February, 2013

# RADIOFREQUENCY (RF) EVALUATION REPORT

Use of Wireless Devices in Educational Settings


*Prepared by:*

URS

12120 Shamrock Plaza
Suite 300
Omaha, NE 68154

*Prepared for:*

Los Angeles Unified School District

Office of Environmental Health and Safety
333 South Beaudry Avenue, 28th Floor
Los Angeles, California 90017


URS Job Project Number: 29406258

# TABLE OF CONTENTS

# TABLE OF CONTENTS



**Tables**



**Figures**

This Electromagnetic Field (EMF) Radiofrequency (RF) Evaluation Report was prepared by URS Corporation (URS) for the Los Angeles Unified School District (LAUSD) to research previous published reports pertaining to the implications of wireless technology into the school system, including recommended and regulatory limits for RF EMF exposure, and research on related wireless technologies as they may apply to wireless local access networks (WLANs).

## 1.1 LITERATURE SUMMARY

The technical literature is conflicted regarding RF EMF exposure and health effects. While many studies conclude that there are no adverse health effects from RF EMF exposure, others conclude that adverse health effects may result from long-term exposure to high level RF EMFs.[1] Fewer studies have been performed on the health effects of RF EMF exposure as compared to studies on extremely low frequency (ELF) EMF exposure, but the literature is also conflicted. Some studies claim no adverse health effects were found, while others claim to have observed adverse health effects.

Based upon the technical research, several agencies have proposed voluntary standards for all EMF exposure. Countries have adopted widely-varying standards, ranging from 10 to 1,000 $\mu W/cm^2$. Independent organizations, such as the Bioinitiative Report, have proposed cautionary levels as low as 0.1 $\mu W/cm^2$ (2007) and 0.0003 $\mu W/cm^2$ (2012), although these are recommendations only.

## 1.2 EVALUATION

Evaluation of any risk associated with RF EMF exposure is difficult, as reports of health effects and RF EMF are diverse and sometimes conflicting. Because of this, URS advocates adopting a conservative, cautionary approach to RF EMF exposure until more research is conducted.

A review of international RF EMF protection standards reveals that the lowest value is 10 $\mu W/cm^2$ (Russia, Switzerland) and the highest value is 1,000 $\mu W/cm^2$ (United States). While the Federal Communications Commission (FCC) limits are based on thermal effects, URS recommends a more conservative standard within the LAUSD public school system to attempt to address potential effects at the biological and cellular level. A more conservative level will hypothetically be more protective than thermal-based standards and will attempt to protect children, who represent a potentially vulnerable and sensitive population. Based on an evaluation of current international RF EMF regulations, a review of reports of potential adverse effects from excessive RF EMF exposure, and an assessment of background RF EMF levels, URS recommends a cautionary level of 0.1 $\mu W/cm^2$, taken as a whole-body, time-averaged value.

[1] The literature acknowledges a link between high extremely low frequency (ELF) EMF exposure and childhood leukemia. More recently, literature indicates that a link may exist between high ELF EMF exposure and adult leukemia and brain tumors. Other research has suggested a link between high ELF EMF exposure and breast cancer, cardiovascular disease, and neurological disorders, although more research is needed to fully characterize these findings.

## 1.3 RECOMMENDATIONS

Based on the previous research and technical literature, URS has compiled a series of recommendations to assist the LAUSD in determining the ramifications of adopting WLAN technology within the school system:

1. Because children represent a particularly vulnerable population, as indicated by the technical literature, the LAUSD is appropriate in adopting a conservative standard.

2. URS recommends a cautionary level of 0.1 $\mu W/cm^2$, taken as a whole-body, time-averaged value, which is consistent with accepted practice (FCC, 1997). This cautionary level is 10,000 times lower than FCC regulations.

3. A recommended cautionary level of 0.1 $\mu W/cm^2$ is attainable within LAUSD classrooms, based on calculations that have been performed.

4. The 2012 Bioinitiative Report recommended cautionary level of 0.0003 $\mu W/cm^2$ is unrealistic and unattainable, as background RF levels are above this precautionary level.

5. Because the recommended cautionary level of 0.1 $\mu W/cm^2$ is conservative, 10,000 times lower than FCC regulations, and attainable, the value is appropriate for use in the LAUSD.

6. The recommendations contained in this paper apply to WLANs only. While other RF technologies that provide wireless broadband access are available for use, such as WiMAX, CDMA, or LTE, these technologies operate at higher power densities and would require further research and evaluation.

## 2.1 PURPOSE AND SCOPE

### 2.1.1 Summary

This Electromagnetic Field (EMF) Radiofrequency (RF) Evaluation Report was prepared by URS Corporation (URS) to research the health implications to children and employees of the Los Angeles Unified School District (LAUSD) with exposure to RF EMFs from wireless devices used within an academic setting. This report includes a brief review of RF EMFs, a summary of current literature research on the subject of RF EMF exposure to human beings, interpretations of previous research, and recommendations for future action. Note that this paper does not address all wireless technologies, such as Worldwide Interoperability for Microwave Access (WiMAX), Code-Division Multiple Access (CDMA), Long Term Evolution (LTE), or infrared (IR) communications, but is limited in scope to wireless local area network (WLAN) devices.

The LAUSD's Board of Education (BOE) drafted several resolutions (2000, 2009) regarding RF EMF exposures associated with cellular towers near schools, whereby a prohibition exists regarding siting towers on school campuses. The resolutions also call for the Federal Communications Commission (FCC) to revise their standards based upon new and emerging information regarding exposure and health. In response, LAUSD staff have referenced a "cautionary" threshold (Bioinitiative Report, 2007) that is viewed by many local and international organizations to be protective of public health.

### 2.1.2 Background

LAUSD's Information Technology Division (ITD) recently completed a Strategic Execution Plan (SEP), which outlines the creation of a Virtual Learning Complex (VLC). Through the VLCs Classroom Technology Modernization Program (CTMP), ITD expects to provide wireless access to classrooms providing all students internet connectivity throughout the District.

In May 2012, concerns were raised during public comment at several BOE meetings regarding the District's goal to provide wireless internet connectivity. It was alleged that by doing so, the LAUSD would be placing cell tower technology within classrooms. In essence, the District would be violating BOE policy and exposing children to excessive RF radiation.

Several BOE resolutions regarding RF EMF exposures associated with cellular towers near schools have resulted in a prohibition regarding siting such towers on school campuses. The resolutions also called for the FCC to revise their standards based upon new and emerging information regarding exposure and health. In response, District staff have referenced a "cautionary" threshold (Bioinitiative Report, 2007) that is viewed by many local and international organizations to be protective of public health. Authors of the Bioinitiative Report (2007) stated at the time of publication that this threshold represented the lower limit for reported human health effects.

In response, Board Member Kayser requested that ITD and the Office of Environmental Health and Safety (OEHS) determine potential RF exposures to students associated with existing and planned WLANs. LAUSD staff initiated this assessment, which included the identification of near-field exposures associated with the operation of access points (APs), selected end-devices (e.g., computers) and multifunctional devices (MFDs).

On August 9, 2012, Superintendent John Deasy announced the District's intent to distribute tablet computing devices to students. In response to the Superintendent's announcement, ITD prepared a Common Core Technology Project Plan (CCTPP). The CCTPP identifies the factors behind the project and outlines the additional components and approach necessary to accomplish the distribution of tablet end-devices. The CCTPP is an addendum to the April 2012 SEP and expands upon the scope of the VLC CTMP.

## 3.1 WIRELESS BASICS

All wireless technologies, including cell phones, WLANs (i.e., WiFi), and Smart Meters, work in essentially the same way. For the purposes of this project, the report will focus on WLAN systems. The device used to connect a wireless end device (laptop, iPad, etc) to the wireless computer network is called an access point (AP). An antenna installed within the AP generates EMFs in the RF portion of the electromagnetic spectrum. The RF EMFs are transmitted in two instances:

1. A basic broadcast signal is transmitted sporadically (approximately every 10 seconds) to allow any device that may be attempting to connect to the network to "see" the AP.

2. A transmission signal containing data based on the type of information that the end user is attempting to download or upload.

Note that some AP devices may have two or three antennae. The number of antenna depends on the number of different frequency bands an AP supports. Two-antenna APs usually support a single frequency range, while three-antenna APs typically support two simultaneously-active frequency ranges. IEEE 802.11 is a set of standards for implementing WLAN computer communication in the 2.4, 3.6 and 5 GHz frequency bands. IEEE 802.11b and 802.11g use the same frequency range (2.4 GHz) while 802.11a operates in the 5 GHz band, and 802.11n operates in both the 2.4 GHz and 5 GHz band. Most of the time, only one antenna is transmitting a signal at a time. In a two-antenna AP, usually one antenna transmits and the other antenna receives. In a three-antenna AP, usually one antenna transmits, while two antennae are dedicated to receiving under the different 802.11 protocols. However, under extreme demand, which is typically when 80% of capacity has been reached (based on either 11 megabytes per second [Mbps] for 802.11b or 54 Mbps for 802.11a or g), the AP may switch one of the antennae to operate partially as a transmitter. Note that this would be a relatively rare occurrence.

***Figure 1:*** *Newer laptops have the antenna in back of the screen.*

In order to receive the signal from the AP, the end device must have an antenna as well. The antenna is located within the body of the end device, in back of the screen in newer models. **Figure 1** illustrates the general location of the antenna within a laptop. The antenna within the end device generates RF EMFs as well. The end device emits RF EMFs attempting to perform the following functions:

1. Communicate with the AP, either downloading or uploading information, called operating in infrastructure mode.

2. Communicating with other wireless devices, called operating in *ad hoc* mode.

3. Detection of other end devices in the area.

**Figure 2** illustrates the general set up of a wireless network and the EMF emissions of the devices.

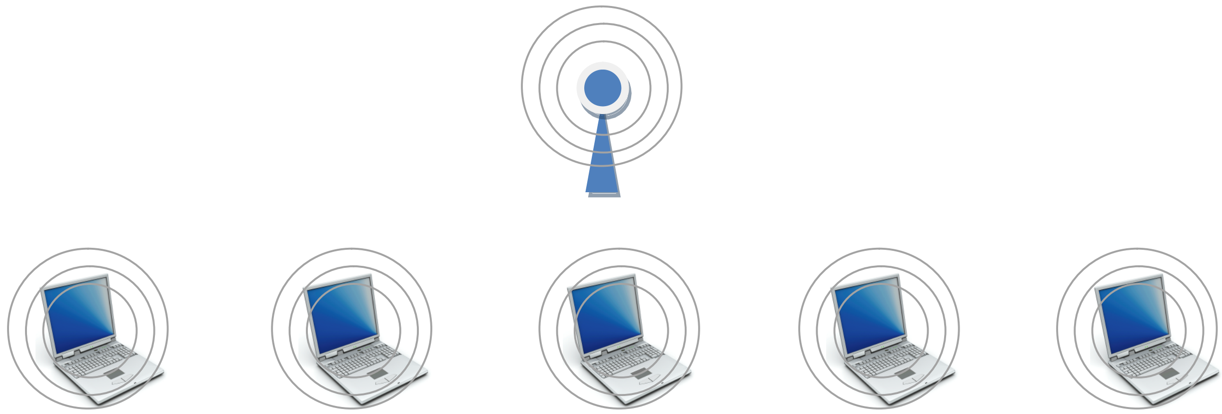

**Figure 2:** *General setup of a wireless network, illustrating that both the AP and the end devices emit RF EMFs.*

## 3.2 WIRELESS AND EMF

RF EMFs from the end device and the AP are not continuous, nor are these RF EMFs of the same power (or strength). (For a summary of basic EMF concepts, refer to **Appendix A**.) Rather, the strength and frequency of the RF EMFs generated are based on several factors, including the following:

1. **Proximity of the end device to the AP.** The closer the end device is to the AP, the lower the signal strength necessary to transmit the information between the two devices. Similarly, the farther away the end device is from the AP, the stronger the signal that must be employed for the AP to accurately receive and transmit. Note that in general, wireless devices normally operate at lower power levels than regulatory limits to conserve battery power.

2. **Antenna gain and directionality.** Normal wireless APs have an antenna gain of less than 6 decibels (dB), but commercial APs can have custom antennas with gains up to 21 dB (or higher). Omnidirectional antennas can be upgraded to gains of 8 to 12 dB, while directional (panels, sectors, etc.) antennas can be upgraded to much higher gains.

3. **Number of end devices.** When few end users are present, the likelihood that several end devices would attempt to receive or transmit at the same time is small. Thus, every time that the end device attempts to transmit to the AP, the signal would succeed and the frequency of EMF transmission would be relatively low. However, as the number of end users increases, congestion on the wireless system increases as multiple end devices attempt to communicate with the AP at the same time. However, the AP can only service

one end user at a time. In this situation, multiple end users could transmit at the same time, generating RF EMFs, without successfully connecting to the AP, which would result in the end device having to re-attempt the connection, and thus generating additional RF EMFs.

4. **Amount of data transferred.** Small files logically take less time to transmit and receive than large files. For example, downloading a webpage to read content would take less time and thus less RF EMF exposure than downloading a streaming video.

5. **Interference/Signal attenuation.** While all EMFs (including RF EMF) can in theory be transmitted unchanged through solid medium, like a wall, in reality, the EMFs can be attenuated by transmission through solid media. This attenuation lowers the signal strength so that the receiving device may have difficulty receiving the signal. In addition, other wireless devices operating within the area can cause interference with the wireless system of interest. In both of these cases, the wireless system can attempt to adjust for the interference. The wireless system may take the following actions to adjust the RF EMF signal and transmit the data:

    a. Increase the signal strength, which will increase the strength of the RF EMF being emitted from the device and may increase the field strength that the user is exposed to.

    b. Slow down the rate of transfer, which increases the time that the user is exposed to the RF EMF.

6. **Regulatory maximums.** The FCC has set forth maximum power strengths that a device may emit. While manufacturers may make devices with strengths lower than these maximums, devices that exceed these power requirements cannot be produced. The FCC guidelines equate to a power density of 1,000 $\mu W/cm^2$. All wireless devices sold in the US go through a formal FCC approval process to ensure that the maximum allowable level when operating at the device's highest possible power level is not exceeded (FCC 2012).

## 3.3 UNITS

Various units are used to express the strength of all EMFs (including RF EMF) and wireless devices. **Table 1** summarizes the units and their applicability.

**Table 1**
**Summary of Units Used**

| Name | Unit Abbreviation<br>Unit Name | Comment |
|---|---|---|
| Duty Factor | -unitless- | Measure of the time that a wireless device is actually |

| Table 1<br>Summary of Units Used | | |
|---|---|---|
| **Name** | **Unit Abbreviation**<br>**Unit Name** | **Comment** |
| | | transmitting. See **Section 4.4** below. |
| Electric Field Strength (E) | V/m<br>Volts per meter | |
| Frequency | Hz<br>Hertz | Cycles per second. How many times per second a wave goes through its maximum value. |
| Magnetic Field Strength (H) | A/m<br>Amperes per meter | |
| Magnetic Flux Density (B) | T (or G)<br>Tesla (or Gauss) | |
| Power Density | $W/m^2$<br>Watts per square meter | The rate of energy flow through a given surface area. Can also be expressed in milliwatts per square centimeter ($mW/cm^2$) or microwatts per square centimeter ($\mu W/cm^2$). |
| Specific Absorption Rate (SAR) | W/kg<br>Watts per kilogram | Measure of the rate that RF energy is absorbed by the body |

## 3.4 DUTY FACTOR

As stated above, wireless devices are not emitting RF EMFs all the time. Because regulations for all EMF exposure are based on exposure over time, the duty factor of the device is important. The duty factor quantifies the amount of time that the wireless device is actually transmitting and, therefore, emitting RF EMFs. The duty factor is the ratio of the amount of time that the device spends transmitting divided by the total amount of time monitored. The duty factor cannot exceed “1” (which would represent transmitting all of the time). Sometimes the duty factor is expressed as a percentage.

Logically, the duty factor for an AP is larger than for an end device, as the AP needs to service the needs of all end users (and their end devices) within a given time frame. Duty factors for some wireless devices have been reported, but reliable duty factor reporting for laptop or tablet-type devices is limited. The sections below summarize relevant wireless technology, including published information on power and duty factors as available.

## 3.5 WIRELESS DEVICES

As illustrated in **Table A1** in **Appendix A**, cell phones, smart meters, and WLANs emit EMFs in the RF area of the electromagnetic spectrum. While their frequencies are similar, each frequency is dedicated to a specific use, much like the radio spectrum contains different frequencies dedicated to different radio stations. However, because each wireless device emits in the RF band, some similarities exist between the wireless technologies. Because of these similarities, often these devices are lumped together as "RF-emitting devices." While it is important to note that each technology operates at a different frequency and power density within the RF spectrum, the basic concepts behind how the devices operate are similar. Thus, while copious amounts of research on any one technology are not available yet, comparisons of the research on all RF technologies can be made based on generalizations between the technologies.

Below is a discussion of the similarities and differences between the applications compared to WLAN. **Table 2** provides a comparison of the power density of these devices.

**Table 2**

**Comparison of Power Density for Wireless Devices**

| Source | Power Density (μW /cm$^2$) |
|---|---|
| Cell phone, held close to ear, during call | 1,000 - 5,000 |
| Cell phone base station, at typical distances of 10-1000 meters | 0.5 – 3 |
| Microwave oven, producing maximum permitted leakage radiation, 30 centimeters from door | 1,000 |
| WiFi computer, 1 meter away, when transmitting | 0.005 – 0.2 |
| radio and TV broadcast signals | 0.005 - 1 |
| Smart Meter, transmitting data in mesh mode to other local meters | 10 - 40 (1 meter away)<br>1 - 4 (3 meter away) |
| Smart Meter, transmitting data in mesh mode to other local meters, average over 1% duty cycle | .1 - .4 (1 meter away)<br>0.01 - 0.04 (3 meter away) |

Source: National Grid, http://www.emfs.info/Sources+of+EMFs/meters/smart/

Because Smart Meters, cell phones, and WLAN devices share many commonalities, a summary of each of these technologies and recent research on RF EMFs pertaining to these devices is summarized below.

### 3.5.1 Cell Phones

Cellular (cell or mobile) phones work on a similar principle to a WLAN network, only over a larger area. Thus, the EMF signal must be stronger in order to travel longer distances. Upon receiving a signal from a satellite or through terrestrial fiber connection, the cellular tower's antenna emits an RF EMF signal capable of contacting the cell phone. The cell phone contains an antenna within the body of the phone, which can receive the signal from the cellular tower and transmit an RF EMF signal to the cellular tower. The cellular tower will have a larger duty factor compared to the cell phone because the tower is serving many cell phones at one time. The cell phone is both receiving and sending during a typical telephone call. The cell phone must also periodically transmit signals to determine where the closest cell phone tower is located relative to the cell phone's location.

RF EMF exposure may be increased based on the type/model of cell phone and features of the cell phone. For example, sending and receiving emails, sending and receiving text messages, and downloading streaming video on a cell phone will increase the EMF exposure. However, based on the duty factor of a cell phone (usually less than 1%), the World Health Organization (WHO) states that the typical power density a human being would experience from a cell phone is 0.1 $W/m^2$ (10 $\mu W/cm^2$) averaged over a day (WHO, 2012).

Newer cell phone service is being offered as 3G or 4G, which refers to the frequency or frequencies that the cell phone operates at as well as the algorithm used to send and receive information. While the terms "3G" and "4G" are most often associated with cellular phones, the concept can be readily applied to other devices, such as tablets.

Below are example reports published related to EMFs and cell phones.

Sage *et al.* (2007) reported on EMF exposure from personal data assistant (PDA) cell phones. Based on a small study of seven PDAs, the authors concluded that elevated ELF EMFs were measured on some of the PDAs during email, downloading, and telephone transmissions. However, the report measured ELF EMF, when PDAs transmit and receive in the RF portion of the electromagnetic spectrum. Additionally, the measurement equipment used in the study was not capable of measuring RF EMF transmissions in the millisecond range, which may have skewed the duration times reported in the paper.

The US Government Accountability Office (GAO) recently sent a report to Congressional Requesters (2012) requesting that the exposure and testing requirements for mobile phones be reassessed. While the GAO was focusing on cell phone standards, they reviewed published research pertaining to all RF sources. As a result of the review, the GAO recommended the following:

- Formally reassess the current RF energy exposure limit, including its effects on human health, the costs and benefits associated with keeping the current limit, and the opinions of relevant health and safety agencies, and change the limit if determined appropriate.

- Reassess whether mobile phone testing requirements result in the identification of maximum RF energy exposure in likely usage configurations, particularly when mobile phones are held against the body, and update testing requirements as appropriate.

Dr. Herberman, previous Director of the University of Pittsburgh Cancer Institute and UPMC Cancer Centers, recently (2008) issued a statement to all employees recommending that employees take steps to protect themselves from RF EMFs from cell phones. Dr. Herberman also testified in front of the Domestic Policy Subcommittee (2008) regarding tumors and cell phone use.

Marino (2010) conducted a review of RF EMF published literature and concluded that RF EMF does not impact the nervous and neuroendocrine systems, auditory system, immune system, cardiovascular system, fertility, development, or behavior.

Cardis *et al.* (2008) measured the SAR for 110 different cell phones and calculated the percent of the SAR distributed in the brain as a result of cell phone use. The paper did not report actual SAR values, but did conclude the following:

- 97–99% of the SAR is absorbed in the brain hemisphere on the side where the phone is used.

- 50–60% of the total SAR absorbed is absorbed in the temporal lobe.

- The SAR distribution was similar across phone models, between older and newer phones and between phones with different antenna types and positions.

However, Wake *et al.* (2011) studied the SAR distribution in both adult and child heads and found a variation in SAR based on the model of phone used and based on adult or child use.

### 3.5.2 Smart Meters

Smart Meters are a means for utility companies to measure the amount of a utility, such as power, that a household uses. Instead of having a human being walking from house to house to read the value on traditional meters, the Smart Meter transmits the value over a wireless network automatically to the utility company. The signal may be sent directly from the meter to the utility company using a mobile phone type network, or indirectly via a mesh network. In a mesh network, information is sent either from one Smart Meter to another, or directly to a local data aggregation point, and then on to the utility company. The radio signal is usually around 900 MHz, close to the frequency of many mobile phones, with a maximum power of 1 W.

In addition, Smart Meters have the capability of communicating with other “smart” appliances within a household that have been equipped for this possibility. The “smart” appliances are equipped with an antenna that can transmit and receive signals from the Smart Meter, which will ultimately allow the Smart Meter to inform household users about their utility usage. Inside the home, Smart Meters usually use wireless signals at 2.4 GHz, with a maximum power of less than 1 W. This frequency is similar to several existing wireless technologies, including WiFi and Bluetooth.

Thus, the Smart Meter emits RF EMF during external communications with the utility company, as well as during internal communications with household appliances. The household appliances also emit RF EMFs when in communication with the Smart Meter. Therefore, Smart Meters behave similarly to both WLAN devices and cell phones, in that they are not operating 100% of the time, operate in the same frequency range, and send signals to antennae using RF EMFs.

Smart Meters send bursts of data lasting a fraction of a second at intervals of minutes or hours. Many different values have been quoted for the duty cycle, which is partly because meters are used in different ways by different utilities. Duty factors ranging from 1% to 0.01%, have been found in many situations. The UK-based National Grid (2012) claims that Smart Meters stay below 5%. As smart grids are developed, communication with individual meters may be more frequent and duty cycles may increase.

Some remote-reading meters do not send data to a central point: instead the meters send out information continuously every second or two, to enable the signal to be picked up by meter-reading equipment that is driving along the street. However, a typical data-transmitting pulse would be 6 ms long, still resulting in a duty cycle of less than 1%.

Smart Meters have come under scrutiny in California and other locations around the globe, including the UK and Canada. Most notably, the following people have raised concerns:

- Cindy Sage (2011) has released a report on the internet stating that measured and simulated RF levels from Smart Meters may exceed the FCC limits (see **Section 4** for a discussion of EMF limits) based on her survey of Smart Meters and collector meters. However, the report has come under sharp criticism (EPRI, 2011) for several flaws with the design and assumptions of the study. The EPRI concludes that the Sage study over-estimated exposures from Smart Meters using assumptions and calculations that are "…inconsistent with the FCC's rule and that do not recognize the basic physical characteristics of RF emissions." Most notably, the Sage study did not time average the data collected, used out-of-date FCC policy, claimed that a 1000%+ reflection was possible, assumed that incident power density is enhanced by reflections uniformly throughout the surrounding space, and did not frequency-weight the contributions from the endpoint meter, the home area network, and the cell relay, all of which operate at different frequencies.

- An article published in Quebec, Canada (LeDevoir ,2012) attempted to allay the public's concern regarding RF EMF exposure associated with the use of Smart Meters, cell phones, and WiFi. However, a rebuttal letter composed by David Carpenter (2012)[2]

[2] Dr. Carpenter serves as director of the Institute for Health and the Environment at the University at Albany's School of Public Health. He previously served as director of the Wadsworth Laboratory of the New York State Department of Health. Carpenter was recently named to New York's Renewable Energy Task Force, charged with implementing plans to reduce

published two weeks later summarized the position of the Bioinitiative Report, claiming potential adverse impacts to human health from all RF-emitting technology, including Smart Meters, cell phones and WLANs.

In response to public concern on RF EMFs, Dr. Kenneth R. Foster, a member of the Bioengineering Department at the University of Pennsylvania and member of the Electric Power Research Institute (EPRI) scientific advisory committee for EMF research, has stated, "…the RF exposure to a resident of a house from a Smart Meter is comparable to that produced by operation of a mobile phone at the same location as the Smart Meter for a few seconds a day." (2010)

### 3.5.3 WLAN

A discussion of how WLAN devices operate was included in **Section 3.1**. WLANs can service a number of end devices, including wireless-enabled laptops and tablets. Although laptops and tablets look different, the operation of the antennae within the devices is essentially the same. Therefore, published data on the duty factor and power density of laptops may be applied to tablet devices as well. While little research has been performed explicitly on tablets, a few studies have been performed on laptops, as discussed below.

Findlay and Dimbylow (2012) in the United Kingdom (UK) have reported calculating the SAR of a 10-year-old child in a school setting using a WLAN. They reported a SAR of 0.057 mW/kg, which is less than 0.01% of the SAR experienced in the head from cell phone usage. For this calculation, they used a duty factor of 0.01 (or 1%), based on the work of Khalid, *et al*. (2011).

The Khalid, *et al*. (2011) study investigated the duty factor of laptops in various school settings in the UK and reported a range of duty factors for both APs and end devices, as summarized in **Table 3**. The study is ground-breaking, as it is the only study to investigate the duty factor of wireless devices used by children in a school setting.

**Table 3**
**Summary Duty Factors from Khalid et al. (2011)**

| Device | Duty Factor | |
|---|---|---|
| | Minimum Observed | Maximum Observed |
| AP | 0.0006 (0.06%) | 0.1167 (11.67%) |
| Laptop | 0.0002 (0.02%) | 0.0096 (0.96%) |

In 2007, Foster measured the RF signal from wireless devices in multiple settings (academic, commercial, health care) and multiple countries (USA and Europe). Foster found a number of interesting results, including the following:

electricity use through new energy efficiency programs in industry and government. Carpenter received his medical doctorate from Harvard Medical School and a co-editor for the Bioinitiative Report (See Section 4 for a discussion).

- The RF signal from most of the networks surveyed was usable by the laptop, but the signal was too small to be measured by the highly-sensitive RF EMF meter employed in the study.

- "In nearly all cases, the field intensities within the band used by WLANs were exceeded by other RF sources."

- RF energy measured in this study (2007) was comparable to RF measurements made in 1980, when the primary RF source was UHF television broadcasting facilities. Note that UHF broadcasting facilities are still present. Thus, this study concluded that wireless technology is not significantly contributing to overall RF exposure given that UHF remains the major contributor.

- "…the peak power output of APs and client cards is comparable to or somewhat below those of mobile telephone handsets."

## 3.6 SUMMARY

Research on wireless devices, including cell phones, Smart Meters, and WLANs, has resulted in similar conclusions. Comparing the statements and conclusions of the various reports, the following points can be made:

- Duty factors for all wireless end devices are reported to be quite low, ranging from 0.01% to 5%, with a typical duty factor for all applications (except APs) around 1%.

- WLAN devices, including laptops and tablets, operate at lower power densities than cell phones because the functional distance that the wireless devices operate over is much lower. Thus, RF EMF exposure from WLAN devices is expected to be lower than for cell phone use.

- The many variations on the way Smart Meters are implemented makes generalizations difficult, but WLAN RF EMF exposure is expected to be lower than that of Smart Meters. This is because of the following reasons:

    - Smart Meters communicate on a frequent, fixed schedule with other devices, where WLAN devices communicate on a sporadic, on-demand schedule.

    - Smart Meters communicate not only with the data-collection end device, but also with multiple appliances within the living space. In contrast, WLAN end devices, which would be responsible for most of a user's RF EMF exposure, communicate primarily with the AP only, and only to a much lesser degree with surrounding end devices.

- Newer tablets and laptops can operate on either WLAN or 3G/4G technology. WLAN operates at lower power densities than 3G or 4G technology, which is essentially using a cell phone to connect to the Internet.

This section summarizes the various RF EMF limits that organizations around the world have proposed or have used. **Table 4** is a summary of these limits, which are discussed further in the following headings. For a thorough summary of power density limits by country, consult Stam (2011).

## 4.1 STATE AND NATIONAL

Several organizations have developed guidelines for all EMF exposure, including individual states, the FCC, the Occupational Safety and Health Administration (OSHA), the Institute of Electrical and Electronics Engineers (IEEE), and the American National Standards Institute (ANSI).

Neither the California government nor the United States government has regulations limiting any EMF exposure to residences.

At the national level, the IEEE standard C95.1, which has been formally adopted by ANSI, specifies Maximum Permissible Exposure (MPE) levels for the general public and for occupational exposure to RF EMFs. Note that the IEEE C95.1 (2005) levels are recommendations only, not regulations.

In 2006, ANSI adopted IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, as its C95.1 Standard for safe human exposure to non-ionizing electromagnetic radiation. The standards are frequency dependent. MPEs are strictest at 100 to 300 MHz because the human body absorbs the greatest percentage of incident energy at these frequencies. The MPE standards become progressively higher at frequencies above 400 MHz because the human body absorbs less energy at these higher frequencies. The C95.1 standards specify different safety levels for occupational and general-public exposure. The general-public exposure safety levels are stricter because workers are assumed to have knowledge of occupational risks and are better equipped to protect themselves (e.g., through use of personal safety equipment). The safety levels are intended to protect all members of the public, including pregnant women, infants, the unborn, and the infirm from short-term and long-term exposure to electromagnetic fields. The safety levels are also set at 10 to 50 times below the levels at which scientific research has shown harmful effects from thermal heating may occur, thereby incorporating a large safety factor (ANSI/IEEE, 2006). The C95.1 MPEs are based on RF EMF levels averaged over a 30 minute exposure time for the general public. For occupational exposure, the averaging time varies with frequency from 6 minutes at 450 MHz to 3.46 minutes at 5,000 MHz.

FCC Regulations at Title 47 CFR §1.1310 are based on the 1992 version of the ANSI/IEEE C95.1 safety standard. The FCC (1999) has developed a series of MPE limits based on the frequency of the EMF. The NCRP and ANSI/IEEE exposure criteria and most other standards specify "time-averaged" MPE limits. This means that exceeding the recommended limits is permissible for given periods of time if the average exposure (over the appropriate period specified) does not exceed the MPE limit. FCC MPEs are based on an averaging time of 30 minutes for exposure of the general public and are based on protection of the general public to adverse effects of thermal heating.

**Table 4**
**Summary of EMF Limits**

| Organization | Type | Power Density µW/cm$^2$ | Notes | Source |
|---|---|---|---|---|
| ANSI | Public | 1,000 | same as IEEE | |
| Bioinitiative Report 2007 | Cautionary level | 0.1 | | Carpenter, D.; Sage, S. (2007). Bioinitiative Report. Available at http://www.bioinitiative.org/. |
| Bioinitiative Report 2012 | Cautionary level | 0.0003 to 0.0006 | | BioInitiative Working Group, Cindy Sage and David O. Carpenter, Editors. BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Radiation at www.bioinitiative.org, December 31, 2012 |
| Salzburg Resolution | Public: cell phone tower | 0.1 | | Salzburg Resolution on Mobile Telecommunication Base Stations. International Conference on Cell Tower Siting, Linking Science & Public Health, Salzburg, June 7-8, 2000. |
| ICNIRP | Public | 1,000 | | International Commission on Non-Ionizing Radiation Protection (1998). Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (Up to 300 GHz). Health Physics, April, 74(4), p 494-522. |
| | Occupational | 5,000 | | |
| IEEE | Public: 2,000 MHz to 100 GHz | 1,000 | | http://www-group.slac.stanford.edu/esh/eshmanual/references/nirreqexplimits.pdf |
| OSHA | Occupational | 10,000 | 6 minute averaging time | 29 CFR §1910.97 |
| US FCC | Public: Frequency Range from 300 to 1,500 MHz | f/1.5 | 30 minute averaging time | http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf |

**Table 4**
**Summary of EMF Limits**

| Organization | Type | Power Density μW/cm² | Notes | Source |
|---|---|---|---|---|
| | Public: Frequency range from 1,500 to 100,000 MHz | 1,000 | | |
| China | Public | 10 | | Foster, K. R. Exposure Limits for Radiofrequency Energy: Three Models. World Health Organization, Conference on Criteria for EMF Standards Harmonization. Available at http://www.who.int/peh-emf/meetings/day2Varna_Foster.pdf. |
| Russia | Public | 10 | | |
| Switzerland | Public | 10 | | |

Abbreviations:
f=frequency in MHz
For a thorough summary of power density limits by country, consult Stam (2011).

The OSHA safety standards for occupational exposure to RF EMF emissions are found at 29 CFR §1910.97. Per OSHA: "For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 MHz to 100 GHz, the radiation protection guide is 10 mW/cm$^2$ (milliwatt per square centimeter) as averaged over any possible 0.1-hour period." This means that the power density cannot exceed 10,000 µW/cm$^2$ during any 6 minute period. In most cases, the OSHA levels do not vary with frequency and are less stringent than the equivalent ANSI/IEEE and FCC MPEs. However, for occupational exposure to fields with frequencies above 5,000 MHz, the OSHA MPE is equal to the C95.1 MPE and is, therefore, two times higher than the FCC MPE.

## 4.2 INDEPENDENT ORGANIZATIONS

In addition to the organizations described in **Section 4.1**, several other independent organizations have proposed EMF guidelines. Note that none of these guidelines are legally enforceable as regulations.

### 4.2.1 Bioinitiative Report

The Bioinitiative Report (2007) is a publication released on the internet by a group of 14 "…scientists, public health and public policy experts to document the scientific evidence on electromagnetic fields." The report claims to have evidence for the following effects of exposure to EMF:

- Modification of gene and protein expression
- Genotoxic effects
- Stress protein response
- Immune function modification
- Effects on neurology and behavior
- Brain tumors and acoustic neuromas
- Childhood cancers
- Melatonin production
- Alzheimer's disease
- Breast cancer

Similarly, the revised Bioinitiative Report, released in 2012, is a publication released on the internet by a group of 29 people. In addition to the effects noted above, the 2012 report adds the following effects:

- Effects on blood-brain barrier
- Fertility and reproductive effects
- Fetal and neonatal effects

- Autism

The group argues that current regulatory limits are set too high based on evidence presented in the report that adverse effects from EMF exposure can occur at lower levels of exposure than previously determined. The 2007 report advocates for an EMF cautionary exposure level of 0.1 $\mu W/cm^2$, which is 10,000 times lower than the FCC limit. The 2012 report advocates for an EMF cautionary exposure level of 0.0003 to 0.0006 $\mu W/cm^2$, which is approximately 1,000 times lower than the 2007 report.

The report claims that EMF limits should be lowered not only because of the effects of exposure stated above, but also based on the fact that EMFs have been successfully used in some medical applications (i.e., bone healing) at much lower levels than the FCC limits. Thus, they argue that health effects of EMF exposure, albeit positive, are observed below the ICNIRP limit for tissue heating.

The authors state that in light of the evidence indicating a possible link between adverse health effects and EMF exposure, the "precautionary principle" should be used to set conservative limits for EMF exposure.

#### *4.2.1.1 Criticism*

The two co-editors of the report, Sage and Carpenter, have attempted to publish the salient points of the Bioinitiative Report in various sources (2009), but the paper has been listed as "in press" since 2009.

The Bioinitiative Report (2007) has come under fierce scrutiny from scientists around the world. For a comprehensive summary of the criticism, see EMF-Link (2012). An outline of salient points is presented here:

- The work is a conglomeration of 29 scientists' reports, which is a relatively small group compared to the vast amount of research conducted by hundreds of researchers around the world.
- Statements made by authors of the report have been classified as misleading, such as the suggestion by Ollie Johansson that lung cancer is not caused only by smoking, but is exacerbated by RF exposure.
- Several of the papers cited by the Bioinitiative Report have been accused of scientific fraud and have been withdrawn from publication by the authors.
- Many countries and organizations have criticized the paper, including the following:
  - EMF-NET (part of the EU)
  - IEEE
  - The Health Council of the Netherlands
  - Australian Centre of Radiofrequency Bio-effects Research
  - EPRI
  - Mobile Manufacturers Forum

  - German Federal Office for Radiation Protection
  - French Agency for Environmental and Occupational Safety
- The report fails to mention the inverse square law applicable to EMFs, which is that the intensity of the EMF decreases as a function of $1/r^2$, where "r" represents the distance from the EMF source. Thus, for a given power density at 1 foot from an EMF source, the power density would be ¼ of this value at 2 feet from the source.

#### *4.2.1.2 Support*
Supporters of the Bioinitiative Report cite the following points:

- The Report was an international collaboration between scientists from countries in Europe, North America, and Asia.
- Countries around the globe have varying regulatory limits for EMF exposure, which vary from 1,000 $\mu W/cm^2$ to 10 $\mu W/cm^2$. Thus, no consensus has been reached regarding the issue.
- Insufficient research currently exists to draw definitive conclusions on whether there is a link between adverse health effects and RF EMFs.
- Current research has indicated a link between childhood leukemia and residential proximity to power lines. Thus, preliminary evidence indicates an adverse link between ELF EMF exposure and human health.
- EMFs have been used medically to heal bone fractures at levels lower than current regulatory limits. This would argue against detractors' claims that no evidence for health effects of EMFs has been observed below regulatory limits.
- The International Agency for Research on Cancer (IARC), which is a part of the World Health Organization (WHO), has classified EMF exposure as a "possible carcinogen," indicating that EMFs may have adverse health effects.
- In light of these points, supporters argue that adoption of the "Precautionary Principle" is justified. This principle states that, until more definitive research is conducted and a link between EMFs and human health is verified or denied, human beings should assume that a negative health impact may exist and take precautions for protection from EMFs.

#### *4.2.1.3 2007 Release*
Based on medical applications of EMF exposure in therapeutic settings as well as on research reports that claim an adverse EMF health effect at levels lower than regulatory limits, the 2007 Bioinitiative Report advocates a markedly-lower EMF exposure limit by way of a cautionary level of 0.1 $\mu W/cm^2$. Note that this recommendation is several orders of magnitude lower than regulatory limits, making the Bioinitiative Report the first entity to make such a recommendation.

#### 4.2.1.4 2012 Release

The 2012 report advocates an EMF exposure limit by way of a cautionary level of 0.0003 $\mu W/cm^2$, which is 1,000 times lower than the 2007 recommendation, and reserves the right to lower this level even farther.

However, the 2012 cautionary level is so extreme as to be unrealistic. The value of 0.0003 $\mu W/cm^2$ is below the ambient (background) power density regardless of location, as illustrated in **Table 5** below.

**Table 5**

**Summary of Ambient Power Densities**

| Type | Power Density ($\mu W/cm^2$) | Details | Source |
|---|---|---|---|
| Bioinitiative Report 2012 | 0.0003 | | |
| Ambient RF (1 GHz to 3.5 GHz) | 0.0063 | In an urban environment | Bouchouicha, *et al.* 2010 |
| Ambient Indoor light | 100 | | Vullers *et al.* 2009 |
| Ambient Outdoor light | 100,000 | | |
| Ambient RF | 0.01 | European residence | Bolte & Eikelboom, 2012 |
| Cell Phone | 300 | | Vullers *et al.* 2009 |
| Ambient laboratory | 0.001 | No high-powered equipment operating | Hagerty *et al.* 2004 |
| WLAN signal | 0.001 | 7 meters (21 feet) from source | Vullers *et al.* 2008 |
| | 0.00001 | 12 meters (36 feet) from source | |

In addition, the World Meteorological Organization (WMO) conducted ambient RF EMF measurements in a variety of settings across the United States, including urban, suburban, rural, and airport environments (Leck, 2006). The WMO found no difference between the magnitudes of the RF EMF power density regardless of location. This indicates that urban environments, where theoretically more RF EMF-generating equipment is in use compared to rural environments, did not have elevated RF EMF levels compared to rural environments.

Since background RF EMF levels are above the 2012 Bioinitiative Report precautionary level, this level is unrealistic and unattainable. Background sources include man-made sources, like television, cellular and radio signals, as well as natural sources, like cosmic radiation and the sun.

### 4.2.2 Salzburg Resolution

In 2000, a group of scientists at the International Conference on Cell Tower Siting proposed the following limits:

- For the total of all high frequency radiation, a limit of 100 mW/m² (10 µW/cm²).
- For preventive public health protection, a preliminary guideline level for the sum of exposures from all ELF pulse modulated high-frequency facilities such as GSM base stations of 1 mW/m² (0.1 µW/cm²).

Note that these guidelines are not legally enforceable as regulations.

## 4.3 INTERNATIONAL

Internationally, many countries have developed their own EMF guidelines. Most of these regulations are based on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommendations, including the European Union (EU).

The ICNIRP exposure guidelines are based on "basic restrictions," which define the highest level of electric and magnetic field that can occur within various parts of the body without adverse health effects. The basic restrictions include reduction factors to account for uncertainties, such as variations among individuals. Because measuring the level of electric and magnetic field within the human body is difficult, the ICNIRP used dosimetry calculations. These calculations quantify the reference levels of external electric and magnetic fields to which humans could be exposed. The ICNIRP developed separate reference levels for occupational exposure and exposure of the general public. ICNIRP published references levels covered the entire frequency range in 1998. In 2010, the ICNIRP updated the reference levels for the 1 Hz to 10 MHz portion of this range, and reaffirmed the 1998 reference levels for the remainder of the frequency ranges (ICNIRP, 2010).

The ICNIRP guidelines are not intended to protect against potential electromagnetic interference with implantable medical devices (ICNIRP, 1998; 2010). In 2004, the Electric Power Research Institute (EPRI) stated that magnetic fields of 1 to 12 G could cause electromagnetic interference (EMI) with implanted medical devices (EPRI, 2004). The ACGIH recommends a maximum exposure level of 5 G for persons wearing cardiac pacemakers (ACGIH, 2008). Researchers and manufactures have been continuously working to improve the immunity of these devices to external electromagnetic fields. In 2007, The Association for Advancement of Medical Instrumentation (AAMI) developed a standard for the level of magnetic field that an implantable medical device (e.g. cardiac pacemakers, implantable cardioverter defibrillators [ICDs]) can withstand without harm to the wearer. The AAMI standard was adopted by ANSI and specifies that cardiac pacemakers and ICDs must be tested by exposure to static magnetic fields with a flux density equal to 1 mT (10 G) without malfunction or harm to the device. As a result, magnetic fields equal to or less than that level will not interfere with operation of the newer models of these devices or harm the device (ANSI/AAMI, 2007).

The International Organization for Standardization (ISO) developed a Draft Standard 14117 for electromagnetic compatibility of active implantable medical devices. Like the AAMI PC69:2007 Standard, the ISO standard is applicable to cardiac pacemakers and ICDs. The ISO standard also applies to cardiac resynchronization devices. Draft Standard 14117 requires that these medical devices operate without malfunction or harm in the presence of specified EMF levels (ISO, 2008). The safety levels prescribed in the ISO 14117 standard are identical to the safety levels contained in the ANSI/AAMI PC69:2007 standard.

The International Agency for Research on Cancer (IARC), which is a section within the World Health Organization (WHO), issued a press release in May of 2011 stating that RF EMFs are possibly carcinogenic to humans. The IARC classified RF EMF radiation in Category 2B, which is "possibly carcinogenic to humans." The IARC maintains a list of 266 substances in this category, which includes coffee, coconut oil, pickled vegetables, gasoline exhaust, talcum powder, and nickel. The IARC definition of the 2B category (2006) states, "This category is used for agents for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals. It may also be used when there is inadequate evidence of carcinogenicity in humans but there is sufficient evidence of carcinogenicity in experimental animals."

## 5.1 EMFS AND THE HUMAN BODY

All EMFs have the potential to interact with the human body in three different ways, each of which will be discussed in further detail below:

- Electric field interactions
- Magnetic field interactions
- Magnetic field energy transfer

### 5.1.1 Electric Field Interactions

Time-varying electric fields may cause ions (either positively or negatively charged molecules or atoms within the human body) to flow, cause the reorientation of polar molecules within the body, and cause the formation of polar molecules that would otherwise be non-polar. The magnitude of the effects depends on the part of the body that is exposed (for example, the brain and blood contain a large number of ions), the frequency of the EMFs, and the magnitude of the electric field. (ICNIRP, 1997)

Certain chemical reactions within the body generate charged molecules, called free radicals, which are susceptible to electric fields. The electric fields may affect how many free radicals are generated, the orientation of the free radicals in space, or the orientation of the electrons within the free radical. These phenomena may, in turn, affect the amount or type of product that results from a chemical reaction within the body. (ICNIRP, 1993)

### 5.1.2 Magnetic Field Interactions

Time-varying magnetic fields couple with the human body and result in induced electric fields, which in turn result in electric currents within the body. The magnitude of the effect depends on the strength of the magnetic field, the size of the person, and the type of tissue exposed. (ICNIRP, 1997)

Certain portions of the body are more susceptible to magnetic fields. Blood, for example, is made up of many charged particles, called electrolytes, flowing through the body. These electrolytes can interact with a magnetic field, thereby causing an electric current within the body as the blood flows. The effect is compounded when human beings move within the magnetic fields, which causes more variation of the magnetic field strength, which in turn causes variations of the induced electric current. (ICNIRP, 1993)

### 5.1.3 Magnetic Field Energy Transfer

For stationary magnetic fields (magnetic fields that do not vary with time), the human body can absorb energy from the fields, causing an increase in body temperature. The energy is absorbed as the ions within the human body attempt to align themselves with the magnetic field, much as a compass needle attempts to orient itself with the Earth's magnetic field. (ICNIRP, 1993) This effect is only significant for EMFs with frequencies above 100 kHz. (ICNIRP, 1997)

## 5.2 HEALTH EFFECTS OF EMFS

Scholarly journals and the Internet are replete with studies reporting the health effects of EMFs. URS has attempted to supply a representative, although not exhaustive, list of articles illustrating the many research studies that have been published in the past 20 years. Because this research focused on the ramifications of using WLANs in public schools, the rest of the report will focus specifically on RF EMF.[3] More research has been performed in the ELF portion of the EM spectrum than the RF portion. For clarification, **Figure 3** illustrates the ICNIRP general public and occupational exposure limits and the frequency bands of interest. (The graph is presented based on the electric field, in volts per meter [V/m].)

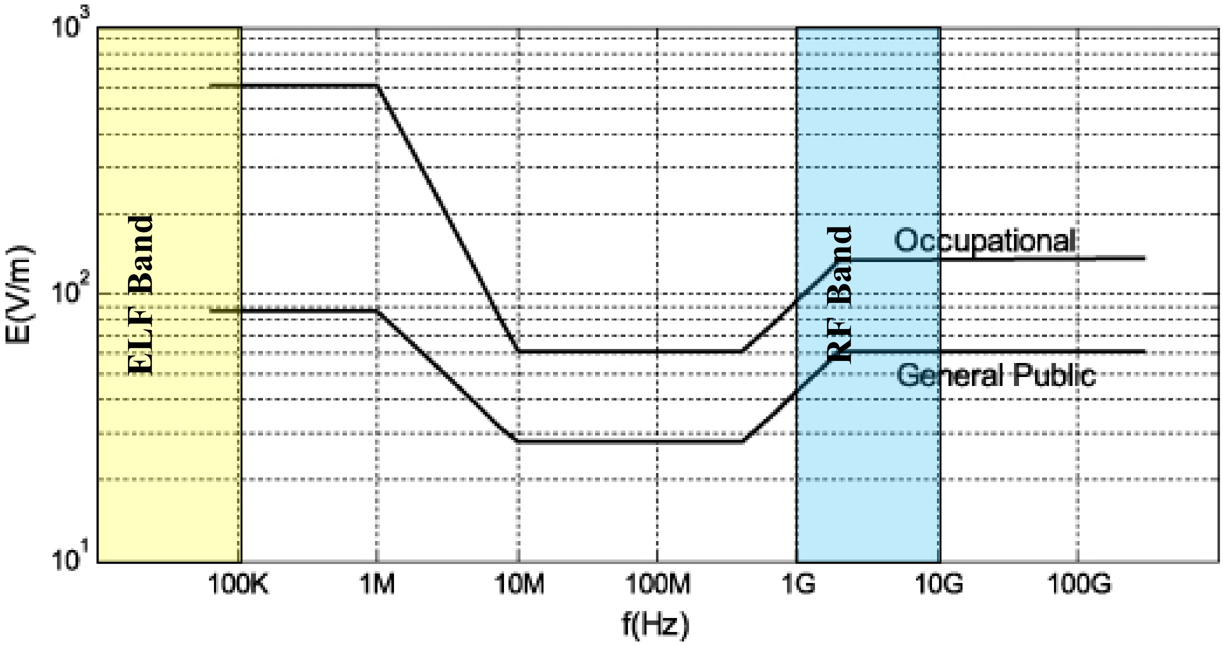


***Figure 3:*** *ICNIRP EMF limits as a function of frequency.*

The publications can be classified in several different ways:

### 5.2.1 Based on positive or negative impacts

The literature is full of papers claiming that RF EMFs can be dangerous, while others claim that they are not. This statement holds true for virtually all endpoints and scientific disciplines, including *in vitro* studies of cell proliferation, genetic and immunological studies, animal experimental data on cancer and non-cancer issues, and human epidemiological investigations (Verschaeve, 2012). Verschaeve (2012) concludes that, of 33 papers reviewed, the consensus was that no adverse health effects from RF EMF exposure were demonstrated. However,

[3] The Bioinitiative Report (2007, 2012) claims that divisions between different frequency regions are artificial, that exposure to multiple EMF frequencies may be additive, and that all EMFs have the potential to adversely affect the human body regardless of frequency. For this reason, notes in this section address other areas of the EMF spectrum.

Carpenter (2007, 2010, 2012) has been a strong advocate for adverse health effects from all EMF. In fact, Dr. Carpenter served as a witness supporting an injunction against the Portland Public School's use of WiFi (2011).[4]

Several recent studies have focused on the potential medical treatment benefits of using RF EMFs under controlled conditions. (Zorzi, *et al.,* 2007) This research claims that localized use of specific EMFs can result in beneficial anti-inflammatory results, especially post-surgery. The Bioinitiative Report (2007) also states that EMFs have been successfully used for positive medical healing of broken bones.

### 5.2.2 Based on location/country

Many studies have been conducted within the United States (US) and are summarized by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (2001). The ICNIRP was very discriminating in their selection of published articles considered for review. Namely, the ICNIRP accepted only those papers published in peer-reviewed, scholarly articles with large enough sample sizes to calculate an effect. The ICNIRP did not accept anecdotal evidence, case studies, or research which had questionable controls or scientific methods.

The European Council has acknowledged adverse health effects from EMF exposure (CSTEE, 2001; Council Recommendation, 1999). The basis for this decision was largely from research concluding that ELF EMF exposure to children caused an increased incidence of childhood leukemia. (CSTEE, 2001) The result has been a Council Recommendation (1999) that set EMF exposure limits for public exposure to all EMFs.

A large number of studies on RF EMF exposure have been conducted in Europe, generated from the Interphone study, a special research project of the IARC, a division of the WHO (IARC, 2010). The Interphone study's goal is to assess whether RF EMF may be carcinogenic. Thirteen countries in Europe participated in the research, which generally found no adverse effects of long-term cell phone use in adults. One paper within the research did indicate that cell phone users may have had larger brain tumors than non-cell phone users. Future research within the study plans to focus on RF exposure to children, as children may be a more sensitive population (IARC, 2010).[5]

---

[4]For ELF EMFs, when an effect was observed, the large majority of research has concluded that negative health effects are correlated with exposure to ELF EMFs. (Bortkiewicz, *et al*., 2006; Bracken, *et al*., 2001; Budi, *et al*., 2007; Cricenti, *et al*., 2008; Genuis, 2008; Hamza, *et al*., 2005; Ippolito & Siano, 2004; Johansen, *et al*., 2002; Kheifets, *et al*., 2006; Raz, 2006; Regel, *et al*., 2007)

[5]The ICNIRP concluded that a potential may exist for adverse health effects from both adult and childhood exposure to high level ELF EMFs, although they state that the link is weak. The ICNIRP focused on health effects that had a high correlation to incidence of disease, such as leukemia and cardiovascular disease. Adult cancer, however, is difficult to correlate to any one source, because cancer can manifest itself years after exposure, many other confounding

### 5.2.3 Based on exposure type

The largest part of the published work on RF EMFs and human health is from studies of the general public (as opposed to occupational exposure).[6] Because URS was specifically looking for studies dealing with the general public or children's exposure to RF EMF, URS gathered sufficient research on the general public to represent the findings of the scientific community without being exhaustive.

Frei (2010) conducted an extensive study of 166 students carrying personal RF EMF dosimeters for one week. Results included the following:

- Mobile phone base stations, mobile phones and cordless phones represented the main contributions to exposure.
- Radio and television broadcast transmitters, WLAN and Tetrapol were shown to be minor exposure sources.
- No impact of RF-EMF exposure in everyday life was observed for somatic complaints, headache, sleep impairment or tinnitus. Both environmental far-field sources and sources operating close to the body were included.
    - The study did observe that individuals reportedly suffered more frequently from non-specific symptoms if they believed that they were subject to higher EMF exposure as compared to the general population.

In a follow up study, Frei *et al.* (2012) sampled 1,375 participants and had similar conclusions to the 2010 study.

Breckenkamp *et al.* (2012) published a study of German subjects and their exposure to RF radiation within their bedroom environments. Results indicated the following:

- Total exposure varied, depending on location of residence (urban vs. rural; building floor).
- Major sources of exposure included cordless phones and wireless LAN/blue tooth, which contributed approximately 82% of total exposure.

---

variables within a person's lifetime may increase the likelihood for cancer, and there are many forms of cancer. Quite a number of ELF EMF health studies have been conducted within Europe (Bortkiewicz, *et al*., 2006; Regel, *et al*., 2007; Frija, *et al*., 2006; San Segundo & Roig, 2007; Hamza, *et al*., 2004;, Ippolito & Siano, 2003; Johansen, *et al*., 2002; Ahlbom, *et al*., 2008; Frei, 2011; Breckenkamp *et al.,* 2012).

[6] For ELF EMF exposure, see CSTEE, 2001; Genuis, 2008; Kheifets, *et al.,* 2006; Raz, 2006; Regel, *et al.,* 2007; and SCENIHR, 2008.

- Total calculated exposure was low: 20.5 μW/m$^2$ (0.002 μW/cm$^2$).

Baliatsas *et al.* (2011) surveyed over 3,000 subjects within the Netherlands for their symptoms and proximity to RF signals and power lines. The results of the survey found that participant's perceived proximity to a base station, psychological components and socio-demographic characteristics were associated with a report of sensitivity to EMF. However, the actual distance to the EMF source did not show up as determinant symptoms.

Yang *et al*. (2012) have developed a model to calculate EMF exposure in children. Based on 436 study participants, the model includes the age, gender, type of house, size of house, distance to a power line and voltage carried on the power line. Unfortunately, this study focused on power line EMF transmission, which is in the ELF portion of the EM spectrum, as opposed to RF transmission. Similarly, Hand (2008) has developed a model for calculating EMFs between 10 MHz and 10 GHz, which includes the frequencies of interest for RF emissions, in the human body. Although no studies have used the approach to calculate values within children, Hand (2008) claims that such calculations could be performed using the model developed. Additionally, Costa *et al.* (2012) have developed a model to calculate RF EMF exposure in outdoor spaces. The model predicts that outdoor exposures are below regulatory limits.

### 5.2.4 Based on type of health effects studied

The literature and Internet contain myriad reports of adverse health effects of RF EMF exposure. The casual reader can find reports claiming that RF EMF exposure can cause anything from rashes to cancer, and everything in between. In order to make an informed decision, readers must be aware of certain caveats when reading any literature relating to EMFs.

1. First, consider the source. Anyone can publish anything on the Internet. This makes Internet sources suspect, unless the source is a reputable authority on the subject, such as the World Health Organization (WHO) or the ICNIRP. Likewise, not all scientific journals are of the same caliber. Some journals, such as the *Journal of Physical Chemistry*, have stringent requirements for publication as well as a rigorous peer-review system to ensure the validity and quality of the articles published. Other journals do not have such high standards.

2. Any research should be based on sound scientific principles, control for all variables, and have an experimental design that includes a study and control group.

3. All reliable research is repeatable. If a study reports findings that cannot be verified by an independent group, the results and conclusions are suspect.

4. A large sample size helps to ensure the applicability of the results. In other words, a small sample size (20 people or less, for example) makes the results and conclusions of the study difficult to generalize to the entire human population. Similarly, anecdotal evidence from one person is relevant to that one person only, and not to the entire human population. On the other hand, the larger the sample size (300 or more people, for example), the more applicable the results are to the rest of the population.

Breast cancer, cardiovascular disease, and neurological disorders have been implicated with increased exposure to ELF EMFs. However, these are more recent findings that have not yet been reproduced or verified.

Note: while case studies are not generally applicable to the entire population, the European Union has acknowledged that a certain portion of the population may be susceptible to a disorder called "EMF hypersensitivity." Such individuals appear to suffer adverse health effects from exposure to much smaller EMF doses than the general population. However, this disorder has not been acknowledged within the US.

#### *5.2.4.1 ICNIRP*

The ICNIRP consulted only reliable research during their EMF research. Based on these criteria, the ICNIRP found no link between RF EMF exposure and adverse health effects. However, the childhood cancer may be suspected with ELF EMF exposure: (ICNIRP, 2001)

More recently, other studies have begun to link ELF EMF exposure to adult leukemia and brain tumors. However, a new report by the ICNIRP in 2010 determined that only childhood leukemia was linked to ELF EMF exposure, and only weakly. Other studies have suggested that RF EMF exposure can cause other types of adult cancer (Bioititiative Report, 2007), but currently there is insufficient evidence to verify or refute this claim. Future research will be necessary to determine whether RF EMF exposure is linked to other forms of cancer. The research that studied brain tumors focused primarily on RF EMF exposure from cellular phones.

#### *5.2.4.2 NIH*

The US National Institutes of Health (NIH) tasked the National Institute of Environmental Health Sciences (NIEHS) with studying and making recommendations on EMF and human health. NIEHS has put out a series of reports outlining their interpretations and recommendations (NIEHS 1998, 1999, 2002). The NIEHS concludes that for most health outcomes, there is no evidence that any EMF exposures have adverse health effects. The NIEHS calls for more studies and continued education on ways of reducing exposures.

#### *5.2.4.3 EU*

The European Health Risk Assessment Network on Electromagnetic Fields Exposure (EFHRAN) monitors and searches for evidence of the health risks associated with exposure to EMFs. Their latest report (2010) summarized the published literature to date and concluded that, for high frequency RF EMF exposure, there is insufficient evidence for a causal association between RF EMF exposure and risk of any disease. The study pointed out that results of the international analyses of glioma and meningioma risk in the Interphone study have been published, which indicated that while an association between mobile phone use and risk of these diseases has not been demonstrated, the study also does not demonstrate an absence of risk. Because most of the subjects in Interphone were light users compared to users today, especially young people, EFHRAN called for further research to evaluate the possible association between RF exposure and risk of tumors. EFHRAN concluded that the possibility remains that long-term mobile phone use may induce symptoms, such as migraine and vertigo, and further work is required to clarify this issue.

This section provides a summary of recent papers attempting to quantify the risk for the use of EMF-generating equipment, specifically RF exposure from wireless technology devices. Based on the reports, URS interpreted the results as they are applicable to LAUSD.

## 6.1 EMF AND RISK

A number of publications have attempted to summarize or quantify the risk associated with RF EMF exposure. The articles summarized below are representative samples of recent publications attempting to address the topic.

Kheifets *et al.* (2010) stated that while the data do not suggest a health risk so long as exposure is below regulatory limits, more research and exposure assessment need to be performed. Kheifets identified public mistrust of the technology and the need to set limits that will allay public concern while more research is performed. In terms of risk-governance, Kheifets identified deficits in problem framing, including both overstatement and understatement of the scientific evidence, consequences of taking protective measures, and limited ability to detect early warnings of risk. Other deficits included the limited public involvement mechanisms, and flaws in the identification and evaluation of tradeoffs in the selection of appropriate management strategies. They conclude that lessons from the power-frequency experience may benefit risk governance of the RF EMFs.

Grigoriev (2010) summarized the limit set forth in 2003 by the Russian National Committee on Non-Ionizing Radiation Protection and discussed the rationale for the limit. The limit of 10 $\mu W/cm^2$ was implemented on the basis that since elevated RF EMF levels can be harmful, then lower exposures of RF EMFs may have some detriment as well. Note that this view is not universal. Grigoriev argued for having a global EMF standard instead of varying standards for different countries.

One of the arguments in favor of a lower EMF limit is that the human race should learn from the experiences of asbestos and smoking, wherein the scientific community did not impose standards for limiting public exposure until significant adverse health effects had already occurred. Karipidis (2007) discussed whether the comparison between EMF exposure and either smoking or asbestos are valid. Karipidis used the Bradford-Hill model for establishing causality, which includes the following nine points in the evaluation:

1. Strength of Association
2. Consistency
3. Specificity
4. Temporality
5. Biological Gradient
6. Plausibility

7. Coherence
8. Experimental Evidence
9. Analogy

Based on these criteria, Karipidis concluded that EMF exposure is not convincingly linked with adverse health effects and that the analogy between EMF and smoking or asbestos exposure is not plausible.

O'Carroll and Henshaw (2008) discussed how two reviews of EMF literature (meta-analyses) could result in different conclusions regarding EMF exposure and human health from similar epidemiological studies. The authors concluded that discrepancies between methodologies led to the different conclusions, and that evidence does exist for a link between leukemia and EMF exposure. As a result of the analysis, O'Carroll and Henshaw made recommendations for unifying the methodology of meta-analyses in the future.

## 6.2 POTENTIAL EMF RISK

The LAUSD has drafted several motions/resolutions related to RF EMF exposure and cell phone towers (2000, 2009). These resolutions exemplify both their concern for exposure to RF EMF and their dedication to maintaining safe and healthful academic environments. In light of the literature review presented in this paper, several points related to RF EMF risk can be made, including the following:

1. The literature is conflicted as to health effects from exposure to RF EMF.
2. Countries have different public EMF exposure limits that vary from 10 $\mu W/cm^2$ to 1,000 $\mu W/cm^2$.
3. Examples of using RF EMF for positive health benefits have been reported in the literature at exposures much less than the current ICNIRP or FCC limits, which would indicate that RF EMFs are capable of interacting with the human body in ways other than thermal heating.
4. While no verifiable mechanism for EMF exposure and human health effects has been identified, scientists do recognize that molecules can absorb energy from RF radiation by increasing the frequency of vibration between two atoms within a covalent bond. Other scientists have postulated that RF EMF radiation may disrupt complex, three-dimensional molecular structures by interfering with intermolecular forces.
5. Everyone agrees that more research regarding the issue is needed.
6. Children are one of the most vulnerable segments of society because of their small size and rapidly dividing cells.

7. While a numerical value cannot be placed on the risk of RF EMF exposure, some scientists argue for a “cautionary” approach to RF EMFs and human health. The cautionary approach advocates using conservative RF EMF exposure limits until more research is performed to determine if a valid link exists between RF EMF exposure and human health.

## 7.1 LITERATURE SUMMARY

The technical literature is conflicted regarding RF EMF exposure and health effects. While many studies conclude that there are no adverse health effects from RF EMF exposure, others conclude that adverse health effects may result from long-term exposure to high level RF EMFs.[7] Fewer studies have been performed on the health effects of RF EMF exposure compared to ELF EMF exposure, but the literature is also conflicted. Some studies claim no adverse health effects were found, while others claim to have observed adverse health effects.

Based upon the technical research, several agencies have proposed voluntary standards for EMF exposure. Countries have adopted widely-varying standards, ranging from 10 to 1,000 $\mu W/cm^2$. Independent organizations, such as the Bioinitiative Report, have proposed cautionary levels as low as 0.1 $\mu W/cm^2$ (2007) and 0.0003 $\mu W/cm^2$ (2012), although these are recommendations only.

## 7.2 EVALUATION

Evaluation of any risk associated with RF EMF exposure is difficult, as reports of health effects and RF EMF are diverse and sometimes conflicting. Because of this, URS advocates adopting a conservative, cautionary approach to RF EMF exposure until more research is conducted.

A review of international EMF protection standards reveals that the lowest value is 10 $\mu W/cm^2$ (Russia, Switzerland) and the highest value is 1,000 $\mu W/cm^2$ (United States). While FCC limits are based on thermal effects, URS recommends a more conservative standard within the LAUSD public school system to attempt to address potential effects at the biological and cellular level. A more conservative level will potentially be more protective than thermal-based standards and will attempt to protect children, who represent a potentially vulnerable and sensitive population. Based on an evaluation of current international RF EMF regulations, a review of reports of potential adverse effects from excessive RF EMF exposure, and an assessment of background RF EMF levels, URS recommends a cautionary level of 0.1 $\mu W/cm^2$, taken as a whole-body, time-averaged value.

## 7.3 RECOMMENDATIONS

Based on the previous research and technical literature, URS has compiled a series of recommendations to assist the LAUSD in determining the ramifications of adopting WLAN technology within the school system:

1. Because children represent a particularly vulnerable population, as indicated by the technical literature, the LAUSD is appropriate in adopting a conservative standard.

---

[7] The literature acknowledges a link between high ELF EMF exposure and childhood leukemia. More recently, literature indicates that a link may exist between high ELF EMF exposure and adult leukemia and brain tumors. Other research has suggested a link between high ELF EMF exposure and breast cancer, cardiovascular disease, and neurological disorders, although more research is needed to fully characterize these findings.

2. URS recommends a cautionary level of 0.1 $\mu W/cm^2$, taken as a whole-body, time-averaged value, which is consistent with accepted practice (FCC, 1997). This cautionary level is 10,000 times lower than FCC regulations.

3. A recommended cautionary level of 0.1 $\mu W/cm^2$ is attainable within LAUSD classrooms, based on calculations that have been performed.

4. The 2012 Bioinitiative Report recommended cautionary level of 0.0003 $\mu W/cm^2$ is unrealistic and unattainable, as background RF levels are above this precautionary level.

5. Because the recommended cautionary level of 0.1 $\mu W/cm^2$ is conservative, 10,000 times lower than FCC regulations, and attainable, the value is appropriate for use in the LAUSD.

6. The recommendations contained in this paper apply to WLANs only. While other RF technologies that provide wireless broadband access are available for use, such as WiMAX, CDMA, or LTE, these technologies operate at higher power densities and would require further research and evaluation.

We appreciate the opportunity to provide our services. Please contact the undersigned if you have any questions regarding this report.

Sincerely,

**URS CORPORATION**

The opinions and judgments expressed in this EMF Technical Report are based on URS's research and interpretations as detailed in **Sections 3** through **6** of this report. The report is limited by the amount and type of information provided to URS by the LAUSD. These conclusions and recommendations may be subject to change if other factors impact the organization.

AAMI. Active Implantable Medical Devices – Electromagnetic Compatibility – EMC Test Protocols for Implantable Cardiac Pacemakers and Implantable Cardiac Defibrillators. ANSI/AAMI PC69:**2007**, July 25, 2008.

ACGIH. **2008** TLVs and BEIs. Publication #0108. Available at http://www.acgih.org/store/ProductDetail.cfm?id=1975.

Alaska court rules for telecom installer in radiation exposure case. *Safety & Health*, Oct, **2007**, 176(4), p29.

Baliatsas, C.; van Kamp, I.; Kelfkens, G.; Schipper, M.; Bolte, J.; Yzermans, J.; Lebret, E. Non-specific physical symptoms in relation to actual and perceived proximity to mobile phone base stations and powerlines. BMC Public Health, 11, **2011**, 421-432.

Beltran San Segundo, H.; Fuster Roig, V. Reduction of low voltage power cables electromagnetic field emission in MV/LV substations. *Electric Power Systems Research*, June, **2008**, 78(6), p1080 – 1088.

Bolte, J; Eikelboom, T. Personal radiofrequency electromagnetic field measurements in the Netherlands: Exposure level and variability for everyday activities, times of day and types of area. *Environ. Int*., 48, Nov 1, **2012**, p. 133-142.

Bortkiewicz, A.; Gadzicka, E.; ZmyŞlony, M.; Szymczak, W. Neurovegetative Disturbances in Workers Exposed to 50 Hz Electromagnetic Fields. *International Journal of Occupational Medicine & Environmental Health*, Jan, **2006**, 19(1), p53 – 60.

Bracken, T. D.; Rankin, R. F.; Senior, R. S.; Kavet, R.; Geissinger, L. G. Magnetic-Field Exposures of Cable Splicers in Electrical Network Distribution Vaults. *Applied Occupational and Environmental Hygiene*, **2001**, 16(3), p 369-379.

Breckenkamp, J.; Blettner, M.; Schüz, J.; Bornkessel, C.; Schmeidel, S.; Schlehofer, B.; Berg-Becckhoff, G. Residential Characteristics and Radiofrequency Electromagnetic Field Exposures from Bedroom Measurements in Germany. *Radiat Environ Biophys,* 51, **2012**, p. 85–92.

Bouchouicha, D.; Dupont, F.; Latrach, M.; Ventura, L. Ambient RF Energy Harvesting. International Conference on Renewable Energies and Power Quality, European Association for the Development of Renewable Energies, Environment and Power Quality, Granada, Spain, March 23 to 25, **2010**.

Budi, A.; Legge, F. S.; Treutlein, H.; Yarovsky, I. Effect of Frequency on Insulin Response to Electric Field Stress. *Journal of Physical Chemistry B*, May, **2007**, 111(20), p5748 – 5756.

Cardis, E.; Deltour, I.; Mann, S.; Moissinnier, M.; Taki, M.; Varsier, N.; Wake, K.; Wiart, J. Distribution of RF Energy Emitted by Mobile Phones in Anatomical Structures of the Brain. *Physics in Medicine and Biology*, 53, **2008**, p. 2771-2783.

Carpenter, D.O. Human Health Effects of EMFs: The Cost of Doing Nothing. Electromagnetic Phenomena and Health-a Continuing Controversy? IOP Conference Series: Earth and Environmental Science, 10, **2010**, available at http://iopscience.iop.org/1755-1315/10/1/012004/pdf/EES10_10_012004.pdf.

Carpenter, D.O. Amended Declaration of Dr. David O. Carpenter, M.D. US Distric Court, District of Oregon, Civil Action # 3:11-cv-00739-MO. December 20, **2011**. Available at http://www.wirelesswatchblog.org/wp-content/uploads/2001/11/Amended-Declaration-of-Dr-David-Carpenter.pdf.

Carpenter, D. O. Smart Meters: Correcting the Gross Misinformation. Maison, June 11**, 2012**. Available at http://maisonsaine.ca/smart-meters-correcting-the-gross-misinformation/www.maisonsaine.ca.

Carpenter, D.; Sage, S. Bioinitiative Report: A Rational for Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF). August 31, **2007**. Available at http://www.bioinitiative.org/.

Carpenter, D.; Sage, S. BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Radiation. December 31, **2012**. Available at http://www.bioinitiative.org.

Costa, C. P.; Fontgelland, G.; Barbin, S. E. Analysis of Passive Electromagnetic Exposure to Multisource Distributed in Outdoor Places. 2012 IEEE Topical Conference on Biomedical Wireless Technolgies, Networks, and Sensing Systems (BiowireleSS), **2012**, p. 81-84.

Council Recommendation (1999/519/EC). On the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). *Official Journal of the European Communities*, July 12, **1999**.

Cricenti, A.; Generosi, R.; Luce, M.; Perfetti, P.; Sanghera, J. S.; Aggarwal, I. D.; Tolk, N. H.; Vobornik, D.; Margaritondo, G.; Piston, D. W.; Manni, V.; Grimaldi, S.; Lisi, A.; Rieti, S. Low-frequency electromagnetic field effects on functional groups in human skin keratinocytes cells revealed by IR-SNOM. *Journal of Microscopy*, Mar, **2008** Supplement, 229(3), p551-554.

Electric Power Research Institute (EIRP). EPRI Comment: Sage Report on Radio-Frequency (RF) Exposures from Smart Meters. February, **2011**. Available at http://www.marbleheadelectric.com/EPRI_SageReport.pdf.

European Health Risk Assessment Network on Electromagnetic Fields Exposure (EFHRAN). Risk Analysis of Human Exposure to Electromagnetic Fields. July **2010**. Available at http://efhran.polimi.it/docs/EFHRAN_D2_final.pdf.

EMF-Link. Information Ventures, Inc. http://infoventures.com/private/federal/q&a/qa-envn2.html. January 12, **2000**.

European directive on electromagnetic fields. *European Radiology*. Dec., **2006**, 16(12), p2886 – 2889.

FCC. Wireless Devices and Health Concerns. Available at http://www.fcc.gov/guides/wireless-devices-and-health-concerns, accessed 11/14/**2012**.

FCC. Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields. Office of Engineering & Technology, OET Bulletin 56, 4th Edition, August, **1999**.

FCC. Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields. Office of Engineering & Technology, OET Bulletin 65, Edition 97-01, August, **1997**.

Findlay, R.P.; Dimbylow, P.J. SAR in children from exposure to wireless local area networks (WLAN). 2012 Asia-Pacific Symposium on Electromagnetic Compatibility (APEMC), May 21-24, **2012**, p. 733 – 736.

Foster, K. R. Radiofrequency Exposure From Wireless LANS Utilizing Wi-Fi Technology. *Health Physics*, March **2007**, 92(3), p. 280-289.

Foster, K. R. Response to Lora Lee Martin Regarding Smart Meters and EMFs, September 23, **2010**, available at http://www.ccst.us/projects/smart/documents/foster_response.pdf.

Foster, K. R. Exposure Limits for Radiofrequency Energy: Three Models. World Health Organization, Conference on Criteria for EMF Standards Harmonization. Available at http://www.who.int/peh-emf/meetings/day2Varna_Foster.pdf.

Frei, P. Personal Exposure to Radiofrequency Electromagnetic Fields and Implications for Health. PhD Thesis, University of Basel, Germany, **2010**. Available at http://edoc.unibas.ch/1255/.

Frei, P.; Mohler, E.; Braun-Fahrländer, C.; Fröhlich, J.; Neubauer, G.; Röösli, M. Cohort study on the effects of everyday life radio frequency electromagnetic field exposure on non-specific symptoms and tinnitus, *Environment International*, 38, **2012**, p. 29–36.

Genuis, Stephen J. Fielding a current idea: exploring the public health impact of electromagnetic radiation. *Public Health*, Feb, **2008**, 122(2), p113 – 124.

Grigoriev, Y. Electromagnetic Fields and the Public: EMF Standards and Estimation of Risk. IOP Conference Series: Earth and Environmental Sciences, 10(1), **2010**. Available at http://iopscience.iop.org/1755-1315/10/1/012003.

Hagerty, J.; Helmbrecht, F.; McCalpin, W.; Zane, R.; Popovic, Z. Recycling Ambient Microwave Energy With Broad-Band Rectenna Arrays. IEEE Transactions on Microwave Theory and Techniques, 52(3), March **2004**, p 1014-1024.

Hamza, A.H.; Mahmoud, Shaher A.; Abdel-Gawad, N.M.; Ghania, Samy M. Evaluation of magnetic induction inside humans at high voltage substations. *Electric Power Systems Research*, May, **2005**, 74(2), p231 – 237.

Hand, J.W. Modeling the Interaction of Electromagnetic Fields (10 MHz-10 GHz) with in the Human Body: Methods and Applications. *Physics in Medicine and Biology*, 53, **2008**, R243–R286.

Herberman, R. B. Tumors and Cell Phone Use: What the Science Says. Domestic Policy Subcommittee, Oversight and Government Reform Committee, Thursday, September 25, **2008**. Available at http://cellphones.procon.org/sourcefiles/Herberman_Testimony.pdf.

Institute of Electrical and Electronics Engineers (IEEE) Standard C95.1-2005, "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz" (IEEE Std C95.1-**2005**).

International Agency for Research on Cancer (IARC). IARC Classifies Radiofrequency Electromagnetic Fields as Possibly Carcinogenic to Humans. World Health Organization, Lyon, France, May 31, **2011**. Available at http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf.

IARC. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. World Health Organization, Lyon, France, **2006**. Available at http://monographs.iarc.fr/ENG/Preamble/CurrentPreamble.pdf.

IARC. Interphone Study Reports on Mobile Phone Use and Brain Cancer Risk, May 17, **2010**. Available at http://www.iarc.fr/en/media-centre/pr/2010/pdfs/pr200_E.pdf.

International Commission on Non-Ionizing Radiation Protection (ICNIRP), Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields, ICNIRP Guidelines, Health Physics Society, April, **1998**, 74(4), p494-522.

ICNIRP. Guidelines on Limits of Exposure to Static Magnetic Fields, *Health Physics*, **2009**, 96(4), p 504-514.

ICNIRP, Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz), *Health Physics*, **2010**. 99(6), p. 818-836.

ICNIRP. Fact Sheet on Guidelines for Limiting Exposure to Time-Varying Electric & Magnetic Fields (1 Hz to 100 kHz), *Health Physics Society*, **2010**, 99(6), p 818-836.

Ippolito, L.; Siano, P. Using multi-objective optimal power flow for reducing magnetic fields from power lines. *Electric Power Systems Research*, Feb, **2004**, 68(2), p93.

IEEE. IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz. IEEE Std C95.1-2005, April 19, **2006**.

ISO. Active Implantable Medical Devices – Electromagnetic Compatibility – EMC Test Protocols for Implantable Cardiac Pacemakers, Implantable Cardiac Defibrillators, and Cardiac Resynchronization Devices. ISO/Draft International Standard 14117, **2010**.

Johansen, C.; Raaschou-Nielsen, O.; Skotte, J.; Thomsen, B. L.; Olsen, J. H. Validation of a Job-Exposure Matrix for Assessment of Utility Worker Exposure to Magnetic Fields. *Applied Occupational & Environmental Hygiene*, Apr, **2002**, 17(4), p304 – 310.

Karipidis, K. K. Is the Risk Comparison Made by the Public Between EMF and Smoking or Asbestos a Valid One? *Journal of Risk Research*, 10(3), April **2007**, p. 307–322.

Khalid, M.; Mee, T.; Peyman, A.; Addison, D.; Calderon, C.; Maslanyj, M.; Mann, S. Exposure to radio frequency electromagnetic fields from wireless computer networks: Duty factors of Wi-Fi devices operating in schools. *Prog. Biophys. Mol. Biol.* 107 (3), **2011**, p. 412-20.

Kheifets, L.; Afifi, A. A.; Shimkhada, R. Public Health Impact of Extremely Low-Frequency Electromagnetic Fields. *Environmental Health Perspectives*, Oct, **2006**, 114(10), p1532 – 1537.

Kheifets, L.; Swanson, J.; Kandel, S.; Malloy, T. Risk Governance for Mobile Phones, Power Lines, and Other EMF Technologies. *Risk Analysis*, 30(10), **2010**, p. 1481-1494.

LAUSD. T-Mobile Cell Tower Notification and Condemnation (Waiver of Board Rule 72), Motions/Resolutions Presented to The Los Angeles City Board of Education for Consideration, December 8, **2009**.

LAUSD. Effects of Non-Ionizing Radiation (Waiver of Board Rule 72), Motions/Resolutions Presented to The Los Angeles City Board of Education for Consideration, June 13, **2000**.

Leck, R. World Meteorological Organization, Results of Ambient RF Environment and Noise Floor Measurements Taken in the U.S. in 2004 and 2005, Commission for Basic Ssytems Steering Group on Radiofrequency Coordination, Geneva, March 16-18, **2006**.

LeDevoir, Smart Meters, Cell Phones, and WiFi. May 24, **2012**: Available at http://www.ledevoir.com/environnement/actualites-sur-l-environnement/350726/pour-un-debat-guidepar-la-science.

Marino, C. Radiofrequency Exposure: a Review of NonCancer Related In Vivo and In Vitro Studies. 2010 Asia-Pacific International Symposium on Electromagnetic Compatibility, April 12 -16, **2010**, Beijing, China.

National Geophysical Data Center (NGDC). Estimated Values of Magnetic Field Properties. http://www.ngdc.noaa.gov/geomagmodels/struts/igrfGridZipE;jsessionid=B9E4D51449B1CD03F9A43E56EEE2E807 **2012**.

National Grid, EMFs.info, Electric and Magnetic Fields, Available at http://www.emfs.info/Sources+of+EMFs/meters/smart/, accessed November 15, **2012**.

O'Carroll, M. J.; Henshaw, D. L. Aggregating Disparate Epidemiological Evidence: Comparing Two Seminal EMF Reviews, *Risk Analysis*, 28(1), **2008**, p. 225-234.

PG&E. RadioFrequency FAQ. Available at http://www.pge.com/mybusiness/edusafety/systemworks/rf/faq/, accessed November 30, **2012**.

Possible effects of Electromagnetic Fields (EMF) on Human Health - Opinion of the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). *Toxicology*, Apr, **2008**, 246(2/3), p248-250.

Purcell, E. M. Electricity and Magnetism. Berkeley Physics Course Volume 2. 2$^{nd}$ Edition. McGraw-Hill, Inc., New York, **1985**.

Raz, Amir. ask the Brains. *Scientific American Mind*, **2006**, 17(4), p82.

Regel, S. J.; Tinguely, G.; Schuderer, J.; Adam, M.; Kuster, N.; Landolt, H.; Achermann, P. Pulsed radio-frequency electromagnetic fields: dose-dependent effects on sleep, the sleep EEG and cognitive performance. *Journal of Sleep Research*, Sept, **2007**, 16(3), p253 – 258.

Sage, C.; Carpenter, D.O. (in press) Public health implications of wireless technologies, *Pathophysiology* **2009**, available at http://www.ntia.doc.gov/legacy/broadbandgrants/comments/6E05.pdf.

Sage, C.; Johansson, O.; Sage, S. Personal Digital Assistant (PDA) Cell Phone Units Produce Elevated Extremely-Low Frequency Electromagnetic field Emissions. Bioelectromagnetics, **2007**. Available at http://www.buergerwelle.de/assets/files/sage_pda_bems_on_line.pdf.

Sage, C. Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters. Sage Associate, Santa Barbara, CA, January 1, **2011**, available at http://sagereports.com/smart-meter-rf/.

Salzburg Resolution on Mobile Telecommunication Base Stations. International Conference on Cell Tower Siting, Linking Science & Public Health, Salzburg, June 7-8, **2000**. Available at http://www.salzburg.gv.at/themen/gs/gesundheit/landessanitaetsdirektion-2/gesundheitsschwerpunkte/umweltmedizin/elektrosmog/celltower_e.htm#ank-salzburg.

Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE). Opinion on Possible effects of Electromagnetic Fields (EMF), Radio Frequency Fields (RF) and Microwave Radiation on human health, Expressed at the 27th CSTEE plenary meeting, Brussels, October 30, **2001**.

Selvam, R.; Ganesan, K.; Narayana R.; Gangadharan, A. C.; Manohar, B. M.; Puvanakrishnan, R. Low frequency and low intensity pulsed electromagnetic field exerts its antiinflammatory effect through restoration of plasma membrane calcium ATPase activity. *Life Sciences*, Jun, **2007**, 80(26), p2403 – 2410.

Stam. R. Comparison of International Policies on Electromagnetic Fields (Power Frequency and Radiofrequency Fields). National Institute for Public Health, the Netherlands, May, **2011**. Available at http://ec.europa.eu/health/electromagnetic_fields/docs/emf_comparision_policies_en.pdf.

US Government Accountability Office, Telecommunications: Exposure and Testing Requirements for Mobile Phones Should be Reassessed, Report to Congressional Requesters, July, **2012,** GAO-12-771.

Verschaeve, L. Evaluations of International Expert Group Reports on the Biological Effects of Radiofrequency Fields. Chapter 20, INTECH 978-953-51-0189-5, March 14, 2012, available at http://www.intechopen.com/books/wireless-communications-and-networks-recent-advances/evaluations-of-international-expert-group-reports-on-the-biological-effects-of-radiofrequency-fields.

Vullers, R.; van Schaijk, R.; Doms, I.; Van Hoof, C.; Mertens, R. Micropower Energy Harvesting. *Solid-State Electronics,* 53, **2009**, p. 684–693.

Wake, K.; Arima, T.; Watanabe, S.; Taki, M. SAR distributions in a child head phantom in the vicinity of recent mobile phones. General Assembly and Scientific Symposium, August 13-20, **2011**.

WHO. What are Electromagnetic Fields? Accessed November 15, **2012**. Available at http://www.who.int/peh-emf/about/WhatisEMF/en/index4.html.

Yang, K.; Ju, M.; Myung, S.; Shin, K.; Hwang, G.; Park, J. Development of a New Personal Magnetic Field Exposure Estimateion Method for Une in epidemiological EMF Surveys Among Children Uner 17 Years of Age. *Journal of Electrical Engineering & Technology*, 7(3), **2012**, p. 376-383.

Zorzi, C.; Dall'Oca, C.; Cadossi, R.; Setti, S. Effects of pulsed electromagnetic fields on patients' recovery after arthroscopic surgery: prospective, randomized and double-blind study. *Knee Surgery, Sports Traumatology, Arthroscopy*, Jul, **2007**, 15(7), p830 – 834.

**Appendix A:**

**EMF Background**

## 10.1 ELECTRIC AND MAGNETIC FIELDS

### 10.1.1 EMF Concepts

Electromagnetic (EM) radiation is a term given to a wide range of energy waves, including X-rays, ultraviolet light, visible light, radio waves, and microwaves. The distinguishing characteristic of EM radiation is that all EM radiation has two components: an electric field and a magnetic field. These components can be thought of as two separate but related waves, which propagate at 90° to each other. All EM radiation moves at the speed of light, 2.99 x $10^8$ meters per second. EM radiation is classified based on either the wavelength, measured in meters, or the frequency (i.e., the number of cycles per second.), measured in Hertz (also known as cycles per second). Wavelength and frequency are inversely related. That is, higher frequencies are associated with shorter wavelengths, and vice versa.

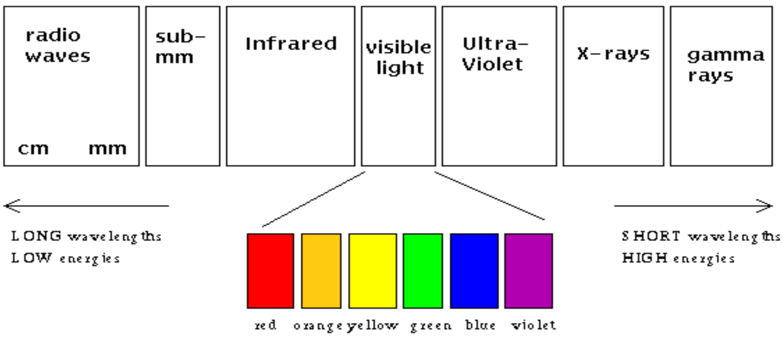


*Figure A1: An overview of the EM spectrum.* Source: http://loke.as.arizona.edu/~ckulesa/camp/spectroscopy_intro.html

**Figure A1** illustrates the wide range of EM radiation. Note that energy increases from left to right in the figure. As energy increases, EM radiation has an increased potential to harm human beings within a given time period. For example, extended exposure to UV light is known to cause skin cancer, while short term exposure to gamma rays can cause immediate damage to human tissue. EM radiation can be divided into ionizing radiation, which occurs at frequencies above $10^{15}$ (i.e., wavelengths less than 300 nanometers) and contains enough energy to remove electrons from biological tissue, and non-ionizing radiation, which does not contain enough energy to remove electrons. Far ultraviolet light and x-rays are two forms of ionizing radiation. Extremely low frequency (i.e., powerline) fields, infrared and microwaves, and radio signals are types of non-ionizing radiation. In recognition of this fundamental property, standards and guidelines for human exposure are correlated with the frequency of the EM radiation.

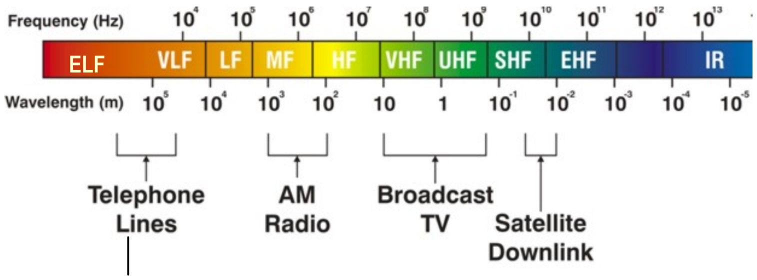


*Figure A2: Detailed view of the left (low energy) side of the EM spectrum. VLF = very low frequency, LF = low frequency, MF = medium frequency, HF = high frequency.* Source: http://www.infocellar.com/networks/fiber-optics/glossaries/e.htm

While a familiar form of EM radiation is visible light, visible light is only one part of the entire EM spectrum. Humans also use other forms within the spectrum (e.g., radio waves for communication, infrared [IR] waves for night-vision goggles, and microwaves for cooking food). EM radiation with energy higher than visible light can be harmful because the rays can deposit enough energy into cells to break the chemical bonds between atoms in DNA, thus altering the DNA which may lead to cancer.

**Figure A2** is a detailed look at the left side of the EM spectrum—from radio waves to visible light. The left side of Figure 4 begins at zero Hertz (Hz). As frequency increases, the energy of the EM radiation also increases. The "radio waves" section of the EM spectrum from Figure 3 is expanded in Figure 4. The "radio waves" section is further broken down into sub-groups, based on frequency. Cell phones, wireless local area networks (WLANs), and Smart Meters are examples of frequencies used within the Ultra-High Frequency (UHF) section of the radiofrequency (RF) section. **Table A-1** contains examples of frequencies used for these devices.

**Table A-1**
**Example Frequencies Used for Wireless Devices**

| Application | Frequency Band(s) (Hz) |
|---|---|
| WLAN | $2.4 \times 10^9$, $3.6 \times 10^9$, $4.9 \times 10^9$, $5.0 \times 10^9$ |
| Cell Phone | $7.0 \times 10^8$, $8.0 \times 10^8$, $8.5 \times 10^8$, $14 \times 10^9$, $1.7 \times 10^9$, $1.8 \times 10^9$, $2.1 \times 10^9$, $2.5 \times 10^9$ |
| Smart Meter | $9.0 \times 10^8$, $2.4 \times 10^9$ |

While a complete discussion of the frequencies and what they are used for is outside of the scope of this document, several good resources exist on the internet, such as Wickipedia and John Neuhaus's summary of frequency allocations (http://www.jneuhaus.com/fccindex/spectrum.html#table_of_contents).

### 10.1.2 Electricity and Magnetism

Electricity and magnetism are inherently linked through EM radiation. Electricity is the motion of electrons. Whenever an electron moves, a magnetic field will also be produced. When electrons move through a wire, the electrons generate both electric and magnetic waves. The opposite is also true: electric fields can be generated by magnets. The electromagnet—making a magnet out of a battery, a nail, and some wire—is an example of this principle.

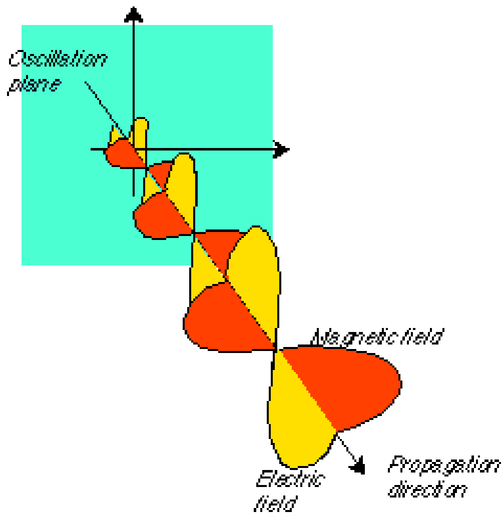


***Figure A3:*** *Detailed representation of an EM wave, illustrating both the electric and magnetic fields.* Source: *http://www.mc2.chalmers.se/pl/lc/engelska/tutorial/light.html*

As shown in **Figure A3**, the electric and magnetic fields are generated at right angles to one another. The electric field and magnetic field generated are inclusively classified as electromagnetic fields (EMFs). Extrapolating this concept out to the flow of electrons through a wire, as the electrons flow, carrying the electricity through the wire, a wave of EMFs are generated in all directions that are perpendicular to the flow of electrons. This results in EMFs arranged concentrically around the wire and emanating outward, as shown in **Figure A4**. Note that the density of the circles illustrates the strength of the field. The EMF waves emanate out in all directions from the wire, dissipating as the EMF waves move farther away from the wire. Note that the wire itself does not move, although the electrons within the wire do move. As a result, the EMFs associated with the electric current extend the entire length of the wire. The EMF field strength is highest closest to the wire and drops off as a function of the inverse of the square of the distance. Thus, the EMF field strength at two feet away from the wire is ¼ of the strength at 1 foot away from the wire.

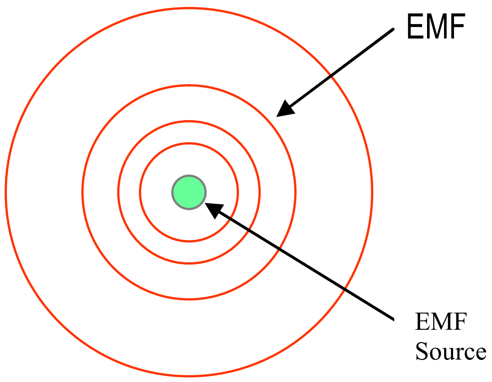


***Figure A4:*** *A source of EMFs (either a wire or a WiFi agent, for example) generates EMFs perpendicular to the source. The strength of the field decreases with distance.*

**Figure A4** can just as easily apply to a wireless EMF source, like WLAN. In a wireless situation, an antenna within the access point radiates a signal, comprised of EMFs, outwards in all directions. Similar to the discussion above, the EMF strength is highest closest to the antenna, and decreases strength as the EMF radiates outward. For an in-depth discussion of wireless devices, see **Section 4**.

Note that the above examples are simplified cases for one EMF source in space. When multiple wires, or other EMF generating sources, are involved, the EMFs generated from each source can interact with each other. The interactions can be either additive, creating larger EMFs, or subtractive, cancelling each other out all or part of the way. **Figure A5** illustrates this principle with a simple example of two sinusoidal waves. When the two waves are "in phase," which means that their peaks and troughs line up, the waves add together, and the result is a larger wave. Conversely, when the waves are "out of phase," which means the peaks and troughs are out of alignment, the waves cancel each other out. In most cases, the waves do not exactly overlap as in **Figure A5**, and the result is an EMF with a complex wave function.

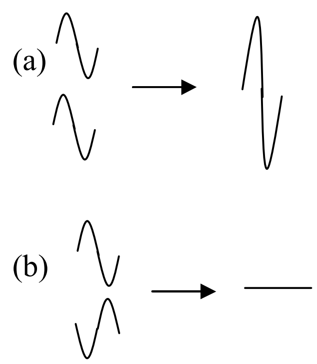


***Figure A5:*** *Simplified representation of EMF interactions. (a) Two sinusoidal waves adding together. (b) Two sinusoidal waves cancelling each other out.*

Since electricity and magnetism are inherently related, the stronger the electrical current, the stronger the magnetic field. The larger the amount of current, the larger the magnitude of EMFs generated. EMF strength is also proportional to proximity: the closer to the source of the EMFs, the stronger the EMF field. The relationship between the strength of the EMF and the distance from the source follows the "inverse square law," which states that exposure is related to one over the square of the distance. Thus, doubling the distance decreases the exposure by a factor of 4. As a result, the closer a human being is to the EMF source, the stronger the EMF that can act upon the human body. Therefore, simply moving farther away from the EMF source will reduce EMF exposure.

## 10.2 EMFS IN CONTEXT

Not all EMFs, or even all RF EMF, cause problems. For example, microwave ovens can have a power density up to 1 $mW/cm^2$ at 5 centimeters from the oven, as regulated by the US Food and Drug Administration (FDA), Title 21. While this is much larger than the some regulatory values, the microwave oven operates for a small fraction of the day. Thus, even if a person stood in front of the oven during a five-minute operation, the total exposure for the day would be a combination of the entire day, or five minutes out of 24 hours.

The combination of EMF strength, the duration of exposure, and distance from the source are what may cause health problems. Many everyday electrical objects emit relatively high RF EMFs when turned on, but are not responsible for causing health problems. **Table A2** illustrates the magnitude some common electrical devices are capable of outputting. (PG&E, 2012)

Some of these values exceed the ICNIRP standard, but the devices are considered safe because people do not use them for extended periods of time. Combine high EMFs with long duration times, and the EMFs may be cause for alarm.

**Table A2**
**Power Density Comparisons**

| Description | Power Density ($\mu W/cm^2$) |
|---|---|
| Adjacent to a gas SmartMeter™ (1 foot) | 0.00166 |
| Adjacent to an electric SmartMeter™ (1 foot) | 8.8 |
| Microwave oven nearby (1 meter) | 10 |
| Wi-Fi wireless routers, laptop computers, cyber cafes, etc., maximum (~1 meter for laptops, 2 - 5 meters for access points) | 10 - 20 |
| Cell phones (at head) | 30 - 10,000 |
| Walkie-Talkies (at head) | 500 - 42,000 |

Source: PG&E, 2012.