**WHAT ARE "RADIOFREQUENCY" AND MICROWAVE RADIATION?**

Electromagnetic radiation consists of waves of electric and magnetic energy moving together (i.e., radiating) through space at the speed of light.  Taken together, all forms of electromagnetic energy are referred to as the electromagnetic "spectrum."  Radio waves and microwaves emitted by transmitting antennas are one form of electromagnetic energy.  They are collectively referred to as "radiofrequency" or "RF" energy or radiation.  Note that the term “radiation” does not mean “radioactive.”  Often, the terms "electromagnetic field" or "radiofrequency field" are used to indicate the presence of electromagnetic or RF energy.

The RF waves emanating from an antenna are generated by the movement of electrical charges in the antenna.  Electromagnetic waves can be characterized by a wavelength and a frequency.  The wavelength is the distance covered by one complete cycle of the electromagnetic wave, while the frequency is the number of electromagnetic waves passing a given point in one second.  The frequency of an RF signal is usually expressed in terms of a unit called the "hertz" (abbreviated "Hz").  One Hz equals one cycle per second.  One megahertz MHz equals one million cycles per second.

Different forms of electromagnetic energy are categorized by their wavelengths and frequencies.  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 (3 kHz) to 300 gigahertz (300 GHz).  Microwaves are a specific category of radio waves that can be loosely defined as radiofrequency energy at frequencies ranging from about 1 GHz to 30 GHz. [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byWHAT 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 of living organisms.  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, is a type of non-ionizing radiation.  Other types of non-ionizing radiation include visible and infrared light.  Often the term "radiation" is used, colloquially, to imply that ionizing radiation (radioactivity), such as that associated with nuclear power plants, is present.  Ionizing radiation should not be confused with the lower-energy, non-ionizing radiation with respect to possible biological effects, since the mechanisms of action are quite different. [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byHOW IS RADIOFREQUENCY ENERGY USED?**

The most important use for RF energy is in providing telecommunications services.  Radio and television broadcasting, cellular telephones, personal communications services (PCS), pagers, cordless telephones, business radio, radio communications for police and fire departments, amateur radio, microwave point-to-point links and satellite communications are just a few of the many telecommunications applications of RF energy.  Microwave ovens are an example of a non-telecommunication use of RF energy.  Radiofrequency radiation, especially at microwave frequencies, can transfer energy to water molecules.  High levels of microwave energy will generate heat in water-rich materials such as most foods.  This efficient absorption of microwave energy via water molecules results in rapid heating throughout an object, thus allowing food to be cooked more quickly in a microwave oven than in a conventional oven.  Other important non-telecommunication uses of RF energy include radar and industrial heating and sealing.  Radar is a valuable tool used in many applications range from traffic speed enforcement to air traffic control and military surveillance.  Industrial heaters and sealers generate intense levels of RF radiation that rapidly heats the material being processed in the same way that a microwave oven cooks food.  These devices 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 also a number of medical applications of RF energy, such as diathermy and magnetic resonance imaging (MRI). [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byHOW IS RADIOFREQUENCY RADIATION MEASURED?**

An RF electromagnetic wave has both an electric and a magnetic component (electric field and magnetic field), and it is often convenient to express the intensity of the RF environment at a given location in terms of units specific to each component. For example, the unit "volts per meter" (V/m) is used to express the strength of the electric field (electric "field strength"), and the unit "amperes per meter" (A/m) is used to express the strength of the magnetic field (magnetic "field strength").  Another commonly used unit for characterizing the total electromagnetic field is "power density."  Power density is most appropriately used when the point of measurement is far enough away from an antenna to be located in the "far-field" zone of the antenna.

Power density is defined as power flow per unit area.  For example, power density is commonly expressed in terms of watts per square meter (W/m2), milliwatts per square centimeter (mW/cm2), or microwatts per square centimeter (µW/cm2).  One mW/cm2 equals 10 W/m2, and 100 µW/cm2 equal one W/m2. With respect to frequencies in the microwave range, power density is usually used to express intensity of exposure.

The quantity used to measure the rate at which RF energy is actually absorbed in a body is called the "Specific Absorption Rate" or "SAR."  It is usually expressed in units of watts per kilogram (W/kg) or milliwatts per gram (mW/g).  In the case of exposure of the whole body, a standing ungrounded human adult absorbs RF energy at a maximum rate when the frequency of the RF radiation is in the range of about 70 MHz.  This means that the "whole-body" SAR is at a maximum under these conditions.  Because of this "resonance" phenomenon and consideration of children and grounded adults, RF safety standards are generally most restrictive in the frequency range of about 30 to 300 MHz.  For exposure of parts of the body, such as the exposure from hand-held mobile phones, "partial-body" SAR limits are used in the safety standards to control absorption of RF energy (see later questions on mobile phones).  [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byWHAT BIOLOGICAL EFFECTS CAN BE CAUSED BY RF ENERGY?**

Biological effects can result from exposure to RF energy.  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 very 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.  Exposure to very high RF intensities can 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.  Two areas of the body, the eyes and the testes, are particularly vulnerable to RF heating because of the relative lack of available blood flow to dissipate the excess heat load.

At relatively low levels of exposure to RF radiation, i.e., levels lower than those that would produce significant heating, the evidence for production of harmful biological effects is ambiguous and unproven.  Such effects, if they exist, have been referred to as "non-thermal" effects.  A number of reports have appeared in the scientific literature describing the observation of a range of biological effects resulting from exposure to low levels of RF energy.  However, in most cases, further experimental research has been unable to reproduce these effects.  Furthermore, since much of the research is not done on whole bodies (in vivo), there has been no determination that such effects constitute a human health hazard.  It is generally agreed that 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 continue to monitor the latest experimental findings to confirm their validity and determine whether changes in safety limits are needed to protect human health. [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byCAN PEOPLE BE EXPOSED TO LEVELS OF RADIOFREQUENCY RADIATION THAT COULD BE HARMFUL?**

Studies have shown that environmental levels of RF energy routinely encountered by the general public are typically far below levels necessary to produce significant heating and increased body temperature.  However, there may be situations, particularly in workplace environments near high-powered RF sources, where the recommended limits for safe exposure of human beings to RF energy could be exceeded.  In such cases, restrictive measures or mitigation actions may be necessary to ensure the safe use of RF energy. [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byCAN RADIOFREQUENCY RADIATION CAUSE CANCER?**

Some studies have also examined the possibility of a link between RF 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.  Many other studies have failed to find evidence for a link to cancer or any related condition.  The Food and Drug Administration has further information on this topic with respect to RF exposure from mobile phones at the following Web site: [FDA Radiation-Emitting Products Page](http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/ucm116335.htm) . [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byWHAT RESEARCH IS BEING DONE ON RF BIOLOGICAL EFFECTS?**

For many years, research into the possible biological effects of RF energy has been carried out in laboratories around the world, and such research is continuing.  Past research has resulted in a large number of peer-reviewed scientific publications on this topic.  For many years the U.S. Government has sponsored research into the biological effects of RF energy.  The majority of this work was initiated 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.  At the present time, other U.S. civilian federal health and safety agencies and institutions, such as the National Toxicology Program and the National Institutes of Health, have also initiated RF bioeffects research.

In 1996, the World Health Organization (WHO) established a program called the International EMF Project, which is 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 maintains a Web site that provides extensive information on this project and about RF biological effects and research ([www.who.int/peh-emf/en/Opens a New Window.](http://www.who.int/peh-emf/en/)).

The FDA, the EPA and other federal agencies responsible for public health and safety have worked together and in connection with the WHO to monitor developments and identify research needs related to RF biological effects.  More information about this can be obtained at the FDA Web site: [FDA Radiation-Emitting Products - Current Research](http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/ucm116335.htm). [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byWHAT LEVELS ARE SAFE FOR EXPOSURE TO RF ENERGY?**

Exposure standards for radiofrequency energy have been developed by various organizations and governments.  Most modern standards recommend safe levels of exposure separately for the general public and for workers.  In the United States, the FCC has adopted and used recognized safety guidelines for evaluating RF environmental exposure since 1985.  Federal health and safety agencies, such as the EPA, FDA, the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have also been involved in monitoring and investigating issues related to RF exposure.

The FCC guidelines for human exposure to RF electromagnetic fields were 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).  Both the NCRP exposure criteria and the IEEE standard were developed by expert scientists and engineers after extensive reviews of the scientific literature related to RF biological effects.  The exposure guidelines are based on thresholds for known adverse effects, and they incorporate prudent margins of safety.  In adopting the current RF exposure guidelines, the FCC consulted with the EPA, FDA, OSHA and NIOSH, and obtained their support for the guidelines that the FCC is using.

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 IEEE, with a few 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.  One of the goals of the WHO EMF Project (see above) is to provide a framework for international harmonization of RF safety standards.  The NCRP, IEEE and ICNIRP exposure guidelines 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 level.  The threshold level is a Specific Absorption Rate (SAR) value for the whole body of 4 watts per kilogram (4 W/kg).

In addition, the NCRP, IEEE and ICNIRP guidelines for maximum permissible exposure are different for different transmitting frequencies.  This is due to the finding (discussed above) 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 when the whole body is exposed.  For devices that expose only part of the body, such as mobile phones, different exposure limits are specified (see below), but these limits are based on the same underlying threshold level.

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 100 kHz to 100 GHz.  The applicable limits depend upon the type of sources (e.g, whether a cellphone or a broadcast transmitting antenna). The actual values can be found in our informational bulletin available in [OET Bulletin 65](https://www.fcc.gov/encyclopedia/oet-bulletins-line#65). [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byWHY HAS THE FCC ADOPTED GUIDELINES FOR RF EXPOSURE?**

The FCC authorizes and licenses devices, transmitters and facilities that generate RF 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), all Federal agencies are required to implement procedures to make environmental consideration a necessary part of an agency's decision-making process.  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.  In 1996, the FCC revised its guidelines for RF exposure as a result of a multi-year proceeding and as required by the Telecommunications Act of 1996.

Facilities under the jurisdiction of the FCC having a high potential for creating significant RF exposure to humans, 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 compliance with RF exposure guidelines whenever an application is submitted to the FCC for construction or modification of a transmitting facility or renewal of a license.  Failure to show compliance with the FCC's RF exposure guidelines in the application process 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](https://www.fcc.gov/encyclopedia/oet-bulletins-line#65) (see "OET Safety Bulletins" listing elsewhere at this Web site).

Low-powered, intermittent, or inaccessible RF antennas and facilities (including many cell sites) are normally "categorically excluded" from the requirement of routine evaluation for RF exposure.  These exclusions are based on calculations and measurement data indicating that such transmitting stations or devices are unlikely to cause exposures in excess of the guidelines under normal conditions of use.  The FCC's policies on RF exposure and categorical exclusion can be found in Section 1.1307(b) of the FCC's Rules and Regulations [47 CFR 1.1307(b)].  It should be emphasized, however, that these exclusions are not exclusions from compliance, but, rather, only exclusions from routine evaluation.  Transmitters or facilities that are otherwise categorically excluded from evaluation may be required, on a case-by-case basis, to demonstrate compliance when evidence of potential non-compliance of the transmitter or facility is brought to the Commission's attention [see 47 CFR 1.1307(c) and (d)]. [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byHOW SAFE ARE MOBILE AND PORTABLE PHONES?**

In recent years, publicity, speculation, and concern over claims of possible health effects due to RF emissions from hand-held wireless telephones prompted various research programs to investigate whether there is any risk to users of these devices  There is no scientific evidence to date that proves that wireless phone usage can lead to cancer or a variety of other health effects, including headaches, dizziness or memory loss.  However, studies are ongoing and key government agencies, such as the Food and Drug Administration (FDA) continue to monitor the results of the latest scientific research on these topics.  Also, as noted above, the World Health Organization has established an ongoing program to monitor research in this area and make recommendations related to the safety of mobile phones.

The FDA, which has primary jurisdiction for investigating mobile phone safety, has stated that it cannot rule out the possibility of risk, but if such a risk exists, "it is probably small."  Further, it has stated that, while there is no proof that cellular telephones can be harmful, concerned individuals can take various precautionary actions, including limiting conversations on hand-held cellular telephones and making greater use of telephones with hands-free kits where there is a greater separation distance between the user and the radiating antenna.  The Web site for the FDA's Center for Devices and Radiological Health provides further information on mobile phone safety: [FDA Radiation-Emitting Products - Cell Phones](http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/default.htm).

The [Government Accountability Office](http://www.gao.gov/) (GAO) prepared [a report](http://www.gao.gov/products/GAO-12-771) of its investigation into safety concerns related to mobile phones.  The report concluded that further research is needed to confirm whether mobile phones are completely safe for the user, and the report recommended that the FDA take the lead in monitoring the latest research results.

The FCC's exposure guidelines specify limits for human exposure to RF emissions from hand-held mobile phones in terms of Specific Absorption Rate (SAR), a measure of the rate of absorption of RF energy by the body.  The safe limit for a mobile phone user is an SAR of 1.6 watts per kg (1.6 W/kg), averaged over one gram of tissue, and compliance with this limit must be demonstrated before FCC approval is granted for marketing of a phone in the United States.  Somewhat less restrictive limits, e.g., 2 W/kg averaged over 10 grams of tissue, are specified by the ICNIRP guidelines used in Europe and most other countries.

Measurements and analysis of SAR in models of the human head have shown that the 1.6 W/kg limit is unlikely to be exceeded under normal conditions of use of cellular and PCS hand-held phones.  The same can be said for cordless telephones used in the home.  Testing of hand-held phones is normally done under conditions of maximum power usage, thus providing an additional margin of safety, since most phone usage is not at maximum power.  Information on SAR levels for many phones is available electronically through the FCC's Web site and database (see next question). [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byHOW CAN I OBTAIN THE SPECIFIC ABSORPTION RATE (SAR) VALUE FOR MY MOBILE PHONE?**

As explained above, the Specific Absorption Rate, or SAR, is the unit used to determine compliance of cellular and PCS phones with safety limits adopted by the FCC.  The SAR is a value that corresponds to the rate at which RF energy absorbed in the head of a user of a wireless handset.  The FCC requires mobile phone manufacturers to demonstrate compliance with an SAR level of 1.6 watts per kilogram (averaged over one gram of tissue).

Information on SAR for a specific cell phone model can be obtained for almost all cellular telephones by using the FCC identification (ID) number for that model.  The FCC ID number is usually printed somewhere on the case of the phone or device.  In many cases, you will have to remove the battery pack to find the number.  Once you have the number proceed as follows. Go to the following website: [Equipment Authorization](https://www.fcc.gov/engineering-technology/laboratory-division/general/equipment-authorization). Click on the link for “[FCC ID Search](https://www.fcc.gov/fccid)”.  Once you are there you will see instructions for inserting the FCC ID number.  Enter the FCC ID number (in two parts as indicated: "Grantee Code" is comprised of the first three characters, the "Equipment Product Code" is the remainder of the FCC ID).  Then click on "Start Search."  Grant(s) of Equipment Authorization for this particular FCC ID number should then be available.  Click on a check under "Display Grant" and the grant should appear.  Look through the Grant for the section on SAR compliance, certification of compliance with FCC rules for RF exposure, or similar language.  This section should contain the value(s) for typical or maximum SAR for your phone.

For portable phones and devices authorized since June 2, 2000, maximum SAR levels should be noted on the grant of equipment authorization.  For phones and devices authorized between about mid-1998 and June 2000, detailed information on SAR levels is typically found in one of the "exhibits" associated with the grant.  Therefore, once the grant is accessed in the FCC database, the exhibits can be viewed by clicking on the appropriate entry labeled "View Exhibit."  Electronic records for FCC equipment authorization grants were initiated in 1998, so devices manufactured prior to this date may not be included in our electronic database.

Although the FCC database does not list phones by model number, there are certain non-government Web sites such as [www.cnet.comOpens a New Window.](http://www.cnet.com/), that provide information on SAR from specific models of mobile phones.  However, the FCC has not reviewed these sites for accuracy and makes no guarantees with respect to them.  In addition to these sites, some mobile phone manufacturers make this information available at their own Web sites.  Also, phones certified by the Cellular Telecommunications and Internet Association (CTIA) are now required to provide this information to consumers in the instructional materials that come with the phones.

If you want additional consumer information on safety of cell phones and other transmitting devices please consult the information available below. In particular, you may wish to read or download our further consumer information: [Cell Phones: Wireless Devices and Health Concerns](https://www.fcc.gov/consumers/guides/wireless-devices-and-health-concerns), [Specific Absorption Rate (SAR) For Cell Phones:](https://www.fcc.gov/consumers/guides/specific-absorption-rate-sar-cell-phones-what-it-means-you) What It Means For You, or [General Wireless Device FAQ's](https://www.fcc.gov/general/telephone-guides). If you have any problems or additional questions you may contact us at: [rfsafety@fcc.gov](mailto:rfsafety@fcc.gov) or you may call: 1-888-225-5322 (1-888-CALL-FCC).  You may also wish to consult a consumer update on mobile phone safety published by the U.S. Food and Drug Administration (FDA) that can be found at: [FDA Radiation-Emitting Products Page](http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/default.htm). [(Back to Index)](https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#top)

**sort byDO "HANDS-FREE" EAR PIECES FOR MOBILE PHONES REDUCE EXPOSURE TO RF EMISSIONS?  WHAT ABOUT MOBILE PHONE ACCESSORIES THAT CLAIM TO SHIELD THE HEAD FROM RF RADIATION?**

"Hands-free" kits with ear pieces can be used with cell phones for convenience and comfort.  In addition, because the phone, which is the source of the RF emissions, will not be placed against the head, absorption of RF energy in the head will be reduced.  Therefore, it is true that use of an ear piece connected to a mobile phone will significantly reduce the rate of energy absorption (or "SAR") in the user's head.  On the other hand, if the phone is mounted against the waist or other part of the body during use, then that part of the body will absorb RF energy.  Even so, mobile phones marketed in the U.S. are required to meet safety limit requirements regardless of whether they are used against the head or against the body.  So either configuration should result in compliance with the safety limit.  Note that hands-free devices using Bluetooth technology also include a wireless transmitter; however, the Bluetooth transmitter operates at a much lower power than the cell phone.

A number of devices have been marketed that claim to "shield" or otherwise reduce RF absorption in the body of the user.  Some of these devices incorporate shielded phone cases, while others involve nothing more than a metallic accessory attached to the phone.  Studies have shown that these devices generally do not work as advertised.  In fact, they may actually increase RF absorption in the head due to their potential to interfere with proper operation of the phone, thus forcing it to increase power to compensate.  The Federal Trade Commission has published a Consumer Alert regarding these shields on its website at: FTC Consumer Information