

## PENETRATED ELECTRIC FIELD AND SPECIFIC ABSORPTION RATE IN HUMAN BODY TISSUES EXPOSED TO ELECTROMAGNETIC RADIATIONS

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### Abstract

The adverse effects electromagnetic radiations on human skin (dry & wet) are being studied here. The human body is usually exposed to electromagnetic radiations emitted from base transceiver station (BTS). The penetrated electric fields inside human skin (dry & wet) and resulting specific absorption rate (SAR) are calculated using their electrical conductivity and permittivity at 4G and 5G frequencies. The penetrated electric fields & SAR inside the human body are simulated at various distances from antenna of BTS and the resulting values inside the tissues at various depths are compared with the safe exposure limit given by the international agencies such as FCC, ICNIRP, and NCRP etc. The results clearly suggest that the electromagnetic radiations are harmful for the human body tissues at shorter distances from BTS in comparison to 3G frequencies.

**Keywords:** Electromagnetic radiation (EMR), SAR, BTS.

### INTRODUCTION

In the present era number of mobile phone users is on increase enormously resulting in the increase of radiation and therefore effect on the human body will also increase. Radiation is energy that comes from a source and travels through space and may be able to penetrate various materials. Electromagnetic radiation refers to waves of the electromagnetic field that propagate through space, carrying electromagnetic radiant energy. Some electromagnetic waves carry so much energy per quantum that they have the ability to break bonds between molecules. In the electromagnetic spectrum, gamma rays are given off by radioactive materials, cosmic rays and X-rays also carry this property and are called ionizing radiation. Fields whose quanta are insufficient to break molecular bonds are called non-ionizing radiation. Here we are concern with non-ionizing radiation which is used by mobile phone communication. The human body has parameters, like electrical conductivity, density and permittivity [3]. When the electromagnetic field falls on the body then some part is absorbed by the body tissues, causing the body's temperature to increase [17] [12]. A base transceiver station (BTS) is a fixed radio transceiver in any mobile network. The BTS connects mobile devices to network. It sends and receives radio signal to mobile device and converts them to digital signals that it passes on the network route to other terminal in the network or to the Internet. BTS radiation is more harmful than the mobile phone radiation [9]. The human head goes near the base transceiver station; the effect of electromagnetic radiation becomes higher [10]. Cihangir et al. [2] simulate the specific absorption rate (SAR) when the eyewear is positioned over a homogeneous SAM phantom and over a

heterogeneous VH (visible Human) phantom and compared with international limit values. Usha Rani et al. [11] analyse SAR in different tissues due to radiation at 900 MHz, 1800 MHz, and 2400 MHz frequency. Owon et al. [16] calculate the SAR value for different type of mobile phones used to test in Nigeria. The least value of head SAR, Tecno S1, above all mobile phones cannot pose serious health problem to the uses. Due to the increase in temperature, the body's tissues are affected [7]. Kaushik et al. [8] calculated the variation of SAR inside the human body for 2G and 3G. Now here, we calculate the value of SAR at different distances from the EMR source for 4G and 5G Global Systems for Mobile Communication (GSM) frequency.

## MATERIAL AND METHODS

### The Electric Field on the human body

The value of electric field  $E_0$ , on the human tissues at a distance  $r$ , from mobile phone antenna of power  $P$ , is given by Polk [18] as

$$P/4\pi r^2 = E_0^2 \epsilon_0 c / 2 \quad (1)$$

$$P = 2\pi r^2 E_0^2 \epsilon_0 c$$

$$E_0 = (P/2\pi r^2 \epsilon_0 c)^{1/2}$$

$$E_0 = 7.746 \sqrt{P/r} \quad (2)$$

Where,  $\epsilon_0 = 8.85 \times 10^{-12} \text{ m}^{-3} \text{ kg}^{-1} \text{ s}^4 \text{ A}^2$

$$c = 3 \times 10^8 \text{ m s}^{-1}$$

For the power radiated from mobile phone antenna, that is 828 W [19], we have

$$E_0 = 222.89/r \quad (3)$$

### Electric field penetrating inside the human body

The electric field at a depth  $z$  inside the human body due to the incident electric field  $E_0$  as [18]

$$E_i = E_0 \exp(-z/\delta) \quad (4)$$

Where, the skin depth  $\delta$  depends on frequency of radiation. For biological body, it is given as

$$\delta = 1/q\omega$$

$$q = [\mu\epsilon \{(1+p^2)^{1/2} - 1\}/2]^{1/2}$$

$$p = \sigma/\omega\epsilon$$

Where,  $\omega$  is radian frequency of radiation,  $\epsilon$  is the permittivity of tissue material,  $\mu$ ,  $\sigma$ , its permeability and conductivity respectively [4]. The value of permittivity, permeability and conductivity for skin (dry & wet) is taken from internet [14].

### Specific Absorption Rate (SAR)

Specific Absorption Rate (SAR) can be defined as [1]

$$\text{SAR} = \sigma E_i^2 / \rho \quad (5)$$

Where,  $E_i$  is the inside electric field of the materials. The density ( $\rho$ ) of human body skin is taken from internet [15].

### Safe Exposure Limit for Specific Absorption Rate

Different agencies like as World health organization (WHO), Federal communications commission (FCC), National council on radiation protection and measurements (NCRP), International commission on non-ionizing radiation protection (INIRP), International non ionizing radiation committee (INIRC), all agree that the value of SAR for whole body should be kept below 1.6 W/kg.

### Results and Discussion

The calculated values of SAR for 4G and 5G GSM frequency spectrum for human skin (dry & wet) are given in Tables 1 and 2 respectively. The calculated values are compared with the safe exposure limit for human body given by various organizations.

**Table-1: Variation of Specific absorption rate (SAR) in Skin (dry & wet) at different distances from the tower operating at 2400 MHz frequency**

S. No.	Distance from the tower (m)	Incident electric field $E_0$ (V/m)	SAR inside the skin (dry) at the depth (W/kg)				SAR inside the skin (wet) at the depth (W/kg)			
			0.01mm	0.03mm	0.06mm	0.09mm	0.01mm	0.03mm	0.06mm	0.09mm
1.	0.5	445.78	257.932	257.483	256.81	256.141	279.608	279.11	278.365	277.623
2.	1.5	148.593	28.659	28.609	28.534	28.46	31.067	31.012	30.93	30.847
3.	2.5	89.156	10.317	10.299	10.272	10.246	11.184	11.164	11.135	11.105
4.	3.5	63.683	5.264	5.255	5.241	5.227	5.706	5.696	5.681	5.666
5.	4.5	49.531	3.184	3.179	3.171	3.162	3.452	3.446	3.437	3.427
6.	5.5	40.526	2.132	2.128	2.122	2.117	2.311	2.307	2.301	2.295
7.	6.5	34.291	1.526	1.524	1.52	1.516	1.655	1.652	1.742	1.643
8.	7.5	29.719	1.146	1.144	1.141	1.139	1.243	1.241	1.237	1.234
9.	8.5	26.222	0.893	0.891	0.889	0.886	0.968	0.966	0.963	0.961
10.	9.5	23.462	0.715	0.713	0.711	0.71	0.775	0.773	0.771	0.769

**Table-2 Variation of Specific absorption rate (SAR) in Skin (dry & wet) at different distances from the tower operating at 3450 MHz frequency**

S. No.	Distance from the tower (m)	Incident electric field $E_0$ (V/m)	SAR inside the skin (dry) at the depth (W/kg)				SAR inside the skin (wet) at the depth (W/kg)			
			0.01mm	0.03mm	0.06mm	0.09mm	0.01mm	0.03mm	0.06mm	0.09mm
1.	0.5	445.78	357.061	356.189	354.884	353.585	406.312	405.246	403.352	402.062
2.	1.5	148.593	39.673	39.577	39.432	39.287	45.145	45.027	44.85	44.674
3.	2.5	89.156	14.283	14.248	14.195	14.144	16.252	16.21	16.146	16.082
4.	3.5	63.683	7.287	7.269	7.243	7.216	8.292	8.271	8.238	8.206
5.	4.5	49.531	4.408	4.397	4.381	4.365	5.016	5.003	4.983	4.964
6.	5.5	40.526	2.951	2.944	2.933	2.922	3.358	3.349	3.336	3.323
7.	6.5	34.291	2.113	2.108	2.1	2.092	2.404	2.398	2.389	2.379
8.	7.5	29.719	1.587	1.583	1.577	1.572	1.806	1.801	1.794	1.787
9.	8.5	26.222	1.236	1.233	1.23	1.223	1.406	1.402	1.397	1.391
10.	9.5	23.462	0.989	0.987	0.983	0.979	1.126	1.123	1.118	1.114
11.	10.5	21.228	0.81	0.808	0.805	0.802	0.921	0.919	0.915	0.912
12.	11.5	19.382	0.675	0.673	0.671	0.669	0.768	0.766	0.763	0.76

On the basis of above calculations, it is concluded that both 4G and 5G GSM frequency spectrum

are harmful for human skin (dry & wet). The values of SAR harmful to human skin are indicated by bold number in the above tables. The above results clearly shows that SAR value for human skin (wet) is higher than the value of human skin (dry). The above calculation also shows that increase in frequency also increases SAR value for human skin, so it can be concluded that 5G GSM frequency spectrum is more harmful than 4G GSM frequency spectrum. Due to increase in frequency human tissues will be almost damaged at short distance and the safety distance of human body will be increase.

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