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Biological effects of RF/ MW radiations on human

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ABSTRACT

In this article, the biological effects of RF and MW radiations (3 kHz–300 GHz) are discussed with emphasis on potential hazards. Most of the modern communication equipment occupies the range 1-40 GHz. A person is supposed to expose near the locations of radio, television transmitters, mobile base stations and wireless networks. This paper investigates the possible effects on human health of exposure to RF / MW radiations. The suggestions / rules framed by different international organizations are briefly sketched in this article.

Key words: Dielectrophoretic forces, electroporation , Microwave (MW), Specific absorption rate (SAR), Radio Frequency (RF).

INTRODUCTION

RF and MW radiations are usually treated together due to similar in characteristics. The Radiofrequency (or RF) and Microwave (MW) Radiation refer to electromagnetic fields with frequencies between 300 kHz -300 MHz and 300 MHz-300 GHz respectively.

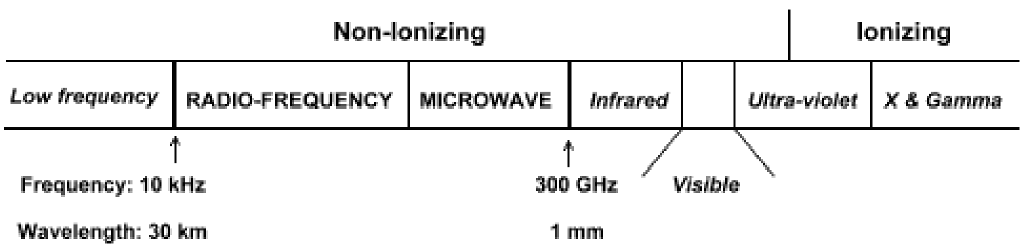

Fig. 1. Spectrum of Electromagnetic Radiations

The most important application of RF/MW found in various communication systems, and microwave heating. The 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.

Most of the modern point to point, wireless, and satellite communications occupy the range 1 GHz to 40 GHz. This paper investigates the possible effects on human health of exposure to radio frequency and microwave radiations. The source of radiation may be from radio and television transmitters, mobile base stations, wireless networks and the like.

Several studies have been initiated all over the world to determine the safe levels of exposure [1-5] 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 organizations.

The paper presents the concept in different sections and subsections. Section II discusses the materials and methods. It presents the concept through subsections like RF radiation & electrical characteristics of tissues, technical terms associated with exposure & dose and classification of human exposure to RF and MW radiations. Section III deals with results and discussion of the RF/MW radiations through the subsections like biological effects of RF and MW radiations, adverse effect of RF on humans, Radiation from TV, radio, mobile base stations and, Exposure limits, safety guidelines for RF radiation. The paper concludes with the conclusion which is addressed in section IV.

This paper basically investigates the effect of radiation from different electronic equipments on human.

MATERIALS AND METHODS

In this section different issues connected to the materials and methods associated with the radiation exposure study is presented in different subsections.

A. RF Radiation and Electrical Characteristics of Tissues

In bioscience, *exposure* is the concentration or a potentially toxic agent in the external environment of a subject. The *dose* is the concentration of the substance in target tissues. Similarly, in RF and MW engineering field levels and those induced in the body corresponds to exposure and dose. The effect of RF and Microwave radiation on the human body depends on the field characteristics like frequency, polarization, and field strength of the source as well as the electrical characteristics of the biological target [1-3].

The dielectric properties of tissue are dispersive in nature and its characters changes as the frequency of radiation changes [6]. This change is accounted due to the charging of cell membranes, dipolar losses in tissue water, and other effects. Charging of cellular membranes is chiefly responsible for the dispersion observed in tissue at megahertz (MHz) frequencies and below. Where as dipolar relaxation of tissue water is the dominant source of dispersion above ~1 GHz. Above ~100 MHz the tissue water content is the chief factor determining the dielectric properties of soft tissues.

B. Technical terms associated with exposure and dose

These technical terms namely exposure and dose [6] will be defined differently for the near fields and external fields.

For external fields:

- E_o, measured in volts/meter (electric field) or amperes per meter (A/m) (magnetic field) used mainly at frequencies below 100 MHz in the near field of the antenna.
- Incident power density S, in W/m^2 used principally at frequencies above 0.5 GHz or in the far fields of radiators.

For Internal fields:

- Current density within the body J_i (in A/m^2), used principally in the frequency range up to 10 MHz; a related measure is internal field strength E_i (V/m), which is related to the current density by Ohm's law.

$$J_i = \sigma E_i \qquad (1)$$

- Total current passed into tissue J, used chiefly to characterize contact currents, principally in the frequency range up to 100 MHz.
- Internal electric field strength E_i, specifically, the electric field induced within body tissues, the induced current density J_i in A/m^2.
- Specific absorption rate (SAR), defined as the power dissipation in watts per kilogram of tissue. In terms of the electric field, E_i in the tissue is depicted in (2).
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$$SAR = \frac{\sigma \left| E_i^2 \right|}{\rho} \qquad (2)$$

Where, ρ is the density of the tissue in (kg/m^3). The SAR can be expressed as a point value at a given instant in time. A value averaged over a specified time and distance, or a value averaged over the whole body of an animal (the whole-body SAR).

SAR is the preferred quantity for RF fields, particularly over the frequency range 100 kHz–10 GHz due to the absorption of tissues. In the frequency range of 300 MHz – 10 GHz specific energy absorption (S.A.) is used. The total absorbed energy in a pulse per kilogram of tissue signifies the S.A.

C. Classification of human exposure to RF and MW radiations

The human exposure [1-6] to the RF and MW radiations can be classified as contact exposure, Near-field exposure, Far-field exposure.

In contact exposure, RF currents are passed into the body when a subject touches a conductive object in the presence of a field. For example, contact currents induced by touching broadcast transmission towers or secondary metallic structures near the towers can induce hazardous contact currents. The magnitude of the contact current is a function of source impedance and the impedance of the subject to be grounded, and is not simply related to the field strength in the vicinity of the subject.

In localized regions near RF sources, very high RF fields can exist, possibly at acutely hazardous levels. Sources include medical equipment (such as magnetic resonance imaging (MRI) scanners), industrial equipment (e.g., induction heaters or microwave drying equipment), radar and broadcast transmitters [7-11].

In a typical far-field exposure scenario, plane-wave energy is incident on large areas of the subject's body. This exposure is important because of public concern about possible health hazards from broadcast transmitters. It is also important in some occupational exposure settings like workers near radar transmitters.

Computer aided exposure models are designed for research. Various parts of the human body exhibit their own resonance; for example, the head exhibits an antenna [6] resonance at approximately 1 GHz.

RESULTS AND DISCUSSION

In this section the results of effect of RF and MW radiation on human is presented in different subsections with the discussion of the mechanism at appropriate places.

A. Biological effect of RF and MW radiations

The energy of photons of radio frequency and microwave fields is unable to disrupt the weakest chemical bonds and to create free radicals. These fields being non-ionizing, in contrast to ionizing radiation such as X rays or ultraviolet light which, disrupt chemical bonds and create highly reactive free radicals.

RF fields can interact with biological systems by exerting forces on charges in tissues [6]. These forces act in the presence of random thermal agitation. The absorbed power in tissues will also generate heat and increase the local temperature and hence affect the biological system. An additional heat load on the body due to exposure to RF energy can also elicit effects due to thermoregulatory responses. The natural rate of power generation in the human body (the basal metabolic rate) is about 1 watt per kilogram of the body mass. Addition of heat by a RF field at levels comparable to or above this rate can produce significant physiological effects.

a. Thermal Mechanism

Thermal mechanisms arise from the deposition of power in the biological systems. The duration of exposure can influence the rate of cooling of the tissue by blood flow, and other factors. The local heating effects in tissue can become significant or even damaging. These include a variety of biological changes and, at sufficient heating levels, leads to Frank tissue damage. Pulsed microwave energy will generate acoustic transients in tissue by transient heating of tissue water with corresponding thermal expansion. Consider a situation when the head is exposed to few microsecond pulses of RF energy with a carrier frequency near 1 GHz, and peak field intensities above 10,000 W/m^2. The pulses produce transient increases in tissue temperature of a few micro degrees, at a high rate. This is sufficient to produce acoustic transients in the head in excess of 100 dB peak sound pressure [5].

b. Non Thermal Mechanism

This is accounted due to the electric fields that can exert forces on charges, and magnetic fields exert torques on magnetic dipoles in biological systems. Shocks and other membrane excitation occur due to this interaction.

Electric fields can create pores in cell membranes (electroporation) by inducing electrical breakdown. This requires membrane potentials of ~1V, which in turn requires tissue field strengths that can exceed 10^4–10^5 V/m. Electric fields exert forces on ions and torques on permanent dipoles, as well as forces and torques on induced dipoles (dielectrophoretic forces). This concept has some important applications in biotechnology.

B. Adverse effect of RF/MW radiations on humans

The nature and the degree of the health effects of overexposure to RF/ MW fields depend on the frequency and intensity of the fields, the duration of exposure, the distance from the source, any shielding that may be used, and other factors.

The main effect of exposure to RF/MW fields is heating of body tissues as discussed in the previous sections. Prolonged exposure to strong RF / MW fields may increase the body temperature, in extreme case's heat stroke. Localized heating, or "hot spots," may lead to heat damage and burns to internal tissues. Hot spots can be caused by non-uniform fields, by reflection and refraction of RF/MW fields inside the body, or by the interaction of the fields with metallic implants, for example, cardiac pacemakers or aneurism clips. There is a higher risk of heat damage with organs, which have poor temperature control, such as the lens of the eye (Cataract) and the testes.

Some laboratory studies have reported biological effects from RF / MW radiation at field levels, which are too low to cause tissue heating. To date, these non-thermal effects are not known to result in health hazards. Although we are constantly exposed to weak RF fields from radio and television broadcasting, no health risks have been identified from this low-level exposure [7-11].

C. Radiation from TV, Radio, Mobile base stations and exposure limits

Radio and TV terrestrial transmitters provide omni-directional broadcasting. The whole population around the coverage area is supposed to exposure of electromagnetic waves with relatively high concentration of energy. Similarly, the Mobile phone base stations may be considered as relatively low-power multi channel two-way radio systems. 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 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 deliver much of their RF energy to very small volumes of the user's body.

Exposure limits for RF / MW radiation are designed to keep the RF/ MW energy absorbed by the body well below the lowest levels associated with demonstrated adverse effects, and to reduce the likelihood of contact shocks and burns.

Table 1 Sources of RF / MW Radiations

Sources of RF / MW Radiation		
Source	**Frequency (MHz)**	**Potential for Over-exposure?**
Video Display Terminal (VDT)	0.015 – 0.3	No
Dielectric Heater	1 – 100 (typically 27.12)	Yes
Diathermy Applicator	13.56, 27.12, 915, 2450	Yes
Transmitters: AM Radio	0.535 - 1.605	Yes
Transmitters: FM Radio	88 – 108	Yes
Transmitters: VHF TV	54-72, 76-88, 174-216	Yes
Transmitters: UHF Radio	470 – 890	Yes
Transmitters: Dish Antenna	800 - 15,000	Yes
CB Radio	27.12	Yes
Cordless Telephone	46- 49	No
Cellular Telephone	824 – 850	No
Traffic Radar	10,500 and 24,000	No
Microwave Oven	915 and 2,450	No*
**During repair work, there is a risk of overexposure to microwave radiation.*		

D. Safety Guidelines for RF radiation and controlling

Safety guidelines for exposure of the public [11] to the RF radiation from transmitting antennas are set by different organizations all over the world. The most widely accepted standards [12-14] 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 station's antennas, which are essentially the same as the (ANSI/IEEE). Total powers produced by all the antennas are taken into account in the presence of multiple antennas.

It will be better to control the RF / MW radiations. The controlling engineering point of view will take care of minimization of radiation from the design of the radiator, there can be administrative control to formulate rules for the radiations and personal protection taken by the person concern who supposed to be exposed to dangerous radiation.

CONCLUSION

The radiation generated from different RF / MW radiators are harmful to the human. The interaction of this radiation of the human tissues is addressed in this paper. 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. The radiation level can be further reduced using the smart antenna concept. There is scope of further research and development.

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