RADIO FREQUENCY RADIATION

(International Practice and Common Public Concerns)

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INTRODUCTION

The Government of Pakistan has raised an issue of proliferation of towers and the resultant hazards affecting human health. The towers using antennas are one of the main sources of producing Electromagnetic Energy or Radio Frequency “RF” Energy, including radio waves and microwaves, which is used for providing telecommunications, broadcast and other services. In Pakistan, Frequency Allocation Board (FAB) and PTA authorize or licenses most RF telecommunications services facilities. Because of its regulatory responsibilities in this area, PTA often receives inquiries concerning whether there are potential safety hazards due to human exposure to RF energy emitted by transmitters. Heightened awareness of the expanding use of RF technology has led some people to speculate that "electromagnetic pollution" is causing significant risks to human health from environmental RF electromagnetic fields. This document will analyze the subject in detail and help develop a strategy addressing this issue. It is very unfortunate that no such research has ever been initiated in Pakistan before; therefore, there are no standards or relevant documents available on the topic under discussion. This document is extracted from various internet resources and modified in a manner that meets the requirement of general public or public carrying some knowledge on the topic of RF electromagnetic field. This document is designed to provide factual information and to answer some of the most commonly asked questions related to this topic.

RADIOFREQUENCY ENERGY:

Radio waves and microwaves are forms of electromagnetic energy that are collectively described by the term "radiofrequency" or "RF." RF emissions and associated phenomena can be discussed in terms of "energy," "radiation" or "fields." Radiation is defined as the propagation of energy through space in the form of waves or particles. Electromagnetic "radiation" can best be described as waves of electric and magnetic energy moving together (i.e., radiating) through space as illustrated in Figure **1.** These waves are generated by the movement of electrical charges such as in a conductive metal object or antenna. For example, the alternating movement of charge (i.e., the "current") in an antenna used by a radio or television broadcast station or in a cellular base station antenna generates electromagnetic waves that radiate away from the "transmit" antenna and are then intercepted by a "receive" antenna such as a rooftop TV antenna, car radio antenna or an antenna integrated into a hand-held device such as a cellular telephone. The term "electromagnetic field" is used to indicate the presence of electromagnetic energy at a given location. The RF field can be described in terms of the electric and/or magnetic field strength at that location.

Like any wave-related phenomenon, electromagnetic energy can be characterized by a wavelength and a frequency. The wavelength (λ) is the distance covered by one complete electromagnetic wave cycle, as shown in Figure **1**. The frequency is the number of electromagnetic waves passing a given point in one second. For example, a typical radio wave transmitted by an FM radio station has a wavelength of about three (3) meters and a frequency of about 100 million cycles (waves) per second or "100 MHz." One "hertz" (abbreviated "Hz") equals one cycle per second. Therefore, in this

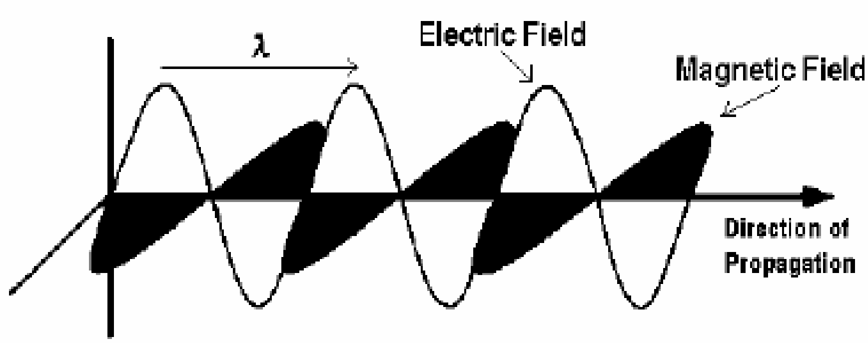


Figure-1 **Electromagnetic Wave**

case, about 100 million RF electromagnetic waves would be transmitted to a given point every second.

Electromagnetic waves travel through space at the speed of light, and the wavelength and frequency of an electromagnetic wave are inversely related by a simple mathematical formula:

Frequency (**f**) times wavelength (**λ**) = the speed of light (**c**), or $f \times \lambda = c$. This simple equation can also be expressed as follows in terms of either frequency or wavelength:

$$f = c/\lambda \text{ or } \lambda = c/f \qquad (1)$$

Since the speed of light in a given medium or vacuum does not change, high-frequency electromagnetic waves have short wavelengths and low-frequency waves have long wavelengths. The electromagnetic "spectrum" (Figure **2**) includes all the various forms of electromagnetic energy from extremely low frequency (ELF) energy, with very long wavelengths, to X-rays and gamma rays, which have very high frequencies and correspondingly short wavelengths. In between these extremes are radio waves, microwaves, infrared radiation, visible light, and ultraviolet radiation, in that order. The RF part of the electromagnetic spectrum is generally defined as that part of the spectrum where electromagnetic waves have frequencies in the range of about 3 kilohertz to 300 gigahertz. One kilohertz (kHz) equals one thousand hertz, one megahertz (MHz) equals one million hertz, and one gigahertz (GHz) equals one billion hertz. Thus, when you tune your FM radio to 100MHz, it means that your radio is receiving signals from a radio station emitting radio waves at a frequency of 100 million cycles (waves) per second.

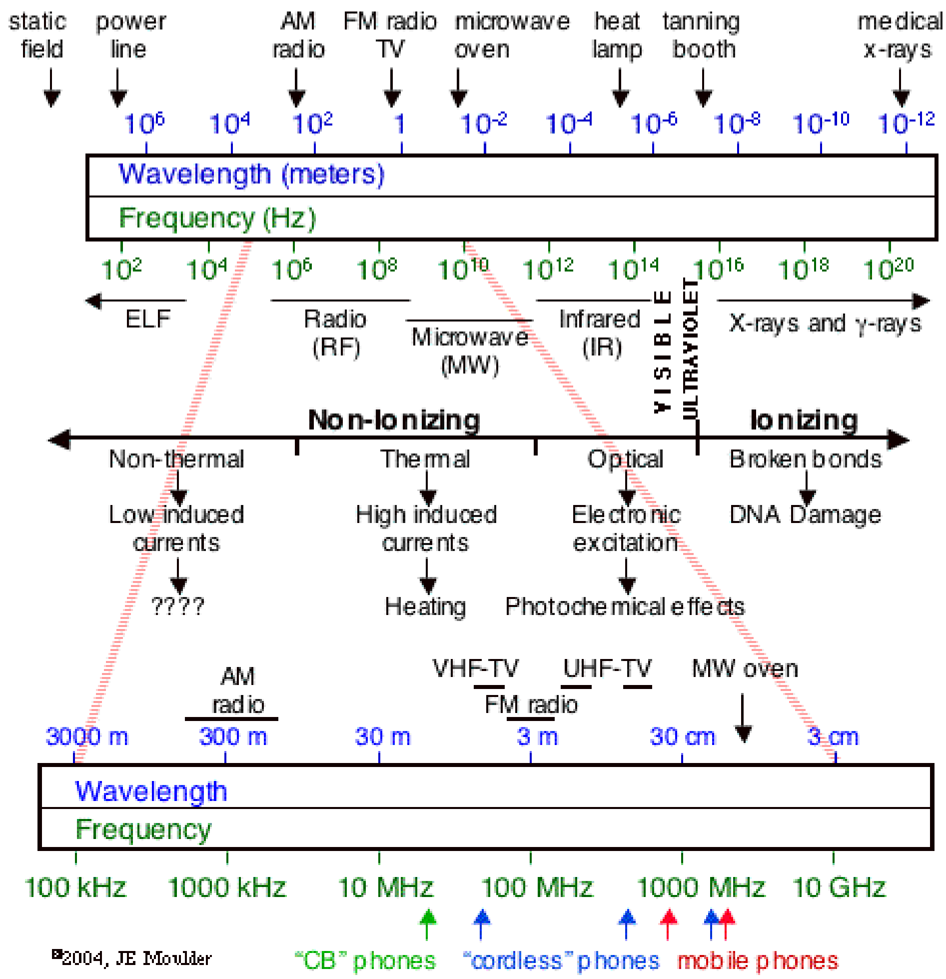


Figure-2 **The Electromagnetic Spectrum**

USE OF RADIOFREQUENCY ENERGY:

Probably the most important use for RF energy is in providing telecommunications services to the public, industry and government. Radio and television broadcasting, cellular telephones, personal communications services (PCS), pagers, cordless telephones, radio services, microwave point-to-point radio links and satellite communications are just a few of the many applications of RF energy for telecommunications.

Microwave ovens and radar are examples of non-communications uses of RF energy. Also important are uses of RF energy in industrial heating and sealing where electronic devices generate RF radiation that rapidly heats the material being processed in the same way that a microwave oven cooks food. RF heaters and sealers have many uses in industry, including molding plastic materials, gluing wood products, sealing items such as shoes and pocketbooks, and processing food products.

There are a number of medical applications of RF energy, including a technique called diathermy, that take advantage of the ability of RF energy to rapidly heat tissue below the body's surface. Tissue heating ("hyperthermia") can be beneficial in the therapeutic treatment of injured tissue and cancerous tumors.

MICROWAVES:

Microwaves are a specific category of radio waves that can be defined as radiofrequency radiation where frequencies range upward from several hundred megahertz (MHz) to several gigahertz (GHz). One of the most familiar and widespread uses of microwave energy is found in household microwave ovens, which operate at a frequency of 2450 MHz (2.45 GHz).

Microwaves are also widely used for telecommunications purposes such as for cellular radio, personal communications services (PCS), microwave point-to-point communication, transmission links between ground stations and orbiting satellites. Microwave radar systems provide information on air traffic and weather and are extensively used in military and police applications. In the medical field microwave devices are used for a variety of therapeutic purposes including the selective heating of tumors as an adjunct to chemotherapy treatment (microwave hyperthermia).

WHAT IS NON-IONIZING RADIATION?

As explained earlier, electromagnetic radiation is defined as the propagation of energy through space in the form of waves or particles. Some electromagnetic phenomena can be most easily described if the energy is considered as waves, while other phenomena are more readily explained by considering the energy as a flow of particles or "photons." This is known as the "wave-particle" duality of electromagnetic energy. The energy associated with a photon depends on its frequency (or wavelength). The higher the frequency of an electromagnetic wave (and the shorter its corresponding wavelength), the greater will be the energy of a photon associated with it. The energy content of a photon is often expressed in terms of the unit "electron-volt" or "eV".

Photons associated with X-rays and gamma rays (which have very high electromagnetic frequencies) have relatively large energy content. At the other end of the electromagnetic spectrum, photons associated with low-frequency waves have many times less energy. In between these extremes ultraviolet radiation, visible light, infrared radiation, and RF energy (including microwaves) exhibit intermediate photon energy content. For comparison, the photon energies associated with high-energy X-rays are billions of times more energetic than the energy of a 1-GHz microwave photon. The photon energies associated with the various frequencies of the electromagnetic spectrum are shown in the lower scale of Figure 2.

Ionization is a process by which electrons are stripped from atoms and molecules. This process can produce molecular changes that can lead to damage in biological tissue, including effects on DNA, the genetic material. This process requires interaction with photons containing high energy levels, such as those of X-rays and gamma rays. A single quantum event (absorption of an X-ray or gamma-ray photon) can cause ionization and subsequent biological damage due to the high energy content of the photon, which would be in excess of 10 eV (considered to be the minimum photon energy capable of causing ionization). Therefore, X-rays and gamma rays are examples of ionizing radiation. Ionizing radiation is also associated with the generation of nuclear energy, where it is often simply referred to as "radiation."

The photon energies of RF electromagnetic waves are not great enough to cause the ionization of atoms and molecules and RF energy is, therefore, characterized as non-ionizing radiation, along with visible light, infrared radiation and other forms of electromagnetic radiation with relatively low frequencies. It is important that the terms "ionizing" and "non-ionizing" not be confused when discussing biological effects of electromagnetic radiation or energy, since the mechanisms of interaction with the human body are quite different.

HOW RADIOFREQUENCY FIELDS ARE MEASURED?

RF electromagnetic field has both an electric and a magnetic component (electric field and magnetic field). It is often convenient to express the intensity of the RF field in terms of units specific for each component. The unit "volts per meter" (V/m) is often used to measure the strength ("field strength") of the electric field, and the unit "amperes per meter" (A/m) is often used to express the strength of the magnetic field.

Another commonly used unit for characterizing an RF electromagnetic field is "power density." Power density is most accurately used when the point of measurement is far enough away from the RF emitter to be located in what is commonly referred to as the "far-field" zone of the radiation source, e.g., more than several wavelengths distance from a typical RF source. In the far field, the electric and magnetic fields are related to each other in a known way, and it is only necessary to measure one of these quantities in order to determine the other quantity or the power density. In closer proximity to an antenna, i.e., in the "near-field" zone, the physical relationships between the electric and magnetic components of the field are usually complex. In this case, it is necessary to determine both the electric and magnetic field strengths to fully characterize the RF environment. At frequencies above about 300 MHz it is usually sufficient to measure only the electric field to characterize the RF environment if the measurement is not made too close to the RF emitter.

Power density is defined as power per unit area. For example, power density can be expressed in terms of mill watts per square centimeter (mW/cm^2) or microwatts per square centimeter ($\mu W/cm^2$). One mW equals 0.001 watt of power, and one μW equals 0.000001 watt. With respect to frequencies in the microwave range and higher, power density is usually used to express intensity since exposures that might occur would likely be in the far-field.

In the far-field of a transmitting antenna, where the electric field vector (E), the magnetic field vector (H), and the direction of propagation can be considered to be all mutually orthogonal ("plane-wave" conditions), these quantities are related by the following equation

$$S = \frac{E^2}{3770} = 37.7\, H^2 \qquad (2)$$

where: S = power density (mW/cm^2)
E = electric field strength (V/m)
H = magnetic field strength (A/m)

(Note: The impedance of free space, 377 ohms, is used in deriving this equation)

WHAT DO THE PHRASES "ANTENNA GAIN", "TRANSMITTER POWER" AND "EFFECTIVE RADIATED POWER (ERP)" MEAN?

The power of a mobile phone base station is usually described by its effective radiated power (ERP) which is given in watts (W). Alternatively, the power can be given as transmitter power (in watts) and the antenna gain.

Transmitter power is a measure of total power, while ERP is a measure of the power in the main beam. If an antenna were omni-directional and 100% efficient, then transmitter power and ERP would be the same. But mobile phone base station antennas (like all antennas) are not omni-directional; they are moderately (low-gain antennas) to highly (high-gain antennas) directional. The fact that they are directional means that they concentrate their power in some directions, and give out much less power in other directions. Antenna gain is a measure of how directional an antenna is, and it is measured in decibels. Depending on the antenna gain, a 20-50 W base station transmitter could produce an ERP of anywhere from about 50 watts to over 1000 watts.

The concept of "gain" and "ERP" are best explained by analogy to light bulbs. Compare a regular 100 W light bulb to a 25 W spot light. The spot light has less total power than the regular light, but is much brighter when you are in its beam and much weaker when you are outside its beam. A mobile phone base antenna (particularly a high-gain sector antenna) is like the spot light, and ERP is equivalent to the effective power in the spot light's main beam.

It is sometimes convenient to use units of microwatts per centimeter squared ($\mu W/cm^2$) instead of mW/cm^2 in describing power density. The following simpler form of Equation can be derived if power density, **S**, is to be expressed in units of $\mu W/cm^2$:

$$S = \frac{33.4\ ERP}{R^2} \qquad (3)$$

where: S = power density in ìW/cm^2

ERP = power in watts

R = distance in meters

An example of the use of the above equations follows:

A station is transmitting at a frequency of 100 MHz with a total nominal ERP (including all polarizations) of 10 kilowatts (10,000 watts) from a tower-mounted antenna. The height to the center of radiation is 50 meters above ground-level. Using the formulas above, what would be the calculated "worst-case" power density that could be expected at a point 2 meters above ground (approximate head level) and at a distance of 20 meters from the base of the tower?

From simple trigonometry the distance **R** can be calculated to be 52 meters [square root of: $(48)^2 + (20)^2$], assuming essentially flat terrain. Therefore, using Equation (3), the calculated conservative "worst case" power density is:

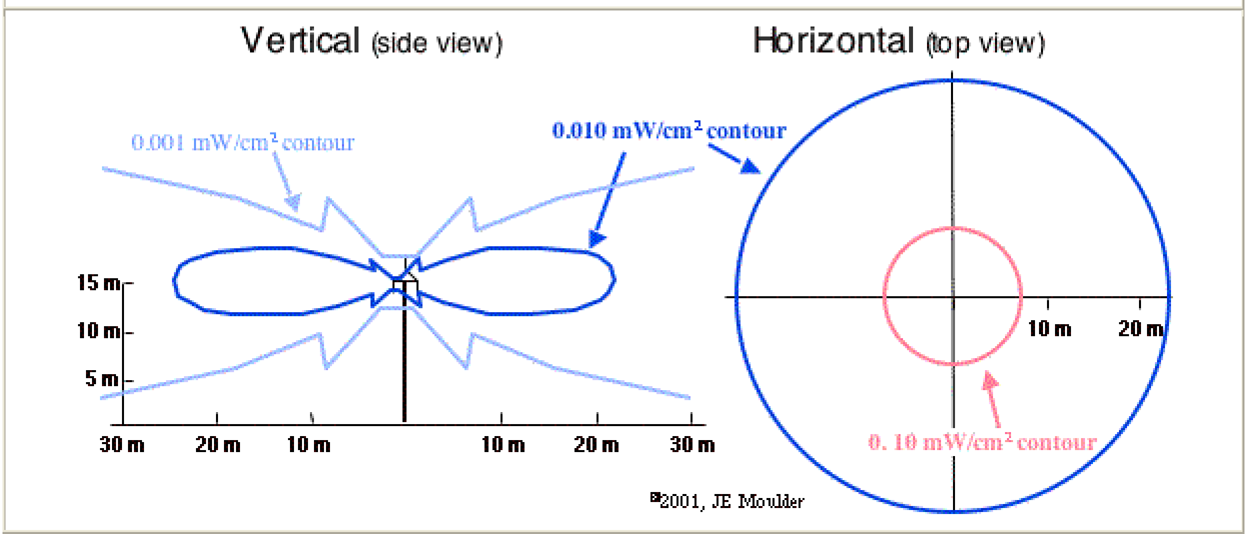
$$S = \frac{33.4\ (10{,}000\ \ watts)}{(52\ m\ )^2} = about\ \ 124\ \ \mu W/\ cm^2 \qquad (4)$$

By consulting Table 1 it can be determined that the limit for general population/uncontrolled exposure at 100 MHz is 0.2mW/cm^2 or 200μW/cm^2. Therefore, this calculation shows that even under worst-case conditions this station would comply with the general population/uncontrolled limits, at least at a distance of 20 meters from the tower. Similar calculations could be made to ensure compliance at other locations, such as at the base of the tower where the shortest direct line distance, R, to the ground would occur.

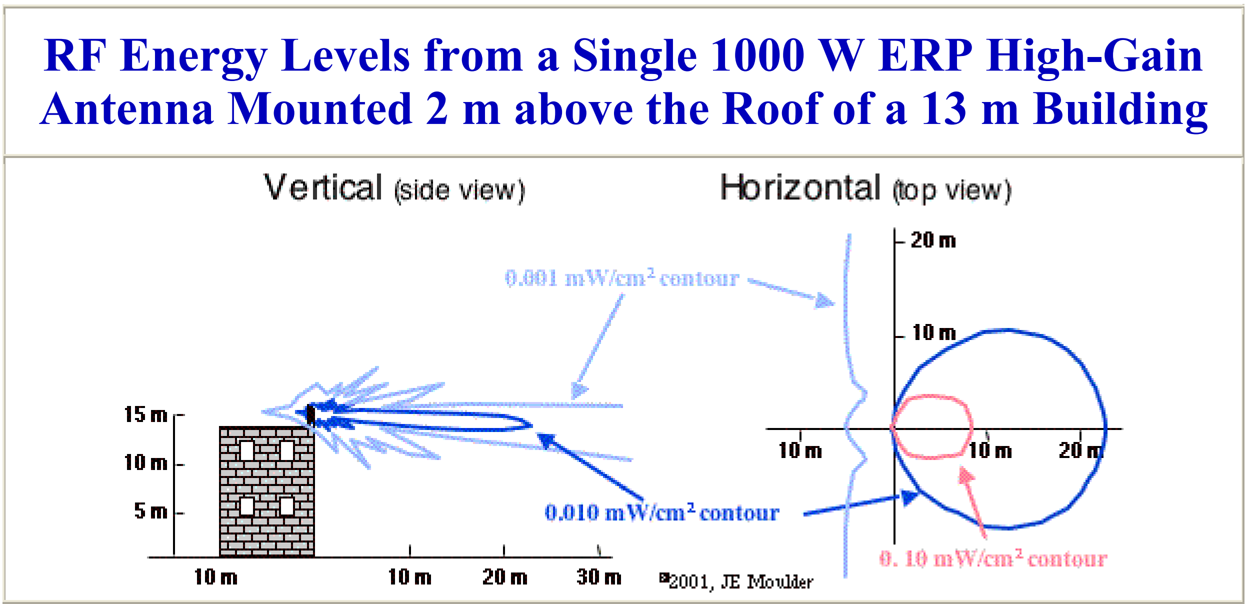
WHAT IS THE DIFFERENCE BETWEEN THE RF PATTERNS FOR HIGH-GAIN AND LOW-GAIN ANTENNAS?

The RF patterns for different types of antennas are very different. For a low-gain antenna with a 1000 W ERP of the type formerly used by many mobile phone base stations, the pattern can look like this:

RF Energy Levels from a 1000 W ERP Low-Gain Antenna on a 15 m Tower



For a high-gain (sector) antenna of the type used in many of the newer base stations, the pattern can look like this:



Keep in mind that mobile phone base station that use high-high-gain sectored antennas will usually use 3 (or occasionally 4) of these transmission antennas, all pointing in different directions.

WHAT BIOLOGICAL EFFECTS CAN BE CAUSED BY RF ENERGY?

A biological effect occurs when a change can be measured in a biological system after the introduction of some type of stimuli. However, the observation of a biological effect, in and of itself, does not necessarily suggest the existence of a biological hazard. A biological effect only becomes a safety hazard when it "causes detectable impairment of the health of the individual or of his or her offspring".

There are many published reports in the scientific literature concerning possible biological effects resulting from animal or human exposure to RF energy. The following discussion only provides highlights of current knowledge, and it is not meant to be a complete review of the scientific literature in this complex field.

Biological effects that result from heating of tissue by RF energy are often referred to as "thermal" effects. It has been known for many years that exposure to high levels of RF radiation can be harmful due to the ability of RF energy to heat biological tissue rapidly. This is the principle by which microwave ovens cook food, and exposure to very high RF power densities, i.e., on the order of 100mW/cm^2 or more, can clearly result in heating of biological tissue and an increase in body temperature. Tissue damage in humans could occur during exposure to high RF levels because of the body's inability to cope with or dissipate the excessive heat that could be generated. Under certain conditions, exposure to RF energy at power density levels of 1-10 mW/cm^2 and above can result in measurable heating of biological tissue (but not necessarily tissue damage). The extent of this heating would depend on several factors including radiation frequency; size, shape, and orientation of the exposed object; duration of exposure; environmental conditions; and efficiency of heat dissipation.

Two areas of the body, the eyes and the testes, are known to be particularly vulnerable to heating by RF energy because of the relative lack of available blood flow to dissipate the excessive heat load (blood circulation is one of the body's major mechanisms for coping with excessive heat). Laboratory experiments have shown that short-term exposure (e.g., 30 minutes to one hour) to very high levels of RF radiation (100-200 mW/cm^2) can cause cataracts in rabbits. Temporary sterility, caused by such effects as changes in sperm count and in sperm motility, is possible after exposure of the testes to high-level RF radiation (or to other forms of energy that produce comparable increases in temperature).

Studies have shown that environmental levels of RF energy routinely encountered by the general public are far below levels necessary to produce significant heating and increased body temperature. However, there may be situations, particularly workplace environments near high-powered RF sources, where recommended limits for safe exposure of human beings to RF energy could be exceeded. In such cases, restrictive measures or actions may be necessary to ensure the safe use of RF energy.

In addition to intensity, the frequency of an RF electromagnetic wave can be important in determining how much energy is absorbed and, therefore, the potential for harm. The quantity used to characterize this absorption is called the "specific absorption rate" or "SAR," and it is usually expressed in units of watts per kilogram (W/kg) or milliwatts per gram (mW/g). In the far-field of a source of RF energy (e.g., several wavelengths distance from the source) whole-body absorption of RF energy by a standing human adult has been shown to occur at a maximum rate when the frequency of the RF radiation is between about 80 and 100 MHz, depending on the size, shape and height of the individual. In other words, the SAR is at a maximum under these conditions. Because of this "resonance" phenomenon, RF safety standards have taken account of the frequency dependence of whole-body human absorption, and the most restrictive limits on exposure are found in this frequency range (the very high frequency or "VHF" frequency range).

Although not commonly observed, a microwave "hearing" effect has been shown to occur under certain very specific conditions of frequency, signal modulation, and intensity where animals and humans may perceive an RF signal as a buzzing or clicking sound. Although a number of theories have been advanced to explain this effect, the most widely-accepted hypothesis is that the microwave signal produces thermo-elastic pressure within the head that is perceived as sound by the auditory apparatus within the ear. This effect is not recognized as a health hazard, and the conditions under which it might occur would rarely be encountered by members of the public. Therefore, this phenomenon should be of little concern to the general population. Furthermore, there is no evidence that it could be caused by telecommunications applications such as wireless or broadcast transmissions.

At relatively low levels of exposure to RF radiation, i.e., field intensities lower than those that would produce significant and measurable heating, the evidence for production of harmful biological effects is ambiguous and unproven. Such effects have sometimes been referred to as "non-thermal" effects. Several years ago publications began appearing in the scientific literature, largely overseas, reporting the observation of a wide range of low-level biological effects. However, in many of these cases further experimental research was unable to reproduce these effects. Furthermore, there has been no determination that such effects might indicate a human health hazard, particularly with regard to long-term exposure.

More recently, other scientific laboratories in North America, Europe and elsewhere have reported certain biological effects after exposure of animals and animal tissue to relatively low levels of RF radiation. These reported effects have included certain changes in the immune system, neurological effects, behavioral effects, evidence for a link between microwave exposure and the action of certain drugs and compounds, a "calcium efflux" effect in brain tissue (exposed under very specific conditions), and effects on DNA.

Some studies have also examined the possibility of a link between RF and microwave exposure and cancer. Results to date have been inconclusive. While some experimental data have suggested a possible link between exposure and tumor formation in animals exposed under certain specific conditions, the results have not been independently replicated. In fact, other studies have failed to find evidence for a causal link to cancer or any related condition. Further research is underway in several laboratories to help resolve this question.

In general, while the possibility of "non-thermal" biological effects may exist, whether or not such effects might indicate a human health hazard is not presently known. Further research is needed to determine the generality of such effects and their possible relevance, if any, to human health. In the meantime, standards-setting organizations and government agencies of North America and Europe continue to monitor the latest experimental findings to confirm their validity and determine whether alterations in safety limits are needed in order to protect human health.

WHAT RESEARCH IS BEING DONE ON RF BIOLOGICAL EFFECTS?

For many years research into possible biological effects of RF energy has been carried out in government, academic and industrial laboratories all over the world, and such research is continuing. Past research has resulted in a very large number of scientific publications on this topic, some of which are listed in the reference section of this document. For many years the U.S. Government has sponsored research into the biological effects of RF energy. The majority of this work has been funded by the Department of Defense, due, in part, to the extensive military interest in using RF equipment such as radar and other relatively high-powered radio transmitters for routine military operations. In addition, some U.S. civilian federal agencies responsible for health and safety, such as the Environmental Protection Agency (EPA) and the U.S. Food and Drug Administration (FDA), have sponsored and conducted research in this area in the past, although relatively little civilian-sector RF research is currently being funded by the U.S. Government. At the present time, much of the non-military research on biological effects of RF energy in the U.S. is being funded by industry organizations such as Motorola, Inc. In general, relatively more research is being carried out in Europe.

In 1996, the World Health Organization (WHO) established a program (the International EMF Project) designed to review the scientific literature concerning biological effects of electromagnetic fields, identify gaps in knowledge about such effects, recommend research needs, and work towards international resolution of health concerns over the use of RF technology. The WHO and other organizations maintain Internet Web sites that contain additional information about their programs and about RF biological effects and research (see list of Web sites in Table **3** of this bulletin). The FDA, the EPA and other federal agencies responsible for public health and safety are working with the WHO and other organizations to monitor developments and identify research needs related to RF biological effects.

WHAT LEVELS ARE SAFE FOR EXPOSURE TO RF ENERGY?

Development of Exposure Guidelines

Exposure standards and guidelines have been developed by various organizations and countries over the past several decades. In North America and most of Europe exposure standards and guidelines have generally been based on exposure levels where effects considered harmful to humans occur. Safety factors are then incorporated to arrive at specific levels of exposure to provide sufficient protection for various segments of the population.

Not all standards and guidelines throughout the world have recommended the same limits for exposure. For example, some published exposure limits in Russia and some eastern European countries have been generally more restrictive than existing or proposed recommendations for exposure developed in North America and other parts of Europe. This discrepancy may be due to the possibility that these standards were based on exposure levels where it was believed no biological effects of any type would occur.

In the United States, although the Federal Government has never itself developed RF exposure standards, the FCC has adopted and used recognized safety guidelines for evaluating RF environmental exposure since 1985. Federal health and safety agencies, such as the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have also been actively involved in monitoring and investigating issues related to RF exposure. For example, the FDA has issued guidelines for safe RF emission levels from microwave ovens, and it continues to monitor exposure issues related to the use of certain RF devices such as cellular telephones. NIOSH conducts investigations and health hazard assessments related to occupational RF exposure.

In 1971, a federal RF radiation protection guide for workers was issued by OSHA based on the 1966 American National Standards Institute (ANSI) RF exposure standard. However, the OSHA regulation was later ruled to be advisory only and not enforceable. Presently, OSHA enforcement actions related to RF exposure of workers are undertaken using OSHA's "general duty clause," which relies on the use of widely-supported voluntary "consensus" standards such as those discussed below.

U.S. federal, state and local governmental agencies and other organizations have generally relied on RF exposure standards developed by expert non-government organizations such as ANSI, the Institute of Electrical and Electronics Engineers (IEEE) and the National Council on Radiation Protection and Measurements (NCRP). For example, in 1966, 1974, and 1982, ANSI issued protection guides for RF exposure developed by committees of experts. These earlier ANSI standards recommended limits for exposure of the public that were the same as those recommended for exposure of workers.

In 1986, the NCRP issued exposure criteria for the workplace that were the same as the 1982 ANSI recommended levels, but the NCRP also recommended more restrictive limits for exposure of the general public. Therefore, the NCRP exposure criteria included two tiers of recommended limits, one for the general population and another for occupational exposure. In 1987, the ANSI committee on RF exposure standards (Standards Coordinating Committee 28) became a committee of the IEEE, and, in 1991, revised its earlier standard and issued its own two-tiered standard that had been developed over a period of several years.

The ANSI/IEEE standards have been widely used and cited and have served as the basis for similar standards in the United States and in other countries. Both the NCRP and ANSI/IEEE guidelines were developed by scientists and engineers with a great deal of experience and knowledge in the area of RF biological effects and related issues.

These individuals spent a considerable amount of time evaluating published scientific studies relevant to establishing safe levels for human exposure to RF energy.

In addition to NCRP and ANSI/IEEE, other organizations and countries have issued exposure guidelines. For example, several European countries are basing guidelines on exposure criteria developed by the International Committee on Non-ionizing Radiation Protection (ICNIRP). The ICNIRP guidelines are also derived from an SAR threshold of 4 W/kg (for adverse effects) and are similar to the 1992 ANSI/IEEE and NCRP recommendations with certain exceptions. For example, ICNIRP recommends somewhat different exposure levels in the lower and upper frequency ranges and for localized exposure due to such devices as hand-held cellular telephones. Many, but not all, countries have based exposure recommendations on the same general concepts and thresholds as those used by the NCRP, ANSI/IEEE and ICNIRP. Because of differences in international standards, the World Health Organization (WHO), as part of its EMF Project, has initiated a program to try and develop an international framework for RF safety standards.

FCC Exposure Guidelines

In 1985, the FCC adopted the 1982 ANSI guidelines for purposes of evaluating exposure due to RF transmitters licensed and authorized by the FCC. This decision was in response to provisions of the National Environmental Policy Act of 1969 requiring all Federal Government agencies to evaluate the impact of their actions on the "quality of the human environment. In 1992, ANSI adopted the 1991 IEEE standard as an American National Standard (a revision of its 1982 standard) and designated it ANSI/IEEE C95.1-1992.

In 1993, the FCC proposed to update its rules and adopt the new ANSI/IEEE guidelines. After a lengthy period to allow for the filing of comments and for deliberation the FCC decided, in 1996, to adopt a modified version of its original proposal. The FCC's action also fulfilled requirements of the Telecommunications Act of 1996 for adopting new RF exposure guidelines.

The FCC considered a large number of comments submitted by industry, government agencies and the public. In particular, the FCC considered comments submitted by the EPA, FDA, NIOSH and OSHA, which have primary responsibility for health and safety in the Federal Government. The guidelines the FCC adopted were based on the recommendations of those agencies, and they have sent letters to the FCC supporting its decision and endorsing the FCC's guidelines as protective of public health.

In its 1996 Order, the FCC noted that research and analysis relating to RF safety and health is ongoing and changes in recommended exposure limits may occur in the future as knowledge increases in this field. In that regard, the FCC will continue to cooperate with industry and with expert agencies and organizations with responsibilities for health and safety in order to ensure that the FCC's guidelines continue to be appropriate and scientifically valid.

The FCC's guidelines are based on recommended exposure criteria issued by the NCRP and ANSI/IEEE. The NCRP exposure guidelines are similar to the ANSI/IEEE 1992 guidelines except for differences in recommended exposure levels at the lower frequencies and higher frequencies of the RF spectrum. Both ANSI/IEEE and NCRP recommend two different tiers of exposure limits. The NCRP designates one tier for occupational exposure and the other for exposure of the general population while ANSI/IEEE designates exposure tiers in terms of "environments," one for "controlled" environments and the other for "uncontrolled" environments. Over a broad range of frequencies, NCRP exposure limits for the public are generally one-fifth those for workers in terms of power density.

The NCRP and ANSI/IEEE exposure criteria identify the same threshold level at which harmful biological effects may occur, and the values for Maximum Permissible Exposure (MPE) recommended for electric and magnetic field strength and power density in both documents are based on this threshold level. In addition, both the ANSI/IEEE and

NCRP guidelines are frequency dependent, based on findings (discussed earlier) that whole-body human absorption of RF energy varies with the frequency of the RF signal. The most restrictive limits on exposure are in the frequency range of 30-300 MHz where the human body absorbs RF energy most efficiently when exposed in the far field of an RF transmitting source. Although the ANSI/IEEE and NCRP guidelines differ at higher and lower frequencies, at frequencies used by the majority of FCC licensees the MPE limits are essentially the same regardless of whether ANSI/IEEE or NCRP guidelines are used.

Most radiofrequency safety limits are defined in terms of the electric and magnetic field strengths as well as in terms of power density. For lower frequencies, limits are more meaningfully expressed in terms of electric and magnetic field strength values, and the indicated power densities are actually "far-field equivalent" power density values. The latter are listed for comparison purposes and because some instrumentation used for measuring RF fields is calibrated in terms of far-field or plane-wave equivalent power density. At higher frequencies, and when one is actually in the "far field" of a radiation source, it is usually only necessary to evaluate power density. In the far field of an RF transmitter power density and field strength are related by standard mathematical equations.

The exposure limits adopted by the FCC in 1996 expressed in terms of electric and magnetic field strength and power density for transmitters operating at frequencies from 300 kHz to 100 GHz are shown in Table **1**. The FCC also adopted limits for localized ("partial body") absorption in terms of SAR, shown in Table **2**, which apply to certain portable transmitting devices such as hand-held cellular telephones.

Time Averaging of Exposure

The NCRP and ANSI/IEEE exposure criteria and most other standards specify **"time-averaged"** MPE limits. This means that it is permissible to exceed the recommended limits for short periods of time as long as the average exposure (over the appropriate period specified) does not exceed the limit. For example, Table 1 shows that for a frequency of 100 MHz the recommended power density limit is 1 mW/cm^2 with an averaging time of six minutes (any six-minute period) for occupational/controlled exposure.

The time-averaging concept can be illustrated as follows for exposure in a workplace environment. The sum of the product (or products) of the actual exposure level(s) multiplied by the actual time(s) of exposure must not be greater than the allowed (average) exposure limit times the specified averaging time. Therefore, for 100 MHz, exposure at 2 mW/cm^2 would be permitted for three minutes in any six-minute period as long as during the remaining three minutes of the six-minute period the exposure was at or near "zero" level of exposure. Therefore, in this example:

$$\sum S_{\exp} t_{\exp} = S_{limit} t_{avg} \qquad (5)$$

where:

S_{exp} = power density level of exposure (mW/cm^2)
S_{limit} = appropriate power density MPE limit (mW/cm^2)
t_{exp} = allowable time of exposure for S_{exp}
t_{avg} = appropriate MPE averaging time

(2 mW/cm^2) X (3 min.) + (0 mW/cm^2) X (3 min.) = (1 mW/cm^2) X (6 min.)

It is very important to remember that time averaging of exposure is only necessary or relevant for situations where temporary exposures might occur that are in excess of the absolute limits for power density or field strength. These situations usually only occur in workplace environments where exposure can be monitored and controlled. For general population/uncontrolled exposures, say in a residential neighborhood, it is seldom possible to have sufficient information or control regarding how long people are exposed, and averaging of exposure over the designated time period (30 minutes) is normally not appropriate. For such public exposure situations, the MPE limits normally apply for continuous exposure. In other words, as long as the absolute limits are not exceeded, indefinite exposure is allowed.

Table 1. FCC Limits for Maximum Permissible Exposure (MPE)

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	$(900/f^2)$*	6
30-300	61.4	0.163	1.0	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6

(B) Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	$(180/f^2)$*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

f = frequency in MHz

*Plane-wave equivalent power density

NOTE 1: Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

NOTE 2: General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

Table 2. FCC Limits for Localized (Partial-body) Exposure

Specific Absorption Rate (SAR)	
Occupational/Controlled Exposure (100 kHz - 6 GHz)	**General Uncontrolled/Exposure (100 kHz - 6 GHz)**
< 0.4 W/kg whole-body **≤ 8 W/kg partial-body**	**< 0.08 W/kg whole-body** **≤ 1.6 W/kg partial-body**

WHY HAS THE FCC ADOPTED GUIDELINES FOR RF EXPOSURE?

The FCC authorizes and licenses devices, transmitters and facilities that generate RF and microwave radiation. It has jurisdiction over all transmitting services in the U.S. except those specifically operated by the Federal Government. However, the FCC's primary jurisdiction does not lie in the health and safety area, and it must rely on other agencies and organizations for guidance in these matters.

Under the National Environmental Policy Act of 1969 (NEPA), the FCC has certain responsibilities to consider whether its actions will "significantly affect the quality of the human environment." Therefore, FCC approval and licensing of transmitters and facilities must be evaluated for significant impact on the environment. Human exposure to RF radiation emitted by FCC-regulated transmitters is one of several factors that must be considered in such environmental evaluations.

Major RF transmitting facilities under the jurisdiction of the FCC, such as radio and television broadcast stations, satellite-earth stations, experimental radio stations and certain cellular, PCS and paging facilities are required to undergo routine evaluation for RF compliance whenever an application is submitted to the FCC for construction or modification of a transmitting facility or renewal of a license. Failure to comply with the FCC's RF exposure guidelines could lead to the preparation of a formal Environmental Assessment, possible Environmental Impact Statement and eventual rejection of an application. Technical guidelines for evaluating compliance with the FCC RF safety requirements can be found in the FCC's OET Bulletin 65.

The FCC's policies with respect to environmental RF fields are designed to ensure that FCC-regulated transmitters do not expose the public or workers to levels of RF radiation that are considered by expert organizations to be potentially harmful. Therefore, if a transmitter and its associated antenna are regulated by the FCC, they must comply with provisions of the FCC's rules regarding human exposure to RF radiation.

In the United States some local and state jurisdictions have also enacted rules and regulations pertaining to human exposure to RF energy. However, the Telecommunications Act of 1996 contained provisions relating to federal jurisdiction to regulate human exposure to RF emissions from certain transmitting devices. In particular, Section 704 of the Act states that, "No State or local government or instrumentality thereof may regulate the placement, construction, and modification of personal wireless service facilities on the basis of the environmental effects of radio frequency emissions to the extent that such facilities comply with the Commission's regulations concerning such emissions."

ARE EMISSIONS FROM RADIO AND TELEVISION ANTENNAS SAFE?

Radio and television broadcast stations transmit their signals via RF electromagnetic waves. There are currently approximately 14,000 radio and TV stations on the air in the United States. Broadcast stations transmit at various RF frequencies, depending on the channel, ranging from about 550 kHz for AM radio up to about 800 MHz for some UHF television stations. Frequencies for FM radio and VHF television lie in between these two extremes. Operating powers ("effective radiated power") can be as little as a few hundred watts for some radio stations or up to millions of watts for certain television stations. Some of these signals can be a significant source of RF energy in the local environment, and the FCC requires that broadcast stations submit evidence of compliance with FCC RF guidelines.

The amount of RF energy to which the public or workers might be exposed as a result of broadcast antennas depends on several factors, including the type of station, design characteristics of the antenna being used, power transmitted to the antenna, height of the antenna and distance from the antenna. Since energy at some frequencies is absorbed by the human body more readily than energy at other frequencies, the frequency of the transmitted signal as well as its intensity is important. Calculations can be performed to predict what field intensity levels would exist at various distances from an antenna.

Public access to broadcasting antennas is normally restricted so that individuals cannot be exposed to high-level fields that might exist near antennas. Measurements made by the FCC, EPA and others have shown that ambient RF radiation levels in inhabited areas near broadcasting facilities are typically well below the exposure levels recommended by current standards and guidelines. There have been a few situations around the country where RF levels in publicly accessible areas have been found to be higher than those recommended by applicable safety standards. But, in spite of the relatively high operating powers of many stations, such cases are unusual, and members of the general public are unlikely to be exposed to RF levels from broadcast towers that exceed FCC limits. Wherever such situations have arisen corrective measures have been undertaken to ensure that areas promptly come into compliance with the applicable guidelines.

In cases where exposure levels might pose a problem, there are various steps a broadcast station can take to ensure compliance with safety standards. For example, high-intensity areas could be posted and access to them could be restricted by fencing or other appropriate means. In some cases more drastic measures might have to be considered, such as re-designing an antenna, reducing power, or station relocation.

Antenna maintenance workers are occasionally required to climb antenna structures for such purposes as painting, repairs, or beacon replacement. Both the EPA and OSHA have reported that in these cases it is possible for a worker to be exposed to high levels of RF energy if work is performed on an active tower or in areas immediately surrounding a radiating antenna. Therefore, precautions should be taken to ensure that maintenance personnel are not exposed to unsafe RF fields. Such precautions could include temporarily lowering power levels while work is being performed, having work performed only when the station is not broadcasting, using auxiliary antennas while work is performed on the main antenna, and establishing work procedures that would specify the minimum distance that a worker should maintain from an energized antenna.

HOW SAFE ARE MICROWAVE AND SATELLITE ANTENNAS?

Point-to-Point Microwave Antennas

Point-to-point microwave antennas transmit and receive microwave signals across relatively short distances (from a few tenths of a mile to 30 miles or more). These antennas are usually rectangular or circular in shape and are normally found mounted on a supporting tower, on rooftops, sides of buildings or on similar structures that provide clear and unobstructed line-of-sight paths between both ends of a transmission path or link. These antennas have a variety of uses such as transmitting voice and data messages and serving as links between broadcast or cable-TV studios and transmitting antennas.

The RF signals from these antennas travel in a directed beam from a transmitting antenna to a receiving antenna, and dispersion of microwave energy outside of the relatively narrow beam is minimal or insignificant. In addition, these antennas transmit using very low power levels, usually on the order of a few watts or less. Measurements have shown that ground-level power densities due to microwave directional antennas are normally a thousand times or more below recommended safety limits. Moreover, as an added margin of safety, microwave tower sites are normally inaccessible to the general public.
Significant exposures from these antennas could only occur in the unlikely event that an individual were to stand directly in front of and very close to an antenna for a period of time.

Satellite-Earth Stations

Ground-based antennas used for satellite-earth communications typically are parabolic "dish" antennas, some as large as 10 to 30 meters in diameter, that are used to transmit ("uplinks") or receive ("downlinks") microwave signals to or from satellites in orbit around the earth. The satellites receive the signals beamed up to them and, in turn, retransmit the signals back down to an earthbound receiving station. These signals allow delivery of a variety of communications services, including long distance telephone service. Some satellite-earth station antennas are used only to receive RF signals (i.e., just like a rooftop television antenna used at a residence), and, since they do not transmit, RF exposure is not an issue.

Since satellite-earth station antennas are directed toward satellites above the earth, transmitted beams point skyward at various angles of inclination, depending on the particular satellite being used. Because of the longer distances involved, power levels used to transmit these signals are relatively large when compared, for example, to those used by the microwave point-to-point antennas already discussed. However, as with microwave antennas, the beams used for transmitting earth-to-satellite signals are concentrated and highly directional, similar to the beam from a flashlight. In addition, public access would normally be restricted at station sites where exposure levels could approach or exceed safe limits.

Although many satellite-earth stations are "fixed" sites, portable uplink antennas are also used, e.g., for electronic news gathering. These antennas can be deployed in various locations. Therefore, precautions may be necessary, such as temporarily restricting access in the vicinity of the antenna, to avoid exposure to the main transmitted beam. In general, however, it is unlikely that a transmitting earth station antenna would routinely expose members of the public to potentially harmful levels of microwaves.

ARE CELLULAR AND PCS TOWERS AND ANTENNAS SAFE? WHAT ABOUT CAR PHONES AND HAND-HELD PHONES?

Base Stations

Cellular radio systems use frequencies between 800 and 900 megahertz (MHz). Transmitters in the Personal Communications Service (PCS) use frequencies in the range of 1850-1990 MHz. The antennas for cellular and PCS transmissions are typically located on towers, water tanks or other elevated structures including rooftops and the sides of buildings. The combination of antennas and associated electronic equipment is referred to as a cellular or PCS "base station" or "cell site." Typical heights for free-standing base station towers or structures are 50-200 feet.

In urban and suburban areas, cellular and PCS service providers now more commonly use "sector" antennas for their base stations. These antennas are rectangular panels, e.g., about 1 by 4 feet in dimension, typically mounted on a rooftop or other structure, but they are also mounted on towers or poles. The antennas are usually arranged in three groups of three each. One antenna in each group is used to transmit signals to mobile units (car phones or hand-held phones), and the other two antennas in each group are used to receive signals from mobile units.

The FCC authorizes cellular and PCS carriers in various service areas around the country. At a cell site, the total RF power that could be transmitted from each transmitting antenna at a cell site depends on the number of radio channels (transmitters) that have been authorized and the power of each transmitter. Typically, for a cellular base station, a maximum of 21 channels per sector (depending on the system) could be used. Thus, for a typical cell site utilizing sector antennas, each of the three transmitting antennas could be connected to up to 21 transmitters for a total of 63 transmitters per site. When omni-directional antennas are used, up to 96 transmitters could be implemented at a cell site, but this would be unusual. While a typical base station could have as many as 63 transmitters, not all of the transmitters would be expected to operate simultaneously thus reducing overall emission levels. For the case of PCS base stations, fewer transmitters are normally required due to the relatively greater number of base stations.

Although the FCC permits an effective radiated power (ERP) of up to 500 watts per channel (depending on the tower height), the majority of cellular base stations in urban and suburban areas operate at an ERP of 100 watts per channel or less. An ERP of 100 watts corresponds to an actual radiated power of about 5-10 watts, depending on the type of antenna used (ERP is not equivalent to the power that is radiated but, rather, is a quantity that takes into consideration transmitter power and antenna directivity). As the capacity of a system is expanded by dividing cells, i.e., adding additional base stations, lower ERPs are normally used. In urban areas, an ERP of 10 watts per channel (corresponding to a radiated power of 0.5 - 1 watt) or less is commonly used. For PCS base stations, even lower radiated power levels are normally used.

The signal from a cellular or PCS base station antenna is essentially directed toward the horizon in a relatively narrow pattern in the vertical plane. The radiation pattern for an omni-directional antenna might be compared to a thin doughnut or pancake centered around the antenna while the pattern for a sector antenna is fan-shaped, like a wedge cut from a pie. As with all forms of electromagnetic energy, the power density from a cellular or PCS transmitter decreases rapidly (according to an inverse square law) as one moves away from the antenna. Consequently, normal ground-level exposure is much less than exposures that might be encountered if one were very close to the antenna and in its main transmitted beam.

Measurements made near typical cellular and PCS installations, especially those with tower-mounted antennas, have shown that ground-level power densities are well below limits recommended by RF/microwave safety standards. For example, for a base-station transmitting frequency of 869 MHz the FCC's RF exposure guidelines recommend a Maximum Permissible Exposure level for the public ("general population/uncontrolled" exposure) of about 580 microwatts per square centimeter (μW/cm^2). This limit is many times greater than RF levels found near the base of typical cellular towers or in the vicinity of lower-powered cellular base station transmitters, such as might be mounted on rooftops or sides of buildings. Measurement data obtained from various sources have consistently indicated that "worst-case" ground-level power densities near typical cellular towers are on the order of 1 ìW/cm^2 or less (usually significantly less). Calculations corresponding to a "worst-case" situation (all transmitters operating simultaneously and continuously at the maximum licensed power) show that in order to be exposed to levels near the FCC's limits for cellular frequencies, an individual would essentially have to remain in the main transmitting beam (at the height of the antenna) and within a few feet from the antenna. This makes it extremely unlikely that a member of the general public could be exposed to RF levels in excess of these guidelines due to cellular base station transmitters. For PCS base station transmitters, the same type of analysis holds, except that at the PCS transmitting frequencies (1850-1990 MHz) the FCC's exposure limits for the public are 1000 μW/cm^2. Therefore, there would typically be an even greater safety margin between actual public exposure levels and recognized safety limits.

When cellular and PCS antennas are mounted at rooftop locations it is possible that ambient RF levels greater than 1 μW/cm^2 could be present on the rooftop itself. However, exposures approaching or exceeding the safety guidelines are only likely to be encountered very close to or directly in front of the antennas. For sector-type antennas RF levels to the side and in back of these antennas are insignificant.

Even if RF levels were higher than desirable on a rooftop, appropriate restrictions could be placed on access. Factoring in the time-averaging aspects of safety standards could also be used to reduce potential exposure of workers who might have to access a rooftop for maintenance tasks or other reasons. The fact that rooftop cellular and PCS antennas usually operate at lower power levels than antennas on free-standing towers makes excessive exposure conditions on rooftops unlikely. In addition, the significant signal attenuation of a building's roof minimizes any chance for persons living or working within the building itself to be exposed to RF levels that could approach or exceed applicable safety limits.

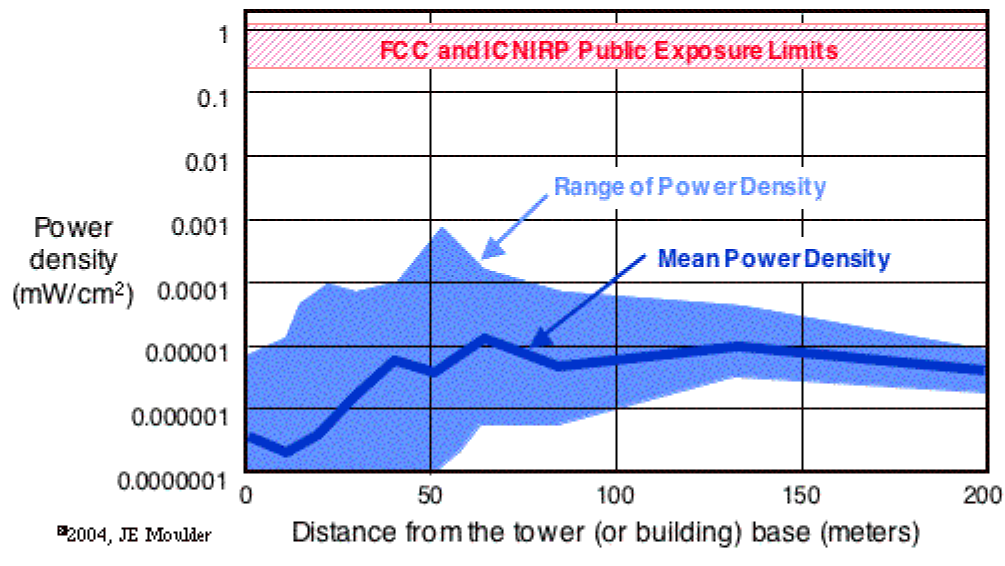
In 1999 in Vancouver Canada, RF levels were measured in five schools, three of which had base stations on them or near them. All schools met Canadian, US and international RF standards by a wide margin. The maximum readings are shown in the following table.

RF Energy Levels in Canadian Schools Near Mobile Phone Base Stations

School	Base Station Location	Maximum RF Level
1	digital (PCS) base station across street	0.00016 mW/cm-sq
2	analog base station on roof	0.0026 mW/cm-sq
3	analog base station across street	0.00022 mW/cm-sq
4 and 5	no antennas nearby	less than 0.00001 mW/cm-sq
	Canadian Standard	less than 0.57 mW/cm-sq

In 2000, the U.K. National Radiation Protection Board measured RF energy levels at 118 publicly-accessible sites around 17 mobile phone base stations. The maximum exposure at any location was 0.00083 mW/cm-sq (on a playing field 60 meters from a school building with an antenna on its roof). Typical power densities were less than 0.0001 mW/cm-sq (less than 0.01% of the ICNIRP public exposure guidelines). Power densities indoors were substantially less than power densities outdoors. When RF energy from all sources (mobile phone, FM radio, TV, etc.) was taken into account the maximum power density at any site was less than 0.2% of the ICNIRP public exposure guidelines. Details are shown in the following figure.

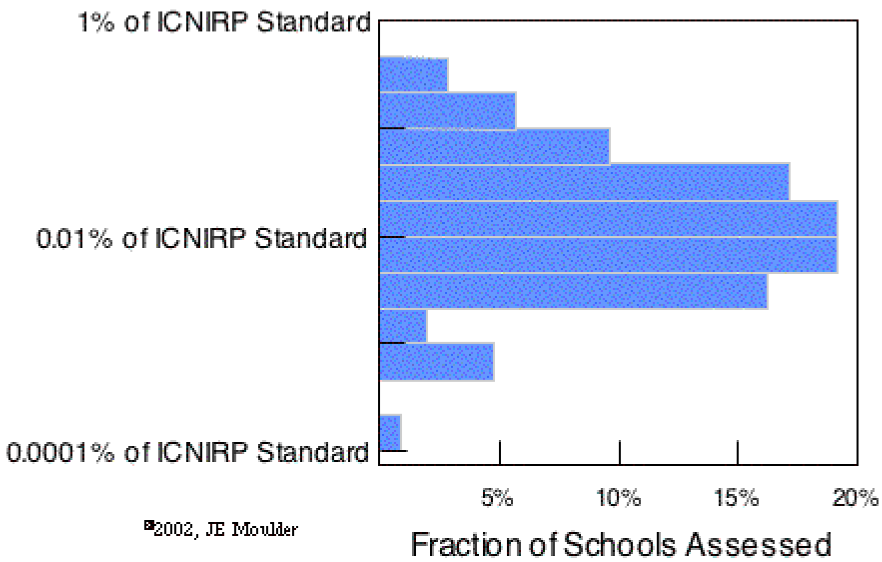
RF Energy Levels Near Mobile Phone Base Stations in the UK



The relationship between the RF power density and distance from the base of the tower or building on which the mobile phone base antenna was located.

In 2001, the Radiocommunications Agency of the UK Department of Trade and Industry measured RF energy levels at 100 schools that had mobile phone base stations on (or near) them. The maximum RF level measured at any school was less than 1% of the ICNIRP standard for public areas; the maximum in most schools was less than 0.05% of that standard. The results of this audit are summarized in the figure below and the details are on the web at: http://www.radio.gov.uk/topics/mpsafety/school-audit/audit.htm.

RF Energy Levels in Schools Near Mobile Phone Base Stations in the UK (in comparison to the ICNIRP guidelines for public areas)



Maximum RF energy levels (in comparison to the ICNIRP standard for public areas) in UK schools that have mobile phone base stations near them. Adapted from http://www.radio.gov.uk/topics/mpsafety/school-audit/audit.htm/.

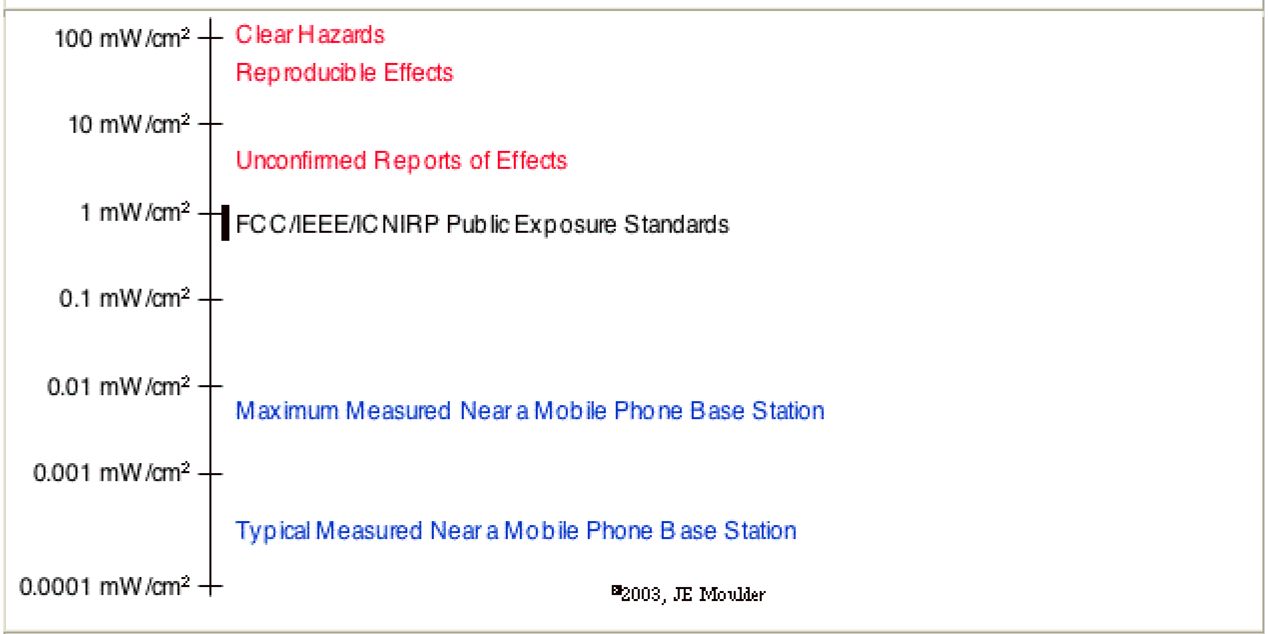
A 2000 survey of GSM base stations by the Australian Radiation Protection and Nuclear Safety Agency found that public exposures to RF energy were less than 0.1% of their standard. The highest exposure level they found was less than 0.0002 mW/cm-sq (less than 0.01% of the ICNIRP public exposure guidelines), and the average exposure level was less than 0.0001 mW/cm-sq. At most of the 13 sites they measured, there were other types of RF signals that were more powerful than the base station signal (AM radio was more powerful in 12 cases, FM radio in 6 cases, and TV in 3 cases). At all sites measured the total RF energy from all sources combined (mobile phone base stations, AM radio, FM radio, VHF TV, UHF TV, paging) was less than 0.1% of the

Australian (or the ICNIRP or FCC) RF safety guidelines. The Australian report is on line at: http://www.arpansa.gov.au/pubs/eme_comitee/rfrep129.pdf

In 2001, measurements of RF energy in buildings in a large town in northern Italy found that radio/TV signals were generally stronger than mobile phone (base plus handset) signals, and that all measurements showed power densities far below even the Italian safety standard (0.01 mW/cm-sq). The peak level was less than 0.003 mW/cm-sq.

The relationship between the RF levels required to produce known biological effects, the RF levels specified in the FCC, IEEE and ICNIRP safety guidelines, and the RF levels found around mobile phone base stations is shown in the following figure.

Standards for Mobile Phone Base Stations



The relationship between the RF power density level required to produce known biological effects, the RF power density levels specified in the safety guidelines, and the RF power density levels actually measured around mobile phone base stations. Because the RF power density required to produce biological effects is dependent on frequency, this figure only applies to frequencies between 800 and 2200 MHz (that is, those currently used by mobile phones).

ARE THERE CIRCUMSTANCES WHERE MOBILE PHONE BASE STATION ANTENNAS COULD FAIL TO MEET THE SAFETY GUIDELINES?

Yes. There are some circumstances under which an improperly designed (or inadequately secured) mobile phone base station site could fail to meet safety guidelines.

Safety guidelines for uncontrolled (public) exposure could be exceeded if antennas were mounted in such a way that the public could gain access to areas within 8 meters/25 feet (horizontal) of the radiating surface(s) of the antennas themselves. This could arise for antennas mounted on or near the roofs of buildings. For antennas mounted on towers, it is somewhat difficult to imagine a situation that would not meet the safety guidelines. However, there are reports (principally from outside North America and Europe) of mobile phone base station antennas facing directly at nearby buildings. Whether these antennas would meet FCC, ANSI/IEEE or ICNIRP safety guidelines would depend on the ERP, the exact geometry and the degree of shielding provided by the building.

Vehicle-Mounted Antennas

Vehicle-mounted antennas used for cellular communications normally operate at a power level of 3 watts or less. These cellular antennas are typically mounted on the roof, on the trunk, or on the rear window of a car or truck. Studies have shown that in order to be exposed to RF levels that approach the safety guidelines it would be necessary to remain very close to a vehicle-mounted cellular antenna for an extended period of time.

Studies have also indicated that exposure of vehicle occupants is reduced by the shielding effect of a vehicle's metal body. Some manufacturers of cellular systems have noted that proper installation of a vehicle-mounted antenna is an effective way to maximize this shielding effect and have recommended antenna installation either in the center of the roof or the center of the trunk. With respect to rear-window-mounted cellular antennas, a minimum separation distance of 30-60 cm (1 to 2 feet) has been suggested to minimize exposure to vehicle occupants that could result from antenna mismatch.

Therefore, properly installed, vehicle-mounted, personal wireless transceivers using up to 3 watts of power result in maximum exposure levels in or near the vehicle that are well below the FCC's safety limits. This assumes that the transmitting antenna is at least 15 cm (about 6 inches) or more from vehicle occupants. Time-averaging of exposure (as appropriate) should result in even lower values when compared with safety guidelines.

Mobile and Portable Phones and Devices

The FCC's exposure guidelines, and the ANSI/IEEE and NCRP guidelines upon which they are based, specify limits for human exposure to RF emissions from hand-held RF devices in terms of specific absorption rate (SAR). For exposure of the general public, e.g., exposure of the user of a cellular or PCS phone, the FCC limits RF absorption (in terms of SAR) to 1.6 watts/kg (W/kg), as averaged over one gram of tissue. Less restrictive limits, e.g., 2 W/kg averaged over 10 grams of tissue, are specified by guidelines used in some other countries.

Measurements and computational analysis of SAR in models of the human head and other studies of SAR distribution using hand-held cellular and PCS phones have shown that the 1.6 W/kg limit is unlikely to be exceeded under normal conditions of use. The same can be said for cordless telephones used in the home. Lower frequency (46-49 MHz) cordless telephones operate at very low power levels that could not result in exposure levels that even come close to the 1.6 W/kg level. Higher frequency cordless phones operating near 900 MHz (near the frequencies used for cellular telephones) operate with power levels similar to or less than those used for cell phones. They are also unlikely to exceed the SAR limits specified by the FCC under normal conditions of use.

In any case, compliance with the 1.6 W/kg safety limit must be demonstrated before FCC approval can be granted for marketing of a cellular or PCS phone. Testing of hand-held phones is normally done under conditions of maximum power usage. However, normal power usage is less since it depends on distance of the user from the base station transmitter. Therefore, typical exposure to a user would actually be expected to be less than that indicated by testing for compliance with the limit.

In recent years, publicity, speculation, and concern over claims of possible health effects due to RF emissions from hand-held wireless telephones prompted industry-sponsored groups to initiate research programs to investigate whether there is any risk to users of these devices. Organizations such as Wireless Technology Research (funded by the cellular radio service industry) and wireless equipment manufacturers, such as Motorola, Inc., have been investigating potential health effects from the use of hand-held cellular telephones and other wireless telecommunications devices.

In 1994, the U.S. General Accounting Office (GAO) issued a report that addressed the status of research on the safety of cellular telephones and encouraged U.S. Government agencies to work closely with industry to address wireless safety issues. In that regard, the Federal Government has been monitoring the results of ongoing research through an inter-agency working group led by the EPA and the FDA's Center for Devices and Radiological Health. In a 1993 "Talk Paper," the FDA stated that it did not have enough information at that time to rule out the possibility of risk, but if such a risk exists, "it is probably small". The FDA concluded that there is no proof that cellular telephones can be harmful, but if individuals remain concerned several precautionary actions could be taken, including limiting conversations on hand-held cellular telephones and making greater use of telephones with vehicle-mounted antennas where there is a greater separation distance between the user and the radiating antennas.

HOW SAFE ARE FIXED AND MOBILE RADIO TRANSMITTERS USED FOR PAGING

AND "TWO-WAY" COMMUNICATIONS?

"Land-mobile" communications include a variety of communications systems which require the use of portable and mobile RF transmitting sources. These systems operate in narrow frequency bands between about 30 and 1000 MHz. Radio systems used by the police and fire departments, radio paging services and business radio are a few examples of these communications systems. They have the advantage of providing communications links between various fixed and mobile locations.

As with cellular and PCS communications, there are three types of RF transmitters associated with land-mobile systems: base-station transmitters, vehicle-mounted transmitters, and hand-held transmitters. The antennas used for these various transmitters are adapted for their specific purpose. For example, a base-station antenna must radiate its signal to a relatively large area, and, therefore, its transmitter generally has to use much higher power levels than a vehicle-mounted or hand-held radio transmitter.

Although these base-station antennas usually operate with higher power levels than other types of land-mobile antennas, they are normally inaccessible to the public since they must be mounted at significant heights above ground to provide for adequate signal coverage. Also, many of these antennas transmit only intermittently. For these reasons, such base-station antennas have generally not been of concern with regard to possible hazardous exposure of the public to RF radiation. However, studies at rooftop locations have indicated that high-powered paging antennas may increase the potential for exposure to workers or others with access to such sites, e.g., maintenance personnel. This could be a concern especially when multiple transmitters are present. In such cases, restriction of access or other corrective actions may be necessary.

Transmitting power levels for vehicle-mounted land-mobile antennas are generally less than those used by base-station antennas but higher than those used for hand-held units. As with cellular transmitters, some manufacturers recommend that users and other nearby individuals maintain a minimum distance (e.g., 1 to 2 feet) from a vehicle-mounted antenna during transmission or mount the antenna in such a way as to provide maximum shielding for vehicle occupants. Studies have shown that this is probably a conservative precaution, particularly when the "duty factor" (percentage of time an antenna is actually radiating) is taken into account since safety standards are "time-averaged." Unlike cellular telephones, which transmit continuously throughout a call, two-way radios normally transmit only when the "press-to-talk" button is depressed. The extent of any possible exposure would also depend on the actual power level and frequency used by the vehicle-mounted antenna. In general, there is no evidence that there would be a safety hazard associated with exposure from vehicle-mounted, two-way antennas when the manufacturer's recommendations are followed.

Hand-held "two-way" portable radios such as walkie-talkies are low-powered devices used to transmit and receive messages over relatively short distances. Because of the relatively low power levels used (usually no more than a few watts) and, especially, because of the intermittency of transmissions (low duty factor) these radios would normally not be considered to cause hazardous exposures to users. As with vehicle-mounted mobile units, time averaging of exposure can normally be considered when evaluating two-way radios for compliance with safety limits, since these units are "push to talk." Laboratory measurements have been made using hand-held radios operating at various frequencies to determine the amount of RF energy that might be absorbed in the head of a user. In general, the only real possibility of a potential hazard would occur in the unlikely event that the tip of the transmitting antenna were to be placed directly at the surface of the eye, contrary to manufacturers' recommended precautions, or if for some reason continuous exposure were possible over a significant period of time, which is unlikely. If hand-held radios are used properly there is no evidence that they could cause hazardous exposure to RF energy.

TOWER SITINGS:

During research for any possible standards of any reasonable number of towers in a sector and its effect on communities due to radiation emission, it was observed that no such engineering standards were developed by any international standard developing agencies. Such matters are mainly handled by Environmental Protection Agencies and local governments in USA and Europe. However studies show that sharing of towers is encouraged by FCC in order to avoid its proliferation.

Applicant seeking permission to erect a tower or to install a transmitter has to go through various steps in order to convince the community and the local government.

The salient features of such application process are as follows:

1. Applicant submits an application with a reason as to why it is needed to raise a tower or install a transmitter in a sector where there are already other mobile operators.
2. Applicant submits all the technical details of the antennas and in case a new pole is required to be erected details of pole are also submitted.
3. Applicant is responsible to evaluate the radiation emission of the area where there are already other transmitter installed. In case radiation emission is above the specified level, the local government asks the operators to bring it to the required level.
4. Applicant is encouraged to share a same pole with other operators if any of the existing poles have the following:
    a. Additional space available
    b. Radiation emission of that particular sector or area will remain within limits.
5. Applicants are given permission to erect new pole for transmitter installation without discrimination and through a fair process.

Local government in USA usually hire consultants to carry out the above mentioned application process and maintain a database of towers and transmitters. Following is the scope of work of a consultant that works off of Washington DC area.

Tower Siting Analysis and Support: Two-Way Radio, Cellular, and PCS Communications

"Columbia Telecommunication Corporation (CTC) work as Tower Coordinator in **Montgomery County, Maryland,** includes serving as a liaison between the various service providers (such as Sprint, AT&T, Cellular One, Nextel, and Bell Atlantic, among others) and numerous interested agencies. CTC ensures that each application conforms with the requirements in the Montgomery County Code and the Montgomery County Zoning Ordinance for the siting process and is appropriate, considering the policies and needs of the involved County agencies. CTC resolves any questions regarding accuracy and completeness of the applications, verifies the zoning of the proposed site, ensures that the applications meet the zoning requirements for the zone of the proposed site, and conducts physical inspections of sites as warranted to determine potential adverse impact on the community. CTC works with agencies and carriers to facilitate co-location of facilities in order to minimize proliferation of obtrusive tower structures in the community -- a key objective of the tower siting process.

CTC's staff provides administrative and engineering staff support to the Tower Siting Committee members, and provides guidance on related engineering issues as they arise (such as, for example, interpretations of FCC guidelines for RF emissions, identification of potential conflicts related to antenna siting, and general explanations of the technical aspects of cellular PCS and RF technology). In addition to reviewing all the technical aspects of applications, CTC prepares all the necessary documentation regarding the application, records minutes of the meetings, leads the Committee through its review of each application, and in the absence of the Committee Chair, CTC staff chair the monthly meeting. CTC staff members also meet with or confer by telephone with interested citizens or community groups to discuss any concerns they may have or provide information to them regarding a particular tower siting proposed for an area."

PICTURES OF COVERT ANTENNAS

Local government in USA and other developed countries encourage operators to preserve the beautification of communities and public areas. The following pages explains how it is done.

Antennas come in many forms, including trees, cactus, gas station signs and even replacement church steeples Below are nine photos of hidden cell towers manufactured by the Larson Company:

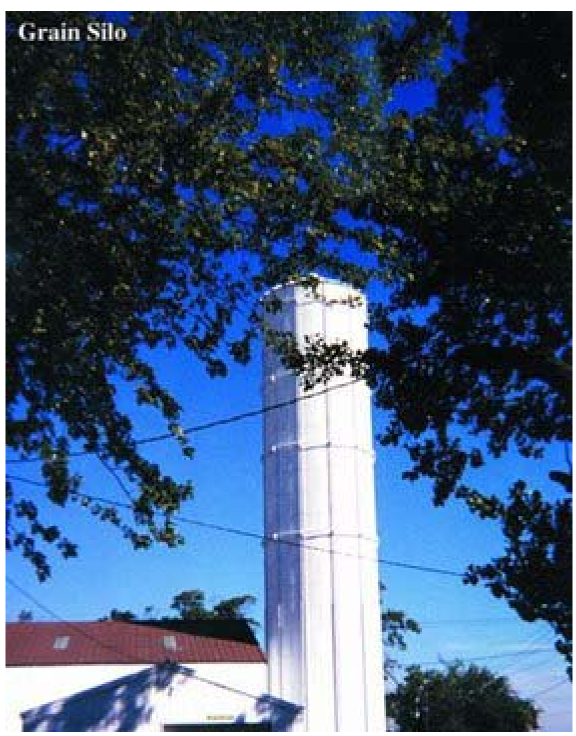
A "PINE TREE" THAT SUPPORTS 6 CELL PHONE CARRIERS
EACH RING ON THE TREE, IS A CARRIER ANTENNA CLUSTER

CELL PHONE EQUIPMENT
HIDDEN IN FAKE "BOULDER"

SAME "BOULDER" OPENED UP

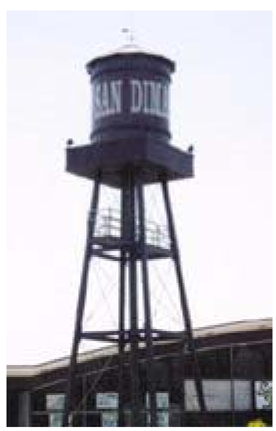
35' TALL SAQUARO CACTUS ANTENNA
Located in Southern CA.

GRAIN SILO



Antennas hidden under cross sign

WATER TOWER ANTENNA



PALM TREES

We can't ignore Local Area Network (LAN) antennas.
These are also a source of radiation, very similar to that of cell towers.

Below is a picture from Mobile Mark's website of their office LAN antenna product. This is a local area network antenna that is ceiling mounted in an office area.

CM Series mounted on ceiling

VIRTUAL BRICKS FOR FIBERGLAS TOWER STRUCTURES

U.K. GASOLINE STATION SIGNS
Antenna is inside the vertical sign with the Shell logo

INTERNATIONAL STANDARS:

Standards for public exposure to RF energy from mobile phone base station antennas in countries other than the U.S. This list is not comprehensive or necessarily up-to-date; the information should be checked with the appropriate regulatory authorities in each country.

- Australian standard:
    - The 2003 Australian standard is: Maximum Exposure Levels to Radiofrequency Fields - 3 kHz to 300 GHz. Australian Radiation Protection and Nuclear Safety Agency, 2003. It is online at: http://www.arpansa.gov.au/pubs/rps/rps3.pdf
      A companion Q and A document is on-line at: http://www.arpansa.gov.au/pubs/rps/rfqa.pdf
      With respect to public exposure to RF energy from mobile phone base stations the Australian standard appears to be largely (if not completely) in agreement with the ICNIRP Guidelines.
- New Zealand standard:
    - The 1999 New Zealand standard is: NZS 2772.1:1999 Radiofrequency fields - Part 1: Maximum exposure levels - 3 kHz to 300 GHz. With respect to public exposure to RF energy from mobile phone base stations the New Zealand standard appears to be largely (if not completely) in agreement with the ICNIRP Guidelines [4]. Also relevant is the "National guidelines for managing the effects of radiofrequency transmitters" from the New Zealand Ministry for the Environment. It is on-line at: http://www.mfe.govt.nz/publications/rma/radio-freq-guidelines-dec00.html
- Canadian standard:
    - [Health Canada: Limits of human exposure to radiofrequency electromagnetic fields at frequencies from 3 kHz - 300 GHz Safety Code

6, Radiation Protection Bureau of Health Canada, 1999)] At the frequencies of relevance to base stations the Canadian standard appears to be identical to the FCC standard.

- UK standard:
    - In mid-2000 the UK stopped using its own standard for mobile phones and mobile phone base stations and adopted the ICNIRP standard [8].
- Greek standard:
    - [Measures for protection of the public from operation of land-installed antennas. Athens, Hellenic Republic, 2000]: The standard is essentially identical to ICNIRP standard.
- Swiss standard:
    - [Regulation about Protection against Nonionizing Radiation. Swiss Federal Council, 1999]: For mobile phone base stations the standard is 4.0 V/m (0.0042 mW/cm-sq) at 900 MHz and 6.0 V/m (0.0095 mW/cm-sq) at 1800 MHz. For broadcast radio (and TV?) the standard is 3.0-8.5 V/m (0.0024-0.019 mW/cm-sq). The scientific basis for this standard is unclear.
- Italian standard:
    - Ministero Dell'Ambientem, Decreto 10 Settembre 1998, n. 381, Regolamento recante norme per la determinazione dei tetti di radiofrequenza compatibili con la salute umana. At mobile phone frequencies the standard appears to be 0.10 mW/cm-sq. For situations where exposure is expected to exceed 4 hours/day, the limit appears are further reduced to 0.010 mW/cm-sq. Local regional administrations appear to have the authority to further reduce these limits, and several regions appear to have limits 4 times lower (0.0025 mW/cm-sq). The scientific basis for this standard is unclear.

TABLE 3. REFERENCES AND INTERNET WEB SITES FOR FURTHER INFORMATION
American Radio Relay League: www.arrl.org **American National Standards Institute: www.ansi.org** **Bioelectromagnetics Society: www.bioelectromagnetics.org** **COST 244 (Europe): www.radio.fer.hr/cost244** **DOD: www.brooks.af.mil/AFRL (**select radiofrequency radiation) **European Bioelectromagnetics Association: www.ebea.org** **Electromagnetic Energy Association: www.elecenergy.com** **Federal Communications Commission: www.fcc.gov/oet/rfsafety** **ICNIRP (Europe): www.icnirp.de** **IEEE: www.ieee.org** **IEEE Committee on Man & Radiation: www.seas.upenn.edu/~kfoster/comar.htm** **International Microwave Power Institute: www.impi.org** **Microwave News: www.microwavenews.com** **J.Moulder, Med.Coll.of Wisc.: www.mcw.edu/gcrc/cop/cell-phone-health-FAQ/toc.html** **National Council on Radiation Protection & Measurements: www.ncrp.com** **NJ Dept Radiation Protection: www.state.nj.us/dep/rpp (**select non-ionizing radiation) **Richard Tell Associates: www.radhaz.com** **US OSHA: www.osha-slc.gov/SLTC** (select subject: radiofrequency radiation) **Wireless Industry (CTIA): www.wow-com.com** **Wireless Industry (PCIA): www.pcia.com** **World Health Organization EMF Project: www.who.ch/peh-emf**

RECOMMENDATIONS:

1. **PAKISTAN ENVIRONMENTAL PROTECTION AGENCY TO IMMEDIATELY CONDUCT A STUDY AND DEVELOP RADIATION EMISSION STANDARDS FOR PUBLIC SAFETY.**

2. **PTA TO ENFORCE THOSE STANDARDS THROUGH REGULATIONS**

3. **ROUTINE EVALUATION OF THE TRANSMITTER SITES BE CONDUCTED AND HIGH PENALTY SHOULD BE IMPOSED ON LICENSEES THAT ARE IN VIOLATION.**

4. **WARNING SIGNS SHOWING "MAXIMUM PERMISSIBLE EXPOSURE" INDICATING DURATION THAT INDIVIDUAL SHOULD NOT REMAIN IN THE AREA FOR MRE THAN SPECIFIED PERIOD OF TIME.**

5. **PTA TO ENCOURAGE OPERATORS TO SHARE POLES FOR ANTENNA INSTALLATIONS**