

# Human Health Effects from Radiofrequency and Microwave Fields

Asma Lak

Young Researchers Club, Bushehr branch, Islamic Azad University, Bushehr, Iran.

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## ABSTRACT

In this paper we talk about probable biological effects of electromagnetic fields of mobile communication and other source of Radiofrequency (RF) and Microwave (MW) fields. Probable effects i.e. thermal and non thermal are described. The thermal biological effects of fields on eye and skin are considered and some non thermal effects such as Blood Brain Barrier, RF hearing, behavioral effects and immune system are considered too. There are many standards for human health safety. In this paper we are introduced some of them, such as FCC, ICNIRP and ANSI/IEEE. Also the recommendations for human health protection are suggested.

**KEYWORDS:** – RF/MW, electromagnetic fields, mobile phone, Biological effects.

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## 1. INTRODUCTION

Today's the mobile communication service is an essential part of human's life. User acceptance of these new technologies has been worldwide. There are many factors that influence the interaction between electromagnetic fields and human tissues for example field frequency and configuration of exposure source, dielectric properties, age, exposure environment, field strength, time intensity factor, geometry and size of tissue, orientation and field polarization [1], [2].

In this paper we talk about the probable health effects on human body at mobile communication and microwave frequency fields.

When the body can't cancel the high temperature of tissues by the normal biological activity of the body, such as the blood flow and sweating, adverse health effects occur. Some researchers have shown that the biological mechanism, such as Blood Brain Barrier (BBB), DNA strand breakage, cancer, brain tumor, pearl, buzzing in the ears may occur. [3]

The biological effects of microwaves and radiofrequency fields depend on the dielectric field inside the body. The internal fields should be determined for establishing a good restriction database for human health protection. Evaluation of the interactions of RF fields with biological tissues determine by dosimetry studies that will be found in. [4], [5]

The electromagnetic fields can be absorbed, reflected or transmitted when it passes from one medium to other medium depend on conductivity of body and the frequency of the source. The absorbed energy of field converts to other form (most of it convert to heat) and can change the normal function of the body by its influence. [5], [6].

## 2. Mechanism of biological effects of RF and microwave

The effects of electromagnetic fields on human organism at various frequencies are different. The human body is affected by two mechanisms: 1- The importance effects at microwave and RF frequency fields are heating. It may be begin by to serious burning. 2- Induce electric and magnetic currents that can affect the normal current of heart or Central Nervous System (CNS). Biological effects of RF and MW are divided into: 1- thermal effects 2- nonthermal effects.

### 2.1 Thermal effects

The human body tissues have dielectric property i.e. permittivity, conductivity and permeability. Because of this, the electromagnetic fields can be absorb by human tissues and induce conduction and displacement currents. The increment of temperature during exposure to microwaves depends on: intensity of field strength; duration of exposure; the specific area of the body exposed and the efficiency of heat elimination; frequency or wavelength; thickness of skin and subcutaneous tissue.

These conduction and displacement currents transform electromagnetic energy into heat. The absorption of fields is depending on water content of tissue. Thick and fatty (more water content) tissues allow electromagnetic waves to penetrate into those more than thin tissues. When the absorbed energy in human body is converted to heat,

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\*Corresponding Author: Asma Lak, Young Researchers Club, Bushehr branch, Islamic Azad University, Bushehr, Iran.  
Email: lak.asmae@gmail.com

thermal effects are occurred. Also when the human body is exposed to an electromagnetic source, body temperature of exposed tissue rises from its normal value and biological effect can occur. The heating are two types: dielectric heating occurs at relatively low frequencies (several kHz to MHz), and induction heating occurs at higher frequency from RF to microwaves. It is noticeable that by increasing in frequency the SAR and the heating is increased too. The blood flow as a thermal regulatory system in the organism can be affect the body temperature rising and regulate it, and consequently the introduced heat by exposure is released. The absorbed energy by tissues at electromagnetic spectrum is in different rate and called SAR that express in watts per kilogram (W/kg) unit.

According to ICNIRP standard when the SAR<sup>1</sup> is lower than 4 W/Kg (whole body for 6 min for frequencies of 100 kHz to 10 GHz) For public environment by taking account to safety factor 10 i.e. 0.4 W/Kg (whole body for 6 min for frequencies of 100 kHz to 10 GHz) is permissible value.[7]-[9]

### 2.1. Eye Damage

The effects of electromagnetic fields on eye are cornea injury, cataract and retina, lens and iris effects. The human eye has unique properties and is an active environment to damage from electromagnetic fields. Blood flow has an important role to cool the heat tissue but the human eye doesn't have it and lake of blood flow in cornea can lead to cataracts. The eye is a sensitive tissue and its properties make this an area which need more caution and concern. The value of rising in body temperature because of electromagnetic fields absorption is related to the water content of the tissue. Thus electromagnetic waves can penetrate in the fatty and thick tissues more than thin tissues. The lens of the eye is a transparent tissues and the electromagnetic energy can penetrate in to head through the lens. [7],[10]-[13].

### 2.2 Skin Damage

Many parts of high frequency (RF/MW) electromagnetic spectrum have low penetration in the biological tissues. Equations 1 and 2 show the relationship between frequencies and depth of penetration. [14]

Because of low penetration the electromagnetic energy is remained at the skin surface and absorbed. It is caused to increase the temperature of the skin on those regions and lead to the burning effects. Possible injuries include skin burns, deep burns, heat exhaustion and heat stroke. [15]

$$\alpha = \sqrt{\pi f \mu \sigma} \quad (1)$$

$$\delta = \frac{1}{\alpha} \quad (2)$$

## 3. Nonthermal effects

The nonthermal effects have been reported by many researchers. Some of these effects are in the following part.

### 3.2 Blood-brain barrier(BBB)

Some substances are important for brain, and these substances cross the BBB which separate the brain from the blood. In fact this barrier has two main functions; one to optimizing the fluids surrounding the brain by allowing selectively permeable some essential substance for example glucose to pass. The other one to protect the brain from risks by excluding the toxins and other harmful compounds. The rising in temprature of brain lead to BBB breakage and it has serious effects on human health. Most of the researchers report that high intensity electromagnetic fields can affect the permeability of the BBB. [16]- [18].

### 3.3 RF Haring

The response of human auditory to the radiofrequency fields is called RF hearing. Some of human and animal studies shows that by low-level microwave, resulting in the subject hearing buzz, clicks, hiss, knock or chirp. According to [19] the RF hearing doesn't depend on average power density and it depends on energy in a single pulse. When the head was exposed to short (less than 70  $\mu$ s) microwave pulses the RF hearing may occur. The various kind of modulations can change these sounds. More informations can be found in [3], [19]-[23].

### 3.4 Behavioral effects

The function of nervous system is electrical and behavior is controlled by the nervous system. So many of researches are done at these topics. Some of these researches show memory loss , sleep disorders and insomnia,

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<sup>1</sup> : Specific Absorption Rate

decrease in REM sleep, slowed motor skills and reaction time in school children, impaired nervous system activity, loss of concentration and “fuzzy thinking”, spatial disorientation, change in the brain’s electrical activity [3], [18].

### 3.5 Immune system and other effects

In the human cell studies the effects are: altered white blood cell activity in school children, headaches, decreased immune function, increased heart rate, increased blood pressure, DNA damage (genetic damage) and changes in DNA repair capacity, cell proliferation and cancer [3],[24], [25].

### 4. Standards

The countries all over the world have standards to reduce the biological effects of electromagnetic fields and protect the human who live and work near the electromagnetic field sources like RADAR and BTS antenna. For example IEEE C95.3, IEEE 1528, CENELEC<sup>2</sup>, FCC<sup>3</sup>, ICNIRP<sup>4</sup>, NRPB<sup>5</sup>, IEEE C95.1 and etc. The maximum exposure to RF and MW fields varies from country to country. Also the limits are different in various guidelines. Table 1 Shows the typical standards. The occupational values are more than public environment because in public environment the people who are at exposure may be a sensitive body to frequency, so a safety factor (for example 5) is defined in establishing a guideline [3], [8], [26]-[29].

Table 1. SAR Limits for RFR [3]

standard	Frequency range	Whole-body SAR		Local SAR in head		Local SAR in limbs	
		Public	Occupational	Public	Occupational	Public	Occupational
FCC	100KHz-6GHz	0.08 (30)	0.4 (6)	1.6 [1]	8 [1] (6)	4 [10] +	20 [10] (6) +
ICNIRP	100KHz-6GHz	0.08 (6)	0.4 (6)	2 [10] (6)	10 [10] (6)	4 [10] (6)	20 [10] (6)
ANSI/IEEE	100KHz-6GHz	0.08 (30)	0.4 (6)	1.6 [1] (30)	8 [1] (6)	4 [10] (30) +	20 [10] (6) +

Note: ( ) Averaging time in minutes. [ ] Averaging mass in grams. + In hands, wrists, feet, and ankles.

## 5. DISCUSSION

The probable bioeffects of electromagnetic fields at RF and MW frequencies spectrum are described. The effects are divided to thermal and nonthermal effects. Consideration of these probable effects is essential and not avoidable. The standards and guidelines are established for human health safety.

Many kinds of waves and EM fields at various frequencies are around us and we should protect ourselves from them because some of them are dangerous for human health. The people who work at occupational environment such as RADAR, know the value and dose of fields and can protect themselves by some device, for example dosimeter. But the people who live around or near to these environments don’t know the value and dose of fields so the standards are established to protect human to exposure EM fields. Because of importance of human health protection from EM fields, as well as standards in previous section in this part some of useful recommendations for reduction of biological effects of electromagnetic fields are:

Children don’t use mobile phone because they have growing immune system. Time of exposure is one of the factors that affect on SAR so by reducing talking duration time, the SAR is reduced too. Distance from EM source exposure reduces the SAR so using handsfree is reducing the SAR. Using standard limitation guidelines for human safety, Shielding of field sources for lower exposure, The worker who works at occupational environments such as RADAR, use test device (dosimeter) to protect themselves, use ferrite materials in devices like mobile phone to absorb the electromagnetic fields [30]-[33].

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<sup>2</sup>European Committee for Electrotechnical Standardization(CENELEC)

<sup>3</sup>Federal Communications Commission (FCC)

<sup>4</sup>International Commissions on Non-Ionizing Radiation Protection

<sup>5</sup>National Radiological Protection Board

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