smart Meters (wireless enabled utility meters) as well as some new systems that provide Internet service to communities by means of arrays of small transmitters mounted on consumers' houses. Other devices provide two-way communication between devices or between computers and devices, Examples include the familiar Wi-Fi and Bluetooth interfaces in computers and smartphones and, increasingly, Wi-Fi enabled home thermostats, bathroom scales, light bulbs, remotely controlled power outlets, and other household appliances.

All of these devices transmit radiofrequency energy, which creates some level of public exposure. In response, some citizens have expressed concerns about the possible health effects of such exposures. RF energy is a form of nonionizing radiation (the photons that carry it have insufficient energy to break chemical bonds and create ions, which is the major cause of tissue damage from ionizing radiation such as X-rays).

For more information on non-ionizing radiation, click here

Comment [ilj1]: Link to non-ionizing content

Wireless Network Technology and Safety

Characteristically, all of the devices considered here transmit signals that consist of streams of brief radiofrequency (RF) pulses. Most of these devices operate at frequencies generally similar to those used by cellular telephones (around 1 gigahertz (GHz)). Many of these devices use the same "unlicensed" frequency bands at 0.9 and 2.4 GHz that are used by other consumer electronic equipment including microwave ovens. The devices typically operate at peak power levels well below 1 watt (and generally at lower levels than transmitted by cellular telephones). Moreover, the devices characteristically transmit energy at very low duty cycle (i.e. they transmit for a small fraction of time), and their average transmitted power is consequently much less than 1 watt.

To be sold in the U.S., devices that transmit RF energy must meet limits for human exposure to RF energy set by the Federal Communications Commission (FCC). These limits are designed to protect against all known hazards of RF energy. For wireless networking devices, as for other RF transmitters, the FCC exposure limits apply to the peak power levels. Depending on the device, the FCC limits may be in terms of peak power density that is incident on the body (for devices that are intended to be used some distance from the body such as Wi-Fi routers) or peak absorbed power in the body (for devices that are intended to be used close to the body, such as tablet computers that are used against the lap). In either case, the FCC limits refer to peak exposure levels while the device is transmitting. Since wireless devices characteristically transmit energy for only a small fraction of the time, typically less than 1% , the average exposure to the user will be far below the peak levels in the FCC limits.

An individual's exposure to RF energy from a wireless devices should be considered in the context of RF exposure from many other sources of RF energy in today's environment. These include radio and TV broadcasting antennas, emergency, police and commercial communications systems, cellular telephone base stations, use of cellular telephones by an individual or by nearby individuals, cordless telephones and microwave ovens in the home, laptop computers, and a diverse variety of networking devices including Smart Meters in the home.

The level of exposure from any device falls off rapidly with distance of a person to the transmitting antenna. Consequently, the RF exposure levels in ordinary environments is highly variable, but generally very low compared to exposure limits.

For example an extensive survey of RF field levels in typical environments (office, homes, transportation, outdoors) in five European countries was reported in 2010 by a group of European investigators[1] The highest exposure to RF energy that an average person experiences in ordinary life is from his/her own use of a cellular phone. The study found that the highest average exposure (apart from ones own use of a cellular phone) was from cellular phones used by nearby individuals, followed by exposures from other sources including wireless communications equipment and other RF sources. In all cases, the RF field levels were small fractions of international limits (which are similar to the FCC limits in the U.S.

Levels of exposures to RF energy from Wi-Fi in schools have been studied extensively by several groups. One recent study in Belgium[2] found generally similar overall RF exposure levels in schools, homes, and offices, although the levels varied considerably. The signals measured in that study were from a variety of sources inside the building (Wi-Fi, use of cell phones by occupants) and external sources (e.g. cellular base station, transmitting equipment). All of the levels measured in that study were far below international exposure limits. In schools the largest contribution to the RF exposure level within the buildings was from Wi-Fi; in other environments it was generally from other persons' use of cellular telephones. Nevertheless, all exposure levels were quite similar.

Despite these complexities, the largest overall exposure that an average citizen receives to RF energy is when he/she uses a cellular telephone. Because exposure falls off rapidly with distance from the transmitting antenna, other RF sources will contribute to the background exposure, at a greater or lesser amount depending on the distance from their antenna to an individual. In generally decreasing amounts, this includes RF energy from the cellular telephone used by a bystander, and then RF signals from other wireless devices, including cordless telephones, Wi-Fi, Smart Meters, and other networking technologies, and (at a generally lower level) from RF sources outside the home.

All of these measured exposure levels are a very small fraction of U.S. and international exposure limits. A "backgrounder" published by the World Health Organization in 2006 concluded that "Considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects".[3] In the view of CDC, this conclusion remains valid today.

<u>What you need to know</u>:

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[1] Joseph, Wout, et al. "Comparison of personal radio frequency electromagnetic field exposure in different urban areas across Europe." Environmental research 110.7 (2010): 658-663.
[2] Verloock, Leen, et al. "Assessment of Radio Frequency Exposures in Schools, Homes, and Public Places in Belgium." Health physics 107.6 (2014): 503-513.
[3] World Health Organization, Electromagnetic fields and public health. Base stations and wireless technologies.

- The FCC's present guidelines on RF energy exposure are based upon standards developed by the National Council on Radiation Protection and Measurements (NCRP) and the Institute of Electrical and Electronics Engineers (IEEE). The FCC's guidelines were developed through a comprehensive [4]process that included input from federal agencies and the public. While the guidelines were adopted in 1996, they are similar to major international guidelines that are presently in effect in many other countries.
- Several health agencies have concluded that major international limits, which are broadly similar to present FCC limits, offer sufficient protection against all known hazards of RF energy.
- Wireless communications and networking devices are required to meet FCC guidelines on RF energy exposure. The FCC limits apply to the peak exposure produced by a device while it is transmitting. Because wireless devices characteristically transmit energy for only a small fraction of the time, typically much less than 1%, the average exposure to the user will be far lower than peak values reported to the FCC.
- There remains no convincing evidence that exposure to such fields creates any health hazard. Moreover, exposure levels to the public from wireless networking devices, Wi-Fi, Smart Meters, and other similar devices is generally much lower than exposure to an individual from use of a cellular phone, and it is probably lower than from use of a cellular phone by a bystanding individual (depending on the distances involved). To the extent that RF exposures can be reduced by an individual, it would be by reducing the use of cellular telephones or wireless equipment that is located close to the individual. CDC does not recommend such measures based on present information however.
- CDC recognizes that there is some level of scientific uncertainty about possible biological effects of RF energy. In particular, in 2011 the International Agency for Research on Cancer (IARC, a component of the World Health Organization) classified RF energy as "possibly carcinogenic to humans" [i] In the formal decision process that IARC used, this indicates a level of suspicion and not a conclusion that RF energy probably or actually does cause cancer. Moreover, most of the evidence leading to this classification pertained to long term use of cellular telephones, which is *a different (relatively much higher) exposure than that produced by wireless networking devices*
- CDC will continue to monitor this topic.

For More Information:
Federal Communications Commission (FCC)
CDC- Frequently Asked Questions about Cell Phones and Your Health
NIH – Cell Phones
National Cancer Institute – Cell Phones and Cancer Risk
WHO – Electromagnetic Fields (EMF)
HPS – Micro/Radio Waves, Radar and Powerlines
WHO World Health Organization, Electromagnetic fields and public health. Base stations and wireless technologies. Backgrounder May 2006 (available at http://www.who.int/peh-emf/publications/facts/fs304/en/)

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31 May 2011 IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS.http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf

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Backgrounder May 2006 (available at http://www.who.int/peh-emf/publications/facts/fs304/en/)

Mobile & Wireless Forum

FCC-MWF MTG

September 17, 2020

Overview of MWF Research Efforts

MWF-Sponsored 5G Research Project Publications

1. Foster, Ziskin and Balzano, “Thermal response of human skin to microwave energy: a critical review”, Health Physics Journal, 2016
2. Foster and Colombi, “Thermal response of tissue to RF exposure from canonical dipoles at frequencies for future mobile communication system, Electronic Letters, 2017
3. Foster, Ziskin and Balzano, “Thermal modeling for the next generation of radiofrequency exposure limits: commentary”, Health Physics Journal, 2017
4. Ziskin, Alekseev, Foster and Balzano, “Tissue models for RF exposure evaluation at frequencies above 6 GHz”, Bioelectromagnetics, 2018
5. Christ, Colombi and Joyner, “Thermal Modeling of the Near-Field Exposure from Wireless 5G Devices”, EuCap 2018
6. Carrasco, Colombi, Foster, Ziskin and Balzano, “Exposure Assessment of Portable Wireless Devices above 6 GHz”, Radiat Prot Dosimetry, 2018
7. Foster, Ziskin, Balzano and Bit-Babik, ”Modeling Tissue Heating From Exposure to Radiofrequency Energy and Relevance of Tissue Heating to Exposure Limits: Heating Factor”, Health Physics Journal, 2018
8. Pfeifer, Carrasco, Crespo-Valero, Neufeld, Kuhn, Samaras, Christ, Capstick and Kuster, “Total Field Reconstruction in the Near Field Using Pseudo-Vector E-Field Measurements”, IEEE EMC, 2018
9. Lundgren, Helander, Gustafsson, Sjöberg, Xu and Colombi, Near Field Reconstruction for Electromagnetic Exposure of 5G Communication Devices, Annual Meeting and Symposium of the Antenna Measurement Techniques Association, 2018
10. Colombi, Xu, Törnevik, Christ, Foster, Ziskin and Balzano, “Comparison between numerically and experimentally assessed skin temperature elevations for localized RF exposures at frequencies above 6 GHz”, BioEM 2018
11. Christ, Samaras, Neufeld and Kuster, “RF-Induced temperature increase in a stratified model of the skin for plane-wave exposure at 6-100 GHz” Radiation Protection Dosimetry, 2020
12. Foster, Ziskin, Balzano and Hirata, “Thermal Analysis of Averaging Times in Radio-Frequency Exposure Limits Above 1 GHz”, IEEE Access, 2019
13. Lundgren, Helander, Gustafsson, Sjöberg, Xu, and Colombi, “Near-Field Measurement and Calibration Technique for RF EMF Exposure Assessment of mm-wave 5G Devices”, in publication on the IEEE Antennas and Propagation Society Magazine.
14. Aerts, Verloock,Van den Bossche, Colombi, Martens, Törnevik, Joseph,”In-Situ Measurement Methodology for the Assessment of 5G NR Base Station Exposure at Sub-6 GHz Frequencies”, IEEE Access, 2019

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MWF's Position

- MWF's response to the NPRM urges:
  - MWF advocates specifically that the power density averaging time allowed under the FCC's time-averaging regulations be aligned with the ICNIRP and IEEE standards -- and that its proposed approach (as reflected in Table 5 of the NPRM) be withdrawn.
- MWF's approach is supported by the latest research by Dr. Foster:
  - Dr. Foster notes that the extreme cases being guarded against by the FCC do not occur in telecom signals. We therefore propose that extreme cases be carved out and telecom signals aligned with the IEEE and ICNIRP standards.
  - Dr. Foster advises that if the goal is to protect against excessive thermal transients from extreme high-fluence mm-wave pulses, however unrealistic such exposures may be, **a scientifically accurate approach would be to limit pulse fluence directly**, as an add-on to existing limits and averaging times. This is the approach taken in the latest revisions of IEEE C95.1 (2019) and ICNIRP (2020). A separate NPRM on this approach for extreme cases would be appropriate.

Dr. Foster's Big-Bang Pulse Analysis [12]

"Big Bang Pulse": We consider the response to a single pulse of duration $\Delta\tau$ and fluence ($I_o\tau_{avg}$), which is the maximum fluence pulse permitted under the limit I_o subject to averaging time τ_{avg} (here assumed to be 6 min). This is the most extreme exposure scenario that would be permitted under the constraints of the limits on time-averaged power density and averaging time.

The thermal transients produced by the "big bang" pulses (Fig. 3) at mm-wave frequencies are as much as 20 times higher than the temperature increases from CW exposure in the steady state. Such "big bang" exposures represent extreme cases that would hardy ever or never be encountered in the real world but are considered as a limiting case. One exception is a military nonlethal weapons system [6].

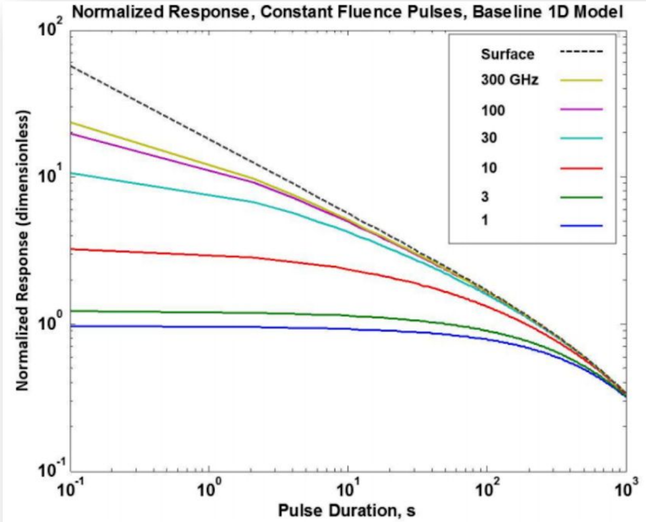

FIGURE 3. Peak transient increase in surface temperature in 1D baseline model produced by a single "big bang" pulse of constant fluence ($I_o\tau_{avg}$) vs. pulse duration. Results are normalized by the steady-state temperature increase for CW exposures at power density I_o Averaging time τ_{avg} is 6 min.

[Back](#)

Mobile & Wireless

Health Physics 105, no. 6 (2013)

WI-FI AND HEALTH: REVIEW OF CURRENT STATUS OF RESEARCH

Kenneth R. Foster* and John E. Moulder†

***Abstract*—This review summarizes the current state of research on possible health effects of Wi-Fi (a commercial name for IEEE 802.11-compliant wireless networking). In response to public concerns about health effects of Wi-Fi and wireless networks and calls by government agencies for research on possible health and safety issues with the technology, a considerable amount of technology-specific research has been completed. A series of high quality engineering studies have provided a good, but not complete, understanding of the levels of radiofrequency (RF) exposure to individuals from Wi-Fi. The limited number of technology-specific bioeffects studies done to date are very mixed in terms of quality and outcome. Unequivocally, the RF exposures from Wi-Fi and wireless networks are far below U.S. and international exposure limits for RF energy. While several studies report biological effects due to Wi-Fi-type exposures, technical limitations prevent drawing conclusions from them about possible health risks of the technology. The review concludes with suggestions for future research on the topic.**

Health Phys. 105(6):561–575; 2013

Key words: e[...] radiofrequency; health effects; radiation protection; ra[...]

to the Internet by laptop computers, although IEEE 802.11 protocols are used for other communications devices, including some electric utility meters.

Initially developed as a wireless replacement for Ethernet cable to connect computers to local area networks, IEEE 802.11 is now the basis of virtually all wireless local area networks present in homes, offices, and other environments. At present, virtually every laptop computer and SmartPhone comes equipped with a Wi-Fi client, and one recent study estimated that 61% of American households presently have Wi-Fi for Internet access (Thota 2012). Increasingly, household devices are incorporating Wi-Fi interfaces to allow remote programming and data acquisition: bathroom scales, gaming devices, audio equipment, household thermostats, and running shoes. While numerous wireless networking technologies are available, virtually all of the WLANs with which an ordinary citizen would be

Acknowledgments—This work was funded by the Wi-Fi Alliance, Washington, DC, and Mobile Manufacturers Forum, Brussels, Belgium. Neither organization had any role in the research for, or preparation of, the manuscript; and they had no knowledge of the contents or conclusions of this review prior to submission for publication. The opinions in this review are those of the present authors only.

Health Physics 92(3):280-9 · April 2007

RADIOFREQUENCY EXPOSURE FROM WIRELESS LANS UTILIZING WI-FI TECHNOLOGY

Kenneth R. Foster*

***Abstract*—This survey measured radiofrequency (RF) fields from wireless local area networks (WLANs) using Wi-Fi technology against a background of RF fields in the environment over the frequency range 75 MHz–3 GHz. A total of 356 measurements were conducted at 55 sites (including private residences, commercial spaces, health care and educational institutions, and other public spaces) in four countries (U.S., France, Germany, Sweden). Measurements were conducted under conditions that would result in the higher end of exposures from such systems. Where possible, measurements were conducted in public spaces as close as practical to the Wi-Fi access points. Additional measurements were conducted at a distance of approximately 1 m from a laptop while it was uploading and downloading large files to the WLAN. This distance was chosen to allow a useful comparison of fields in the far-field of the antenna in the laptop, and give a representative measure of the exposure that a bystander might receive from the laptop. The exposure to the user, particularly if the antenna of the client card were placed against his or her body, would require different measurement techniques beyond the scope of this study. In all cases, the measured Wi-Fi signal levels were very far below international exposure limits (IEEE C95.1-2005 and ICNIRP) and in nearly all cases far below other RF signals in the same environments. An Appendix discusses technical aspects of the IEEE 802.11 standard on which WLANs operate that are relevant to determining the levels of RF energy exposure from WLANs...**

wireless local-area network "hot spots" in operation around the world.[†] This study concerns WLANs that based on the widely utilized Wi-Fi technology; other technologies such as WiMAX are not considered. The technology has occasionally prompted questions from the public about health and safety issues related to exposure to RF energy, and in U.K. schools, WLANs have been removed due to health concerns (Bale 2006).

While WLANs clearly operate at low power, little quantitative information is available to the public or to health physicists and other professionals about the levels of exposure that they produce to the public. A few technical reports have recently appeared (e.g., Schmid et al. 2005), but little if anything is presently available in the conventional scientific literature. This study reports a survey of RF fields associated with WLAN technologies and other environmental sources of RF energy in a variety of locations that are typical of those that might be accessible to the general public. An Appendix provides more detailed considerations related to RF exposure from WLANs.

Almost all WLANs are based on the IEEE 802.11

Acknowledgments— This work was supported by the Wi-Fi Alliance.

Tissue Models for RF Exposure Evaluation at Frequencies above 6 GHz

Marvin C. Ziskin,[1]* Stanislav I. Alekseev,[2] Kenneth R. Foster,[3] and Quirino Balzano[4]

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[2]*Institute of Cell Biophysics, Russian Academy of Sciences, Pushchino, Russia*
[3]*Department of Bioengineering, University of Pennsylvania, Philadelphia, Pennsylvania*
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Exposures to radiofrequency (RF) energy above 6 GHz are characterized by shallow energy penetration, typically limited to the skin, but the subsequent increase in skin temperature is largely determined by heat transport in subcutaneous layers. A detailed analysis of the energy reflection, absorption, and power density distribution requires a knowledge of the properties of the skin layers and their variations. We consider an anatomically detailed model consisting of 3 or 4 layers (stratum corneum, viable epidermis plus dermis, subcutaneous fat, and muscle). The distribution of absorbed power in the different tissue layers is estimated based on electrical properties of the tissue layers inferred from measurements of reflected millimeter wavelength energy from skin, and literature data for the electrical properties of fat and muscle. In addition, the thermal response of the model is obtained using Pennes bioheat equation as well as a modified version incorporating blood flow rate-dependent thermal conductivity that provides a good fit to experimentally-found temperature elevations. A greatly simplified 3-layer model (Dermis, Fat, and Muscle) that assumes surface heating in only the skin layer clarifies the contribution of different tissue layers to the increase in surface skin temperature. The model shows that the increase in surface temperature is, under many circumstances, determined by the thermal resistance of subcutaneous tissues even though the RF energy may be deposited almost entirely in the skin layer. The limits of validity of the models and their relevance to setting safety standards are briefly discussed. Bioelectromagnetics. 39:173–189, 2018.

Keywords: skin; radiofrequency; permittivity; reflectivity; temperature elevation

INTRODUCTION

Humans are increasingly exposed to radiofrequency (RF) electromagnetic energy above 6 GHz from many different sources, such as military usage [Bains, 1993], automotive radar [Hasch et al., 2012], airport scanners [Scheen et al., 2001], and millimeter wave therapy [Rojavin and Ziskin, 1998]. Newly developed 5G mobile communication systems will significantly add to this exposure. Limits for human exposure to RF energy are recommended by major international health and safety organizations such as IEEE C95.1–2006, 2005]. To achieve and maintain these goals, the limits are constantly being reviewed to determine if any need to be updated.

The limits for RF electromagnetic energy exposures above 6 GHz are expressed in terms of incident power density, which is directly related to tissue

Grant sponsor: Mobile and Wireless Forum (MWF).

Conflicts of interest: None.

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MODELING TISSUE HEATING FROM EXPOSURE TO RADIOFREQUENCY ENERGY AND RELEVANCE OF TISSUE HEATING TO EXPOSURE LIMITS: HEATING FACTOR

Kenneth R. Foster,[1] Marvin C. Ziskin,[2] Quirino Balzano,[3] and Giorgi Bit-Babik[4]

***Abstract*—This review/commentary addresses recent thermal and electromagnetic modeling studies that use image-based anthropomorphic human models to establish the local absorption of radiofrequency energy and the resulting increase in temperature in the body. The frequency range of present interest is from 100 MHz through the transition frequency (where the basic restrictions in exposure guidelines change from specific absorption rate to incident power density, which occurs at 3–10 GHz depending on the**

in thickness of tissue layers, the effects of normal physiological variation in tissue blood flow have been relatively unexplored.

Health Phys. 115(2):295–307; 2018

Key words: exposure; radiofrequency; radiation; nonionizing; radiofrequency; safety standards

INTRODUCTION

Q.B., K.R.F, and M.Z. were supported in this project by Mobile and Wireless Forum, which did not review and had no control over preparation of this manuscript. The authors thank A. Hirata, Nagoya Institute of Technology, Japan, for providing results used to prepare Fig. 3, and Dr. Vitas Anderson and Dr. C-K Chou for helpful discussion of earlier drafts of this paper. The views and opinions expressed herein are solely those of the authors and are not to be attributed to Motorola Solutions or any of its operating companies.

THERMAL MODELING FOR THE NEXT GENERATION OF RADIOFREQUENCY EXPOSURE LIMITS: COMMENTARY

Kenneth R. Foster,* Marvin C. Ziskin,† and Quirino Balzano‡

Abstract—This commentary evaluates two sets of guidelines for human exposure to radiofrequency (RF) energy, focusing on the frequency range above the "transition" frequency at 3–10 GHz where the guidelines change their basic restrictions from specific absorption rate to incident power density, through the end of the RF band at 300 GHz. The analysis is based on a simple thermal model based on Pennes' bioheat equation (BHTE) (Pennes 1948) assuming purely surface heating; an Appendix provides more details about the model and its range of applicability. This analysis suggests that present limits are highly conservative relative to their stated goals of limiting temperature increase in tissue. As applied to transmitting devices used against the body, they are much more conservative than product safety standards for touch temperature for personal electronics equipment that are used in contact with the body. Provisions in the current guidelines for "averaging time" and "averaging area" are not consistent with scaling characteristics of the bioheat equation and should be refined. The authors suggest the need for additional limits on fluence for protection against brief, high intensity pulses at millimeter wave frequencies. This commentary considers only thermal hazards, which form the basis of the current guidelines, and excludes considerations of reported "non-thermal" effects of exposure that would have to be evaluated in the process of updating the guidelines.

Health Phys. 113(1):41–53; 2017

Key words: exposure, radiofrequency radiation, nonionizing

of Electrical and Electronics Engineers (IEEE) (IEEE 2005). Most national limits [in the U.S., the limits of the Federal Communications Commission (FCC 2010)] are generally similar to IEEE and ICNIRP limits. All three sets of limits are in the process of revision and updating.

The frequency range above 3–10 GHz through the top of the RF band (300 GHz) has heretofore received relatively little attention by the committees that develop the guidelines, despite a large number of (generally low-powered) devices that already operate in this wide band (Fig. 1). Largely, this is because most devices operating in this frequency range have little potential for high-level exposure to humans, and partly because few consumer devices operate at present in this frequency range and there has been little controversy about the safety of such devices. However, this broad frequency band is about to gain much wider use with the introduction of a new generation (5 G) of wireless communications (Andrews et al. 2014) and the development of high-powered millimeter wave devices (30–300 GHz) for industrial and military applications.

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Thermal Analysis of Averaging Times in Radio-Frequency Exposure Limits Above 1 GHz

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The work of K. R. Foster, M. C. Ziskin, and Q. Balzano was supported in part by Mobile and Wireless Forum.

ABSTRACT This paper considers the problem of choosing an appropriate "averaging time" in radiofrequency (RF) exposure limits to protect against thermal hazards, focusing on the RF frequency range above 3–10 GHz. Analysis is based on examination of the dynamic properties of thermal models for tissue using Pennes' bioheat equation. Three models are considered: a baseline model consisting of a uniform half space with dielectric and thermal properties similar to those of human skin with adiabatic boundary conditions; a layered 1D model with dielectric and thermal properties similar to those of skin, fat, and underlying

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Thermal response of tissue to RF exposure from canonical dipoles at frequencies for future mobile communication systems

K. Foster and D. Colombi✉

The level of protection against thermal hazard of the current RF EM field (EMF) exposure limits is estimated at the transition frequency where the basic restrictions change from specific absorption rate to power density. It is shown that the calculated steady-state temperature increase in the skin generated by a nearby dipole transmitting at maximum power to meet compliance with the EMF limits presents a significant discontinuity at this frequency. The results suggest that for exposure to limited areas of the body at frequencies where basic restrictions are provided in terms of power density, the currently existing exposure guidelines need to be revised. These findings might have large implications on the development of future radio access technologies operating at the millimetre wave.

Acknowledgment: This work was supported in part by the Mobile Manufacturers Forum.

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Are Children More Exposed to Radio Frequency Energy From Mobile Phones Than Adults?

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ABSTRACT There has been long-standing controversy, both among scientists and in the public, about whether children absorb more radio frequency (RF) energy in their heads than adults when using a mobile telephone. This review summarizes the current understanding of this issue, and some of the complexities in comparing the absorption of RF energy in different individuals from use of mobile phones. The discussion is limited to dosimetric issues, i.e., possible age-related differences in absorption of RF energy in the heads of mobile phone users. For most metrics of exposure, in particular those relevant to assessing the compliance of handsets with regulatory limits, there is no clear evidence for age-related differences in exposure. For two metrics of exposure, there is a clear evidence that age can play a factor: 1) the local specific absorption rate (SAR), in particular anatomically defined locations within th... will vary with head size and hence with age and 2) the SAR, in particular tissues ... age-related differences in the dielectric properties ... that are below the 1-g or 10-g peak spatial SAR ... significance for compliance assessment. Age-relat... presently considered are difficult to generalize to ... due to many variables that determine SAR during

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RADIOFREQUENCY ENERGY EXPOSURE FROM THE TRILLIANT SMART METER

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Abstract—**This paper reviews radiofrequency (RF) field levels produced by electric utility meters equipped with RF transceivers (so-called Smart Meters), focusing on meters from one manufacturer (Trilliant, Redwood City, CA, USA, and Granby, QC, Canada). The RF transmission levels are summarized based on publicly available data submitted to the U.S. Federal Communications Commission supplemented by limited independent measurements. As with other Smart Meters, this meter incorporates a low powered radiofrequency transceiver used for a neighborhood mesh network, in the present case using ZigBee-compliant physical and medium access layers, operating in the 2.45 GHz unlicensed band but with a proprietary network architecture. Simple calculations based on a free space propagation model indicate that peak RF field intensities are in the range of 10 mW m^{-2} or less at a distance of more than 1–2 m from the meters. However, the duty cycle of transmission from the meters is very low (< 1%). Limited measurements identified pulses from the meter that were consistent with data reported by the vendor to the U.S. Federal Communications Commission. Limited measurements conducted in two houses with the meters were unable to clearly distinguish emissions from the meters from the considerable electromagnetic clutter in the same frequency range from other sources, including Wi-Fi routers and, when it was activated, a microwave oven. These preliminary measurements disclosed the difficulties that would be encountered in characterizing the RF exposures from these meters in homes in the face of background signals from other household devices in the same frequency range. An appendix provides an introduction to Smart Meter technology. The RF transmitters in wireless-equipped Smart Meters operate at similar power levels and in similar frequency ranges as many other digital communications devices in common use, and their exposure levels are very far below U.S. and international exposure limits.**
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INTRODUCTION

THROUGHOUT THE world, electric utilities are installing advanced utility meters, called Smart Meters, on customers' houses that enable frequent (hourly or more) reading of meters, prompted in part by government incentives to move to time-of use pricing to promote a more efficient use of the power grid. While the design of Smart Meter systems varies with the vendor, most systems incorporate low-powered radiofrequency (RF) transceivers that link neighboring meters into a network (called a neighborhood area network or NAN) to enable reliable communication with the utility. In addition, the meters may include separate transceivers to support a second network (a Home Area Network or HAN) that links the meter with household appliances. In part because of citizens' concerns about RF exposure, Smart Meters have become controversial in many areas, and there is considerable discussion (often inaccurate) on the Internet about levels of exposure to RF energy that they produce.

So far, only one study has appeared in the scientific literature on RF exposure from Smart Meters, based on measurements of meters from one vendor (Itron, West Union SC) that had been modified to transmit at 100% duty cycle (Tell et al. 2012). This present study considers exposure characteristics of a different meter (by Trilliant, 1100 Island Dr., #201, Redwood City, CA USA and Granby, QC, Canada), using numerical calculations based on design data and limited measurements from meters in homes

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