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# Thermal Effect Due to Induced Field of Broadcasting Radiation

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## ABSTRACT

Thermal effect inside the tissues causes due to penetration and absorption of radio frequency radiation emitted by radio broadcasting antenna. Numerical calculation is made for the specific absorption rate in consequence of induced electric field due to radio tower at different distances from the transmission tower. The depth of penetration inside the blood and cerebro spinal fluid is also varied. The temperature of the body is maintained at a set point through the thermoregulatory mechanism of the body, is also discussed. The damage of tissues may cause due to unavailability of sufficient mechanisms to carry away all of the unwanted heat during the gain of heat energy deposited through broadcasting antenna, which would be harmful for human being. The comparison is made by the international guidelines of World Health Organization (WHO) and International Commission on Non-Ionization Radiation Protection (ICNIRP) for the amount of energy deposition due to radio frequency of high power broadcasting antenna inside the selected tissues. To follow the international guidelines carefully for installation of high power transmitters of radio frequency radiation is recommended and the suggestion is made for the minimum distance of human being from broadcasting antenna for safe exposure

***Keywords:*** *Induced electric field, Specific absorption rate, Rate of Change of temperature, Thermoregulatory mechanism, Broadcasting antenna.*

## INTRODUCTION

In present times of faster communication, we are exposed to many types of radiation from all types of communication systems like TV, radio and mobile telephony etc. Generally speaking, some radiation penetrates and is being absorbed by the human body when it is exposed to it. Depending on the frequency of radiation, the human body interacts with such a field via induced currents and thermal effects. The field generated within the body, the so-called internal field, is determined by the amount by which a body is influenced by electromagnetic fields. The EMF can be characterized by several different parameters (field strength, field direction, field orientation, field complexity and so on) (Gandhi and Mohammad, 2008). The quantity used to measure how much RF energy is actually absorbed in a body is called the specific absorption rate (SAR). 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). The heat generated in the medium is proportional to the absorbed power. The biological effects of radiofrequency energy depend on the rate at which power is absorbed (Osepchuk and Petersen, 2003). If the organism cannot dissipate this heat energy as fast as heat is produced, the internal temperature of the body will rise.

Exposure from TV and Radio transmitters have been studied by Joseph and Martens (2006) and Sirav and Seyhan (2009). Pathak et al. (2003) and Kumar et al. (2008) assessed the temperature change in tissues per second by taking the TV transmitters of high frequency radiation as a point source. Due to exposure to microwave radiation many health risks have been studied including brain tumors, acoustic neuroma, leukemia and testicular cancer, sleep disturbances and headache (Johansen, 2004; Takebayashi et al. 2006, 2008; Hardell et al. 2007). Wessapan (2011) calculated the local SARs and temperature increase of human model for various operating frequencies, also focusing on the interaction between electromagnetic field and organs in the human trunk.

In this manuscript the specific absorption rate as a result of induced electric field is assessed due to the radio frequency antenna of All India Radio, situated in Mussoorie (Uttarakhand), India. The calculation of induced electric field and SAR in selected tissues is made by taking the transmitter of finite length dipole antenna. The frequency used for the calculation is 102.1 MHz of FM (rel.) broadcasting and power of the antenna is 10 kW. The calculation is made at different distances from the antenna and at different depth inside the tissues.

Public access to broadcasting antennas is normally restricted so individuals cannot be exposed to high-level fields that might exist near antennas. Ambient RF radiation levels in inhabited areas near broadcasting facilities must be typically well below the exposure levels recommended by current

standards and guidelines. Therefore, precautions must be taken to ensure that maintenance personnel are not exposed to unsafe RF fields.

## Thermoregulation

Thermoregulation of the human body in the presence of RF fields follows the laws of thermodynamics in which heat and work are balanced and conserved. The whole gain energy becomes equal to the spend energy by the body. Thus there is no excess temperature in the body in this natural process. More specialized adaptation of the relevant equations has been developed by thermal physiologists. The balance of heat energy is expressed by the following equation;

$$M + W = E \pm R \pm C \pm D \pm S \quad , \qquad (1)$$

where $M$ is the rate at which thermal energy is produced through metabolic processes, $W$, the rate at which the work is produced, $E$, the rate of exchange with the surroundings via evaporation, $R$, the rate of heat exchange with the surroundings via radiation, $C$, the rate of heat exchange with the environment via convection, $D$, the rate of heat exchange with the surroundings via conduction and $S$ represents the rate of body heat storage.

The ability of various thermal sensors to initiate mechanisms of heat loss, during the gain of heat energy deposited by the dissipation of electrical currents deposited by RF energy depends on the availability of sufficient mechanisms (vasomotor, sudomotor in addition to convection and radiation) to carry away all of the unwanted heat. Without this, cooling cannot occur and the core body temperature will continue to rise.

Thus, 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.

$$M \pm W + E_R = E \pm R \pm C \pm D \pm S \quad , (2)$$

where $E_R$ is the energy due to electromagnetic radiation of broadcasting antenna.. Above equation becomes un-equilibrium 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.

## MATERIAL AND METHODS

As we want to access the effect of broadcasting antenna, whose power P is the only parameter we know, we have to relate the electric field (more generally $E_{rms}$ ) to the power of transmitters which is distance far from the biological body (Prasad, 1999).

$$E_{rms} = \frac{\sqrt{90P}}{r} = 9.487\frac{\sqrt{P}}{r} \quad , \qquad (3)$$

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).

$$E_i = E_{rms} \exp\left(\frac{-z}{\delta}\right) \quad , \qquad (4)$$

where $\delta$ is skin depth, which is the distance over which the field decreases to 0.368 of its value just inside the boundary at angular frequency $\omega$ , given as

$$\delta = \frac{1}{\omega\sqrt{\frac{\mu\varepsilon}{2}\left\{\left[(1+p^2)^{\frac{1}{2}} - 1\right]\right\}}} \quad , \qquad (5)$$

where $\mu$ is the permeability of body material, $\varepsilon$ , its permittivity and biological material ratio $p = \frac{\sigma}{\varepsilon\omega}$, $\sigma$ being its conductivity.

It is generally accepted that the 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 $E_i\,(V/m)$ can be determined at any point from the relation (Hirata et al., 2008)

$$SAR = \frac{\sigma E_i^2}{\rho} \quad , \qquad (6)$$

where $\sigma$ is the conductivity of the tissues for which the calculation is made and $\rho$ is their mass density.

## Calculation

This electromagnetic wave penetrates inside the body. Thus, the induced electric field at different distances in the blood and cerebro spinal fluid of the human body at different depth is numerically evaluated in Table 1 and 2. The induction of field causes the deposition of energy in the form of SAR. The values of SAR corresponding to induced electric field are also calculated in Table 3 and 4. The conductivity of the body tissues is taken from Gabriel et al. (1996 a, b, c)

**Table 1:** Induced Electric Field (V/m) at different depths in blood at different distances due to radiation from All India Radio Antenna of power 10 kW at 102.1 MHz

| Distance (m) | 10 µm | 20 µm | 30 µm | 40 µm | 50 µm |
|---|---|---|---|---|---|
| **10** | 94.8522 | 94.8344 | 94.8166 | 94.7988 | 94.7810 |
| **20** | 47.4261 | 47.4172 | 47.4083 | 47.3994 | 47.3905 |
| **30** | 31.6171 | 31.6111 | 31.6052 | 31.5993 | 31.5933 |
| **40** | 23.7135 | 23.7091 | 23.7046 | 23.7002 | 23.6957 |
| **50** | 18.9704 | 18.9669 | 18.9633 | 18.9598 | 18.9562 |
| **60** | 15.8090 | 15.8061 | 15.8031 | 15.8001 | 15.7972 |
| **70** | 13.5505 | 13.5479 | 13.5454 | 13.5428 | 13.5403 |
| **80** | 11.8568 | 11.8545 | 11.8523 | 11.8501 | 11.8479 |
| **90** | 10.5390 | 10.5370 | 10.5351 | 10.5331 | 10.5311 |
| **100** | 9.4852 | 9.4834 | 9.4817 | 9.4799 | 9.4781 |
| **110** | 8.6234 | 8.6218 | 8.6201 | 8.6185 | 8.6169 |
| **120** | 7.9045 | 7.9030 | 7.9015 | 7.9001 | 7.8986 |

**Table 2:** Induced Electric Field (V/m) at different depths in cerebro spinal fluid at different distances due to radiation from All India Radio Antenna of power 10 kW at 102.1 MHz

| Distance (m) | 10 µm | 20 µm | 30 µm | 40 µm | 50 µm |
|---|---|---|---|---|---|
| **10** | 94.8454 | 94.8207 | 94.7961 | 94.7715 | 94.7469 |
| **20** | 47.4227 | 47.4104 | 47.3981 | 47.3858 | 47.3735 |
| **30** | 31.6148 | 31.6066 | 31.5984 | 31.5902 | 31.5820 |
| **40** | 23.7118 | 23.7057 | 23.6995 | 23.6934 | 23.6872 |
| **50** | 18.9691 | 18.9641 | 18.9592 | 18.9543 | 18.9494 |
| **60** | 15.8079 | 15.8038 | 15.7997 | 15.7956 | 15.7915 |
| **70** | 13.5495 | 13.5460 | 13.5424 | 13.5389 | 13.5354 |
| **80** | 11.8559 | 11.8528 | 11.8498 | 11.8467 | 11.8436 |
| **90** | 10.5383 | 10.5355 | 10.5328 | 10.5301 | 10.5273 |
| **100** | 9.4845 | 9.4821 | 9.4796 | 9.4772 | 9.4747 |
| **110** | 8.6228 | 8.6205 | 8.6183 | 8.6160 | 8.6138 |
| **120** | 7.9039 | 7.9019 | 7.8998 | 7.8978 | 7.8957 |
| **130** | 7.2961 | 7.2942 | 7.2923 | 7.2904 | 7.2885 |
| **140** | 6.7742 | 6.7725 | 6.7707 | 6.7690 | 6.7672 |
| **150** | 6.3234 | 6.3217 | 6.3201 | 6.3184 | 6.3168 |
| **160** | 5.9275 | 5.9259 | 5.9244 | 5.9228 | 5.9213 |

**Table 3:** Specific Absorption Rate (W/kg) at different de[illegible] blood at different distances due to radiation from All India Radio Antenna of power 10 kW at 102.1 MHz

| Distance (m) | 10 µm | 20 µm | 30 µm | 40 µm | 50 µm |
|---|---|---|---|---|---|
| **10** | 10.4763 | 10.4724 | 10.4685 | 10.4645 | 10.4606 |
| **20** | 2.6191 | 2.6181 | 2.6171 | 2.6161 | 2.6152 |
| **30** | 1.1640 | 1.1636 | 1.1631 | 1.1627 | 1.1623 |
| **40** | 0.6548 | 0.6546 | 0.6543 | 0.6541 | 0.6538 |
| **50** | 0.4191 | 0.4189 | 0.4187 | 0.4186 | 0.4184 |
| **60** | 0.2910 | 0.2909 | 0.2908 | 0.2907 | 0.2906 |
| **70** | 0.2138 | 0.2137 | 0.2136 | 0.2136 | 0.2135 |
| **80** | 0.1637 | 0.1636 | 0.1636 | 0.1635 | 0.1635 |
| **90** | 0.1293 | 0.1293 | 0.1292 | 0.1292 | 0.1291 |
| **100** | 0.1048 | 0.1047 | 0.1047 | 0.1046 | 0.1046 |
| **110** | 0.0866 | 0.0866 | 0.0865 | 0.0865 | 0.0865 |
| **120** | 0.0728 | 0.0727 | 0.0727 | 0.0727 | 0.0726 |

**Table 4:** Specific Absorption Rate (W/kg) at different depths in cerebro spinal fluid at different distances due to radiation from All India Radio Antenna of power 10 kW at 102.1 MHz

| Distance (m) | 10 µm | 20 µm | 30 µm | 40 µm | 50 µm |
|---|---|---|---|---|---|
| **10** | 18.8526 | 18.8428 | 18.8330 | 18.8232 | 18.8134 |
| **20** | 4.7131 | 4.7107 | 4.7082 | 4.7058 | 4.7034 |
| **30** | 2.0947 | 2.0936 | 2.0925 | 2.0914 | 2.0903 |
| **40** | 1.1783 | 1.1777 | 1.1771 | 1.1765 | 1.1759 |
| **50** | 0.7541 | 0.7537 | 0.7533 | 0.7529 | 0.7525 |
| **60** | 0.5237 | 0.5234 | 0.5232 | 0.5229 | 0.5226 |
| **70** | 0.3848 | 0.3846 | 0.3844 | 0.3842 | 0.3840 |
| **80** | 0.2946 | 0.2944 | 0.2943 | 0.2941 | 0.2940 |
| **90** | 0.2327 | 0.2326 | 0.2325 | 0.2324 | 0.2323 |
| **100** | 0.1885 | 0.1884 | 0.1883 | 0.1882 | 0.1881 |
| **110** | 0.1558 | 0.1557 | 0.1557 | 0.1556 | 0.1555 |
| **120** | 0.1309 | 0.1309 | 0.1308 | 0.1307 | 0.1307 |
| **130** | 0.1116 | 0.1115 | 0.1114 | 0.1114 | 0.1113 |
| **140** | 0.0962 | 0.0961 | 0.0961 | 0.0960 | 0.0960 |
| **150** | 0.0838 | 0.0838 | 0.0837 | 0.0837 | 0.0836 |

| | | | | | |
|---|---|---|---|---|---|
| **160** | 0.0736 | 0.0736 | 0.0736 | 0.0735 | 0.0735 |

## RESULTS AND DISCUSSION

Table 1 and 2 show the induced electric field and table 3 and 4 represent SAR at different distances from the broadcasting antenna in the blood and cerebro spinal fluid. The depth of penetration ranges from 10 µm to 50 µm. The broadcasting antenna of power 10 kW is used for calculation which is running at radio frequency i.e. to broadcast the signals. The values of SAR are above up to the distance 110 m than the value recommended by WHO and ICNIRP guidelines. However, the corresponding values for blood at a distance of 120 m are below the guidelines but, Table 4 represents that the corresponding values for cerebro spinal fluid up to a distance of 150 m are very near to the limiting point of the guidelines. These tables also represent the variation in induced electric field and SAR on increasing the depth inside the tissues. For blood the variation is not very large after 70 m and it become approximately constant after 120 m and for cerebro spinal fluid the variation is not very large after 90 m and it become approximately constant after 160 m.

## CONCLUSION

However, while technologies have been a vital part of our daily and we cannot avoid this, nor would we wish to, because technology makes our lives healthier, wealthier and safer but these radiations penetrate the tissues and may heat the tissue due to long term exposure, to its extent to bear which would be harmful for our health. Therefore, the international guidelines for installation of high power radio frequency transmitters must be made very clear and followed strictly. The installation of high power broadcasting antenna must be kept at least 150 m away from the high populated area. The public should also be made aware of the use of radio frequency sources and the minimum distance which must be kept by them to live safer and healthy.

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