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# Assessment of electromagnetic radiation for second and third generation frequency spectrum on human body

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The rapid diffusion of wireless communication systems such as mobile phones has caused an increased concern for the potential effects on human health deriving from exposure to electromagnetic fields emitted by antennas and base stations of these systems. A number of studies have been conducted on the topic of electromagnetic field effects over human body. All earlier studies were centered on the second generation (2G) global system for mobile communication (GSM). Now, third generation (3G) mobiles and towers have been launched in the market, therefore, it is high time to calculate the radiation effect of increased frequency of 3G system over human body. In this paper, the specific absorption rate (SAR) value for skin (dry and wet) tissues of human body have been evaluated at 900, 1800 and 2140 MHz frequency bands. The first two frequencies represent the second generation (2G) and the third frequency represents the third generation (3G), respectively. The skin exposure due to base transceiver station (BTS) is calculated through SAR up to a distance of 3.5 mm inside skin for these frequencies. It has been found that values of SAR for electromagnetic radiation due to 2G and 3G frequency spectrums are very highly distributed near the source of radiation (BTS) and SAR have more effect on skin as one moves towards higher frequency band.

**Keywords:** Mobile phone, Radio frequency electromagnetic field, Specific absorption rate (SAR), Electromagnetic wave, Base transceiver station (BTS), Code division multiple access (CDMA), Universal mobile telecommunication system (UMTS)

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## 1 Introduction

In the last decade, the mobile communication system has experienced very high growth rate all over the world. All the mobile communication is based on radio frequency electromagnetic fields (RF-EMF). The human body is particularly sensitive to radio frequency electromagnetic fields because at this frequency, the body absorbs a significant amount of the radiated energy. There are numerous scientific evidences that RF radiation effects human body, which may be of short term (behavioural changes, lack of concentration, less sleep, etc.) or long term (DNA effect, cancer, miscarriage risks, etc.).

According to a study of WHO’s International Agency for Research on Cancer (IARC), published in Hindustan Times 02 June 2011, cell phone use is classified as carcinogenic. A group of 31 scientists from 14 countries have reported that the radio frequency electromagnetic field, associated with wireless phone use, has an increased risk of glioma, a malignant type of brain cancer.

The radio frequency exposure can be classified in terms of the amount of energy absorbed by a unit mass of the object[1]. This is expressed as the specific absorption rate (SAR) with units of W $kg^{-1}$. SAR decides whether the radio emission is hazardous to human or not. It is acceptable up to a reference value. The increased value of SAR raises the body temperature which finally causes an increased risk to human body[2]. The objective of this paper is to find out that whether 2G and 3G frequency spectrums used by base transceiver stations (BTSs) play vital role in increasing hazards to human body and if, yes, then the safe limit beyond which SAR is under the range should be predicted.

## 2 Methodology

### 2.1 Incident electric field at some distance with base transceiver station (BTS)

The BTS radiating power, P (watt), gradually decreases with the increase in distance. Thus,

$P \propto 1/r$ ... (1)

The electric field intensity at a distance 'r' from BTS is given as[3]:

$E_o = 7.746\sqrt{P/r}$ (V m$^{-1}$) … (2)

where, P, is the total effective isotropically radiated power (EIRP) in a given direction. The equivalent isotropically radiated power in the direction of maximum antenna gain (in watts) after calculating various traffic channel powers as shown in Fig. 1 is given by[4]:

P or EIRP [T] = EIRP (BCCH) watts + EIRP (BCCH) watts × 0.9 × 0.9 × (Carriers / Sector – 1) = 827.9 ≈ 828

where, EIRP (BCCH) = T × Power – Combiner loss – (Cable length × Unit loss) + Antenna gain (dBm)

The value of P placed in Eq. (2):

$E_o = 7.746 \times (\sqrt{828})/r = 222.85/r$ V m$^{-1}$ … (3)

#### 2.2 Induced electric field inside the body

The electric field induced in the body varies with various tissues of human body. It can be represented by[3]:

$E_i = E_0 \exp^{(-z/\delta)}$ … (4)

where, $E_0$, is the electric field at which human body is exposed at various distances; z, the thickness inside the tissues; and δ, the skin depth [equals to 1/qω; where, q, is the charge; and ω, the frequency in radian]

#### 2.3 Specific absorption rate (SAR)

SAR is the unit of measurement of RF energy absorbed by the body during exposure of EM radiation. Here, SAR is being evaluated for two different frequency bands, i.e. 900 and 2100 MHz as used by transmitters of 2G and 3G, respectively. The SAR values were evaluated for different distances from BTS and for different depths inside the body[5]. It can be described as the mass averaged rate of energy absorption in body tissue. In terms of the energy absorbed ***dW*** in the mass element ***dm*** in time ***dt***, SAR (W Kg$^{-1}$) is given by Adair & Peterson[6] as:

SAR = d/dt (dW/dm) … (5)

If the volume of element is dV and ρ is the density of element, dm = ρdV, hence

SAR = d/dt (dW/ρdV) … (6)

By using Poyinting vector theorem for sinusoidal electromagnetic field, one gets:

$SAR = \sigma E_i^2/\rho$ … (7)

where, σ, is electrical conductivity; ρ, the tissue density of the body material; and $E_i$, the electric field inside that tissue. SAR has been calculated for dry and wet skin at 900, 1800 and 2140 MHz frequencies where the values of σ and ρ are taken from Stuchly & Stuchly[7].

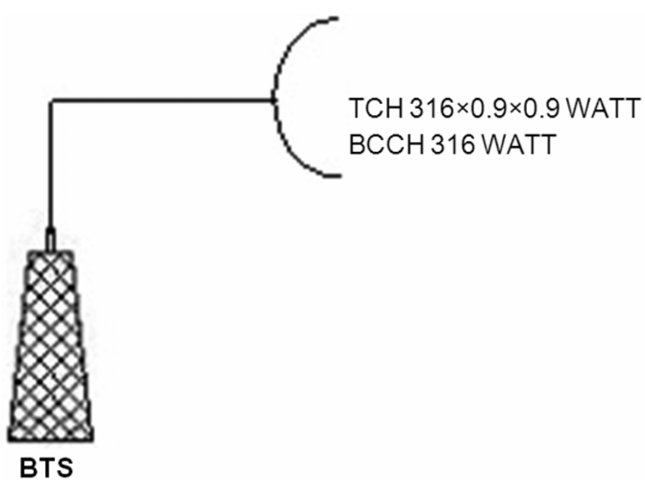


Fig. 1 — Various traffic channels power

## 3 Results and Discussion

It is known that the radiated electric field varies inversely with distance from the transmission tower as shown in Eq. (2). This electric field propagates around the tower when the base station tower starts functioning and its strength varies with the distance as shown in Table 1. SAR values are calculated for skin (dry and wet) tissues of human body at three different frequencies[9], i.e. 900, 1800 and 2140 MHz. The SAR effect for human body is shown in Tables 2 - 4. The depth of penetration is taken up to 3.5 mm inside skin.

It is found that the harmful values of SAR for skin (dry and wet) are up to a distance of 4 m from BTS at 900 MHz while it is dangerous up to a distance of 5 m for 1800 and 2140 MHz. Harmful values are shown as dark in tables.

Table-1 — Incident electric field at different distances from BTS

| S No | Distance from BTS, m | Incident electric field Eo, V m$^{-1}$ |
|---|---|---|
| 1 | 1 | 222.85 |
| 2 | 2 | 111.43 |
| 3 | 4 | 55.71 |
| 4 | 5 | 44.57 |
| 5 | 7 | 31.84 |
| 6 | 10 | 22.29 |
| 7 | 20 | 11.14 |

Table 2 — Variation of SAR in skin (dry and wet) at different distances (m) from BTS operating at 900 MHz

| Distance from BTS, m | Incident electric field ($E_o$), $Vm^{-1}$ | SAR inside the skin at the depth, W $kg^{-1}$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1.5 mm | | 2.5 mm | | 3.5 mm | |
| | | dry | wet | dry | wet | dry | wet |
| 1 | 222.85 | 35.49 | 34.79 | 33.76 | 33.22 | 32.11 | 31.73 |
| 2 | 111.43 | 8.87 | 8.70 | 8.44 | 8.31 | 8.03 | 7.93 |
| 4 | 55.71 | 2.22 | 2.17 | 2.11 | 2.08 | 2.01 | 1.98 |
| 5 | 44.57 | 1.42 | 1.39 | 1.35 | 1.33 | 1.28 | 1.27 |
| 7 | 31.84 | 0.72 | 0.71 | 0.69 | 0.68 | 0.66 | 0.65 |
| 10 | 22.29 | 0.36 | 0.35 | 0.34 | 0.33 | 0.32 | 0.32 |
| 20 | 11.14 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 |

Table 3 — Variation of SAR in skin (dry and wet) at different distances (m) from BTS operating at 1800 MHz

| Distance from BTS, m | Incident electric field ($E_o$), $Vm^{-1}$ | SAR inside the skin at the depth, W $kg^{-1}$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1.5 mm | | 2.5 mm | | 3.5 mm | |
| | | dry | wet | dry | wet | dry | wet |
| 1 | 222.85 | 46.48 | 44.71 | 43.74 | 41.73 | 40.73 | 38.95 |
| 2 | 111.43 | 11.74 | 11.18 | 10.94 | 10.43 | 10.18 | 9.74 |
| 4 | 55.71 | 2.94 | 2.79 | 2.73 | 2.61 | 2.54 | 2.73 |
| 5 | 44.57 | 1.88 | 1.79 | 1.75 | 1.67 | 1.63 | 1.56 |
| 7 | 31.84 | 0.96 | 0.91 | 0.89 | 0.85 | 0.83 | 0.80 |
| 10 | 22.29 | 0.47 | 0.45 | 0.44 | 0.42 | 0.41 | 0.39 |
| 20 | 11.14 | 0.12 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 |

Table 4 — Variation of SAR in skin (dry and wet ) at different distances (m) from BTS operating at 2140 MHz

| Distance from BTS, m | Incident electric field ($E_o$), $Vm^{-1}$ | SAR inside the skin at the depth, W $kg^{-1}$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1.5 mm | | 2.5 mm | | 3.5 mm | |
| | | dry | wet | dry | wet | dry | wet |
| 1 | 222.85 | 51.84 | 55.24 | 47.85 | 50.99 | 44.18 | 47.06 |
| 2 | 111.43 | 12.96 | 13.81 | 11.96 | 12.75 | 11.05 | 11.77 |
| 4 | 55.71 | 3.24 | 3.45 | 2.99 | 3.19 | 2.76 | 2.94 |
| 5 | 44.57 | 2.07 | 2.21 | 1.91 | 2.04 | 1.77 | 1.88 |
| 7 | 31.84 | 1.06 | 1.13 | 0.98 | 1.04 | 0.90 | 0.96 |
| 10 | 22.29 | 0.52 | 0.55 | 0.48 | 0.51 | 0.44 | 0.47 |
| 20 | 11.14 | 0.13 | 0.14 | 0.12 | 0.12 | 0.11 | 0.11 |

International Commission on Non Ionizing Radiation Protection (ICNIRP) and The Institute of Electrical & Electronic Engineers (IEEE) agree that the exposure of general public should be kept below the whole body SAR of 1.6 W $kg^{-1}$ for safe exposure from cellular devices. Many other agencies working in this regard are National Council on Radiation Protection & Measurement (NCRP)[8], World Health Organization (WHO) and Federal Communications Commission (FCC).

## 4 Conclusions

From the above analysis, it is concluded that frequencies used in 2G and 3G wireless communications are radiation prone and harmful for the human health. As already mentioned that SAR values beyond 1.6 W $Kg^{-1}$ are harmful for human body as decided by many national and international agencies. These are clearly shown as dark in Tables 2-4. The results depicts that the increase in frequency also increases SAR value, thus, one can say that 2140 MHz has more radiation effects than 1800 and 900 MHz. This hazardous value may be the reason for many diseases and disorders in human beings. The radiation becomes more harmful and beyond tolerable limits as the distance from transmission tower becomes less because the penetrating power gets very high near transmission tower due to high SAR value. Therefore, it is suggested that no transmission tower should be placed near populated areas and nobody should be in direct contact with the radiation up to a distance of 5 meter because the radiation is beyond tolerable limits.

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