Radio Frequency Safety and Health Background

What is radio frequency (RF) energy ?

Radio frequency (RF) energy is another name for radio waves. It is one form of electromagnetic energy that makes up the electromagnetic spectrum. Some of the other forms of energy in the electromagnetic spectrum are gamma rays, X-rays, and light. Electromagnetic energy (or electromagnetic radiation) consists of waves of electric and magnetic energy moving together (radiating) through space. The area where these waves are found is called an electromagnetic field.

Radio waves are created due to the movement of electrical charges in antennas. As they are created, these waves radiate away from the antenna. All electromagnetic waves travel at the speed of light. The major differences between the different types of waves are the distances covered by one cycle of the wave and the number of waves that pass a certain point during a set time period. The wavelength is the distance covered by one cycle of a wave. The frequency is the number of waves passing a given point in one second. For any electromagnetic wave, the wavelength multiplied by the frequency equals the speed of light. The frequency of an RF signal is usually expressed in units called hertz (Hz). One Hz equals one wave per second. One kilohertz (kHz) equals one thousand waves per second, one megahertz (MHz) equals one million waves per second, and one gigahertz (GHz) equals one billion waves per second.

RF energy includes waves with frequencies ranging from about 3000 waves per second (3 kHz) to 300 billion waves per second (300 GHz). Microwaves are a subset of radio waves that have frequencies ranging from around 300 million waves per second (300 MHz) to three billion waves per second (3 GHz).

What is non ionizing radiation?

"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 high levels of electromagnetic energy. Those types of electromagnetic radiation with enough energy to ionize biological material include X-radiation and gamma radiation. Therefore, X-rays and gamma rays are examples of ionizing radiation.

The energy levels associated with RF and microwave radiation, on the other hand, are not great enough to cause the ionization of atoms and molecules, and RF energy is, therefore, a type of non ionizing radiation. Other types of non ionizing radiation include visible light, infrared radiation, and other forms of electromagnetic radiation with relatively low frequencies. Often the term "radiation" is used to apply to ionizing radiation such as that associated with nuclear power plants. Ionizing radiation should not be confused with the lower energy, non ionizing, radiation with respect to possible biological and health effects, since the mechanisms of action are quite different.

How is radio frequency energy used?

Probably the most important use of RF energy is for telecommunications. Radio and TV broadcasting, wireless phones, pagers, cordless phones, police and fire department radios, point-to-point links, and satellite communications all rely on RF energy.

Other uses of RF energy include microwave ovens, radar, industrial heaters and sealers, and medical treatments. RF energy, especially at microwave frequencies, can heat water. Since most food has high water content, microwaves can cook food quickly. Radar relies on RF energy to track cars and airplanes. Industrial heaters and sealers use RF energy to mold plastic materials, glue wood products, seal leather items such as shoes and pocketbooks, and process food. Medical uses of RF energy include pacemaker monitoring and programming.

How do cellular phone networks operate?

- **Outgoing calls**

  When a call is made from a cellular phone, the phone sends the conversation by radio link to the nearest monopole. The monopole is connected to the main land line phone network, which connects the call through to its final destination.

- **Incoming calls**

  If a cell phone is switched on, the cellular phone network keeps track of which monopole it is closest to. When a call is made to that phone, the cellular phone network directs the call through land lines to that monopole, from which the final radio link to the phone is made.

- **Network design**

  In designing their networks, telecommunications companies have to balance a number of factors: providing coverage over as much of the country as their customers require, providing sufficient capacity to handle all the calls people wish to make, and preventing radio interference between adjacent monopoles. Monopoles in rural areas are mostly designed to provide coverage over a wide area – each site may cover a radius of several tens of miles. In urban and suburban areas, the priority is usually to provide sufficient capacity, and each site covers a much smaller area. The area covered by each monopole is called a “cell”. Busy cells, in which the number of calls often exceeds the capacity of the monopole to handle them, may be split into several smaller cells, each handling a smaller area.

- **Monopoles**

  A monopole is a low powered radio transmitter. A site consists of two main components: an equipment shelter and antennas.

- **Equipment shelter**

  This houses the electronic equipment which processes the calls being handled by the site, generates the radio signals sent to the phones and listens for calls originating from phones.

- **Antennas**

  The radio signals are transmitted from specialized antennas. These may be mounted on a purpose-built monopole, or attached to existing structures (like water towers or other antennas. The antennas are designed to transmit most of the signal away horizontally, or just below the horizontal, rather than at steep angles toward the ground. The radio transmitters used at monopoles are of much lower power than those used for commercial TV and radio transmissions. At many monopoles, especially those covering a small area, the transmitter power is similar to that in the radio-telephones used in trucks and taxis.

How is radio frequency radiation measured?

RF waves and RF fields have both electrical and magnetic components. It is often convenient to express the strength of the RF field in terms of each component. For example, the unit "volts per meter" (V/m) is used to measure the electric field strength, and the unit "amperes per meter" (A/m) is used to express the magnetic field strength. Another common way to characterize an RF field is by means of the power density. Power density is defined as power per unit area. For example, power density can be expressed in terms of milliwatts (one thousandth of a watt) per square centimeter (mW/cm^2 or microwatts (one millionth of a watt) per square centimeter ($\mu W/cm^2$).

Note the use of the quantity power density, which is the rate of flow of electromagnetic energy per unit surface area. This quantity is particularly meaningful in the "far field" region of an antenna, a region where the radiation field has a plane-wave character, with the electric and magnetic field vectors perpendicular to each other and the direction of propagation of the wave and in a constant ratio (E/H = 377 ohms). It is only necessary to measure the electric field strength or the magnetic field strength in the "far field," since either one defines the other as well as the power density. Closer to an antenna, it is necessary to measure both electric and magnetic field strengths separately for comparison with the exposure limits.

What biological effects can be caused by RF energy?

The biological effects of radiofrequency energy should not be confused with the effects from other types of electromagnetic energy.

Very high levels of electromagnetic energy, such as those found in X-rays and gamma rays, can ionize biological tissues. Ionization is a process by which electrons are stripped away from their normal locations in atoms and molecules. It can permanently damage biological tissues including DNA, the genetic material. Ionization only occurs with very high levels of electromagnetic energy such as X-rays and gamma rays. Often the term radiation is used when discussing ionizing radiation (such as that associated with nuclear power plants).

The energy levels associated with radio frequency energy, including both radio waves and microwaves, are not great enough to cause the ionization of atoms and molecules. Therefore, RF energy is a type of non-ionizing radiation. Other types of non ionizing radiation include visible light, infrared radiation (heat), and other forms of electromagnetic radiation with relatively low frequencies.

Large amounts of RF energy can heat tissue. This can damage tissues and increase body temperatures. Two areas of the body, the eyes and the testes, are particularly vulnerable to RF heating because there is relatively little blood flow in them to carry away excess heat.

The amount of RF radiation routinely encountered by the general public is too low to produce significant heating or increased body temperature. Still, some people have questions about the possible health effects of low levels of RF energy. It is generally agreed that further research is needed to determine what effects actually occur and whether they are dangerous to people. In the meantime, standard-setting organizations and government agencies are continuing to monitor the latest scientific findings to determine whether changes in safety limits are needed to protect human health.

FDA, EPA, and other U.S. government agencies responsible for public health and safety have worked together and in connection with the World Health Organization (WHO) to monitor developments and identify research needs related to RF biological effects.

What levels of RF energy are considered safe?

Various organizations and countries have developed standards for exposure to radio frequency energy. These standards recommend safe levels of exposure for both the general public and for workers. In the United States, the FCC has used safety guidelines for RF environmental exposure since 1985.

The FCC guidelines for human exposure to RF electromagnetic fields are derived from the recommendations of two expert organizations, the National Council on Radiation Protection and Measurements (NCRP) and the Institute of Electrical and Electronics Engineers (IEEE). In both cases, the recommendations were developed by scientific and engineering experts drawn from industry, government, and academia after extensive reviews of the scientific literature related to the biological effects of RF energy.

Many countries in Europe and elsewhere use exposure guidelines developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The ICNIRP safety limits are generally similar to those of the NCRP and the IEEE, with a few exceptions. For example, the ICNIRP recommends different exposure levels in the lower and upper frequency ranges and for localized exposure from certain products such as hand-held wireless telephones. Currently, the World Health Organization is working to provide a framework for international harmonization of RF safety standards.

The NCRP, the IEEE, and the ICNIRP all have identified a whole-body specific absorption rate (SAR) value of 4 watts per kilogram (4 W/kg) as a threshold level of exposure at which harmful biological effects may occur. Exposure guidelines in terms of field strength, power density and localized SAR were then derived from this threshold value. In addition, the NCRP, IEEE, and ICNIRP guidelines vary depending on the frequency of the RF exposure. This is due to the finding that whole-body human absorption of RF energy varies with the frequency of the RF signal. The most restrictive limits on whole-body exposure are in the frequency range of 30-300 MHz where the human body absorbs RF energy most efficiently. For products that expose only part of the body, such as wireless phones, exposure limits in terms of SAR only are specified.

The exposure limits used by the FCC are expressed in terms of SAR, electric and magnetic field strength, and power density for transmitters operating at frequencies from 300 kHz to 100 GHz.

The FCC exposure limits for cell phone base station antennae (monopoles) using the American Personal Communication System (PCS) frequencies 1850 MHz to 1910 MHz and 1930 MHz to 1990 MHz for general population/uncontrolled exposure is 1 milliwatt per centimeter squared (mW/cm^2) or 1,000 microwatts per centimeter squared (uW/cm^2).

The FCC exposure limits for radio and television transmission towers (the local radio FM transmit bands (88 MHz to 107.9 MHz) and the local television transmit bands (174.0 MHz to 806.0 MHz, consisting of local television channels 7 thru 70) for general population/uncontrolled exposure is 200 uW/cm^2 for the FM radio/television frequencies 88 to300 MHz and ranges from 201 uW/cm^2 to 537 uW/cm^2 for the television frequencies from 301 to 806 MHz.

What are the affiliations of IEEE safety levels committee members?

- University research 30%
- Nonprofit research 6%
- Military research 12%
- Govt. research (EPA, FDA etc) 24%
- Industry 10%
- Industry - consulting 3%
- Govt. - administration 4%

- Public, independent consultants 11%

What is the status of health effects research?

The possible health effects of exposure to RF radiation have been studied for over fifty years. Several different types of study have been carried out.

- **Epidemiology**

  Epidemiological studies are observational studies which look at the relationships between exposures to agents and health outcomes in the exposed group of people. For RF radiation, such studies have been carried out on people who live near TV and radio transmitters, and people who work with radio or radar equipment. There have not been any studies on people who live around monopole sites, but there is currently a large study under way looking at cell phone users.

- **Cellular studies**

  Cellular studies look at the effects of an agent on isolated cell or tissue culture. Many such studies have been carried using RF radiation to investigate, for example, whether RF radiation might influence the progression of cancer, or affect the way cells signal to each other.

- **Animal studies**

  Long and short term animal studies have been carried out to investigate whether RF radiation affects cancer, learning and other end points.

What is the current opinion on health effects from RF energy?

One clear effect of exposures to high levels of RF radiation is heating of exposed tissues. The body has effective ways to regulate its temperature, but if exposures are too intense the body no longer copes. Experiments have shown that mammals start to show signs of stress above an exposure threshold. Effects relating to heating are usually called thermal effects.

Exposures around monopole sites are generally many thousand times lower than the threshold required to cause any thermal effects. Much of the debate about monopole sites (and other transmitters) centers around the possibility of there being athermal effects (i.e., effects which occur at exposures too low to cause any heating).

Some experiments have suggested that there may be biological effects at a-thermal exposure levels, but the evidence is often contradictory or has not been independently replicated. A biological effect is not the same as a health effect, but simply a physiological response to a stimulus, which is within the range that the body can normally accommodate and is readily reversed when conditions change. For example, when moving from a bright to a dark room, the pupil dilates. The pupil contracts again on moving back into the bright room. This is a biological effect, but not a health effect.

Certainly, there are some studies which have been interpreted as suggesting that there may be adverse health effects from low exposures, and it is acknowledged that further research is needed to improve our understanding in some areas. However, when the research is viewed as a whole, there is a wide consensus that there is no persuasive evidence that such relatively weak exposures do cause short or long term health effects. Epidemiology studies, in which exposures are almost always at athermal levels, have not shown any clear, consistent evidence of health effects.

What are some of the findings of recent international reviews?

Public concern in many countries regarding both cell phones and base stations has resulted in a number of independent expert groups being requested by governments to carry out detailed reviews of the research literature. The most recent reviews, and brief quotes from their findings are presented below.

The United Kingdom Independent Expert Group (Stewart) Report (2000)

"The balance of evidence to date suggests that exposures to RF radiation below ICNIRP guidelines do not cause adverse health effects to the general population." "We conclude that the balance of evidence indicates that there is no general risk to the health of people living near to base stations on the basis that exposures are expected to be small fractions of guidelines."

The Royal Society of Canada (1999)

“No consistent increases in health risk due to exposure to RF radiation are evident to date.” “It appears that exposure of the public to RF fields emitted from wireless telecommunication base stations is of sufficiently low intensity that biological or adverse health effects are not anticipated.”

The Health Council of the Netherlands (2000)

“The chance of health problems occurring among people living and working below base stations as a result of exposure to electromagnetic fields originating from the antennae is, in the Committee’s opinion, negligible.”

The World Health Organization (WHO) Fact Sheet

“While RF fields around cell sites are not considered a health risk, planning decisions should take into account aesthetics and public sensitivities.”

The Swedish Radiation Protection Institute (1998)

“To summarize, mobile telephony base stations do not constitute any risk regarding radiation protection.” All of these reviews consistently report that there are no credible health risks associated with monopoles sites."

What does the FDA say about wireless telephone base station safety?

The electromagnetic RF signals transmitted from base station antenna stations travel toward the horizon in relatively narrow paths. For example, the radiation pattern for an antenna array mounted on a tower can be likened to a thin pancake centered around the antenna system. The individual pattern for a single array of sector antennas is wedge-shaped, like a piece of pie. As with all forms of electromagnetic energy, the power decreases rapidly as one moves away from the antenna. Therefore, RF exposure on the ground is much less than exposure very close to the antenna and in the path of the transmitted radio signal. In fact, ground-level exposure from such antennas is typically thousands of times less than the exposure levels recommended as safe by expert organizations. So exposure to nearby residents would be well within safety margins.

Cellular and PCS base stations in the United States are required to comply with limits for exposure recommended by expert organizations and endorsed by government agencies responsible for health and safety. Measurements made near cellular and PCS base station antennas mounted on towers have confirmed that ground-level exposures are typically thousands of times less than the exposure limits adopted by the FCC. In fact, in order to be exposed to levels at or near the FCC limits for cellular or PCS frequencies, an individual would essentially have to remain in the main transmitted radio signal (at the height of the antenna) and within a few feet from the antenna. This is, of course, very unlikely to occur.

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