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Full Length Research Paper

Thermal Distribution in Different Tissues Due to Mobile Phone Tower at 800 MHz

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Abstract
The mathematical computation of induced electric field, specific absorption rate and rate of the change of temperature in consequence of above is also calculated in this manuscript. The mobile phone tower of 19.5 W, working at the frequency 800 MHz is used here for this study. By taking the different distances of biological body from the tower, the calculation is made at the various depths ranging from 0.1 to 0.5 mm inside the body. Thermoregulatory mechanism is considered for controlling the variation of temperature inside the tissues. The calculations are compared with the guidelines of International Commission on Non-Ionization Radiation Protection (ICNIRP) and World Health Organization (WHO). The result shows that microwave radiation produce the thermal effect due to extra energy of electromagnetic energy.

Keywords: *Induced electric field, Specific absorption rate, Temperature change, Thermoregulation.*

Introduction

In the recent time, microwave fields have become a driving force of our civilization through their numerous applications in the scientific and the industrial as well as the military and civilian world. Today, due to the development of modern technology, in the field of communication, radar, radio astronomy, navigation and power etc and widespread use of these waves among common generation causes the adverse health effect (Adair and Black, 2003; Adair et. al, 2005; Karunarathna and Dayawansa, 2006). There are much attention has been paid to health implications with these exposure since the last two decades. A large amount of literature has been published on the biological effects of microwave radiation (Bachmann et. al, 2007; Adair, 2008; Kesari and Behari, 2010; Kwon and Hamalainen, 2011). Since, the biological substances such as blood, brain, bone, muscle and fat behave as conductive or lossy dielectrics, the microwave energy directed onto the body may be scattered, reflected and absorbed depending on the field strength, the frequency, exposure time and the electric properties of the tissues. Specific absorption rate (SAR) is the most appropriate metric for determining such exposure near the fields of such radiation sources. This SAR also varies with the dimension of tissues (Dein and Amr, 2010). The absorbed microwave energy produces molecular vibration and converts the energy into heat. When the rate of energy absorption is high, it produces heating in living tissues (Ozen et. al, 2008). If the organism cannot dissipate this heat energy as fast as heat is produced, the internal temperature of the body will rise. This heat may damage this biological tissue permanently. Microwave frequency for which the wavelength are of the same magnitude as the dimension of the human body produce close coupling between the body and microwave field. A large amount of heat can be generated to cause severe damage in the body. Such effect of microwave is termed as 'thermal effect'.

The scientific literatures reported these thermal effect and SAR distribution in biological object due to these radiations from different sources (Ghandi and Mohammad, 2008; Rhattoy et. al, 2010; Ahma et. al, 2010). Exposure from TV and radio transmitters has been previously studied by Joseph and Martens (2006) and Sirav and Seyhan (2009). In present scenario mobile phone has become the basic necessity of human to communicate the distant one. Hence, to provide a better networking large amount mobile phone towers have been installed depending on the area of coverage and location of site. Nielsen et al. illustrate the perceived risk from mobile phones and mobile masts in residential areas (Nielsen, 2010). Tripathi and Pathak (2012, 2013) have already been assessed the rate of temperature change in tissues by taking All India Radio and TV broadcasting antennas of power 10 kW. This work is an extension of our previous research for computing the induced electric field inside the different tissues, Specific absorption rate (SAR) and consequently the rate of change in temperature due to mobile phone tower of power 19.5 W at different distances.

Due to the installation of numerous towers, the most of the population are in direct contact to this radiation continuously. This prolonged exposure can increase the thermal hazards many fold, but the thermoregulatory mechanism of the human being compensate the effect and reduces the risk at some extent. To regulate the balance between heat production and heat loss the temperature regulation in humans has evolved with the development of autonomic and behavioral mechanisms.

The core temperature (i.e., rectal, colonic, brain) is tightly regulated in the face of marked variations in ambient heat and cold stress, depending on the species. The skin and mucosal surfaces of the body and tissues under the surfaces whose temperature may deviate from the core owing to heat exchange with the environment. Though the human body could compensate for and handle the extra energy load through the thermoregulatory mechanisms without obvious increase in temperature, stress could still develop. Various

international agencies have defined safety limits for radiation exposure. International Radiation Protection Association (IRPA) sets the (Permissible Exposure levels) for general public. Some more clear and accurate guidelines must be recommended and followed strictly (Walters et. al, 2000; Huber et. al, 2003).

Thermo Regulation of the Body

In natural process the heat energy is produced inside the human body due to:
(i) The rate at which thermal energy is produced through metabolic processes (M).
(ii) The rate at which the work is produced (W).
Total heat energy gain by the body = M±W
This energy is spent in five parts as follows:
(i) The rate of exchange with the surroundings via evaporation (E).
(ii) The rate of heat exchange with the surroundings via radiation (R).
(iii) The rate of heat exchange with the environment via convection (C).
(iv) The rate of heat exchange with the surroundings via conduction (D).
(v) The rate of body heat storage (S).

Total heat energy spent by the body = $E \pm R \pm C \pm D \pm S$
The whole gain energy becomes equal to the spend energy by the body and equation (1) becomes balanced. Thus there is no excess temperature in the body in this natural process. The balance of heat energy is expressed by the following equation;

$$M \pm W = E \pm R \pm C \pm D \pm S.$$

But when electromagnetic radiation is penetrated inside the body, the energy is absorbed by the tissues of the biological material. It works as a source of production of extra energy inside the body.

$$M \pm W + E_R \neq E \pm R \pm C \pm D \pm S$$

Where;
E_R Energy due to electromagnetic radiation of transmission tower of mobile phone.

Above equation becomes unequilibrium because production of energy becomes greater to the energy inside the body. This excess energy may increase the temperature of the tissue and may harmful in much other way for tissue life. Change of body temperature is detected, especially externally at the skin and internally by a specialized region of the brain. The information is integrated in the CNS, and regulation is achieved by autonomic and behavioral thermoregulatory reactions.

Materials and Methods

When a human body is exposed to the EM wave of electric field E_{rms}, it penetrates into the body. It results into inside or induced field E_i at a given depth z given by Polk (1996).

$$E_i = E_{rms} exp\left(\frac{-z}{\delta}\right) \quad (1)$$

Where; δ is skin depth, which is the distance over which the field decreases to 0.368 of its value just inside the boundary.

For biological materials the ratio $p = \frac{\sigma}{\varepsilon\omega}$, is of the order of one $(0.1 < p < 10)$ over a wide frequency range, it is frequently necessary to use the more general expression for the skin depth at angular frequency ω to be given as

$$\delta = \frac{1}{\omega\sqrt{\left\{\frac{\mu\varepsilon}{2}\left[(1+p^2)^{\frac{1}{2}} - 1\right]\right\}}}, \quad (2)$$

μ is permeability of body material and ε its permittivity.

As we want to access the effect of radio tower, whose power is the only parameter we know, we have to relate the electric field (more generally E_{rms}) to the power of transmitters.

Power radiated at wavelength λ through a vertically short dipole antenna of length l and having sinusoidal current distribution I_{rms} is given by Prasad (1999) to be

$$P = 80\pi^2(l_e/\lambda)^2 I_{rms}^2 \quad (3)$$

Where; l_e is the effective length of vertically short dipole antenna and given

$$l_e = \frac{2l}{\pi} \quad (4)$$

The electric field strength at a point at distance r within the range of direct ray of short dipole antenna is

$$E_{rms} = \frac{60\pi I_{rms} l_e}{\lambda r} \quad . \qquad (5)$$

But for the case of grounded vertical antenna of effective length l_e, the apparent length will be $2l_e$ due to image effect, so

$$P = 320\pi^2 (l_e/\lambda)^2 I_{rms}^2 \qquad (6)$$

and

$$E_{rms} = \frac{120\pi I_{rms} l_e}{\lambda r} . \qquad (7)$$

Eqn. (6) gives the power radiated through a sphere at the centre of which the antenna of length $2l_e$ is put. Since earth antenna radiate through a hemisphere, power radiated by it is half of that given in eqn. (6)

$$P = 160\pi^2 (l_e/\lambda)^2 I_{rms}^2 \quad . \qquad (8)$$

Now taking the ratio of square of eqn. (7) to (8), we get

$$E_{rms} = \frac{\sqrt{90P}}{r} = 9.487 \frac{\sqrt{P}}{r} , \qquad (9)$$

The influence of electromagnetic waves on the human body mainly contributes to heating effect, which is generated by the absorption of energy above 100 kHz (Akimoto et. al, 2009). It is generally accepted that The specific absorption rate (SAR) is the most appropriate metric for determining electromagnetic exposure, i.e. the mass averaged rate of energy absorption in tissue, is related to the induced electric field EI (V/m) can be determined at any point from the relation (Adair and Peterson, 2002;Hirata et. al, 2008; Osepchuk and Peterson, 2008)

$$SAR = \frac{\sigma E_i^2}{\rho} \qquad (10)$$

where σ is the conductivity of the tissues for which the calculation is made and ρ is their mass density.

The absorption of electromagnetic waves produces temperature change , when a human body of specific heat C, otherwise in thermal equilibrium with environment, is exposed for a duration Δt seconds to these waves, then the local heating to be given by equation (Osepchuk and Peterson, 2008; Stuchly and Stuchly, 1996)

$$C\Delta T = SAR(\Delta t) . \qquad (11)$$

Calculation

Electric field strength reduces with the distance from the mobile tower antenna of power 19.5 W. Table 1 gives the value of electric field at different distances

Table 1. Electric Field Strength (V/m) at Different Distances

Distance from the Tower (in meters)	50	100	150	200	250	300
Electric Field Strength E_{rms} (in V/m)	0.838	0.419	0.279	0.209	0.168	0.139

This electromagnetic wave penetrates inside the tissues. Thus, the induced electric field and SAR values at different distances, for different kinds of tissues of the human body at different depth are numerically evaluated from Table 2 to Table 13.The conductivity of the body tissues is taken from Gabriel et al. (1996 a; 1996 b; 1996 c).

Table 2. Induced Electric Field (V/m) at Different Depth and 50 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.8351	0.8322	0.8293	0.8265	0.8236
Bone Marrow	0.8377	0.8375	0.8372	0.8370	0.8367
Brain Grey Matter	0.8361	0.8342	0.8323	0.8304	0.8285
Brain White Matter	0.8366	0.8352	0.8338	0.8324	0.8311
Cartilage	0.8363	0.8345	0.8328	0.8310	0.8293
Cerebro Spinal Fluid	0.8338	0.8296	0.8254	0.8212	0.8171
Cornea	0.8352	0.8325	0.8297	0.8270	0.8243
Dura	0.8359	0.8337	0.8316	0.8295	0.8274
Fat	0.8377	0.8373	0.8370	0.8367	0.8364
Gland	0.8360	0.8340	0.8320	0.8300	0.8280
Lens	0.8363	0.8345	0.8328	0.8311	0.8294

Mucous Membrane	0.8362	0.8343	0.8325	0.8307	0.8289
Muscle	0.8361	0.8342	0.8323	0.8304	0.8286
Skin Dry	0.8360	0.8340	0.8321	0.8301	0.8281
Vitreous Humor	0.8350	0.8321	0.8292	0.8262	0.8233
Cerebellum	0.8354	0.8328	0.8302	0.8276	0.8250
Tongue	0.8361	0.8343	0.8324	0.8305	0.8287

Table 3. Induced Electric Field (V/m) at Different Depth and 100 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.4175	0.4161	0.4147	0.4132	0.4118
Bone Marrow	0.4189	0.4187	0.4186	0.4185	0.4184
Brain Grey Matter	0.4180	0.4171	0.4161	0.4152	0.4142
Brain White Matter	0.4183	0.4176	0.4169	0.4162	0.4155
Cartilage	0.4181	0.4173	0.4164	0.4155	0.4147
Cerebro Spinal Fluid	0.4169	0.4148	0.4127	0.4106	0.4085
Cornea	0.4176	0.4162	0.4149	0.4135	0.4121
Dura	0.4179	0.4169	0.4158	0.4147	0.4137
Fat	0.4188	0.4187	0.4185	0.4183	0.4182
Gland	0.4180	0.4170	0.4160	0.4150	0.4140
Lens	0.4181	0.4173	0.4164	0.4155	0.4147
Mucous Membrane	0.4181	0.4172	0.4163	0.4153	0.4144
Muscle	0.4181	0.4171	0.4162	0.4152	0.4143
Skin Dry	0.4180	0.4170	0.4160	0.4150	0.4141
Vitreous Humor	0.4175	0.4160	0.4146	0.4131	0.4117
Cerebellum	0.4177	0.4164	0.4151	0.4138	0.4125
Tongue	0.4181	0.4171	0.4162	0.4153	0.4143

Table 4. Induced Electric Field (V/m) at Different Depth and 150 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.2780	0.2771	0.2761	0.2752	0.2742
Bone Marrow	0.2789	0.2788	0.2787	0.2787	0.2786
Brain Grey Matter	0.2784	0.2777	0.2771	0.2765	0.2758
Brain White Matter	0.2785	0.2781	0.2776	0.2771	0.2767
Cartilage	0.2784	0.2778	0.2773	0.2767	0.2761
Cerebro Spinal Fluid	0.2776	0.2762	0.2748	0.2734	0.2720
Cornea	0.2781	0.2772	0.2763	0.2753	0.2744
Dura	0.2783	0.2776	0.2769	0.2762	0.2755
Fat	0.2789	0.2788	0.2787	0.2786	0.2785
Gland	0.2783	0.2777	0.2770	0.2763	0.2757
Lens	0.2784	0.2778	0.2773	0.2767	0.2761
Mucous Membrane	0.2784	0.2778	0.2772	0.2766	0.2760
Muscle	0.2784	0.2777	0.2771	0.2765	0.2759
Skin Dry	0.2783	0.2777	0.2770	0.2764	0.2757
Vitreous Humor	0.2780	0.2770	0.2761	0.2751	0.2741
Cerebellum	0.2781	0.2773	0.2764	0.2755	0.2747
Tongue	0.2784	0.2778	0.2771	0.2765	0.2759

Table 5. Induced Electric Field (V/m) at Different Depth and 200 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.2083	0.2076	0.2068	0.2061	0.2054
Bone Marrow	0.2089	0.2089	0.2088	0.2087	0.2087
Brain Grey Matter	0.2085	0.2080	0.2076	0.2071	0.2066
Brain White Matter	0.2087	0.2083	0.2080	0.2076	0.2073
Cartilage	0.2086	0.2081	0.2077	0.2073	0.2068
Cerebro Spinal Fluid	0.2079	0.2069	0.2058	0.2048	0.2038
Cornea	0.2083	0.2076	0.2069	0.2063	0.2056
Dura	0.2085	0.2079	0.2074	0.2069	0.2063

Fat	0.2089	0.2088	0.2088	0.2087	0.2086
Gland	0.2085	0.2080	0.2075	0.2070	0.2065
Lens	0.2086	0.2081	0.2077	0.2073	0.2068
Mucous Membrane	0.2085	0.2081	0.2076	0.2072	0.2067
Muscle	0.2085	0.2081	0.2076	0.2071	0.2066
Skin Dry	0.2085	0.2080	0.2075	0.2070	0.2065
Vitreous Humor	0.2083	0.2075	0.2068	0.2061	0.2053
Cerebellum	0.2083	0.2077	0.2070	0.2064	0.2058
Tongue	0.2085	0.2081	0.2076	0.2071	0.2067

Table 6. Induced Electric Field (V/m) at Different Depth and 250 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.1674	0.1668	0.1663	0.1657	0.1651
Bone Marrow	0.1679	0.1679	0.1678	0.1678	0.1677
Brain Grey Matter	0.1676	0.1672	0.1669	0.1665	0.1661
Brain White Matter	0.1677	0.1674	0.1672	0.1669	0.1666
Cartilage	0.1677	0.1673	0.1670	0.1666	0.1663
Cerebro Spinal Fluid	0.1672	0.1663	0.1655	0.1646	0.1638
Cornea	0.1674	0.1669	0.1663	0.1658	0.1653
Dura	0.1676	0.1671	0.1667	0.1663	0.1659
Fat	0.1679	0.1679	0.1678	0.1677	0.1677
Gland	0.1676	0.1672	0.1668	0.1664	0.1660
Lens	0.1677	0.1673	0.1670	0.1666	0.1663
Mucous Membrane	0.1676	0.1673	0.1669	0.1665	0.1662
Muscle	0.1676	0.1672	0.1669	0.1665	0.1661
Skin Dry	0.1676	0.1672	0.1668	0.1664	0.1660
Vitreous Humor	0.1674	0.1668	0.1662	0.1656	0.1651
Cerebellum	0.1675	0.1670	0.1664	0.1659	0.1654
Tongue	0.1676	0.1672	0.1669	0.1665	0.1661

Table 7. Induced Electric Field (V/m) at Different Depth and 300 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.1385	0.1380	0.1376	0.1371	0.1366
Bone Marrow	0.1390	0.1389	0.1389	0.1388	0.1388
Brain Grey Matter	0.1387	0.1384	0.1381	0.1377	0.1374
Brain White Matter	0.1388	0.1385	0.1383	0.1381	0.1378
Cartilage	0.1387	0.1384	0.1381	0.1378	0.1376
Cerebro Spinal Fluid	0.1383	0.1376	0.1369	0.1362	0.1355
Cornea	0.1385	0.1381	0.1376	0.1372	0.1367
Dura	0.1386	0.1383	0.1379	0.1376	0.1372
Fat	0.1389	0.1389	0.1388	0.1388	0.1387
Gland	0.1387	0.1383	0.1380	0.1377	0.1373
Lens	0.1387	0.1384	0.1381	0.1379	0.1376
Mucous Membrane	0.1387	0.1384	0.1381	0.1378	0.1375
Muscle	0.1387	0.1384	0.1381	0.1377	0.1374
Skin Dry	0.1387	0.1383	0.1380	0.1377	0.1374
Vitreous Humor	0.1385	0.1380	0.1375	0.1370	0.1366
Cerebellum	0.1386	0.1381	0.1377	0.1373	0.1368
Tongue	0.1387	0.1384	0.1381	0.1378	0.1375

Table 8. Specific Absorption Rate (W/kg) at Different Depth and 50 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.0010	0.0010	0.0010	0.0010	0.0010
Bone Marrow	0.0000	0.0000	0.0000	0.0000	0.0000
Brain Grey Matter	0.0006	0.0006	0.0006	0.0006	0.0006
Brain White Matter	0.0004	0.0004	0.0004	0.0004	0.0004
Cartilage	0.0005	0.0005	0.0005	0.0005	0.0005
Cerebro Spinal Fluid	0.0016	0.0016	0.0016	0.0016	0.0016
Cornea	0.0009	0.0009	0.0009	0.0009	0.0009
Dura	0.0006	0.0006	0.0006	0.0006	0.0006
Fat	0.0000	0.0000	0.0000	0.0000	0.0000
Gland	0.0007	0.0007	0.0007	0.0007	0.0007
Lens	0.0005	0.0005	0.0005	0.0005	0.0005
Mucous Membrane	0.0005	0.0005	0.0005	0.0005	0.0005
Muscle	0.0006	0.0006	0.0006	0.0006	0.0006
Skin Dry	0.0005	0.0005	0.0005	0.0005	0.0005
Vitreous Humor	0.0011	0.0011	0.0011	0.0011	0.0011
Cerebellum	0.0008	0.0008	0.0008	0.0008	0.0008
Tongue	0.0006	0.0006	0.0006	0.0006	0.0006

Table 9. Specific Absorption Rate (10^{-3} W/kg) at Different Depth and 100 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.2465	0.2448	0.2431	0.2414	0.2397
Bone Marrow	0.0064	0.0064	0.0064	0.0064	0.0064
Brain Grey Matter	0.1516	0.1509	0.1502	0.1495	0.1489
Brain White Matter	0.0945	0.0942	0.0939	0.0936	0.0933
Cartilage	0.1177	0.1172	0.1167	0.1162	0.1157
Cerebro Spinal Fluid	0.4096	0.4054	0.4014	0.3973	0.3933
Cornea	0.2192	0.2177	0.2163	0.2149	0.2134
Dura	0.1445	0.1438	0.1431	0.1423	0.1416
Fat	0.0093	0.0093	0.0093	0.0093	0.0093
Gland	0.1666	0.1658	0.1650	0.1642	0.1634
Lens	0.1269	0.1264	0.1259	0.1254	0.1249
Mucous Membrane	0.1359	0.1353	0.1347	0.1341	0.1335
Muscle	0.1519	0.1512	0.1505	0.1498	0.1491
Skin Dry	0.1295	0.1289	0.1283	0.1276	0.1270
Vitreous Humor	0.2779	0.2759	0.2740	0.2721	0.2701
Cerebellum	0.2043	0.2030	0.2018	0.2005	0.1993
Tongue	0.1512	0.1506	0.1499	0.2414	0.1485

Table 10. Specific Absorption Rate (10^{-3} W/kg) at Different Depth and 150 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.1093	0.1085	0.1078	0.1070	0.1063
Bone Marrow	0.0028	0.0028	0.0028	0.0028	0.0028
Brain Grey Matter	0.0672	0.0669	0.0666	0.0663	0.0660
Brain White Matter	0.0419	0.0418	0.0416	0.0415	0.0414
Cartilage	0.0522	0.0520	0.0517	0.0515	0.0513
Cerebro Spinal Fluid	0.1816	0.1798	0.1780	0.1762	0.1744
Cornea	0.0972	0.0965	0.0959	0.0953	0.0946
Dura	0.0641	0.0638	0.0634	0.0631	0.0628
Fat	0.0041	0.0041	0.0041	0.0041	0.0041
Gland	0.0739	0.0735	0.0731	0.0728	0.0725
Lens	0.0563	0.0561	0.0558	0.0556	0.0554
Mucous Membrane	0.0603	0.0600	0.0597	0.0595	0.0592
Muscle	0.0673	0.0670	0.0667	0.0664	0.0661
Skin Dry	0.0574	0.0571	0.0569	0.0566	0.0563
Vitreous Humor	0.1232	0.1223	0.1215	0.1206	0.1198

Cerebellum	0.0906	0.0900	0.0895	0.0889	0.0884
Tongue	0.0671	0.0668	0.0665	0.0662	0.0659

Table 11. Specific Absorption Rate (10^{-3} W/kg) at Different Depth and 200 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.0613	0.0609	0.06048	0.06006	0.05964
Bone Marrow	0.0016	0.0016	0.00158	0.00158	0.00158
Brain Grey Matter	0.0377	0.0375	0.03738	0.03721	0.03704
Brain White Matter	0.0235	0.0234	0.02336	0.02328	0.02320
Cartilage	0.0293	0.0292	0.02904	0.02892	0.02880
Cerebro Spinal Fluid	0.1019	0.1009	0.09986	0.09885	0.09786
Cornea	0.0545	0.0542	0.05381	0.05346	0.05311
Dura	0.0360	0.0358	0.03559	0.03541	0.03523
Fat	0.0023	0.0023	0.00232	0.00232	0.00232
Gland	0.0414	0.0412	0.04105	0.04085	0.04066
Lens	0.0316	0.0315	0.03132	0.03119	0.03107
Mucous Membrane	0.0338	0.0337	0.03352	0.03337	0.03323
Muscle	0.0378	0.0376	0.03745	0.03728	0.03711
Skin Dry	0.0322	0.0321	0.03191	0.03176	0.03161
Vitreous Humor	0.0691	0.0687	0.06817	0.06769	0.06721
Cerebellum	0.0508	0.0505	0.05020	0.04989	0.04958
Tongue	0.0376	0.0375	0.03729	0.03712	0.03696

Table 12. Specific Absorption Rate (10^{-4} W/kg) at Different Depth and 250 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.3962	0.3935	0.3908	0.3881	0.3854
Bone Marrow	0.0102	0.0102	0.0102	0.0102	0.0102
Brain Grey Matter	0.2437	0.2426	0.2415	0.2404	0.2393
Brain White Matter	0.1519	0.1514	0.1509	0.1504	0.1499
Cartilage	0.1892	0.1884	0.1876	0.1869	0.1861
Cerebro Spinal Fluid	0.6584	0.6518	0.6452	0.6387	0.6323
Cornea	0.3523	0.3500	0.3477	0.3454	0.3432
Dura	0.2324	0.2312	0.2300	0.2288	0.2277
Fat	0.0150	0.0150	0.0150	0.0150	0.0150
Gland	0.2678	0.2665	0.2652	0.2640	0.2627
Lens	0.2041	0.2032	0.2024	0.2016	0.2007
Mucous Membrane	0.2185	0.2175	0.2166	0.2156	0.2147
Muscle	0.2442	0.2431	0.2420	0.2409	0.2398
Skin Dry	0.2081	0.2072	0.2062	0.2052	0.2042
Vitreous Humor	0.4468	0.4436	0.4405	0.4374	0.4343
Cerebellum	0.3285	0.3264	0.3244	0.3224	0.3204
Tongue	0.2431	0.2420	0.2410	0.2399	0.2388

Table 13. Specific Absorption Rate (10^{-4} W/kg) at Different Depth and 300 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.2712	0.2694	0.2675	0.2656	0.2638
Bone Marrow	0.0070	0.0070	0.0070	0.0070	0.0070
Brain Grey Matter	0.1668	0.1661	0.1653	0.1646	0.1638
Brain White Matter	0.1040	0.1037	0.1033	0.1030	0.1026
Cartilage	0.1295	0.1290	0.1284	0.1279	0.1274
Cerebro Spinal Fluid	0.4507	0.4462	0.4417	0.4373	0.4328
Cornea	0.2412	0.2396	0.2380	0.2365	0.2349
Dura	0.1591	0.1583	0.1574	0.1566	0.1558
Fat	0.0103	0.0103	0.0103	0.0102	0.0102
Gland	0.1833	0.1824	0.1816	0.1807	0.1798
Lens	0.1397	0.1391	0.1386	0.1380	0.1374
Mucous Membrane	0.1496	0.1489	0.1483	0.1476	0.1470

Muscle	0.1671	0.1664	0.1656	0.1649	0.1641
Skin Dry	0.1425	0.1418	0.1411	0.1405	0.1398
Vitreous Humor	0.3058	0.3037	0.3015	0.2994	0.2973
Cerebellum	0.2249	0.2235	0.2221	0.2207	0.2193
Tongue	0.1664	0.1657	0.1649	0.1642	0.1635

Table14. Rate of Change of Temperature (10^{-6} deg C/sec) at Different Depth and 50 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.2528	0.2510	0.2493	0.2476	0.2459
Bone Marrow	0.0085	0.0085	0.0085	0.0085	0.0085
Brain Grey Matter	0.1596	0.1589	0.1581	0.1574	0.1567
Brain White Matter	0.1080	0.1077	0.1073	0.1069	0.1066
Cartilage	0.1308	0.1302	0.1297	0.1291	0.1286
Cerebro Spinal Fluid	0.4096	0.4054	0.4014	0.3973	0.3933
Cornea	0.2435	0.2419	0.2403	0.2387	0.2372
Dura	0.1606	0.1598	0.1590	0.1581	0.1573
Fat	0.0124	0.0124	0.0124	0.0124	0.0124
Gland	0.1904	0.1895	0.1885	0.1876	0.1868
Lens	0.1693	0.1686	0.1679	0.1672	0.1665
Mucous Membrane	0.1510	0.1503	0.1497	0.1490	0.1484
Muscle	0.1599	0.1591	0.1584	0.1577	0.1570
Skin Dry	0.1439	0.1432	0.1425	0.1418	0.1412
Vitreous Humor	0.2779	0.2759	0.2740	0.2721	0.2701
Cerebellum	0.2209	0.2195	0.2181	0.2168	0.2154
Tongue	0.1833	0.1825	0.1817	0.1809	0.1801

Table 15. Rate of Change of Temperature (10^{-6} deg C/sec) at Different Depth and 100 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.0632	0.0628	0.0623	0.06189	0.06147
Bone Marrow	0.0021	0.0021	0.0021	0.00212	0.00212
Brain Grey Matter	0.0399	0.0397	0.0395	0.03935	0.03917
Brain White Matter	0.0270	0.0269	0.0268	0.02674	0.02665
Cartilage	0.0327	0.0326	0.0324	0.03229	0.03215
Cerebro Spinal Fluid	0.1024	0.1014	0.1003	0.09933	0.09833
Cornea	0.0609	0.0605	0.0601	0.05968	0.05929
Dura	0.0401	0.0399	0.0397	0.03954	0.03933
Fat	0.0031	0.0031	0.0031	0.00310	0.00310
Gland	0.0476	0.0474	0.0471	0.04691	0.04669
Lens	0.0423	0.0421	0.0420	0.04179	0.04162
Mucous Membrane	0.0378	0.0376	0.0374	0.03726	0.03710
Muscle	0.0400	0.0398	0.0396	0.03943	0.03925
Skin Dry	0.0360	0.0358	0.0356	0.03546	0.03529
Vitreous Humor	0.0695	0.0690	0.0685	0.06801	0.06753
Cerebellum	0.0552	0.0549	0.0545	0.05419	0.05386
Tongue	0.0458	0.0456	0.0454	0.04521	0.04501

Table16. Rate of Change of Temperature (10^{-7} deg C/sec) at Different Depth and 150 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.2802	0.2783	0.2763	0.2744	0.2725
Bone Marrow	0.0094	0.0094	0.0094	0.0094	0.0094
Brain Grey Matter	0.1769	0.1761	0.1753	0.1745	0.1737
Brain White Matter	0.1197	0.1193	0.1189	0.1185	0.1181
Cartilage	0.1449	0.1443	0.1437	0.1431	0.1426
Cerebro Spinal Fluid	0.4540	0.4494	0.4449	0.4404	0.4360
Cornea	0.2699	0.2681	0.2664	0.2646	0.2629
Dura	0.1780	0.1771	0.1762	0.1753	0.1744
Fat	0.0138	0.0138	0.0138	0.0138	0.0138

Gland	0.2110	0.2100	0.2090	0.2080	0.2070
Lens	0.1876	0.1868	0.1861	0.1853	0.1845
Mucous Membrane	0.1674	0.1667	0.1659	0.1652	0.1645
Muscle	0.1772	0.1764	0.1756	0.1748	0.1740
Skin Dry	0.1595	0.1587	0.1580	0.1572	0.1565
Vitreous Humor	0.3080	0.3059	0.3037	0.3016	0.2994
Cerebellum	0.2448	0.2433	0.2418	0.2403	0.2388
Tongue	0.2032	0.2023	0.2014	0.2005	0.1996

Table17. Rate of Change of Temperature (10^{-7} deg C/sec) at Different Depth and 200 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.1572	0.1561	0.1551	0.1540	0.1529
Bone Marrow	0.0053	0.0053	0.0053	0.0053	0.0053
Brain Grey Matter	0.0993	0.0988	0.0984	0.0979	0.0975
Brain White Matter	0.0672	0.0670	0.0667	0.0665	0.0663
Cartilage	0.0813	0.0810	0.0807	0.0803	0.0800
Cerebro Spinal Fluid	0.2548	0.2522	0.2497	0.2471	0.2446
Cornea	0.1515	0.1505	0.1495	0.1485	0.1475
Dura	0.0999	0.0994	0.0989	0.0984	0.0979
Fat	0.0077	0.0077	0.0077	0.0077	0.0077
Gland	0.1184	0.1178	0.1173	0.1167	0.1162
Lens	0.1053	0.1048	0.1044	0.1040	0.1036
Mucous Membrane	0.0939	0.0935	0.0931	0.0927	0.0923
Muscle	0.0994	0.0990	0.0985	0.0981	0.0977
Skin Dry	0.0895	0.0891	0.0886	0.0882	0.0878
Vitreous Humor	0.1729	0.1716	0.1704	0.1692	0.1680
Cerebellum	0.1374	0.1365	0.1357	0.1348	0.1340
Tongue	0.1140	0.1135	0.1130	0.1125	0.1120

Table 18. Rate of Change of Temperature (10^{-7} deg C/sec) at Different Depth and 250 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.1016	0.1009	0.1002	0.0995	0.0988
Bone Marrow	0.0034	0.0034	0.0034	0.0034	0.0034
Brain Grey Matter	0.0641	0.0638	0.0636	0.0633	0.0630
Brain White Matter	0.0434	0.0433	0.0431	0.0430	0.0428
Cartilage	0.0526	0.0523	0.0521	0.0519	0.0517
Cerebro Spinal Fluid	0.1646	0.1630	0.1613	0.1597	0.1581
Cornea	0.0979	0.0972	0.0966	0.0960	0.0953
Dura	0.0645	0.0642	0.0639	0.0636	0.0632
Fat	0.0050	0.0050	0.0050	0.0050	0.0050
Gland	0.0765	0.0761	0.0758	0.0754	0.0751
Lens	0.0680	0.0677	0.0675	0.0672	0.0669
Mucous Membrane	0.0607	0.0604	0.0602	0.0599	0.0596
Muscle	0.0643	0.0640	0.0637	0.0634	0.0631
Skin Dry	0.0578	0.0575	0.0573	0.0570	0.0567
Vitreous Humor	0.1117	0.1109	0.1101	0.1093	0.1086
Cerebellum	0.0888	0.0882	0.0877	0.0871	0.0866
Tongue	0.0737	0.0733	0.0730	0.0727	0.0724

Table 19. Rate of Change of Temperature (10^{-7} deg C/sec) at Different Depth and 300 m apart from the Tower

Tissue name	0.1mm	0.2mm	0.3mm	0.4mm	0.5mm
Blood	0.0695	0.0691	0.0686	0.0681	0.0676
Bone Marrow	0.0023	0.0023	0.0023	0.0023	0.0023
Brain Grey Matter	0.0439	0.0437	0.0435	0.0433	0.0431
Brain White Matter	0.0297	0.0296	0.0295	0.0294	0.0293
Cartilage	0.0360	0.0358	0.0357	0.0355	0.0354
Cerebro Spinal Fluid	0.1127	0.1115	0.1104	0.1093	0.1082

Cornea	0.0670	0.0666	0.0661	0.0657	0.0653
Dura	0.0442	0.0440	0.0437	0.0435	0.0433
Fat	0.0034	0.0034	0.0034	0.0034	0.0034
Gland	0.0524	0.0521	0.0519	0.0516	0.0514
Lens	0.0466	0.0464	0.0462	0.0460	0.0458
Mucous Membrane	0.0415	0.0414	0.0412	0.0410	0.0408
Muscle	0.0440	0.0438	0.0436	0.0434	0.0432
Skin Dry	0.0396	0.0394	0.0392	0.0390	0.0388
Vitreous Humor	0.0765	0.0759	0.0754	0.0749	0.0743
Cerebellum	0.0608	0.0604	0.0600	0.0596	0.0593
Tongue	0.0504	0.0502	0.0500	0.0498	0.0495

Results and Discussion

Table 1 represents the incident electric field around the transmission tower of mobile phone tower of power 19.5 W. In general 800 MHz to 2450 MHz frequency of electromagnetic waves are used for communication in the most of the countries in the world. In this manuscript, we select 800 MHz frequency of radiation of electromagnetic waves in all these frequencies. When these electromagnetic waves penetrate inside the body, the electric fields are induced around all the biological tissues. Some tissues are selected for this study. Since most of the tissues are tolerant to low temperature, organism have evolved various sets of sophisticated control mechanism to avoid this i.e. physiological or behavioral which includes convected heat energy or inhale air. This serves to guard against thermal hazards .There are thermal sensors throughout the body in different tissues which monitor the temperature and report back to the central control unit i.e. brain stem. This control mechanism is most sensitive and obviates the need for controlling the central heating (Black, 2006). With a particular thermoregulatory mechanism, the brain controls the heating with heat exchange with the blood that flows through its tissues (Rodrigues et. al, 2007).

Table 2 to 7 represents the induced electric field inside the different tissues at different distances 50 to 300 m from the tower respectively. According to IEEE and ICNIRP, the safe limits of electric field are 27.5 and 28 V/m respectively. Although, these tables show that on behalf of IEEE and ICNIRP the induced electric field are safe for health but these electric fields are absorbed in the form of energy by the tissues. Table 8 to 13 show the specific absorption rate (SAR) by the different tissues at the distances of 50 to 300 m from the tower respectively for the above mentioned tissues. As given in the above tables, the maximum and minimum SAR is in Cerebro Spinal Fluid and in bone marrow respectively. In these above tissues of the body, 98% absorption is more in Cerebro Spinal Fluid than bone marrow. The maximum to minimum order of absorption for tissues are given as Cerebro Spinal Fluid, Vitreous Humor, Blood, Cornea, Cerebellum, Gland, Muscle, Brain Grey Matter, Tongue, Dura, Mucous Membrane, Skin Dry, Lens, Cartilage, Brain White Matter, Fat and Bone Marrow respectively. Although, the values of SAR given in tables are below to these limits which are announced by the International Agencies, but due to the incident electromagnetic radiations, extra energies are absorbed by the body. The excess of energy may be harmful in some another way. Due to the absorption of energy, the temperature of the tissues in increased. Table 14 to 19 gives the computation of the rate of change of temperature in different tissues at the depth ranging from 0.1to 0.5 mm inside the body. Rate of change of temperature shows the increased temperature in tissues per second. The maximum and minimum increase in temperature is for Cerebro Spinal Fluid and for Bone Marrow respectively. The maximum to minimum order of increasing temperature are Cerebro Spinal Fluid, Vitreous Humor, Blood, Cornea, Cerebellum, Gland, Tongue, Lens, Dura, Muscle, Brain Grey Matter, Mucous Membrane, Skin Dry, Cartilage, Brain White Matter, Fat and Bone Marrow. There is a lot of variation in temperature in different tissues. 98.4% of extra temperature of Cerebro Spinal Fluid is increased than Bone Marrow. Similar difference is observed in other tissues. As the exposure limit of radiation is increased, the temperature of the tissues is increased very rapidly. When this temperature increases greater to 39^{o}C, it can produce many diseases in tissues and may become harmful for the life of tissues (Habash, 2008).

Conclusion

Now days, the microwave towers are installing in thickly populated area, therefore, the users of these radiation should be made aware for their possible health risks. The people should know the permissible limit of the radiation and about the hazards due to excessive exposure of these radiations. Therefore, high power transmitters should be installed away from the thickly populated area, so that the harmful effects of radiation become minimized.

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