Proceedings of the International Conference on Non-Ionizing Radiation at UNITEN (ICNIR 2003)
Electromagnetic Fields and Our Health
20th 22nd October 2003

High Frequency Radiation and Human Exposure

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INTRODUCTION

In many applications, electromagnetic waves are generated and travel through free space at the speed of light. Radio waves and microwaves emitted by transmitting antennas are one form of electromagnetic energy. This electromagnetic energy is characterized by its frequency (in Hz) and wavelength. Radio frequency waves occupy the frequency range 3 kHz to 300 GHz. Microwaves are a specific category of radio waves that cover the frequency range 1 GHz to approximately 100 GHz.

RF and microwave radiation is non-ionizing because the energy levels associated with it are not high enough to cause ionization of atoms and molecules.

The most important application of RF energy is in providing telecommunication services. These applications include radio and television broadcasting, cellular telephony, personal communication services (PCS), cordless telephones, business radio, radio communications for the police, amateur radio, microwave point-to-point links and satellite communications. Other applications of microwaves utilize its heating properties. Microwave cooking is a good example of a non-communication use of RF energy. This application utilizes the efficient absorption of microwave energy in the water molecules of food which results in rapid heating through out the object material. Other applications include radar, which is used in traffic enforcement, air traffic control and other military applications. Industrial heating and medical applications are examples of other applications.

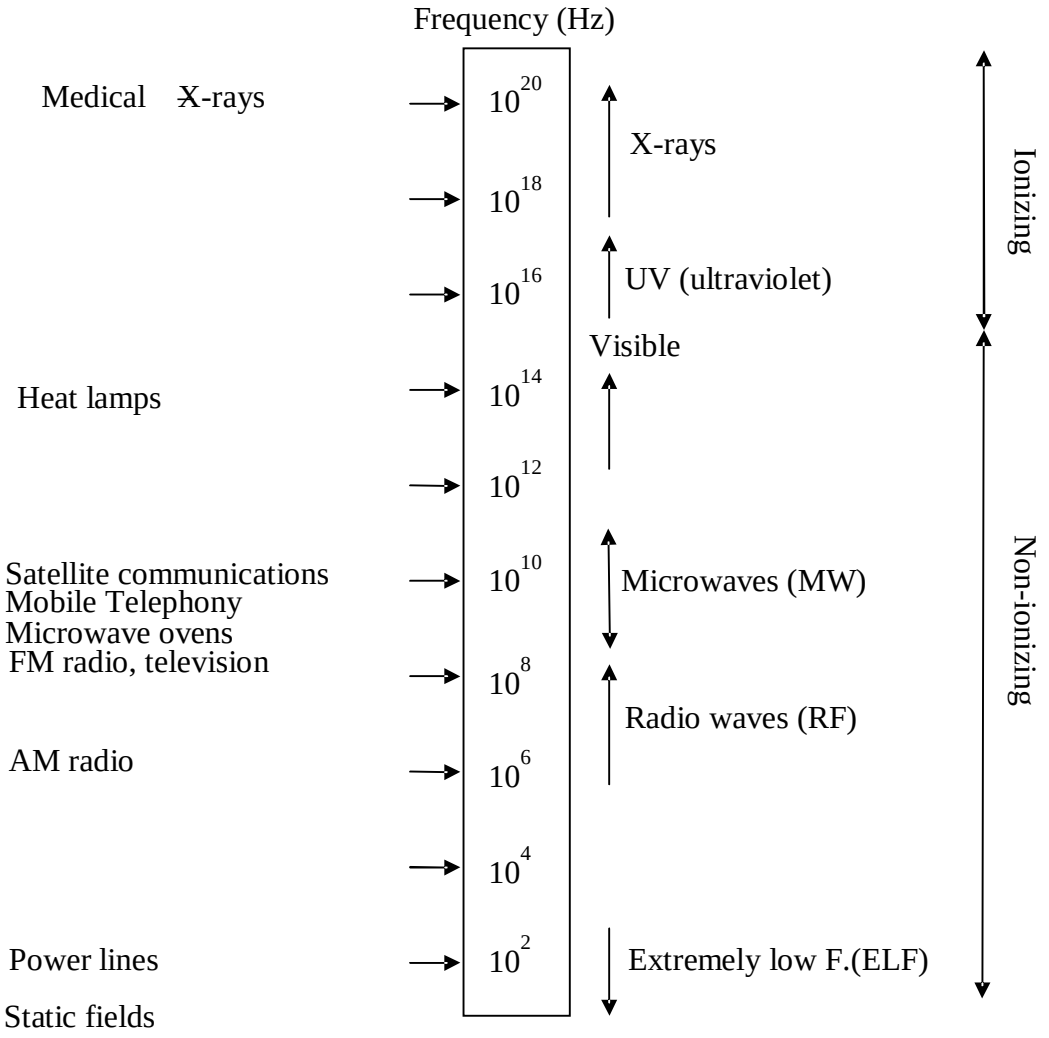
Radio frequency spectrum spans the range of 3 kHz to several hundred GHz. The most utilized range is the microwave range, which can be defined as 1 GHz to @40 GHz. Most of modern point to point, wireless, and satellite communications occupy this range.

The possible effects on human health of exposure to radio frequency and microwave radiations are of public concern near the locations of radio and television transmitters, mobile base stations, wireless networks and the like. It has been the utmost concern to investigate the non-ionizing radiation levels that result from these sources and their effects on humans. Several studies have been initiated all over the world to determine the safe levels of exposure to RFR (Radio Frequency Radiation) for occupational workers and general public. Several guidelines and standards have been issued by ANSI/IEEE, ICNIRP, NCRP, and other organisations.

This presentation will include an overview of classification of the concerned high frequency range and their applications. The sources of concerns to human exposure consist of mobile phones and their base stations, radio and television transmitters and personal communication systems.

THE ELECTROMAGNETIC SPECTRUM

Radio waves used for communications can be classified according to the type of application. It starts from approximately 300 kHz for long wave radio up to around 300 GHz. The electromagnetic spectrum is illustrated in the following figure.



The Electromagnetic spectrum

Continuous wave energy radiated by antennas oscillates at radio frequencies. The associated waves range in length from thousands of meters at the long wave extreme to fraction of a

millimetre at the short wave extreme. The relationship between wavelength and frequency for the different frequency ranges as follows:

Band	Frequency	Wavelength
ELF	30-300 Hz	10-1 Mm
VLF	3-30 KHz	100-1 Km
LF	30-300 MHz	1 Km-100M
HF	3-30 MHz	100-10m
VHF	30-300 MHz	10-1m
UHF	300-3000 MHz	1m-10 cm
SHF	3-30 GHz	10-1 cm
EHF	30-300 GHz	1 cm-1 mm

The following table shows the main application in each frequency range.

AM broadcast band	535-160 kHz
Short wave radio	3-30 MHz
FM broadcast band	88-108 MHz
VHF TV (2-4)	54-72 MHz
VHF TV (5-6)	76-88 MHz
UHF TV (7-13)	174-216 MHz
UHF TV (14-83)	470-890 MHz
Microwave Radio links and Satellite Communication	1GHz-20 GHz
Mobile Telephony	800 MHz-3GHz

In these frequency bands, suitable transmitting and receiving antennas are used to provide the required coverage range for the particular application.

Different classes of transmitting antennas are used which range in electrical size from a fraction of the wavelength to many wavelengths. Their radiation coverage range from omni-directional, which are mainly wire antennas to directive antenna arrays. Mobile base station antennas provide wide coverage in the horizontal plane and several antennas are used to cover the whole range of the cell.

RADIO AND TELEVISION TRANSMITTERS

Radio and TV terrestial transmitters provide an omni-directional coverage area in order to serve the whole population around the site. Omni directional radiating antenna is used for this purpose. Usually a restricted zone around the transmitting antennas is provided to limit the exposure of the general public to the electromagnetic waves with relatively high concentration of energy. Measurements of power density can be performed around such sites

in order to verify that the exposure levels of the general public are within the maximum permissible exposure levels.

The calculated power densities around the antenna site can be performed from a knowledge of the types of antennas used. Verification of these results can be confirmed by a measurement program using the appropriate instruments.

An example of a studied radio transmitter s'site radiation levels is described here. Predicted and measured power densities were obtained for radio transmitter built inside a residential area. The site contained two types of antennas.

(a) Omni directional short dipole antennas used for AM broadcasting with maximum radiated power of 10 kW, and operating in the frequency range (415-515 kHz),

(b) A high gain log periodic antennas with gain of 14.2 dB and operating in the frequency range (4-30 MHz).

The power densities were calculated in the direction of maximum radiation to ensure the worst case situation and to yield the maximum power densities that will result in any horizontal direction away from the antenna site.

The predicted power density levels were calculated at distances of 10, 75, and 100 meters from the radiation sources. These distances were chosen to account for the real distances of the road, residential areas and educational building around the site. The calculated power densities were as follows:

1. Omni directional AM antenna

$$W = \frac{P}{4\pi R^2} G_t$$

where

W is the power density in W/m^2
P is the transmitted power in W
R is the distance from the antenna in m, and
G_t is the gain of the short dipole.

The results are given in the following table:

R	W (mW/cm^2)
10	1194
75	21.2
100	11.94

The log periodic high gain antenna gave the following results:

R	W (muW/Cm^2)
10	26390
75	468.5
100	263.9

These values for the high gain antenna refer to the intended direction of maximum radiation and decay rapidly away from that direction at a rate depending on the shape of the radiation pattern of the particular antenna.

A set of measurements were performed around the site and the maximum power density found was 52 mW/Cm^2. This confirms that the operational levels were below the predicted ones.

MOBILE TELEPHONE BASE STATIONS

Mobile phone base stations may be considered as relatively low-power multi channel two way radio systems. They comprise transmitter and receiver systems and the transmit-receive antennas. These antennas produce radio frequency radiation and they expose people near them to electromagnetic radiation. The exposure levels are generally low, because the communication system made up from the mobile phone and base station is considered low-power system. The consensus of the scientific community is that the power from these mobile base stations antennas is far too low to produce health hazards as long as the general public are kept away from direct access to the antennas. It is also important to differentiate between the antennas that produce the RF radiation and the towers (or masts), which are the structures that support the antennas.

The concern about human health effects is more for the hand-held mobile phones rather than the base stations. This concern is because the mobile phone antennas delivers much of their RF energy to very small volumes of the user s body.

SAFETY GUIDELINES FOR RF RADIATION

Safety guidelines for exposure of the public to the RF radiation from transmitting antennas are set by different organizations all over the world. The most widely accepted standards are those developed by the Institute of Electrical and Electronics Engineers (IEEE) and American National Standards Institute (ANSI), the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the National Council on Radiation protection and Measurements (NCRP).

These standards are expressed in power density in (mW/Cm^2). The 1992 ANSI/IEEE exposure standard for the general public is 1.2 mW/Cm^2 for antennas operating in the 1800-2000 MHz range. The limit for antennas operating in the 900 MHz range is 0.57 mW/Cm^2. The ICNIRP standards are slightly lower and the NCRP standards are identical.

The Federal Communications Commission (FCC) guidelines include standards for mobile base stations antennas which are essentially the same as the (ANSI/IEEE). In the presence of multiple antennas, these standards apply to the total power produced by all antennas.

The measurement programs that were conducted in the United Kingdom and Canada near schools showed that the measurements were below the maximum limits set by the different standards. The maximum measured RF levels in the Canadian schools were between 0.00001 mW/cm^2 and 0.0026 mW/cm^2. the Canadian standard is less than 0.57 mW/cm^2.

In the UK, measurements were performed at 118 publicly accessible sites around 17 mobile phone base stations. The maximum exposure at any location was 0.00083 mW/cm^2. Typical power densities were less than 0.00001 mW/cm^2. This is less than 0.01% of the ICNIRP public exposure guidelines. When RF radiation from all sources was taken into account, the maximum power density at any site was less than 0.2% of the ICNIRP public exposure guidelines.

The RF levels produced by mobile base stations that can produce known biological effects are summarized in the following table:

100 mW/Cm^2	Clear Hazard
40 mW/Cm^2	Reproducible effects
4 mW/Cm^2	Unconfirmed reports of effects
1 mW/Cm^2	FCC public exposure standard (2000 MHz)
0.5 mW/Cm^2	FCC public exposure standard (00 MHz)
0.01 mW/Cm^2	Maximum near a cell phone tower
0.0002 mW/Cm^2	Typical near a modern phase tower

CONCLUSION

High frequency radiation exists in free space around us from an increasing number of sources and cover a wide range of the electromagnetic spectrum. By for the most important and rapidly expanding source is the mobile phone base stations. Fortunately, the radiated power densities around these base stations are below the standard limits set by the different world organizations. It is important to take care in the design of new base stations to meet the guidelines set for the antennas and their mounting so that the minimum required distance can be observed for the public access. New trends in the design of such antennas such as the smart antenna concept, can be applied in order to further reduce the radiation power levels.

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