**Electromagnetic Radiation and Human Health**

Sandeep Kumar1

1, Department of Physics, Dhanauri P.G. College, Dhanauri (Haridwar)

**ABSTRACT:**

The Vedas and metaphysics allow us to try to gain knowledge of such things that are not limited to our physical perceptions, senses and experiments, perhaps there is much more unseen, unheard and unknown to existence then we all realize or even dream of you need metaphysics. Initially all the source of energy is described in our Rig-Veda’s and all the form of energy are found in creation and mankind of human being. In this paper author’s try to raise the awareness for the general public or society regarding health issues due to electromagnetic radiation (Non-ionizing radiation). Author’s also evaluate specific absorption rate (SAR) inside human body tissues with the help of mathematical modeling and compare it with standard permitted values of SAR given by many national and international agencies like international commission known ionizing radiation committee (IRIRC), world Health organization (WHO), National council on radiation protection and measurement (NCRP) and Federal communication commission (FCC) etc.

**KEYWORDS:** Electromagnetic radiation (EMR), Specific absorption rate (SAR), radio frequency (RF), Electromagnetic field (EM) etc.

**1. INTRODUCTION:**

The use ofEMR is increasing in various applications and there is a growing concern about possible health hazards. Thus, there is a need to study the interaction of microwave with living organisms. The interaction ofRadiofrequency fields with biological tissues and bodies are complex functions of numerous parameters like conductivity, permittivity and density. Dissymmetric studies attempt to quantify these interactions. Adey (1990) delivered a plenary lecture on “Electromagnetic Fields and Essence of Living Systems” at Prague (URSI). Radio waves in free space are characterized by the frequency, intensity of the electric (E) and magnetic (H) fields, their direction, and polarization. However, only the field inside the tissues and biological bodies can interact with them, and therefore it is necessary to determine these fields for any meaningful and general quantification of biological data obtained experimentally.

When biological bodies exposed to known external electromagnetic fields, then the induced fields inside the biological body can be calculated by solving Maxwell’s equation subject to given boundary conditions. A biological body is described by the complex permittivity, conductivity and mass density, etc., the in homogeneity of the dielectric properties and the complexity of the shape make a solution, or sometimes even a full formulation of the problem. The other approach is an experimental one, which is also subject to considerable limitations.

The intensity of the internal fields depend on the parameters of the external field, viz., the frequency, intensity, 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/cm2 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 safety guidelines for exposure of the public to the RF 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) (ICNIRP, 1998) and the National Council on Radiation Protection and Measurement (NCRP) (NCRP, 1986). In 2001, the IEEE published a statement on mobile phone base station (IEEE, 2001). This report concluded that in nearly all circumstances, public exposure to RF field near wireless base stations is far below the recommended safety limits. Consequently, wireless base stations are not considered to present a risk to the general population including aged people, pregnant women and children.

Inherent health risk from RFR exposures are directly depends on the rate of energy absorption (Osephuk and Peterson, 2003) and distribution of RFR energy in the body, and the absorption and distribution are strongly dependent on body size, orientation, frequency and polarization of the incident radiation. Both theoretical and experimental dissymmetric data show that RFR absorption approaches maximum when the long axis of the body is both parallel to the E-field vector and equal to the four-tenths of the wavelength of the incident RFR field.

**2. INTERACTION OF EMR WITH HUMAN HEALTH AND METHODOLOGY:**

The interaction of RF/MW radiation with living system, including human being is a complex function of many parameters. Biological responses are due to the EMF inside the biological body. The amount of radiation reflected, transmitted and absorbed for a given exposure field, is determined with the help of electrical properties of living systems. The exposure field is characterized by the frequency, intensity, polarization and near-field of a radiator. The interaction of biological material with an electromagnetic source depends on the frequency of the source (Moulder and Foster, 1995). It can be considered on a macroscopic or microscopic (molecular, cellular) level. On the molecular level, two basic mechanisms govern the interactions, viz., space charge polarization at lower RF 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, i.e., 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 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 body temperature (Mclntosh et al., 2005).]

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



where  is speed of light or EMR and  the permittivity of free space.





Thus, the electric field around the transmission tower is inversely proportional to the distance from the towers.

The electric field at depth  inside human body due to incident electric field  on the surface of body is given by Polk (1996)



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







Where = radian frequency of radiations,

 = Permittivity of tissue material

 = Permeability of tissue material

 = Conductivity of tissue material.

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

**2.1 Specific Absorption Rate** (SAR):

The SAR is defined as the time derivatives of the incremental energy (dW) absorbed by or dissipated is an

Incremental mass (dm) contained in a volume element (dV) of a given density (ρ). It can be defined as

SAR = d/dt (dW/dm) = d/dt (dW/ ρdV

For sinusoidal electro-magnetic fields

SAR = σ E2i/ρ

σ= conductivity of the tissues

Ei= induced electric field inside human body tissues

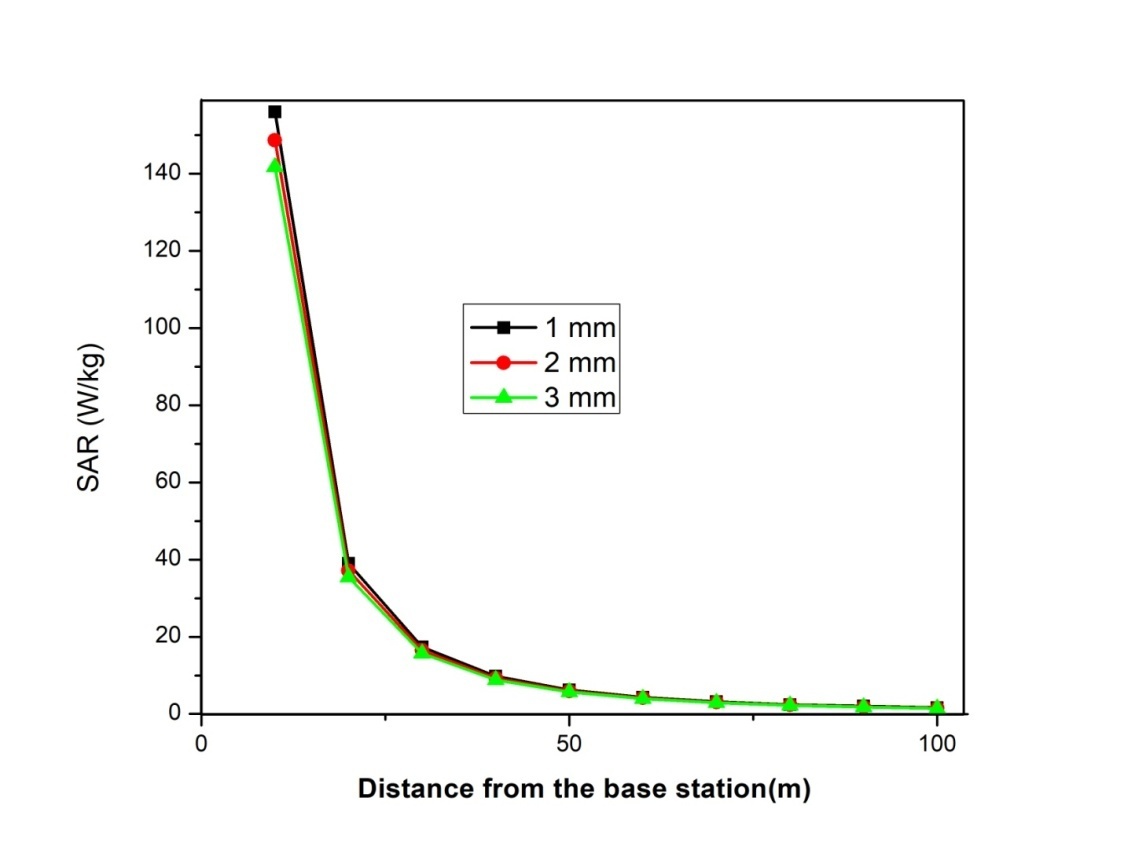
ρ = density of tissues materials

**2.2 Specific Absorption Rate in Skeletal Muscles at 935 and 960 MHz**

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

**Table 1 Induced electric field and SAR inside skeletal muscles of human body at 935 MHz (20 W)**

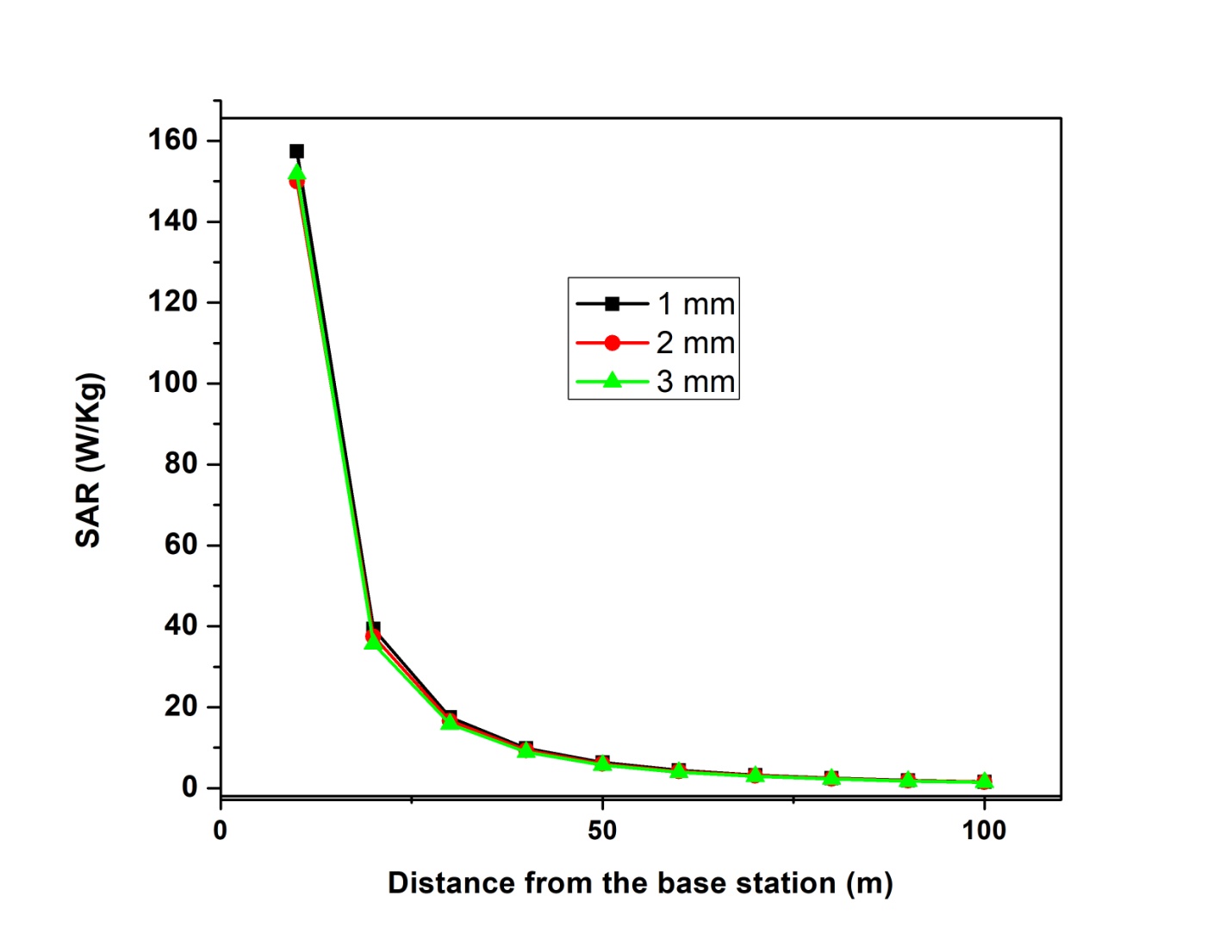
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Distance from the base station  (m) | Incident electric field  (V/m) | SAR x 10-3 (W/kg) | | |
| 1 mm | 2 mm | 3 mm |
| 10  20  30  40  50  60  70  80  90  100 | 3.464  1.732  1.154  0.866  0.693  0.577  0.495  0.433  0.385  0.346 | **156.03**  39.00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

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**Graph 1: Induced electric field and SAR inside skeletal muscles of human body at 935 MHz (20 W)**

**Table2Induced electric field and SAR inside skeletal muscles of human body at 960 MHz (20 W)**

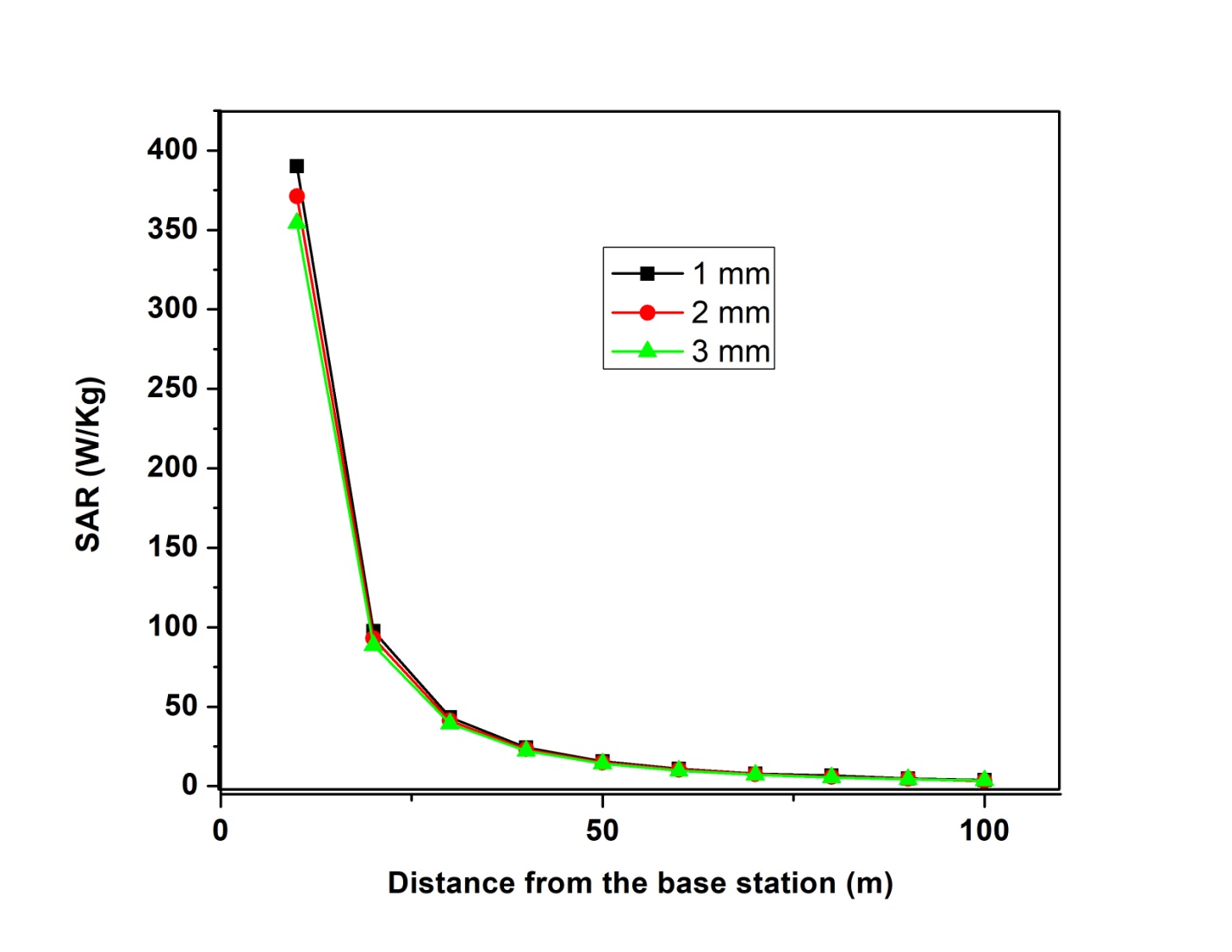
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Distance from the base station  (m) | Incident electric field  (V/m) | SAR x 10-3 (W/kg) | | |
| 1 mm | 2 mm | 3 mm |
| 10  20  30  40  50  60  70  80  90  100 | 3.464  1.732  1.154  0.866  0.693  0.577  0.495  0.433  0.385  0.346 | **157.44**  39.36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

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**Graph 2:Induced electric field and SAR inside skeletal muscles of human body at 960 MHz (20 W)**

**Table 3 Induced electric field and SAR inside skeletal muscles of human body at 935 MHz (50 W)**

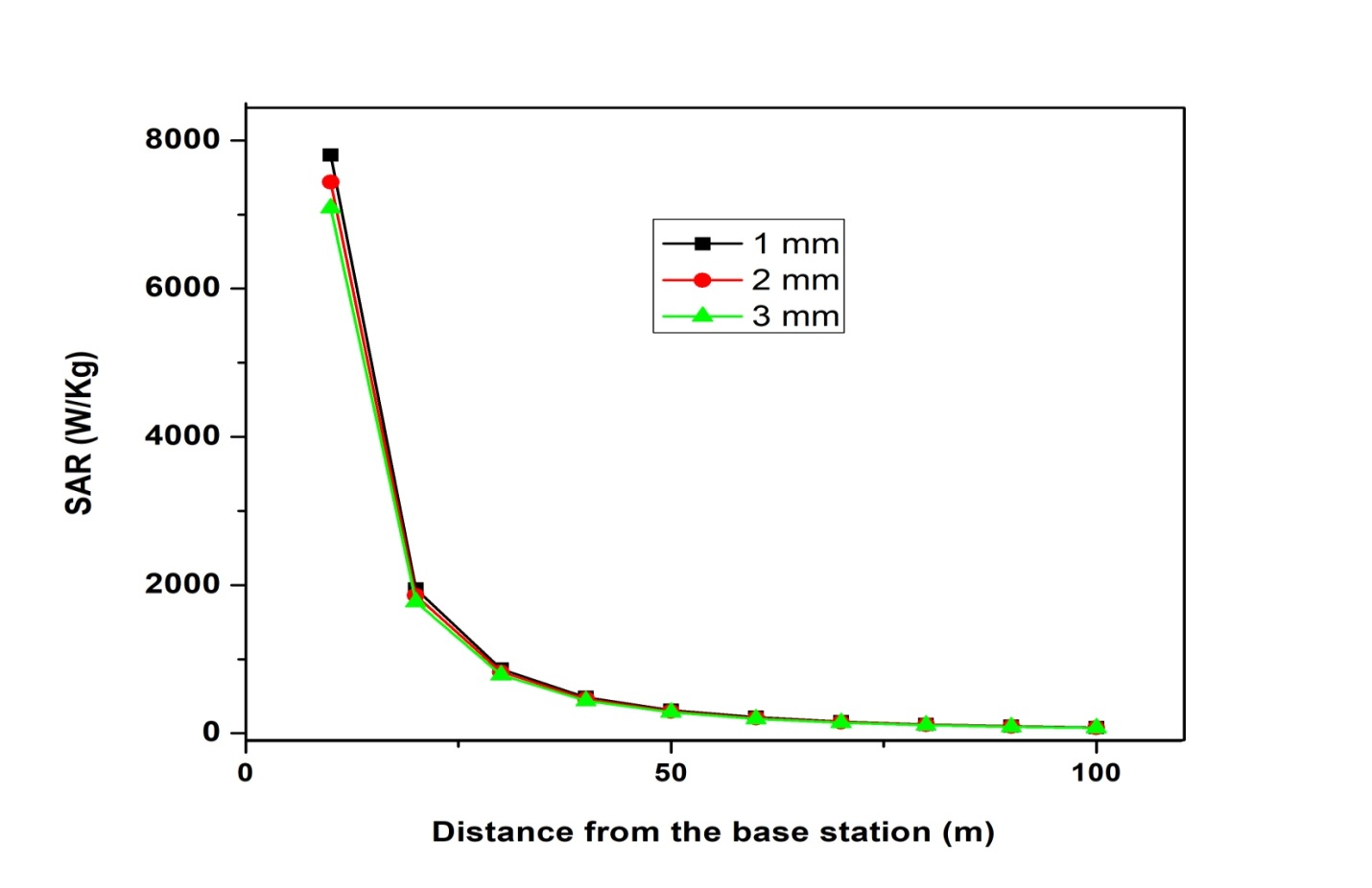
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Distance from the base station  (m) | Incident electric field  (V/m) | SAR x 10-3 (W/kg) | | |
| 1 mm | 2 mm | 3 mm |
| 10  20  30  40  50  60  70  80  90  100 | 5.477  2.74  2.825  1.369  1.095  0.913  0.782  0.685  0.608  0.547 | **390.0**  **97.6**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

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**Graph 3 Induced electric field and SAR inside skeletal muscles of human body at 935 MHz (50 W)**

**Table 4 Induced electric field and SAR inside skeletal muscles of human body at 935 MHz (1000 W)**

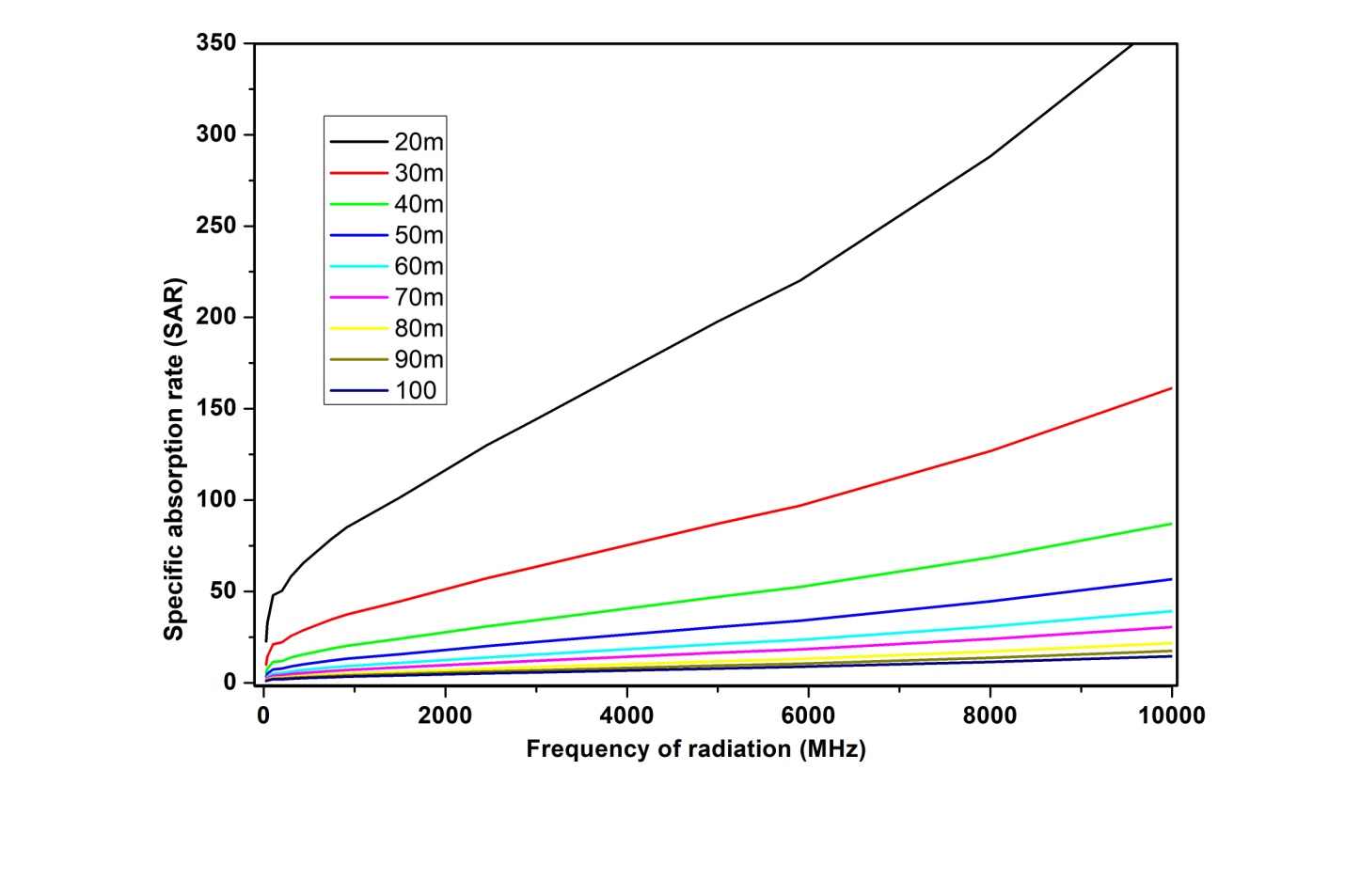
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Distance from the base station  (m) | Incident electric field  (V/m) | SAR x 10-3 (W/kg) | | |
| 1 mm | 2 mm | 3 mm |
| 10  20  30  40  50  60  70  80  90  100 | 24.495  12.247  8.165  6.112  4.898  4.081  3.498  3.061  2.721  2.449 | **7799**  **1948**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

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**Graph 4 Induced electric field and SAR inside skeletal muscles of human body at 935 MHz (1000 W)**

**Table 5 The variation of specific absorption rate (SAR) of bone cortical with different frequencies of EMR at different distances from the tower**

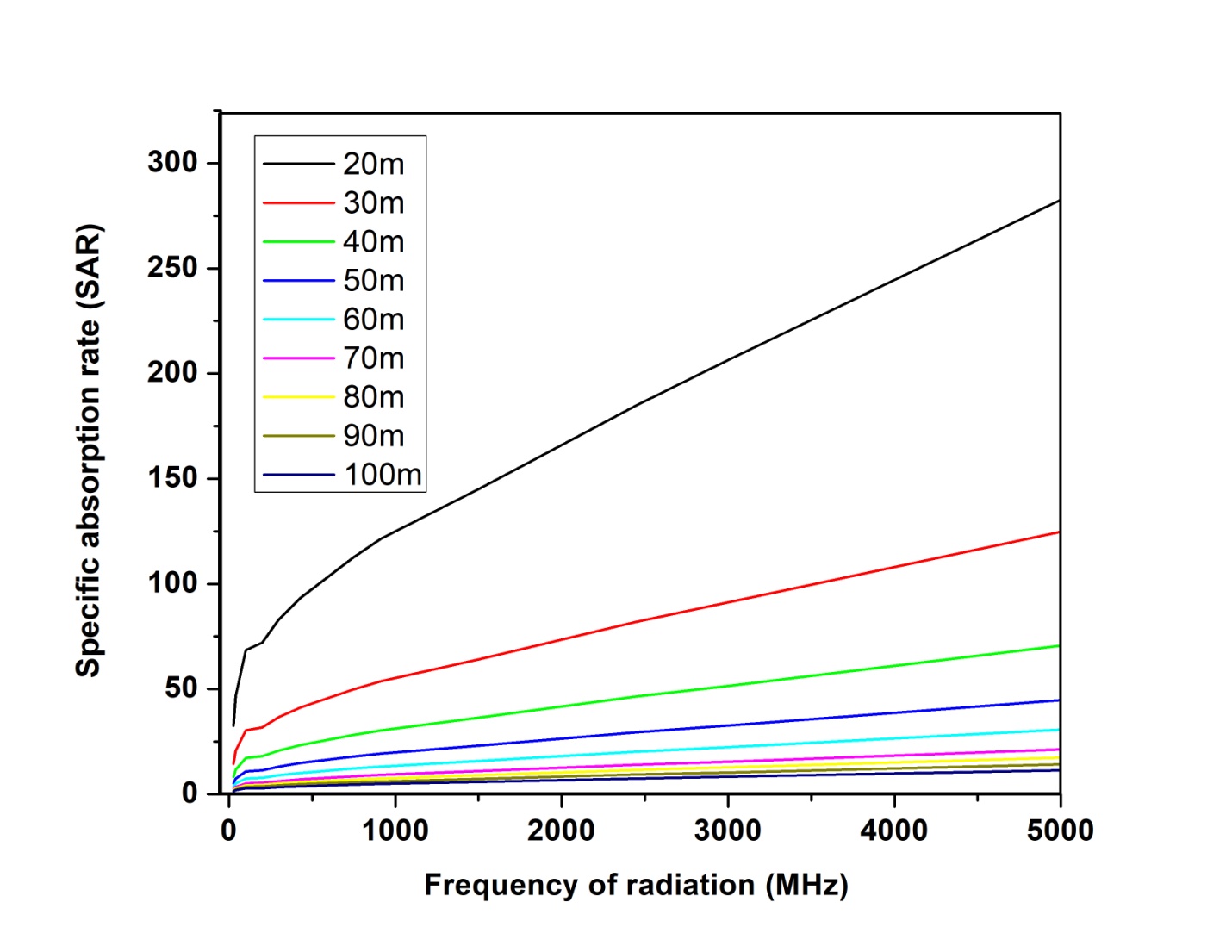
|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Frequency  of radiation  (MHz) | Specific absorption rate (SAR)  at different distances from the tower (10-3 W/kg) | | | | | | | | | |
| 10m | 20m | 30m | 40m | 50m | 60m | 70m | 80m | 90m | 100m |
| 27.12 | **90.6** | 22.72 | 10.0 | 5.40 | 3.51 | 2.43 | 1.90 | 1.35 | 1.08 | 0.91 |
| 40.68 | **130.6** | 32.76 | 14.43 | 7.80 | 5.07 | 3.51 | 2.73 | 1.95 | 1.56 | 1.30 |
| 100 | **191.1** | 47.9 | 21.1 | 11.40 | 7.41 | 5.13 | 3.99 | 2.85 | 2.28 | 1.91 |
| 200 | **201** | 50.4 | 22.2 | 12.00 | 7.80 | 5.40 | 4.20 | 3.00 | 2.40 | 2.01 |
| 300 | **232.1** | 58.21 | 25.6 | 13.86 | 9.00 | 6.23 | 4.85 | 3.46 | 2.77 | 2.32 |
| 433 | **261.1** | 65.47 | 28.84 | 15.60 | 10.13 | 7.01 | 5.45 | 3.90 | 3.12 | 2.61 |
| 750 | **314.5** | 78.87 | 34.74 | 18.78 | 12.20 | 8.45 | 6.57 | 4.70 | 3.75 | 3.14 |
| 915 | **339.3** | **85.09** | 37.5 | 20.26 | 13.17 | 9.11 | 7.09 | 5.06 | 4.05 | 3.39 |
| 1500 | **405.01** | **101.5** | 44.7 | 24.18 | 15.70 | 10.90 | 8.46 | 6.04 | 4.83 | 4.05 |
| 2450 | **518.2** | **129.9** | 57.23 | 30.94 | 20.11 | 13.90 | 10.83 | 7.73 | 6.19 | 5.18 |
| 3000 | **576.2** | **144.4** | 63.64 | 34.40 | 22.36 | 15.50 | 12.04 | 8.60 | 6.88 | 5.76 |
| 5000 | **788.9** | **197.8** | **87.13** | 47.10 | 30.61 | 21.20 | 16.48 | 11.77 | 9.42 | 7.88 |
| 5900 | **877.7** | **220.08** | **96.94** | 52.40 | 34.06 | 23.58 | 18.34 | 13.10 | 10.48 | 8.77 |
| 8000 | **1149** | **288.1** | **126.9** | 68.60 | 44.60 | 30.87 | 24.01 | 17.15 | 13.72 | 11.49 |
| 10000 | **1461.6** | **366.5** | **161.4** | **87.20** | 56.70 | 39.27 | 30.54 | 21.81 | 17.45 | 14.61 |

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**Graph 5 The variation of specific absorption rate (SAR) of bone cortical with different frequencies of EMR at different distances from the tower**

**Table 6 The variation of specific absorption rate (SAR) of spongy bone with different frequencies of EMR at different distances from the tower**

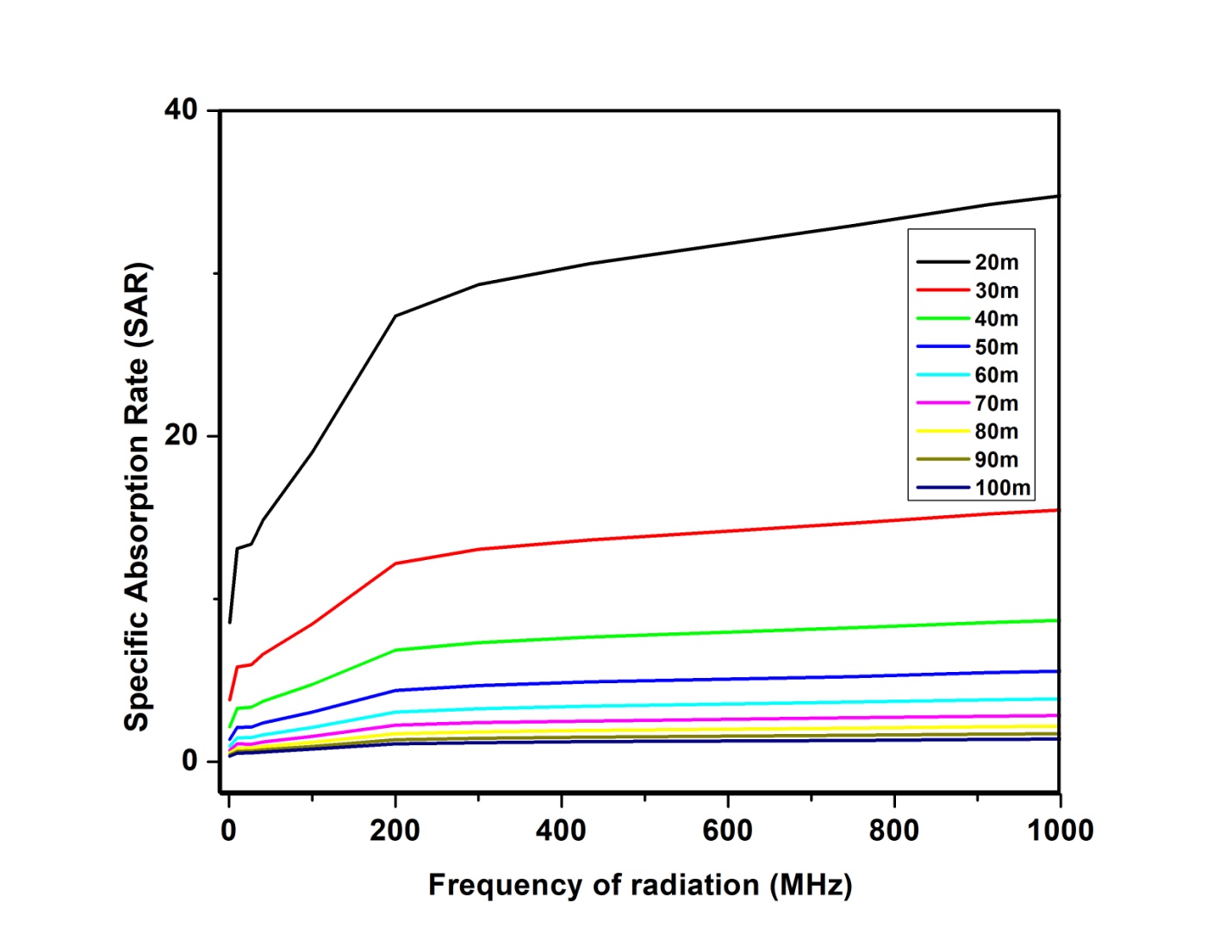
|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Frequency  of radiation  (MHz) | Specific absorption rate (SAR)  at different distances from the tower (10-3 W/kg) | | | | | | | | | |
| 10m | 20m | 30m | 40m | 50m | 60m | 70m | 80m | 90m | 100m |
| 27.12 | **129.84** | 32.46 | 14.33 | 8.11 | 5.13 | 3.51 | 2.43 | 2.00 | 1.62 | 1.29 |
| 40.68 | **187.20** | 46.80 | 20.67 | 11.70 | 7.41 | 5.07 | 3.51 | 2.88 | 2.32 | 1.87 |
| 100 | **273.84** | 68.46 | 30.23 | 17.11 | 10.83 | 7.41 | 5.13 | 4.22 | 3.42 | 2.73 |
| 200 | **288.00** | 72.00 | 31.80 | 18.00 | 11.40 | 7.80 | 5.40 | 4.44 | 3.60 | 2.88 |
| 300 | **332.60** | **83.16** | 36.72 | 20.79 | 13.16 | 9.00 | 6.23 | 5.12 | 4.15 | 3.32 |
| 433 | **374.16** | **93.50** | 41.31 | 23.38 | 14.81 | 10.13 | 7.01 | 5.76 | 4.67 | 3.74 |
| 750 | **450.70** | **112.70** | 49.76 | 28.17 | 17.84 | 12.20 | 8.45 | 6.94 | 5.63 | 4.50 |
| 915 | **486.24** | **121.50** | 53.68 | 30.39 | 19.24 | 13.16 | 9.11 | 7.49 | 6.07 | 4.86 |
| 1500 | **580.30** | **145.08** | 64.07 | 36.27 | 22.97 | 15.70 | 10.88 | 8.94 | 7.25 | 5.80 |
| 2450 | **742.56** | **185.04** | **81.99** | 46.41 | 29.39 | 20.11 | 13.92 | 11.44 | 9.28 | 7.42 |
| 3000 | **825.60** | **206.40** | **91.16** | 51.50 | 32.68 | 22.36 | 15.48 | 12.72 | 10.32 | 8.25 |
| 5000 | **1130.40** | **282.60** | **124.80** | 70.65 | 44.74 | 30.61 | 21.19 | 17.42 | 14.13 | 11.30 |
| 5900 | **1257.60** | **314.40** | **138.80** | 78.60 | 49.78 | 34.06 | 23.58 | 19.38 | 15.72 | 12.50 |
| 8000 | **1646.40** | **411.60** | **181.80** | **102.90** | 65.17 | 44.59 | 30.87 | 25.38 | 20.58 | 16.46 |
| 10000 | **2094.20** | **523.56** | **231.23** | **130.90** | **82.89** | 56.71 | 39.26 | 32.28 | 26.17 | 20.94 |

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**Graph 6 The variation of specific absorption rate (SAR) of spongy bone with different frequencies of EMR at different distances from the tower**

**Table 7 The variation of specific absorption rate (SAR) of skeletal muscles with different frequencies of EMR at different distances from the tower**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Frequency  of radiation  (MHz) | Specific absorption rate (SAR)  at different distances from the tower (10-3 W/kg) | | | | | | | | | |
| 10m | 20m | 30m | 40m | 50m | 60m | 70m | 80m | 90m | 100m |
| 1.0 | 34.28 | 8.56 | 3.80 | 2.14 | 1.36 | 0.95 | 0.70 | 0.53 | 0.42 | 0.34 |
| 10 | 52.44 | 13.09 | 5.82 | 3.27 | 2.09 | 1.45 | 1.09 | 0.82 | 0.64 | 0.52 |
| 27.12 | 53.56 | 13.37 | 5.95 | 3.34 | 2.13 | 1.48 | 1.07 | 0.83 | 0.65 | 0.53 |
| 40.68 | 59.39 | 14.83 | 6.59 | 3.70 | 2.37 | 1.65 | 1.21 | 0.93 | 0.73 | 0.59 |
| 100 | 76.18 | 19.02 | 8.46 | 4.75 | 3.04 | 2.10 | 1.55 | 1.19 | 0.93 | 0.76 |
| 200 | **109.69** | 27.39 | 12.18 | 6.84 | 4.37 | 3.04 | 2.24 | 1.71 | 1.34 | 1.09 |
| 300 | **117.40** | 29.31 | 13.04 | 7.32 | 4.68 | 3.26 | 2.39 | 1.83 | 1.44 | 1.17 |
| 433 | **122.55** | 30.60 | 13.61 | 7.65 | 4.89 | 3.40 | 2.50 | 1.91 | 1.50 | 1.22 |
| 750 | **131.97** | 32.95 | 14.66 | 8.23 | 5.23 | 3.66 | 2.70 | 2.06 | 1.61 | 1.30 |
| 915 | **137.12** | 34.24 | 15.23 | 8.56 | 5.47 | 3.80 | 2.80 | 2.14 | 1.68 | 1.37 |
| 1500 | **151.68** | 37.87 | 16.85 | 9.46 | 6.05 | 4.20 | 3.09 | 2.37 | 1.85 | 1.50 |
| 2450 | **189.39** | 47.29 | 21.03 | 11.82 | 7.55 | 5.20 | 3.30 | 2.96 | 2.32 | 1.89 |
| 3000 | **193.68** | 48.36 | 21.51 | 12.09 | 7.72 | 5.37 | 3.90 | 3.02 | 2.37 | 1.90 |
| 5000 | **335.94** | **83.88** | 37.31 | 20.97 | 13.40 | 9.32 | 6.86 | 5.25 | 4.11 | 3.36 |
| 5900 | **405.36** | **101.22** | 45.02 | 25.30 | 16.10 | 11.20 | 8.27 | 6.33 | 4.96 | 4.05 |
| 8000 | **655.60** | **163.71** | 72.82 | 40.92 | 26.10 | 18.20 | 13.38 | 10.25 | 8.03 | 6.55 |
| 10000 | **882.70** | **220.42** | **98.05** | 55.10 | 35.20 | 24.50 | 18.02 | 13.80 | 10.80 | 8.82 |

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**Graph 7 : The variation of specific absorption rate (SAR) of skeletal muscles with different frequencies of EMR at different distances from the tower**

**3. Results and Discussion:**

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 valuesacross the standard limit given by many national and international agencies like NCRP,WHO,DOT,NICRP etc. Tables and graphical representation of specific absorption rate shows that up to 20 meters distances from mobile phone towers are in danger 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 20 meters distances and towers does not setup near the schools and colleges, railway stations, bus stands, and in dense populated areas.

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