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Electromagnetic Radiation and Human Health

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Abstract:- In this paper author try to raise the awareness for the general public or society regarding health issues due to electromagnetic radiation (Non-ionizing radiation) especially those people are living nearby mobile phones towers. Author's also evaluate absorption energy in term of Specific Absorption Rate (SAR) inside human body tissues(skeletal muscle) with the help of mathematical modeling and compare the calculated results with standard permitted values of SAR given by many national and international agencies like "International Commission Non- Ionizing Radiation Protection" (ICNIRP), "World Health Organization" (WHO), "National Council on Radiation Protection and Measurement" (NCRP) "Federal Communication Commission" (FCC), and "Department of Telecommunications" (DOT) etc.

Keywords:- *Electromagnetic Radiation (EMR), Specific Absorption Rate (SAR), Radio Frequency (RF), and Electromagnetic Field (EMF) etc.*

I. INTRODUCTION

The use of EMR is rapidly increasing and we are living in the sea of invisible radiation comes from natural and manmade sources of EMR; there are growing concerns about human health hazards. Thus, there is a need to studies the interaction of microwave/radiofrequency radiation with living organisms. These tissues of human body are complex functions of numerous parameters like "conductivity", permittivity & density. The dissymmetric studies attempt to quantify the interaction of EMR with human being. Adey (1990) delivered a plenary lecture on "Electromagnetic Fields and Essence of Living Systems" at Prague (URSI). The microwaves in free space are characterized by the frequency, intensity of the electric field and magnetic field, direction, and polarization.

When human bodies exposed to Non-Ionizing electromagnetic radiation , the induced electric field inside the biological body tissues can be determine by solving Maxwell's equation subject to given boundary conditions. The human body is described by the complex permittivity; conductivity and mass density, etc.

The intensity of the electromagnetic field depend on the parameters of the external field, viz., the frequency, intensity, density, resistivity , conductivity, polarization and on the size, shape and dielectric properties of the exposed body, spatial configuration between the exposure source and the exposed body, and the presence of other objects in the vicinity with a complex dependence on so many parameters, it is apparent that the internal fields in a mouse and a man exposed to the same external field can be dramatically different, and so will be their biological response, regardless of physiological differences. Conversely, different exposure conditions, e.g., different frequencies, may induce similar fields inside such diverse shapes as a mouse and a man.The development and application of devices that emit RF radiation have significantly increased the quality of life through the world. Yet the beneficial aspects of RF/MW technology have been somewhat overshadowed in recent years by the public's fear of potential adverse effects. This fear, in turn, has led to increased radio frequency radiation (RFR) research and to new RFR safety guidelines. The new exposure standards are based on what is known about any biological effect. In general, the new guidelines provide an added margin of safety over those previously used. In 2000, the U.K. National Radiation Protection Board measured RF radiation level at 118 publicly accessible sites around 17 mobile phone base stations. The maximum exposure was 0.00083 mW/cm^2 on a playing field 60 m from a school building with an antenna on its roof. Typically, power densities were less than 0.01 % of the ICNIRP public exposure guidelines. The power densities indoors were substantially less than power densities outdoors. When RF radiation from all sources (the mobile phone, FM, T.V., and their transmitters, etc.) was taken into account, the maximum power density at any site was less than 0.2 % of the ICNIRP public exposure guidelines.

The National and International authorities established safety guidelines for exposure of the public to the Radiofrequency radiation are most widely accepted standards which is developed by the "Institute of Electrical and Electronics Engineers" and "American National Standards Institute" (ANSI/IEEE). The "International Commission on Non-Ionizing Radiation Protection" (ICNIRP 1998) and the "National Council on Radiation Protection and Measurement" (NCRP, 1986). In 2001, the IEEE published a paper on mobile phone base station (IEEE, 2001). This report finally concluded that in all circumstances, public exposure to Radiofrequency field near wireless mobile phone base stations is below the recommended safety limits standards. Although wireless base stations are not considered to present a risk to the general population residing near to the stations and including aged people, pregnant women and children's.

Inherent health risk from microwave radiation exposure are directly depends on the rate of energy absorption (Osephuk and Peterson, 2003) and distribution of energy in the body. The absorption and distribution of energy are strongly dependent on body size, shape, orientation,

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frequency and polarization of the incident electromagnetic radiation. The theoretical and experimental dissymmetric data shows that microwave radiation absorption approaches maximum limits when the long axis of the body is both parallel to the E-field vector and equal to the 4-10 th of the wavelength of the incident microwave radiation.

II. INTERACTION OF EMR WITH HUMAN HEALTH AND METHODOLOGY

The interaction of microwave radiation with human body tissues, including human being is a complex function of many parameters which are described already. The biological effects are due to the EMF inside the tissues. The amount of radiation absorbed for a given exposure field, is determined with the help of electrical properties of living organism systems. The exposure radiated field is characterized by the various parameters frequency, intensity, density, conductivity, resistivity, polarization and near-field of a radiator. The interaction of biological material with an electromagnetic source depends on the frequency of the source studied by Moulder and Foster (1995). This interaction can be considered at two levels one is macroscopic (molecular) and second one is microscopic (cellular) level, on the molecular level two basic mechanisms govern the interactions, viz., space charge polarization at lower Radiofrequency and field-induced rotations of polar molecules at higher RF and microwave frequencies (Health Aspects, Part I and II, 1977, 1978). The space charge polarization is due to travelling charge carriers, i.e., ions and the applied field affects the whole movement of the ions. Polar molecules having an uneven spatial distribution of charges, such as water and proteins, experience a torque when placed in an electric field; both of these mechanisms are of a relaxation character. In moderate fields, only a relatively small number of charges or molecules are actually affected by the field. The thermal motion of molecules and charges hinders the movements, and the kinetic energy undergoes a conversion into the heating energy that is thermal energy. In these interactions the electromagnetic energy is converted into kinetic energy of molecules, and subsequently converted into thermal energy which produce heating or raise the human body temperature (McIntosh et al., 2005).The analysis of specific absorption rate due to the thermal energy in tissues of human body at 900 Mz., 1800 Mhz. and 2400 Mhz is evaluated by Rani et.al (2018).

When EMR from transmission towers falls on the human body, it penetrates into the human body and affecting the biological tissues of human body. The electric field is propagated from the tower in all directions and thus the value of electric field depends upon the distance r from the tower and its transmission power P is given by Polk (1996).

$$\frac{P}{4\pi r^2} = E_0^2 \varepsilon_0 C/2$$

Where C is speed of light and ε_0 the permittivity of free space.

$$E_0 = \frac{P}{(2\pi r^2 \varepsilon_0 C)^{1/2}}$$

$$E_0 = \frac{7.746\sqrt{P}}{r}$$

Thus the electric field around the transmission tower is inversely proportional to the distance from the towers. The electric field at depth z inside human body due to incident electric field E_0 on the surface of body is also given by Polk (1996)

$$E_z = E_0 \exp|-z/\delta|$$

Where δ is the skin depth (The distance at which the field is reduced to $1/e$ of its original value at the boundary). It depends upon the frequency of radiation for biological body is given by

$$\delta = \frac{1}{q\omega}$$

$$q = \left[\frac{\mu\varepsilon\left\{(1+p^2)^{1/2} - 1\right\}}{2}\right]^{1/2}$$

$$p = \frac{\sigma}{\omega\varepsilon}$$

Where

ω is radian frequency of radiations
ε is Permittivity of tissue material
μ is Permeability of tissue material
σ is Conductivity of tissue material.

The above mathematical formulation can be used to evaluate the electric field inside the human body tissues at different depths.

A. *Specific Absorption Rate (SAR):*

SAR is defined as the amount of energy absorbed by the tissues which is the mathematically defined as the time derivative of the incremental energy (dW) absorbed or dissipated is an incremental mass (dm) contained in a volume element (dV) of a given density (ρ)

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SAR = d/dt (dW/dm) = d/dt (dW/ ρdV)

For sinusoidal electro-magnetic fields

$SAR = \sigma E_i^2/\rho$
σ is conductivity of the tissues
E_i is induced electric field inside human body tissues
ρ is the density of tissue material

The value of SAR is calculated for skeletal muscles tissues of human body at different frequencies with different emitted power of tower (20,50,1000W) by using various parametric properties viz. conductivity, resistivity and frequencies.

B. SAR for Skeletal Muscles at 935 and 960 Mhz:

The values of SAR in skeletal muscles at different distances from tower of transmitted tower of 2 W have been calculated by Pathak et al. (2008). In this paper author is calculated the values of SAR for skeletal muscles at transmitted power 20 W, 50 W and 1000 W, values are given in Tables 1 and 2 for 20 W transmitted power at frequencies 935 MHz and 960 Mhz., and Tables 3 and 4 for 50 W and 1000 W at frequency 935 Mhz.. The variation of SAR inside skeletal muscles at 935 MHz is shown in Figure 1 & 2 at 20 W and Figures 3 & 4 at 50 W & 1000 W respectively. The variation of SAR at 960 MHz has been found to be similar as that at 935 MHz frequency.

Table 1: SAR for Skeletal Muscles of Human Body at 935 MHz (20 W)

Distance from the base station (m)	E_i (V/m)	SAR x 10^{-3} (W/Kg)		
		1 mm	**2 mm**	**3 mm**
10	3.464	**156.03**	**148.73**	**141.79**
20	1.732	39.00	37.18	35.44
30	1.154	17.31	16.50	15.73
40	0.866	9.75	9.29	8.86
50	0.693	6.24	5.94	5.67
60	0.577	4.33	4.13	3.94
70	0.495	3.18	3.03	2.89
80	0.433	2.43	2.32	2.21
90	0.385	2.02	1.83	1.75
100	0.346	1.64	1.48	1.42

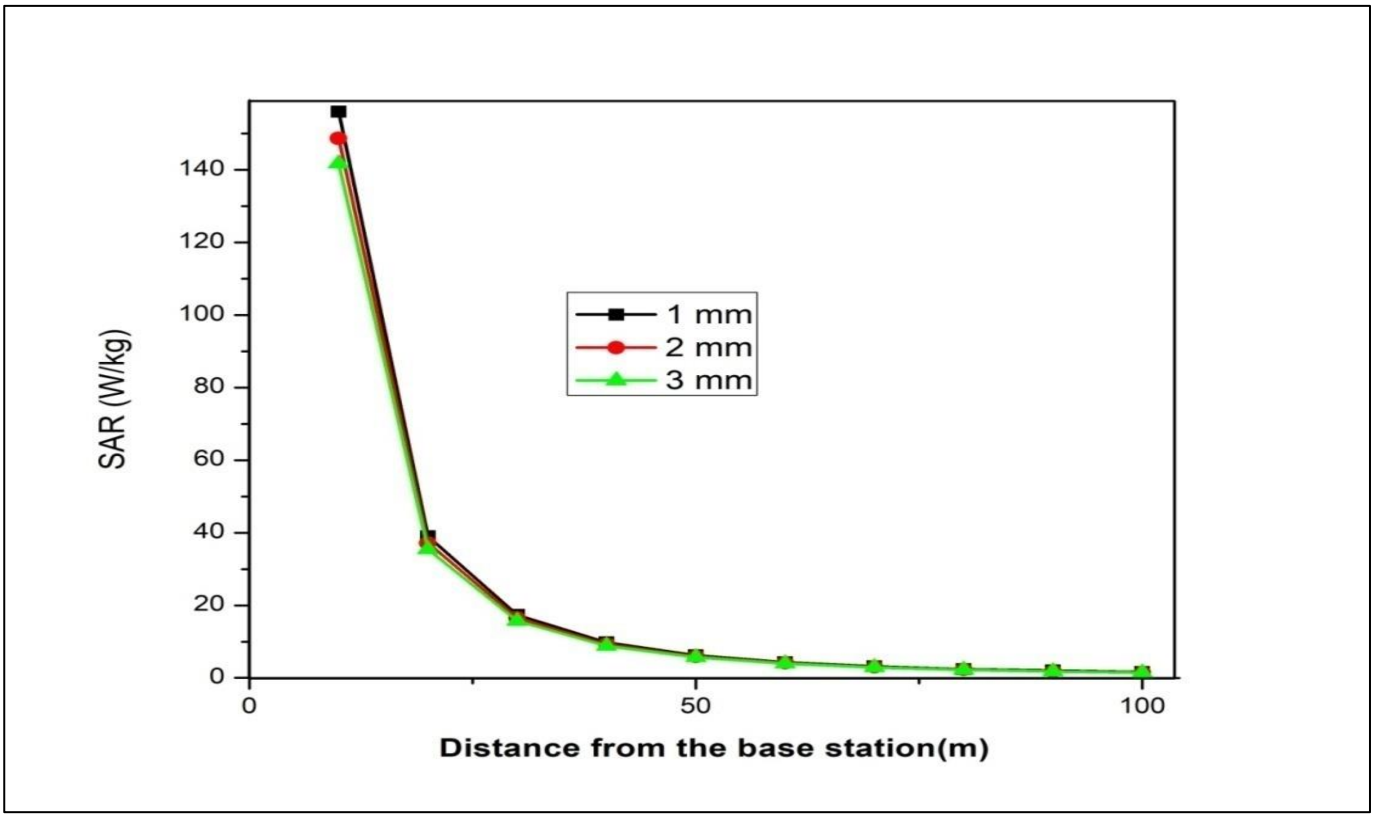

Fig. 1: SAR Inside Skeletal Muscles of Human Body at 935 MHz (20 W)

Table 2: SAR for Skeletal Muscles of Human Body at 960 MHz (20 W)

Distance from the Base Station (m)	E_i (V/m)	SAR x 10^{-3} (W/Kg)		
		1 mm	2 mm	3 mm
10	3.464	**157.44**	**149.98**	**151.93**
20	1.732	39.36	37.49	35.72
30	1.154	17.47	16.63	15.86
40	0.866	9.84	9.37	8.93
50	0.693	6.30	6.00	5.72
60	0.577	4.37	4.16	3.97
70	0.495	3.21	3.06	2.92
80	0.433	2.45	2.34	2.23
90	0.385	1.94	1.85	1.76
100	0.346	1.57	1.49	1.42

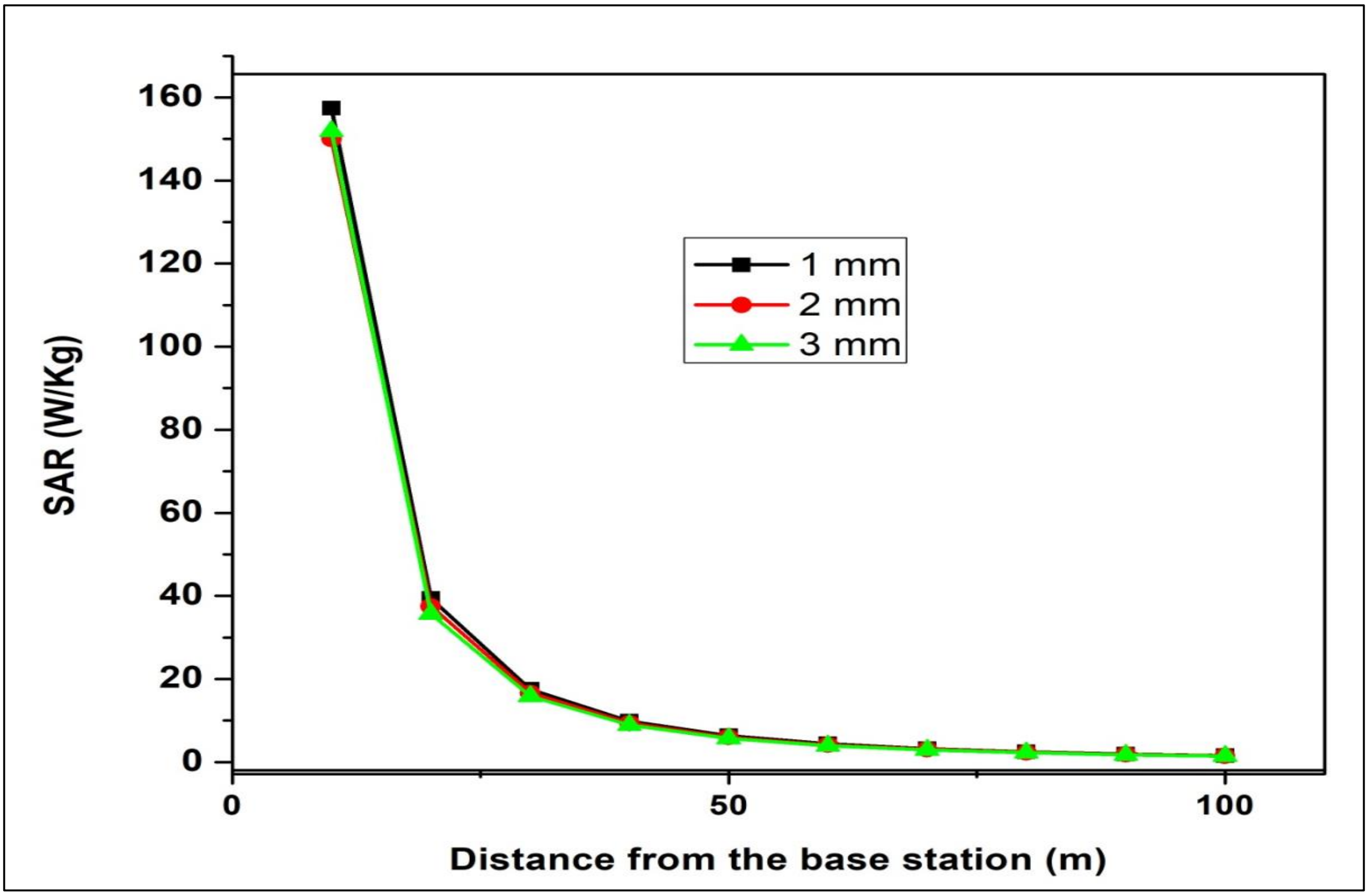

Fig 2: Variation of SAR for Skeletal Muscles of Human Body at 960 MHz (20 W)

Table 3: SAR for Skeletal Muscles of human Body at 935 MHz (50 W)

Distance from the Base Station (m)	E_i (V/m)	SAR x 10^{-3} (W/Kg)		
		1 mm	2 mm	3 mm
10	5.477	**390.0**	**371.2**	**354.4**
20	2.74	**97.6**	**93.05**	**88.71**
30	2.825	43.3	41.28	39.33
40	1.369	24.4	23.23	22.14
50	1.095	15.5	14.86	14.16
60	0.913	10.8	10.33	9.85
70	0.782	7.9	7.58	7.23
80	0.685	6.6	5.81	5.54
90	0.608	4.8	4.58	4.36
100	0.547	3.8	3.21	3.53

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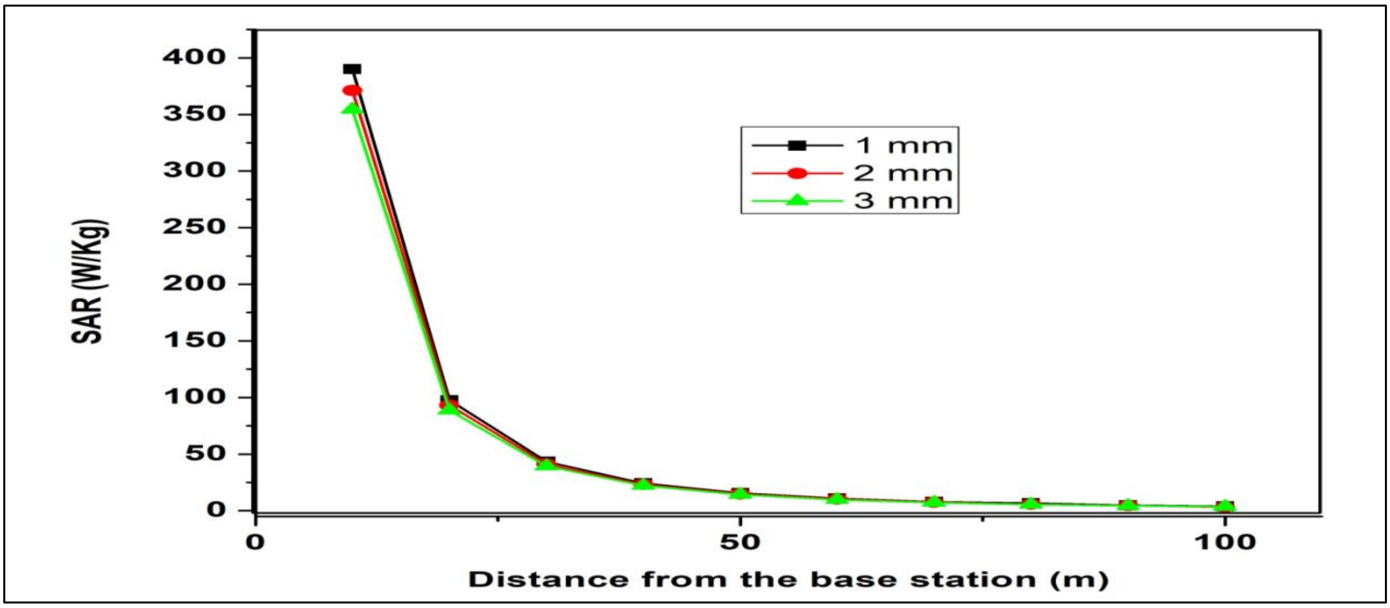

Fig. 3: Variation of SAR for Skeletal Muscles of Human Body at 935 MHz (50 W)

Table 4: SAR for Skeletal Muscles of Human Body at 935 MHz (1000 W)

Distance from the Base Station (m)	E_i (V/m)	SAR x 10^{-3} (W/Kg)		
		1 mm	**2 mm**	**3 mm**
10	24.495	**7799**	**7437**	**7085**
20	12.247	**1948**	**1858**	**1772**
30	8.165	**866.8**	**826.9**	**785.9**
40	6.112	**485.7**	**463.1**	**441.4**
50	4.898	**311.9**	**297.3**	**283.4**
60	4.081	**216.5**	**206.4**	**196.7**
70	3.498	**159.1**	**151.6**	**144.5**
80	3.061	**121.8**	**116.1**	**110.6**
90	2.721	**96.24**	**91.72**	**87.4**
100	2.449	77.5	74.32	70.8

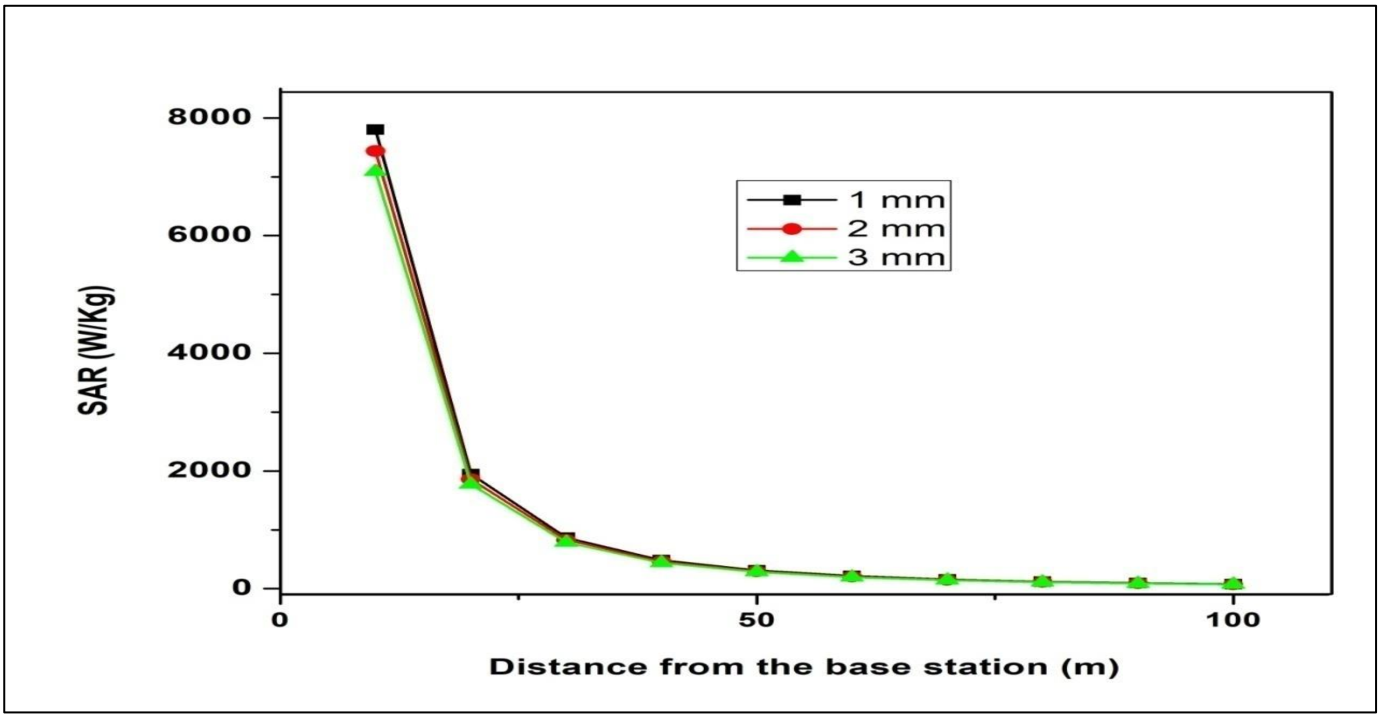

Fig. 4: Variation of SAR for Skeletal Muscles of Human Body at 935 MHz (1000 W)

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III. RESULTS AND DISCUSSIONS

From above tables the harmful values of SAR are shown in bold digits and these values above 0.08 w/kg. The Induced electric field and SAR at Effective radiated power 20W, 50W, and 1000 Watt are calculated. The distances from towers 10 meter to 100 meters is to be used for calculation of SAR. For above stated tissues of human body is observed that the SAR values across the standard limit given by many national and international agencies like NCRP,WHO,DOT,NICRP & IEEE etc. Tables and graphical representation of specific absorption rate shows that up to 90 meters distances from mobile phone towers are in critical zone and harmful for human being. The Authors are advised to the people that do not reside near the towers of mobile phone up to 90 meters distances and also suggest the set up guidelines of the transmission towers for the authorities that towers does not setup near the schools and colleges, railway stations, bus stands, and in dense populated areas up to specified distances.

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