

Microwave Radiation and its Effect on Human Body: A Review

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Abstract: Twenty first century is the age of revolution in the field of telecommunication. The use of Mobile is the part of our daily life. But we have hard knowledge of its effect on our body or health. In recent time, the newspapers, electronic media, social network, various non-profit organization has circulated the information of its hazardous effects. MW radiations coming from the cell phones has various effects on different systems of human body such as cardiovascular, nervous, endocrine, reproductions, metabolism, skin etc. In this paper, I shall review recent studies that have explored the effects of microwave radiation on various parts of human body.

Key Words: SAR, Radiations, Human Body, Metabolism, Microwave.

1. INTRODUCTION:

In metropolitan cities or even in the rural areas nowadays mobile phones and tablets have become the most effective communication tools¹. Cell phones emit microwave radiations with frequency ranging from 300 MHz to 300 GHz from their antennas. Electromagnetic radiations can be classified into two types, ionizing and non-ionizing. These two types of radiations differ by the energies associated with them. The non-ionization radiation is low in frequency and thus low in energy. Whereas the ionization radiation is high in frequency and correspondingly high in energy². The ionising radiations are more harmful than non-ionising radiations. We cannot avoid the exposure to the ionising radiations like cosmic rays, γ -rays or even the X-rays used for the medical purposes. But the non-ionising radiations generated from various devices that we use in our daily lives listed below give many hazardous effects on human health. These radiations get absorbed by the human body or even by the animals. And depending on the absorbed radiation energy various physical and biological reactions occur inside the body. Brain is the primary organ of the body exposed to the radiation coming from the cell phones, thus neurological effects are the major concern in young person nowadays³. Accordingly, there are also adverse effect on the memory, learning and cognitive function in the young and the children. The energy of the EM waves are strongest at the antenna and losses its energy with the distance. The organs which are close to the device gets more affected by the radiation. However, with the popularization of this device has increased the concerns about the human health.

The devices we are using in our daily life and their frequency range of microwaves is listed below³.

Table: 1 Application and Frequency Range

Application	Frequency range (MHz)
FM radio and TV broadcasting antennas	80–800
Mobile phones	453.5–1980.0
Mobile phone base station	463.5–2170.0
Microwave links	1000
Cordless phones	1880–1900
Bluetooth devices	2450
Wireless local area networks	2400 and 5000
Smart meters	900–1900 or 2400
Surgical and physiotherapeutic	2450
Diathermy	2450 and 434
Microwave ovens	915–2450
Radar	30–300,000

2. UNITS OF ABSORPTION OF RADIATION BY HUMAN BODY:

To measure absorption of electromagnetic energy by the human body, it is first necessary to define the units in which it is measured. Specific Absorption Rate (SAR) is the quantity used to measure the amount of power from an electromagnetic wave is absorbed per unit mass by a human body.^{4,5}

$$SAR = \frac{P_{abs}}{m} \text{ watts / kg}$$

SAR can be calculated by Equation

$$SAR = \frac{\sigma \times E^2}{\rho_m}$$

Where E is the induced electric field strength in the tissue, σ is the tissue's conductivity and ρ_m is its mass density. This equation is used to average over the whole body. The other measurable quantity is the absorption cross section (ACS). ACS (denoted as σ_a) is calculated as the ratio of power absorbed by the object divided by the incident power density (denoted as S_c). The value of ACS can be calculated by the relation

$$\sigma_a = \frac{P_{abs} (W)}{S_c (W/m^2)}$$

$$\sigma_a = \frac{P_{abs}}{S_c} m^2$$

And ACS (σ_a) can be calculated using SAR as

$$\sigma_a = \frac{(SAR) \times (m)}{S_c} m^2$$

For passive absorber there are two cross sections, namely Absorption Cross Section (ACS) and Scattering Cross Section (SCS). These two cross sections together give the Extinction Cross Section (XCS)⁴. XCS given by the relation

$$XCS = S_c (SCS + \sigma_a)$$

Another measurable quantity on which absorption depend is the Absorption Efficiency (Q_a) of the absorbing object⁴. This is the proportion of energy absorbed by the object. And is given by the relation

$$Q_a = \frac{\sigma_a}{G_s}$$

Where G_s is the silhouette area of the absorbing object in the plane normal to the incident wave. Human biological tissue may be considered as composed of two components. They are water and organ specific tissues. The main part of the biological tissue i.e. the water content changes as a function of age². The dielectric properties of the body depends on the water present inside the body and hence Q_a . The Total Body Water (TBW) for male and female can be calculated using the relations⁴

$$TBW = 2.447 - 0.09516A + 0.1074h + 0.3362m \quad \text{for male}$$

$$TBW = -2.097 + 0.1069h + 0.2466m \quad \text{for female}$$

where A is age in years, h is height in metres and m is mass in kilograms.

The SAR values for few mobile phones are:

Table: 2 Device name, Device number, Head SAR value and Body SAR

Device name	Device no.	Head SAR value (W/Kg)	Body SAR (W/Kg)
Redmi	Redmi 4	0.75	
Samsung Galaxy J5 Prime	SM-G570F	0.713	
Samung Galaxy JMax	SMT285YD	0.493	
VIvo	Vivo Y21L	1.062	1.120
Galaxy J7	SM-J700F	0.571	
Realme 3 Pro	RMX1851	1.159	0.739
Moto	Moto C PLus	0.736	1.250
Asus	Asus_X00TD	0.549	1.340
Samsung Galaxy J2		0.903	
OPPO A71k		0.459	0.462
OPPOA83	CPH1729	1.380	0.715
Redmi	Redmi 5A	1.072	
Redmi	Redmi Y1	1.092	

Xiaomi	Xiaomi Mi max 2	1.39	
OPPO	OPPO Neo 7	0.368	0,795
Apple	iPhone 7	1.10	1.14

3. INFLUENCE OF RADIATION ON BIOLOGICAL TISSUES:

SAR depends directly on electromagnetic properties i.e. the permittivity and conductivity of exposed biological tissue.⁶ Thus to analyse SAR value first we need to understand the electromagnetic properties of the biological tissues².

The time rate of RF energy absorbed per unit mass of biological tissue of the body is given by²

$$SAR = \frac{(\sigma + \omega \epsilon_0 \epsilon_r) E_i^2}{\rho} \text{ W/kg}$$

Where

σ - Conductivity of biological tissue, measured in Siemens /meter,

ω -Angular frequency,

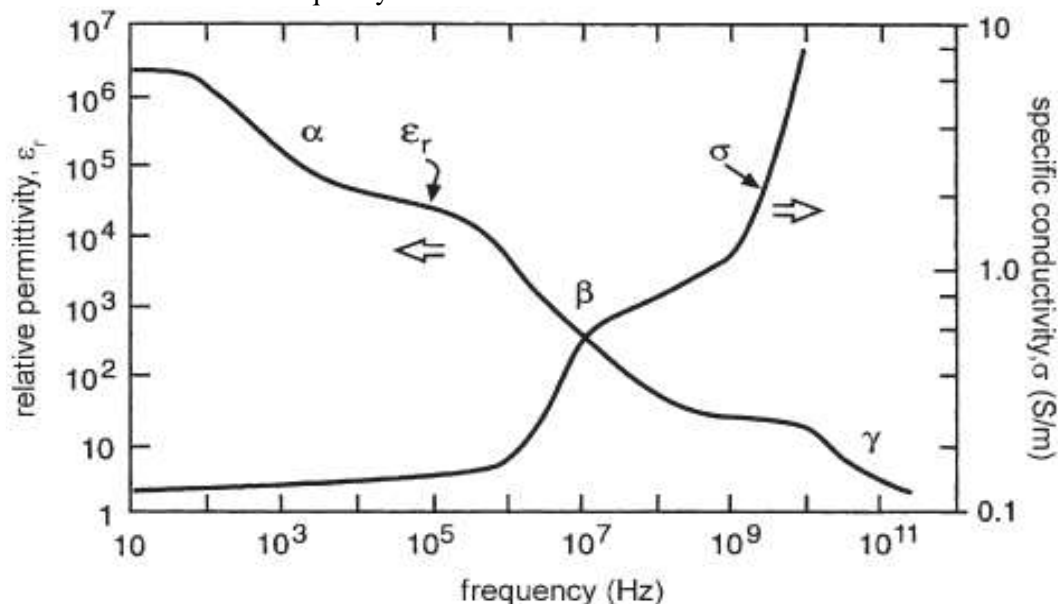
ϵ_r - Imaginary part of complex permittivity,

ϵ_0 - Permittivity of free space,

ρ -tissue density,

E_i - induced value of electrical field as a result of exposure to external field measured by unit Volts/meter.

The interaction of external electromagnetic field with medium can be described by the parameters above and also determines the flow of current through the body. These parameters vary with the frequency of the applied signal. The variation of permittivity and conductivity as a function of frequency is shown in figure (Source: The Age-Dependence of Microwave Dielectric Parameters of Biological Tissues, Mimoza Ibrani, Luan Ahma and Enver Hamiti, p- 141)². This shows that the relative permittivity decreased with the increase in frequency and the conductivity of the biological tissues increased with the frequency.



4. STUDIES OF MICROWAVE RADIATION ON DIFFERENT PARTS OF HUMAN BODY AND ANIMALS

Blood is the most important component of human body. The water molecules present in the blood tissue gets reoriented in presence of external electric field. The relative permittivity of brain tissue is reasonably low. And the conductivity increases with increasing frequency. Studies shows that Neurotransmitter concentrations of four amino acids (glutamate, aspartic acid, glycine, and gamma-aminobutyric acid) in hippocampus were increased in the 2.5 and 5 mW/cm² groups and decreased in the 10 mW/cm² group. There was evidence of neuronal degeneration and enlarged perivascular spaces in the hippocampus. Also mitochondria became swollen and cristae were disordered. These data suggest that the hippocampus can be injured by long-term microwave exposure, which might result in impairment of cognitive function due to neurotransmitter disruption⁴.

Study shows that MW exposure has influence on the cardiovascular system of Wistar rats, both the blood pressure and pulse rate were initially raised from 125 mmHg to 145 mmHg and from 430 BPM to 480 BPM respectively, immediately after exposure⁵.

To study the effect of EM radiation on thyroid gland Anna Mathew et al surveyed to collect information from all medical students in a medical college in South India. They found there was a significant correlation between total radiation exposure and an increase in TSH among both groups –in those with and without family history of thyroid illness⁶.

Liver is a large organ which plays an important role in metabolism and regulation of glycogen storage. It needs a plenty of blood. The large water content due to large content of blood in liver increases the conductivity⁷. The fat has poor conductivity due to less content of water⁷.

The depth of penetration of the microwaves inside the tissue depends on the frequency of the wave and also on the nature of the tissue. The penetration depth is inversely proportional to the frequency of the MW. Thus lower frequency penetrates deeper inside the tissue^{4,16}. Tissues with high water content show higher MW radiation absorption. And since the lower frequency penetrate deeper, skin may not be significantly damaged for the exposure to the low frequency radiation for small duration but the muscles, nerves or the blood vessels may damage significantly¹¹.

Agarwal et al. suggested that using mobile phones adversely affects the quality of semen by decreasing the sperm count, motility, viability and morphology, which might contribute to male infertility^{13,15}.

5. CONCLUSION :

This article is to highlight the negative effects of the MW radiations due to the exposure to the radiation. Mainly the non ionising radiations i.e. the low frequency radiations coming from mobile phones, laptops, microwave ovens which penetrates more than the high frequency radiations. In India the Federal communication commission (FCC) adopted the limit for SAR for public exposure from cellular phones is 1.6W/Kg. Most of the Smartphone companies declared their SAR value, but the SAR for the simultaneous transmission i. e. cellular plus Wi-Fi is much more than specified and also higher when using hotspot. The greatest polluting element in the earth's environment is the proliferation of electromagnetic fields. In the list of environmental pollutants electro-pollution or the electro-smog is in the upper level¹⁹. However more research is needed on the protective measures of the health hazards due to the radiations.

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