INTRODUCTION

The Federal Communications Commission (FCC) is responsible for licensing or authorizing many of the transmitting devices in the United States that use radiofrequency (RF) radiation to provide a variety of important telecommunications services. Because of its responsibilities in this regard the FCC often receives inquiries concerning potential health risks from exposure to the RF radiation emitted by these transmitters.

Recent years have witnessed increasing interest and concern on the part of the public with respect to this issue. The expanding use of RF technology has resulted in speculation concerning the alleged "electromagnetic pollution" of the environment and the potential dangers of exposure to non-ionizing radiation. This publication is designed to provide factual information to the public by answering some of the most commonly asked questions about this complex and often misunderstood topic.

WHAT IS RADIOFREQUENCY RADIATION?

Radiofrequency (RF) radiation is one of several types of electromagnetic radiation. Electromagnetic radiation consists of waves of electric and magnetic energy moving together through space. These waves are generated by the movement of electrical charges. For example, the movement of charge in a transmitting radio antenna, i.e., the alternating current, creates electromagnetic waves that radiate away from the antenna and can be picked up by a receiving antenna.

Electromagnetic waves travel through space at the speed of light. Each electromagnetic wave has associated with it a wavelength and frequency which are inversely related by a simple mathematical formula: (frequency) times (wavelength) = the speed of light. Since the speed of light is a fixed number, electromagnetic waves with high frequencies have short wavelengths and waves with low frequencies have long wavelengths.

The electromagnetic "spectrum" includes all of the various forms of electromagnetic radiation ranging from extremely low frequency (ELF) radiation (with very long wavelengths) to X-rays and gamma rays which have very high frequencies and correspondingly short wavelengths. In between these extremes lie radio waves, microwaves, infrared radiation, visible light, and ultraviolet radiation. The RF part of the electromagnetic spectrum is generally defined as electromagnetic radiation with frequencies in the range from about 3 kilohertz to 300 gigahertz. One "hertz" equals one cycle per second. A kilohertz (kHz) is one thousand hertz, a megahertz (MHz) is one million hertz, and a gigahertz is one billion hertz. The diagram below illustrates the electromagnetic spectrum and the approximate relationship between the various forms of electromagnetic radiation.

WHAT IS MICROWAVE RADIATION?

Microwave radiation is a high-frequency form of RF radiation. Microwave frequencies occupy the upper part of the RF electromagnetic spectrum, usually defined as the frequency range from about 300 MHz to 300 GHz. The most familiar use of microwave radiation is in household microwave ovens which rely on the principle that microwaves generate heat throughout an object rather than just at the surface. Therefore, microwave ovens can cook food more rapidly than conventional ovens. Other uses of microwaves are: the transmission of telephone and telegraph messages through low-power microwave relay antennas, military and civilian radar systems, the transmission of signals between ground stations and satellites, and the transmission of signals in certain broadcasting operations. Certain medical devices use microwave frequencies in therapeutic applications of RF radiation.

WHAT ARE TYPICAL USES OF RADIOFREQUENCY RADIATION?

Many uses have been developed for RF energy. Familiar applications involving telecommunications include AM and FM radio, television, citizens band (CB) radio, hand-held walkie-talkies, amateur radio, short-wave radio, cordless telephones, and microwave point-to-point and ground-to-satellite telecommunications links. Non-telecommunications applications include microwave ovens and radar, as mentioned above. Also important are devices that use RF energy in industrial heating a nd sealing operations. The latter devices generate RF radiation that rapidly heats the material being processed in the same way that a microwave oven cooks food. These 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. Medical applications of RF radiation include a technique called diathermy that takes advantage of RF energy's ability to heat tissue below the body's surface rapidly. The term "hyperthermia" is used in reference to therapeutic RF heating of cancerous tumors. RF energy is also used in the stimulation of bone healing.

WHAT IS NON-IONIZING RADIATION, AND HOW DOES IT DIFFER FROM IONIZING RADIATION?

The energy associated with electromagnetic radiation depends on its frequency (or wavelength); the greater the frequency (and shorter the wavelength), the higher the energy. Therefore, x-radiation and gamma radiation, which have extremely high frequencies, have relatively large amounts of energy; while, at the other end of the electromagnetic spectrum, ELF radiation is less energetic by many orders of magnitude. In between these extremes lie ultraviolet radiation, visible light, infrared radiation, and RF radiation (including microwaves), all differing in energy content.

Of the various forms of electromagnetic radiation, x-radiation and gamma radiation represent the greatest relative hazard because of their greater energy content and corresponding greater potential for damage. In fact, X-rays and gamma rays are so energetic that they can cause ionization of atoms and molecules and thus are classified as "ionizing" radiation. Ionization is a process by which electrons are stripped from atoms and molecules, producing molecular changes that can lead to significant genetic damage in biological tissue. Less energetic forms of electromagnetic radiation, such as microwave radiation, lack the ability to ionize atoms and molecules and are classified as "non-ionizing" radiation. It is important that the terms, "ionizing" and "non-ionizing," not be confused when referring to electromagnetic radiation, since their mechanisms interaction of the human body are quite different. Biological effects of (non-ionizing) RF radiation are discussed in a later section.

HOW IS RADIOFREQUENCY RADIATION MEASURE?

Since radiofrequency radiation has both an electric and a magnetic component, it is often convenient to express intensity of radiation field in terms of units specific to each component. The unit "volts per meter" (V/m) is used for the electric component, and the unit "amperes per meter" (A/m) is used for the magnetic component. We often speak of an electromagnetic "field," and these units are used to provide information about the levels of electric and magnetic "field strength" at a measurement location.

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 referred to as the "far field" zone of the radiation pattern. In closer proximity to the transmitter, i.e., in the "near field" zone, the physical relationships between the electric and magnetic components of the field can be complex, and it is best to use the field strength units discussed above. Power density is measured in terms of power per unit area, for example, milliwatts per square centimeter (mW/cm^2). When speaking of 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 zone. A detailed discussion of the physics of RF fields and their measurement can be found in Reference 1.

WHAT BIOLOGICAL EFFECTS CAN BE CAUSED BY RADIATION?

There is a relatively extensive body of published literature concerning the biological effects of RF radiation. The following discussion only provides highlights of current knowledge in this area. Detailed information on this topic can be found in References 2-14.

It has been known for some time that high intensities 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 high RF power densities, i.e., on the order of 100 mW/cm^2 or more, can result in heating of the human body and an increase in body temperature. Tissue damage can result primarily because of the body's inability to cope with or dissipate the excessive heat. Under certain conditions, exposure to RF power densities of about 10 mW/cm^2 or more could result in measurable heating of biological tissue. The extent of heating would depend on several factors including frequency of the radiation; size, shape, and orientation of the exposed object; duration of exposure; environmental conditions; and efficiency of heat dissipation. Biological effects that result from heating of tissue by RF energy are often referred to as "thermal" effects.

Two areas of the body, the eyes and the testes, can be particularly susceptible to heating by RF energy because of the relative lack of available blood flow to dissipate the excessive heat load. Laboratory experiments have shown that short-term exposure to 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.

It should be emphasized that environmental levels of RF radiation routinely encountered by the public are far below the levels necessary to produce significant heating and increased body temperature. In fact, the U.S. Environmental Protection Agency has estimated that 98-99% of the population in seven U.S. urban areas studied is exposed to less than 0.001 mW/cm^2 (Reference 15). However, there may be situations, particularly workplace environments, where RF safety standards are exceeded and people could be exposed to potentially harmful levels of RF radiation.

In addition to intensity, the electromagnetic frequency of RF radiation is important in determining the relative hazard. At a distance of several wavelengths from a source of RF radiation, whole-body absorption of RF energy by humans will occur at a maximum rate when the frequency of the radiation is between about 30 and 300 MHz. Because of this "resonance" phenomenon, RF safety standards take this frequency dependence into account. Therefore, as discussed in a later section, the most stringent standards are in this frequency range of maximum absorption.

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 less clear . A number of reports have appeared in the Russian and East European literature claiming a wide range of low-level biological effects. The low-level effects on animals and humans reported in the Soviet and East European literature have included behavioral modifications, effects on the blood forming and immunological system, reproductive effects, changes in hormone levels, headaches, irritability, fatigue, and cardiovascular effects. However, further research is needed to confirm the existence of these effects and to determine whether they might constitute a health hazard, particularly with regard to long-term exposure.

In recent years some Western scientists have also reported biological effects after exposure of animals and animal tissue to relatively low levels of RF radiation. These effects, often referred to as "non-thermal" effects, have included changes in the immune system, neurological effects, behavioral effects, evidence for a link between microwave exposure and the action of certain drugs and compounds, and a "calcium efflux" effect in brain tissue (discussed below). Experimental results have also suggested that microwaves might be involved in cancer "promotion" under certain conditions. However, contradictory experimental results have also been reported in many of these cases, and further experiments are needed to determine the generality of these effects and whether they constitute a threat to human health. It is possible that "non-thermal" mechanisms exist that could cause harmful biological effects in animals and humans exposed to RF radiation. However, whether this is the case remains to be proven.

One of the "non-thermal" biological effects that appears to be reproducible is the "calcium efflux" effect. This effect can be described as the observation that the release of calcium ions from animal brain tissue is enhanced after exposure to certain low intensities of RF radiation under discrete conditions of frequency and signal modulation. This effect has been observed at RF levels well below those necessary to produce heating of tissue . The extent to which this effect might indicate a hazard is not presently known, and further research is needed to determine the relevance, if any, of this phenomenon to human health.

Another RF biological effect that has received attention is the so-called microwave "hearing" effect. Under certain specific conditions of frequency, signal modulation, and intensity, it has been shown that animals and humans can 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 thermoelastic pressure within the head that is perceived as sound by the auditory apparatus within the ear. It is important to emphasize that the conditions under which this effect occurs would not normally be encountered by members of the general public.

WHAT ARE SAFE LEVELS FOR EXPOSURE TO RADIOFREQUENCY/ MICROWAVE RADIATION?

There is disagreement over exactly what levels of RF radiation are "safe," particularly with regard to low levels of exposure. In the Soviet Union and several Eastern European countries occupational and population exposure standards are generally more restrictive than existing or proposed standards in most Western countries. This discrepancy may be due, at least in part, to the likelihood that Russian and East European standards are based on levels where it is believed no biological effects of any sort would occur, rather than where recognized hazards exist. Western standards generally are based on levels where hazards are known to exist, and a safety factor is then incorporated to provide sufficient protection.

In the United States there is currently (early 1989) no official, mandatory federal standard for protection of the public or workers from potentially hazardous exposure to RF radiation. There is a performance standard established by the U.S. Food and Drug Administration for microwave ovens, but that standard is an emission standard (as opposed to an exposure standard) that only defines acceptable levels of RF energy that can be radiated from microwave ovens. Until recently the U.S. Environmental Protection Agency (EPA) was developing federal guidelines ("Federal Guidance") for exposure of the public to RF radiation. However, the EPA recently stated its intention to defer that activity indefinitely.

A federal RF radiation protection guide for workers was issued by the Occupational Safety and Health Administration (OSHA) in 1971 but it was later ruled to be advisory only. This protection guide was based on an earlier RF exposure standard recommended by the American National Standards Institute (ANSI), a non-government organization that develops recommended standards for a variety of applications. To date, OSHA has not updated its 1971 guideline, although its sister agency, the National Institute for Occupational Safety and Health (NIOSH), has been working on a recommended worker standard for RF exposure for several years. There is currently no indication that NIOSH will issue a recommendation in the near future.

In 1982, ANSI issued revised RF protection guidelines based on more recent data on the interaction of RF radiation with the human body. The ANSI protection guide is probably the most widely used and technically supportable exposure standard available today. As discussed in a later section of this bulletin, the FCC now uses the ANSI protection guides for purposes of evaluating environmental impact from the RF transmitters it regulates.

The 1982 ANSI guidelines recommend frequency-dependent exposure limits covering RF frequencies from 300 kHz to 100 GHz (Reference 16). The guidelines Incorporate data showing that the human body absorbs RF energy at some frequencies more efficiently than at others. The most restrictive limits are in the frequency range of 30*-300 MHz where maximum levels of 1 mW/cm^2, as averaged over any six minute period of exposure, are recommended.

The ANSI standard was developed over a period of several years by scientists and engineers with considerable experience and knowledge in the area of RF biological effects and related issues. The recommendations were based on a determination that the threshold f*br hazardous biological effects was approximately 4 watts per kilogram (4 W/kg) ["W/kg" is an expression for the rate of energy absorption in the body given in terms of the "specific absorption rate" or "SAR"]. A safety factor of ten was then incorporated to arrive at the final recommended protection guidelines. In other words, the protection guides can be correlated with an SAR threshold of about 0.4 W/kg.

The guidelines are intended to apply to non-occupational as well as to occupational exposures. However, ANSI states that because of "limitations in the biological effects data base" the guide indicates upper limits of safe exposure, particularly for the general public. It should be noted that ANSI is currently (early 1989) in the process of revising its 1982 standard in light of more recent data on biological effects. Therefore, a new ANSI recommendation may be forthcoming in the next one or two years that could be more restrictive with respect to some exposure situations. In particular, the new guidelines could differentiate between exposure of workers and exposure of the general public using an approach similar to that followed by other standard-setting organizations (see later discussion).

The 1982 ANSI guidelines are summarized in the following table. Note that recommended exposure levels are given in terms of the squares of the electric and magnetic field strengths as well as in terms of power density. For the lower frequencies listed, intensities are best expressed in terms of field strength values, and the indicated power density is essentially a "far field equivalent" power density. At higher frequencies, and when one is in the "far field" of a radiation source at any frequency, the actual power density is an appropriate unit to use. It is important to remember that the ANSI standard is a "time-averaged" standard, i.e., it is permissible to exceed the recommended limits for short periods of time as long as the average exposure (over 6 minutes) does not exceed the limits.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
1982 RADIOFREQUENCY PROTECTION GUIDE

Frequency Range (MHz)	Electric Field Strength E^2 (V^2/m^2)	Magnetic Field Strength H2 (A^2/m^2)	Power Density (mW/cm^2)
0.3-3	400,000	2.5	100
3-30	4,000($900/f^2$)	0.025($900/f^2$)	$900/f^2$
30-300	4,000	0.025	1.0
300-1500	4,000 (f/300)	0.025(f/300)	f/300
1500-100,000	20,000	0.125	5.0

Note: f = frequency in megahertz (MHz)
E^2 = electric field strength squared
H^2 = magnetic field strength squared
V^2/m^2 = volts squared per meter squared
A^2/m^2 = amperes squared per meter squared
mW/cm^2 = milliwatts per centimeter squared

The 1982 ANSI RF protection guide excludes radiating devices with input powers of seven watts or less that operate at frequencies between 300 kHz and 1000 MHz (1 GHz). The guidelines also state that the exposure limits may be exceeded if exposure conditions can be shown to produce specific absorption rates below 0.4 W/kg, as averaged over the whole body, or below 8 W/kg, as averaged over any one gram of tissue.

Other organizations besides ANSI have issued health and safety standards for RF radiation. The National Council on Radiation Protection and Measurements (NCRP) is a nonprofit corporation chartered by the U.S. Congress to develop information and recommendations concerning radiation protection, radiation measurements, and related issues. In 1986, the NCRP issued a report (Reference 11) that contained a review of the literature on biological effects of radiofrequency radiation as well as specific recommendations for exposure of workers and the general public.

The NCRP exposure guidelines differ from the 1982 ANSI protection guide in that separate exposure levels are recommended for workers and for the general public. The NCRP recommendations for worker exposure are essentially the same as the ANSI recommendations. However, NCRP recommended that the average exposure limits for the public be generally one-fifth that of the limits recommended for workers, although the averaging time specified for public exposure was 30 minutes rather than the 6-minute period for worker exposure. The NCRP noted that its two-tiered recommendation was more traditional and consistent with past NCRP practice in differentiating between occupational and public exposure by providing for a greater margin of safety for the general public.

Exposure guidelines have also been issued by the International Radiation Protection Association (IRPA) and by the American Council of Governmental Industrial Hygienists (ACGIH). The IRPA guidelines (Reference 17) are similar to the NCRP recommendations in that a greater degree of protection is recommended for the general public than for workers. The ACGIH guidelines (Reference 18) are basically a modified version of the 1982 ANSI guidelines and only apply to workers.

Largely because of the lack of guidelines from the Federal Government, some local and state jurisdictions have adopted, or have considered adopting, population and/or occupational standards for RF radiation. Local or state RF standards have been established or proposed in Oregon, Washington, Massachusetts, New York and New Jersey. Many of these standards are more restrictive than the 1982 ANSI standard for exposure of the general public.

HOW SAFE ARE MICROWAVE OVENS?

The Center for Devices and Radiological Health (CDRH), a part of the U.S. Food and Drug Administration, has regulated radiation from microwave ovens since 1971. CDRH has established a radiation performance standard for microwave ovens that allows leakage (measured at five centimeters from the oven surface) of 1 mW/cm^2 at the time of manufacture and a maximum level of 5 mW/cm^2 during the lifetime of the oven. The standard also requires ovens to have two independent interlock systems that prevent the oven from generating microwaves the moment that the latch is released or the door of the oven is opened. On the basis of current knowledge about microwave radiation, CDRH believes that ovens that meet its standards and are used according to the manufacturer's recommendations are safe for use.

IS IT SAFE TO USE AN ELECTRONIC CARDIAC PACEMAKER NEAR A RADIOFREQUENCY DEVICE SUCH AS A MICROWAVE OVEN?

In the past there may have been occasional problems due to signals from RF devices interfering with the proper operation of certain implanted electronic pacemakers. Because pacemakers are electronic devices, they can be susceptible to electromagnetic signals that could cause them to malfunction and thereby incorrectly regulate a user's heartbeat. However, it is doubtful that signals from a microwave oven would be strong enough to cause such interference.

This situation has now been largely remedied by the incorporation of electromagnetic shielding into the design of modern pacemakers. This shielding prevents undesirable RF signals from being picked up by the electronic circuitry in the pacemaker. The potential for the "leads" of pacemakers to pick up RF radiation has also been of some concern, but this does not appear to be a serious problem. Patients with pacemakers should consult their physician if they believe that they may have a problem related to RF interference. However, there should be no problem of electromagnetic interference from a properly maintained and operated microwave oven.

HOW SAFE IS THE RADIOFREQUENCY RADIATION EMITTED BY RADIO AND TELEVISION BROADCASTING ANTENNAS?

Radio and television broadcast stations transmit their signals via RF electromagnetic waves. These signals can be a significant source of RF energy in the environment since there are currently over 11,000 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.

Ground-level intensities of the RF electromagnetic fields resulting from broadcast transmissions depend 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. Calculations can be performed to predict what field intensity levels would exist at various distances from an antenna. Since energy at some frequencies is absorbed by the human body more readily than energy at other frequencies, the existence of a possible hazard would depend on the frequency of the transmitted signal as well as the intensity.

Public access to broadcasting antennas is normally restricted so that individuals cannot be exposed to high-level fields that might exist near an antenna. Measurements made by EPA and others (References 15 and 19) have shown that RF radiation levels in inhabited areas near broadcasting facilities are generally well below levels believed to be hazardous. There have been a few situations around the country where exposure levels have been found to be higher than those recommended by applicable safety standards (e.g., Reference 20). But such cases are relatively rare, and few members of the general public are likely to be routinely exposed to excessive levels of RF radiation from broadcast towers.

In unusual cases where exposure levels 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 redesigning an antenna, reducing power, or station relocation.

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 hazardous levels of RF radiation if work is performed on an active tower or in areas immediately surrounding a radiating antenna (References 21 and 22). Therefore, precautions should be taken to ensure that maintenance personnel are not exposed to hazardous field intensities. 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.

IS THERE ANY DANGER FROM POINT-TO-POINT MICROWAVE RELAY ANTENNAS? WHAT ABOUT DISH ANTENNAS USED FOR SATELLITE-EARTH COMMUNICATION?

Point-to-point microwave relay antennas transmit and receive microwave signals across relatively short distances. These antennas are usually rectangular or circular in shape and are normally found mounted at the top or midway up a supporting tower. These antennas have a variety of uses such as transmitting telephone and telegraph messages and serving as links between broadcast or cable-TV studios and their broadcast antennas.

The microwave 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. Such levels are much lower than power levels used, for example, by broadcast stations. Measurements have shown that ground-level power densities due to microwave directional antennas are normally a thousand times or more below recommended safety limits. In fact, an individual would likely have to stand directly in front of such an antenna for a significant period of time in order to be exposed to microwave levels that might be considered harmful. In addition, as an added margin of safety, microwave tower sites are normally made inaccessible to the general public.

Satellite-earth stations consist of parabolic "dish" antennas, some as large as 10 to 30 meters in diameter, that are used to transmit or receive microwave signals via 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 a variety of communications services to be performed, including long distance telephone service.

Since earth-station antennas are directed toward satellites above the earth, the 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 great when compared to those used for the microwave point-to-point relay links discussed above. However, as with the microwave relay links, the beams used for transmitting earth-to-satellite signals are relatively narrow and highly directional. In addition, public access to a station site would normally be restricted. For these reasons it would be unlikely that a transmitting earth-station antenna could expose members of the public to hazardous levels of microwaves. Some earth station antennas are used only to receive RF signals. Since these antennas do not transmit any signals, there would, of course, be no danger of exposure from them.

WHAT ABOUT PORTABLE RADIO TRANSMITTERS? IS THERE MY RISK FROM EXPOSURE TO RF RADIATION FROM HAND-HELD WALKIE-TALKIES, CELLULAR TELEPHONES, VEHICLE MOUNTED ANTENNAS, OR CORDLESS TELEPHONES?

"Land-mobile" communication refers to a variety of communications systems which involve the use of portable RF transmitters. Police radio, business radio, and cellular radio are a few examples of these communications systems. They have the advantage of providing communications links between various fixed and mobile locations. Cordless telephones are consumer products that also make mobility possible in communication, although over shorter distances.

There are basically 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 transmitter must transmit to a relatively large area, and, therefore, its antenna would generally be more powerful than a vehicle-mounted or hand-held radio transmitter.

Although base-station antennas usually operate with higher power levels than the other types of land-mobile antennas, their powers are still quite a bit lower than high-powered transmitters such as most radio and television broadcast stations. Land-mobile base-station antennas 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, base-station antennas have generally not been of concern with regard to possible hazardous exposure to RF radiation.

Transmitting power levels for vehicle-mounted antennas are generally less than those used by base-station antennas but higher than those used for hand-held units. At least one manufacturer recommends that users and other nearby individuals maintain a distance of a few feet from a vehicle-mounted antenna during transmission. However, studies have shown that this is probably a conservative precaution, particularly when the "duty factor" (percentage of time the antenna is actually transmitting) is taken into account since safety standards are "time-averaged." 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 is any safety hazard associated with RF exposure from vehicle-mounted antennas.

Hand-held portable radios such as walkie-talkies and cellular radios are generally low-powered devices used to transmit and receive messages over relatively short distances. Because of the low power levels used (usually only a few watts or less) these radios would normally not be considered as possible sources of hazardous exposure to RF fields. However, questions relating to the safety of these devices have arisen because the RF signal is emitted in the immediate vicinity of the user's head and some of these radios use microwave frequencies.

At least one manufacturer has conducted extensive tests of hand-held radios operating at various frequencies in order to determine the amount of RF energy that might be absorbed in the head of an individual using one of these devices. The only potential hazard found could occur in the unlikely event that the antenna tip was placed directly at the surface of the eye. Other studies (e.g., Reference 23) have concluded that during routine use of hand-held radios exposures would normally be in compliance with accepted safety guidelines. Significant absorption might occur if the transmitting antenna of the radio were placed within a distance of about 1-2 centimeters (less than an inch) from the head or eye. However, this would be a very unlikely user position, and even if it occurred the overall time-averaged exposure would probably be acceptable. Therefore, if hand-held radios are used properly there is no evidence that they could cause hazardous absorption of RF energy.

Cordless telephones are consumer products that use RF energy to communicate with a telephone "base" unit. These devices operate at very low power levels, and there is no evidence that users experience any significant RF exposure.

WHICH FEDERAL AGENCIES HAVE RESPONSIBILITIES RELATED TO HEALTH EFFECTS OF RADIOFREQUENCY RADIATION?

Several agencies in the Federal Government have been involved to various degrees in investigating or controlling human exposure to RF radiation. By authority of the Radiation Control for Health and Safety Act of 1968, the Center for Devices and Radiological Health (CDRH) of the U.S. Food and Drug Administration (FDA) develops performance standards for the emission of radiation from electronic products including X-ray equipment and other medical devices, television sets, microwave ovens, and sunlamps. As discussed previously, CDRH has established a radiation safety standard for microwave ovens that limits the amount of radiation that an oven can leak throughout its lifetime. However, leakage standards have not been issued for other RF-emitting devices.

The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor is responsible for protecting workers from exposure to hazardous chemical and physical agents. In 1971, OSHA issued a protection guide for exposure of workers to RF radiation [29 CFR 1910.97]. The guide, covering the frequency range between 10 MHz and 100 GHz, stated that exposure of workers should not exceed a power density of ten milliwatts per square centimeter (10 mW/cm^2) as averaged over any 6-minute period of the workday. However, this guide was later ruled to be only advisory and not mandatory. Moreover, it was based on an earlier (1966) American National Standards Institute (ANSI) RF protection guide that has been superseded by revised versions in 1974 and 1982 (see previous discussion of standards).

The National Institute for Occupational Safety and Health (NIOSH) of the U.S. Department of Health and Human Services has for some years been considering issuing a recommendation for occupational exposure to RF radiation that would be transmitted to OSHA for consideration in establishing an exposure standard for workers. However, at the present time (early 1989) there is no indication from NIOSH as to when such an official recommendation might be forthcoming.

There is currently no official federal standard for exposure of the general public to RF radiation. It is generally agreed that federal responsibility for developing national guidelines for public exposure to non-ionizing radiation rests with the U.S. Environmental Protection Agency (EPA). Until recently, EPA was developing "Federal Guidance" for RF radiation that would have recommended safe levels of exposure for the public. If approved, such a recommendation would have been transmitted to other federal agencies for implementation. However, as noted previously, EPA has apparently decided to abandon that effort and to "defer" indefinitely its program dealing with non-ionizing electromagnetic radiation due to budgetary constraints and a lack of resources. At press time it was unclear whether that decision might be reversed.

WHAT IS THE ROLE OF THE FCC IN EVALUATING POTENTIAL RADIOFREQUENCY HAZARDS?

The FCC licenses and approves equipment and facilities that generate RF and microwave radiation. Although the FCC would not knowingly authorize a facility or device that resulted in a health hazard, the FCC's primary jurisdiction does not lie in the health and safety area. Therefore, the FCC must rely on other agencies and organizations for guidance in these matters.

The issue of potential hazards due to RF radiation emitted by FCC regulated facilities was first addressed by the Commission in a 1979 Notice of Inquiry. Subsequently, several other items related to RF radiation hazards have been approved by the Commission. The FCC's basic policy was outlined in a 1985 Report and Order [50 Fed. Register 11151, 1985].

As an agency of the Federal Government, the FCC has certain responsibilities under the National Environmental Policy Act of 1969 (NEPA) to consider whether its actions will "significantly affect the quality of the human environment." Therefore, FCC approval and licensing of facilities and operations must be evaluated for significant impact on the environment. The 1985 FCC Order made clear that human exposure to RF radiation emitted by FCC-regulated entities is one of several factors that must be considered in such environmental evaluations.

In making the determination that environmental RF radiation would be evaluated, the Commission decided to specify the 1982 ANSI RF radiation protection guides (see earlier discussion of standards) for use in determining safe levels of exposure for the public and for workers. It was decided that, in view of the lack of an official standard issued by a federal agency such as EPA, the FCC must use what it considered to be the best available standard at the time. The 1982 (non-government) ANSI standard was chosen because it was considered to be widely accepted and technically supportable.

Because of the 1985 FCC Order and subsequent adopted items, major RF transmitting facilities under the jurisdiction of the FCC, such as radio and television broadcast stations, satellite-earth stations, and experimental radio stations, are subject to environmental evaluation for compliance with the identified RF health and safety guidelines. Failure to comply with these guidelines could lead to preparation of a formal Environmental Impact Statement and possible rejection of an application for a transmitting facility. Facilities and operations that operate with lower power levels or are judged to offer insignificant environmental risk from RF radiation have been categorically exempted from these requirements.

The FCC's rules on evaluation of environmental RF radiation are found in Section 1.1307(b) of the FCC's Rules and Regulations [47 CFR 1.1307(b)]. Guidelines for compliance with the FCC's rules can be found in an FCC technical bulletin (OST Bulletin No. 65, Reference 24). Subsequent FCC items adopted since the first Order have dealt primarily with which RF sources are subject to the RF environmental rule and which are excluded [52 Federal Register 13240, 1987; 52 Federal Register 49032, 1987; 53 Federal Register 28223, 1988; 53 Federal Register 40918, 1988].

WHERE CAN FURTHER INFORMATION BE OBTAINED REGARDING RADIOFREQUENCY RADIATION AND RELATED MATTERS?

Within the Federal Government the number of individuals assigned to this area is relatively small, and some agencies are reducing or eliminating personnel in this field. Nevertheless, it is usually possible to obtain at least some basic information concerning RF transmitters or problems. The following federal agencies should be able to provide some information and assistance in this area.

FDA: Questions about radiation from microwave ovens and other consumer and industrial products can be directed to: Center for Devices and Radiological Health (CDRH), Food and Drug Administration, Rockville, MD 20857.

EPA: The Environmental Protection Agency's Office of Radiation Programs (401 M. St., S.W., Washington, D.C. 20460 or P.O. Box 98517, Las Vegas, Nevada 89193-8517) studies exposure of the public to RF radiation. However, at the present time (early 1989) EPA has apparently decided to phase out the Washington office that deals with RF exposure and to limit future EPA activities in this area to its Las Vegas office.

OSHA/NIOSH: The Occupational Safety and Health Administration's (OSHA) Health Response Team (390 Wakara Way, P.O. Box 8137, Salt Lake City, Utah 84108) has been involved in studies related to occupational exposure to RF radiation in the past.

However, OSHA has limited involvement in this area at the present time. The National Institute for Occupational Safety and Health (NIOSH) maintains a limited program for studying exposure of workers to non-ionizing radiation. The address is: NIOSH, Physical Agents Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

FCC: The FCC maintains a limited program in this area. Questions regarding potential RF hazards from FCC-regulated transmitters can be directed to the Spectrum Engineering Division, Office of Engineering and Technology, FCC, Washington, D.C. 20554.

In addition to federal agencies, there are other sources of information and possible assistance regarding environmental RF energy. A few states maintain non-ionizing radiation programs or, at least, some expertise in this field. These state activities are usually part of a department of public health or environmental control. Also, the list of references at the end of this bulletin should be consulted for detailed information on specific topics related to RF exposure.

A non-government source of information on RF energy is the Electromagnetic Energy Policy Alliance (EEPA), an organization that provides educational and other services in this field. EEPA is an association of manufacturers and users of electronic and electrical systems. The group's self-described purpose is "to work for a responsible and rational public policy regarding electromagnetic energy." EEPA's address is: 1255 23rd St., N.W., Washington, D.C. 20037.

REFERENCES

[Reports with NTIS Order Numbers are U.S. Government publications and can be ordered for a fee from the National Technical Information Service, U.S. Department of Commerce, (800) 336-47001]

(1) "Radiofrequency Electromagnetic Fields; Properties, Quantities and Units, Biophysical Interaction, and Measurements," NCRP Report No. 67, 1981. National Council on Radiation Protection and MeasurementshePurchasing information: NCRP Publications, 7910 Woodmont Ave., Suite 1016, Bethesda MD 20814; (301) 657-2652.

(2) "Symposium on Health Aspects of Non-ionizing Radiation,"Bulletin of the New York Academy of Medicine, Vol. 55 (11), December 1979.

(3) "Biological Effects and Medical Applications of Electromagnetic Energy," Proceedings of the IEEE, Vol. 68 (1), January 1980.

(4) Gandhi, O.P., "Biological Effects and Medical Applications of RF Electromagnetic Fields," IEEE Transactions on 30(11):1831 (1982).

(5) Cleary, S. F., "Microwave Radiation Effects on Humans," BioScience, 33(4): 269 (1983).

(6) Petersen, R.C., "Bioeffects of Microwaves: A Review of Current Knowledge," Journal of Occupational Medicine, 25(2): 103 (1983).

(7) Lerner, E.J., "The Drive to Regulate Electromagnetic Fields," IEEE Spectrum, March 1984, p. 63.

(8) Steneck, N.H., Ed., Risk/Benefit Analysis: The Microwave Case, 1982, San Francisco Press, San Francisco, CA 94101.

(9) "Biological Effects of Radiofrequency Radiation," Report No. EPA-600/8-83-026F, 1984, U.S. Environmental Protection Agency, NTIS Order No. PB85-120848.

(10) Steneck, N.H., The Microwave Debate, MIT Press, 1984, Cambridge, MA.

(11) "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, 1986. National Council on Radiation Protection and Measurements. Purchasing information: NCRP Publications, 7910 Woodmont Ave., Suite 1016, Bethesda, MD 20814; (301) 657-2652.

(12) Foster, K.R., and A.W. Guy, "The Microwave Problem," Scientific American, 255(3): 32 (September 1986).

(13) Gandhi, O.P. (ed.), "Biological Effects of Electromagnetic Radiation," IEEE Engineering in Medicine and Biology," 6(1): 14-58 (March 1987).

(14) Yost, Michael G., "Non-ionizing Radiation Questions and Answers," 1988. San Francisco Press. Copies may be purchased from: San Francisco Press, Inc., Box 6800, San Francisco, CA 9410l-6800.

(15) Athey, T.W . , et al. , "Radiofrequency Radiation Levels and Population Exposure in Urban Areas of the Eastern United States," Tech. Report EPA520/2-77-008, 1978, U. S. Envtl. Prot. Agency, [NTIS Order No. PB 292 855).

(16) "American National Standard Safety Level with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 Ghz," ANSI C95.1-1982. American National Standards Institute, 1430 Broadway, New York, NY 10018. Purchasing information: (212) 354-3300.

(17) "Guidelines on Limits of Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 100 kHz to 300 GHz, "Health Physics, 54(1): 115-123 (1988).

(18) "Threshold Limit Values for Chemical Substances in the Work Environment Adopted by ACGIH for 1983-1984; Radiofrequency/Microwave Radiation." American Conference of Governmental Industrial Hygienists (ACGIH), 1983. ACGIH, 6500 Glenway Ave., Bldg. D-5, Cincinnati, Ohio 45211.

(19) Tell, R. A., and E. D. Mantiply, "Population Exposure to VHF to UHF Broadcast Radiation in the United States," Technical Note ORP/EAD 78-5, June 1978, U. S. Environmental Protection Agency [NTIS order No. PB 284 637].

(20) "An Investigation of Radiofrequency Radiation Levels on Lookout Mountain, Jefferson County, Colorado," Electromagnetics Branch, U.S. Environmental Protection Agency, Las Vegas, NV 89114, February 1987.

(21) Curtis, Robert A., "Occupational Exposures to Radiofrequency Radiation from FM Radio and TV Antennas," in Non-Ionizing Radiation: Proceedings of a Topical Symposium, 1980, ACGIH, Cincinnati, OH 45201.

(22) Tell, R. A., "A Measurement of RF Field Intensities in the Immediate Vicinity of an FM Broadcast Station Antenna," Technical Note ORP/EAD-76-2, 1976, U. S. Environmental Protection Agency, [NTIS order No. PB 284 637].

(23) Cleveland, R.F., Jr., and T. W. Athey, "Specific Absorption Rate (SAR) in Models of the Human Head Exposed to Hand-Held UHF Portable Radios," Bioelectromagnetics, Volume 10(2), 1989 (in press).

(24) "Evaluating Compliance with FCC-Specified Guidelines for Human Exposure to Radiofrequency Radiation," OST Bulletin No. 65, 1985, Federal Communications Commission, Washington, D.C. 20554. NTIS Order No. PB86-127081.