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AN INVESTIGATION ON MOBILE TOWER RADIATION AND ITS EFFECT ON HUMAN BODY

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ABSTRACT

To address health issues regarding mobile tower radiation, Indian Government and ICNIRP recommended human exposure limit as 450mW/m^2 and 4.5W/m^2, respectively. The present work is a part of our endeavour to provide detailed sets of experimental data (followed by simulation) on mobile tower radiation exposure involving crowded places of India. Peak power density was measured within 900-960 MHz frequency in crowded areas of Kolkata and Gurugram and was found to be much higher than the prescribed limit in many places. At Sector44 and Barbeque Nation, the densities are 11 and 13W/m^2, respectively - much higher than the present guideline. Using the measured peak radiation power, simulated Specific Absorption Radiation (SAR) is found to be nearly 35 times the prescribed Indian standard; yielding corresponding increase in temperature within the head as 0.52^{0}C for 30minutes duration. This effect is highest within the skin and fat tissues, which may increase further with exposure time. This work, for the first time, investigates (by measuring & simulating) mobile tower radiation in two big cities of India. The non-compliance of Indian standard by mobile operators, as our study exposes, may be an important issue to deal with in near future, by the Government and local residents.

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INTRODUCTION

The continual conflict between growth and development of human civilization with sustenance of natural environment is a ubiquitous fact (Johnson, 1993; Rai *et al.,* 2014; Suvarna Lakshmi *et al.,* 2008). The harmony with nature and human being is possible, if and only if we understand correctly the very meaning of environment and its pollution. As given by Environment Protection Act 1986, environment is the sum total of land, water, air, inter relationships among themselves and also with the human beings and other living organisms. Pollution is the introduction of different harmful pollutants into certain environment that makes this environment unhealthy to live in. Air, water and noise pollution are the three major types of pollution. All these components are perceptible to human sense organs. But modern human lifestyle has put us in contact with another component of pollution, which is completely invisible and imperceptible to human being. This is the pollution created due to exposure of electromagnetic waves, more specifically the radio waves originated from mobile phones and mobile towers (Kumar and Kumar, 2009).

Acquisition and use of mobile phones have witnessed a tremendous increase across India over last one decade and nobody can deny the fact that mobile phone has remarkable benefits to the society. However, this seemingly welcomed development and life changing technology may be associated with health implications due to the electromagnetic radiations from both the mobile handset and the mobile towers *i.e.* the base stations (Ushie *et al.*, 2011).

There are over 1.6 billion mobile phone users worldwide. Associated mobile base station sites have also been estimated to be about 5 million, a number expected to grow to more than 11 million by 2020 (WHO, 2006). In India, mobile network uses the global system for mobile communication (GSM) where mobile towers emit radio frequency (RF) radiation within the frequency band 900-960 MHz. This band is distributed to various mobile operators. Each operator may transmit 50 to 100W of power and total power radiation by the tower may vary depending on total number of operators. Besides, the gain of antennas may multiply the power emitted up to several kW (Kumar, 2010).

The tremendous increase of usage of mobile phone among the residents of India has encouraged the mobile service providers to erect mobile base towers within and around public places such as schools, offices and even on the top of living apartment and houses. The mobile phone towers radiate non-ionizing electromagnetic (EM) field (UK, 2013). People living in proximity to those base towers are being exposed almost continuously to such radiation. Exposure to mobile radiation may cause two-fold harmful effects on human body. One is thermal effect due to the absorbed mobile microwave radiation in biological tissues of human body. A long term exposure can severely harm the tissues by increasing the temperature beyond the recommended limit of 2^{o}C. However, there is also concern about the effect of cumulative RF radiation resulting from continuous exposure (WHO, 2006; UK, 2013). Again, different non-thermal effects have been observed on the refolding kinetics of the heme binding site in an intracellular protein

(Mancinelli *et al.,* 2004) of the cell DNA. The combined effect of both thermal and non-thermal events can be detrimental to living being, causing cell damage, brain tumour, even cancer and death (Hardell, 2007; Kumar, 2010; UK, 2013). The basic idea behind this work is to investigate the extent of mobile tower radiation in crowded areas and to simulate its effect on human body in our country.

Before proceeding to the brief review of existing literature, it is important to understand the mobile tower radiation norms (in terms of power density ~ W/m^2 unit) prevailing within the countries. Due to the health concern, different countries set up their mobile tower radiation norms. International Commission on Non-ionizing Radiation Protection (ICNIRP) in collaboration with World Health Organization (WHO), in 1998, proposed a maximum exposure of radiation of 4.5W/m^2 from mobile towers to eliminate health concerns (ICNIRP, 1998). In India, this limit is 450mW/m^2. However, some countries, like Italy, follow more stringent rules (exposure limit 95mW/m^2 in crowded areas).

The absorption of mobile radiation is generally presented by the specific absorption rate SAR. It is an index that measures the level of radio frequency electromagnetic field in the human head or body, as emitted by the mobile phone (or mobile base station) when operating at full power. Its unit is W/ kg and calculated as:

$SAR = \frac{\sigma E^2}{\rho}$, where electric field strength E is in V/m, ρ is the mass-density of tissue in kg/m^3, σ is electrical conductivity in S/m. SAR averaged over X-g of tissue is denoted by X-g SAR. In USA, Institute of Electrical and electronics Engineers (IEEE) and Federal Communication Commission (FCC) have recommended peak 1-g SAR not exceeding 1.6 W/kg, but in Europe and Japan, ICNIRP has recommended 10-g SAR not exceeding 2W/kg as upper safety limit. In India, this limit was 2W/kg which has recently been changed to 1.6W/kg over 1g of tissue (Kumar, 2010).

The mobile base tower radiation has been studied in the past by different groups in different countries. Haumann et al (2002) measured the radiation at residential areas of Germany during the years 2001 to 2002 and they found a few locations where radiation had exceeded 1mW/m^2. 1mW/m^2 may well be the threshold power density for non-thermal effects in the human body, as a few researchers generally demand (Mancinelli, 2004; Miclaus, 2007; Ragy, 2015). Ayinmode (2014) found radiation level, in crowded areas of Lagos, Nigeria, less than 5mW/m^2 for a distance more than 200m away from mobile towers. Seyfi (2013) measured EM radiation level in an apartment of Turkey from mobile towers located 200m or further distance away and showed that it was below ICNIRP norms. In India, in a recent work (Kumar, 2010) the radiation power of mobile base stations at locations like Gurgaon-Delhi (GD) highway and a few places of Delhi and Mumbai were measured. At the GD highway, power density was found to be about 700mW/m^2 (Kumar 2010). There are also reports (Chitranshi et al, 2014; Jain et al, 2014, Parandham, 2013) of increasing power density with the increase in the number of carriers in a mobile base station. There the exposure to power density was found to be enhanced for the people residing within 50-300m from the nearest mobile tower.

To investigate the effect of radiation, researchers directly exposed human cells to mobile radiation and also carried out simulations. Repacholi (1998) found that pulsed radio waves within GSM frequency band could damage cell membrane channels. Simulations were also done to estimate the thermal effects of mobile phone and SAR in human brain, kidney and retina (Ali, 2014; Ragy, 2015). Several studies on DNA breakage and cancer induction due to exposure to mobile tower and phone radiation have also been reported (Diem *et al,* 2005; Repacholi *et al*., 1997). Sabbah (2010), Lak and Oraizi (2013) carried out simulations to find the heating effect of brain due to mobile radiations. There the increase in temperature in human brain was found to be more than 0.1^{0}C for a SAR value of 1W/kg. The maximum increase in temperature was inside the skin and the fat tissues.

However, the harmful effects of mobile tower radiation and mobile phone radiation are yet to be ascertained completely due to lack of comprehensive investigations in the crowded cities. In crowded cities flats, tall office buildings, hospitals etc are found to be exposed to mobile towers within a very close distance, even less than 100m or so. In spite of that, a part of the researcher community does not believe that mobile phone radiation harms human being at all. This is mostly due to the inconclusive evidences and lack of wide ranging data (Lerchl and Wilhelm, 2010; Moulder *et al*., 1999). On the other hand, recent epidemiological study done by Kumar (2010) showed increased possibility of brain tumour and cancer of the people living near mobile base towers. Interestingly, recently in an incident, people protested against setting up of mobile towers in Gurugram in the fear of environmental pollution and health hazards (Times of India, 2014). Under these confusing situations, it is important to investigate the mobile tower radiation power density in a detail and systematic manner in the crowded areas of our country. A pool of data is required to predict the harmful effects. Therefore, an initiative has been taken in the present study to measure mobile tower radiation power density in major cities of India, especially at highly crowded areas.

MATERIALS AND METHODS

The present measurement of GSM 900MHz radio frequency power density was performed using the spectrum analyzer (Spectran HF 4040V3 with hyperlog antenna) in densely urban places in Kolkata, Gurugram and New Delhi. The measurement has been done according to the method given in Haumann et al (2002). All measurements are performed obeying Swiss BUWAL guideline (BUWAL, 2002) of measurement regarding the time of exposure, orientation of the detector etc. The minimum detection limit of the spectrum analyser used is 0.001μW/m^2. The distances of the towers from the measurement sites were from 50m to 500m and all the data were taken in the crowded places. In a few places more than one tower was present in the locality within 50m-100m distance.

The heat developed and temperature increased in the brain tissue is calculated from the bioheat equation: $C\frac{dT}{dt} = SAR$, assuming that the temperature increase is in the worst case, where all the electromagnetic energy is used to increase the temperature and any mechanism of heat dissipation is not present. Here $\frac{dT}{dt}$ is the rate of increase of temperature with time t and C is the tissue specific heat). We also neglect the thermal conduction within the body (Miclaus, 2007).

RESULTS AND DISCUSSION

The peak values of the power density measured over 2 minutes at different places are given in table 1. The same is also plotted as bar chart in Fig 1. Recommended Indian and ICNIRP standards are also shown in the same figure. It is clear from the figure that the maximum peak mobile phone radiation power density observed in many locations is higher than the recommended values of India Government. A few areas of Gurugram, Sector44 and Barbeque Nation, even violate ICNIRP norm which is much lenient than present Indian standard. The name of the location 'Barbeque Nation' (near Susantlok) draws special attention as it has recently attracted news in leading newspapers regarding the widespread establishment of mobile phone towers and the protest thereby from inhabitants against the use of those towers(Times of India, 2014). Kolkata, in comparison to Gurugram, is found to be using mobile towers with radiation generally less than ICNIRP standards but still has many locations with radiation much higher than Indian standard. The exceptionally high value of peak radiation power density as observed at multi-provider base station is alarming indeed.

In previous measurements (Kumar, 2010), data collected from Delhi and Mumbai were rather meagre. Moreover, the data did not represent crowded areas and the method of data collection was also reported not in detail. In Jain et al (2014), the data were collected from the campus of IIT, Roorkee only. Our work, for the very first time in India, represents most crowded areas of two big cities -- Kolkata and Gurugram along with a few places of New Delhi. This shows the dire need of

Table 1: The peak radiation from the towers at different places in Kolkata, Gurugram, New Delhi and the distances involved

	Place	Peak radiation power density	Distance from the tower
KOLKATA	Ruby More	360mW/m^2	100 m from 2 towers
	Medica Hospital (Outside)	1W/m^2	50m from 4 towers
	Medica Hospital (inside)	670μW/m^2	200m from 4 towers
	AMRI	485 mW/m^2	100m
	Mukandpur	454 mW/m^2	100m
	RN Tagore Hospital	1 mW/m^2	200m from 1 tower
	Abhisikta	87mW/m^2	200m from 1 tower
	PG Hospital (out)	2 W/m^2	50m from 2 towers
	Apollo Hospital (out)	3 W/m^2	50m
	Apollo Hospital (in)	1 mW/m^2	200m
	Big Bazar	2 W/m^2	120m from 5 towers
	South City	500 mW/m^2	150m
	Lake Town	626 mW/m^2	200m
	Mani Square	700 mW/m^2	150m
GURUGRAM&	Kutubminar Metro Station	800μW/m^2	200m from 2 towers
NEWDELHI	Chattarpur Hill Road (near 60ft Road)	12mW/m^2	100m from 2 towers
	Ahimsa Sthall	1mW/m^2	200m
	Barbeque Nation	13W/m^2	5 towers, 70m
	Susantlok	15mW/m^2	300m from 2 towers
	Sector 44	11W/m^2	100m from 3 towers
	Taj Vivanta (near Siddharth apartment)	4W/m^2	50 m
	Giescke & Devrient	10mW/m^2	200m from 1 tower
	Spencer	5W/m^2	Towers located at the roof of the mall
	Pumpkin House School	1W/m^2	2 towers, 80m
	IFFCO Chowk	608μW/m^2	500m
	Beverly Park	5mW/m^2	300m
	Fortis Hospital entrance	800μW/m^2	500m
	HUDA City Centre	3W/m^2	50m
	Galleria Road/Max Hospital gate	500mW/m^2	50m
	MG Road Metro	1W/m^2	50m

Table 2: The properties of six layer human head at frequency 900MHz.

Layer	Relative permittivity	Bulk conductivity (S/m)	Mass density (Kg/m^3)	Specific heat C (J/K-kg)
Skin	41.4	0.87	1100	3600
Fat	5.46	0.051	920	3000
Bone	12.45	0.14	1850	3100
Dura	44.4	0.96	1050	3600
CSF	68.7	2.41	1060	4000
Brain	45.8	0.77	1030	3650

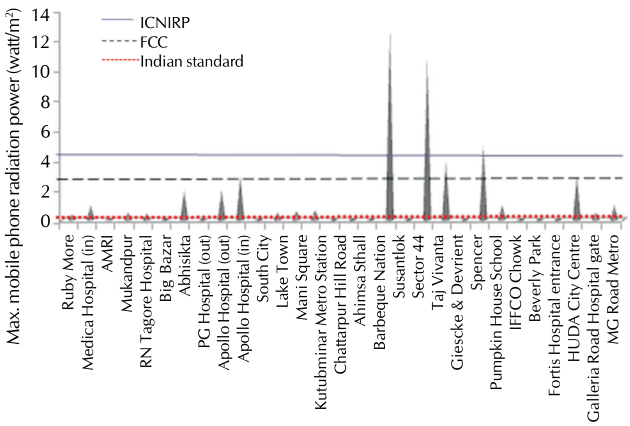

Figure 1: The bar chart of radiation power density at different locations of Kolkata, Gurugram and New Delhi

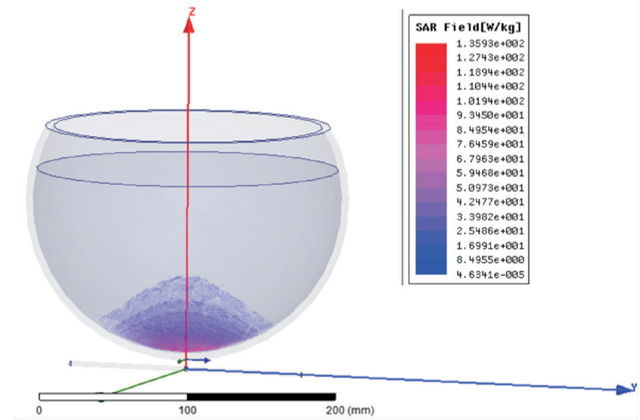

Figure 2: The human head one layer model along with SAR distribution. This human head model is taken in the HFSS simulation

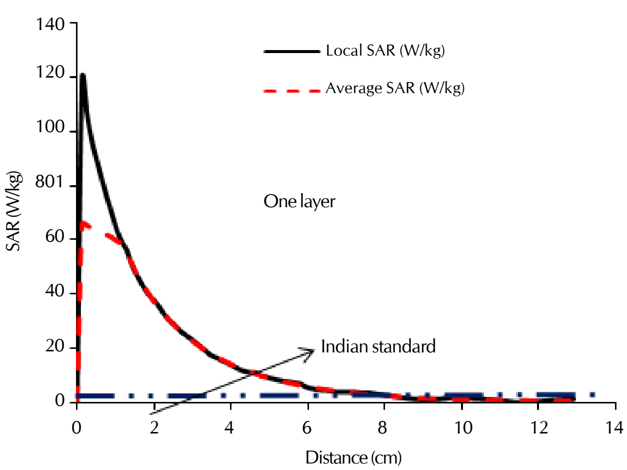

Figure 3: 10g local and average SAR distribution within one layer human head estimated by HFSS simulation. The Indian standard SAR is also shown by blue double dotted-dashed line

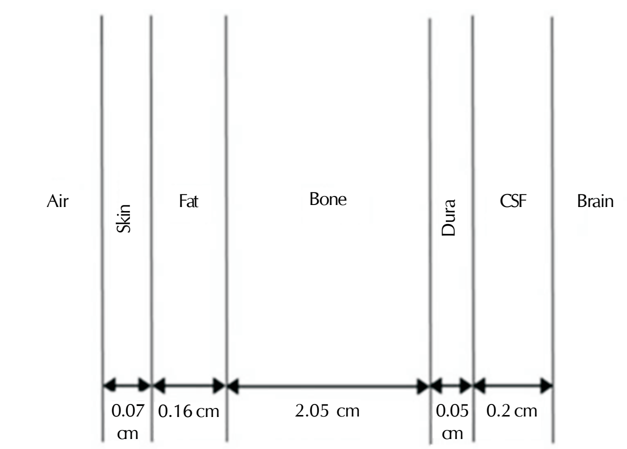

Figure 4: The six layer human head model along with distance from the skin

adequate planning in the part of the Government as well as the common people so that the radiation limit can be brought under the recommended values.

The effect of this radiation from mobile tower on human body is simulated using FDTD (Finite Difference Time Domain) method within the purview of electromagnetism. The major objective of the simulation is to calculate the heating effect in the human brain barring any kind of complicated brain structure.

Due to the availability of commercial system in High Frequency Structure Simulator (HFSS), the most common model of human head is a thin bowl (a 5mm thick shell of inner and outer radii as 10.65 cm and 11.15 cm, respectively with relative permittivity as 4.6). It contains brain tissue equivalent material (relative permittivity of 42.9 and bulk conductance 0.77 S/m) in the form of hemispherical bowl. This method of simulation by HFSS was adopted in Lak and Oraizi (2013) and Choi *et al* (2014). Figure 2 shows the model along with a dipole antenna (of length 14.9 cm) source which radiates dipole radiation of frequency 940MHz and power of 13W. In the simulation done in this work, the power of mobile radiation is chosen as the maximum power achieved during our measurement.

The 10g average and local Specific absorption radiation (SAR) in the brain tissue as a function of distance are plotted in Fig 3. The SAR is found to be highest in the beginning which gradually decays almost exponentially. The highest average SAR is found to be nearly 60W/kg near the skin as was also found in Kapdi *et al*. (2008), which is almost 40 times the recommended value of 1.6W/kg in India.

Since the human head contains different layers of tissue materials, it cannot be simulated correctly considering only one layer. Previously, human head was simulated by six different layers (Sabbah, 2010) as shown in Fig 4 and the basic properties of different materials are described in Table 2. Therefore, we have tried to simulate human brain containing brain fluid having relative permittivity, bulk conductivity and mass density averaged over different layers as shown in Fig 4 taking weightage on the length of the layers. The weighted average of relative permittivity, bulk conductivity and mass density are found as 36.42, 0.63 S/m and 1030kg/m^3, respectively. Next the simulation event is generated taking the power of radiation as 13W. The local and average 10g SAR

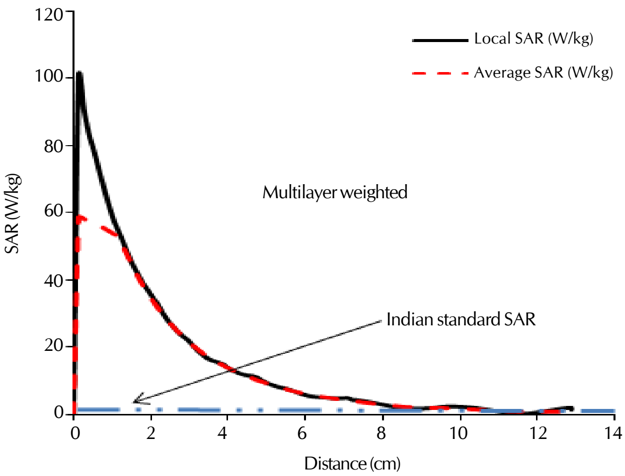

Figure 5: The local and average SAR distribution in a multilayer human head model

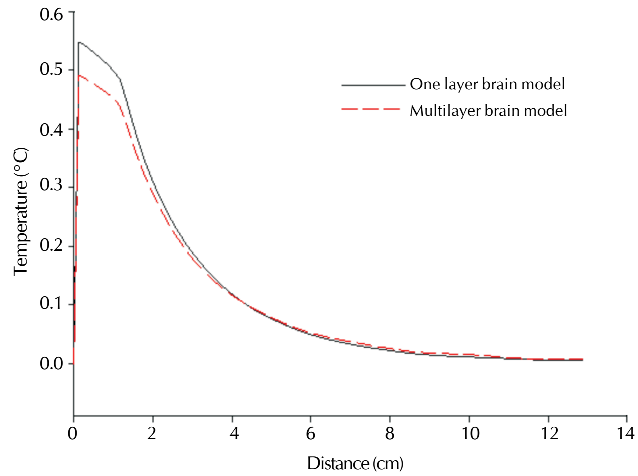

Figure 6: The change in temperature within human head estimated by bioheat equation for 30min time duration

are shown in Fig 5 and like in single layer case, the SAR is highest in the skin and much higher than the Indian standard (almost 35 times). Thus the SAR distribution indicates that the worst affected areas are skin and fat tissues. The brain inside is much less affected.

Figure 6 shows the change in temperature within the human head due to the exposure of the mobile tower radiation for time duration of 30 minutes, calculated using bioheat equation as stated earlier. The black continuous line and red dashed line are due to one layer and multilayer head simulations, respectively. Temperature change observed is highest in skin and fat tissues and gradually decreases thereafter. It is found that if the exposure time increases, the change in temperature would rise very fast, which may pose severe threat even to human brain, by increasing the temperature by more than 2ºC, the limit mentioned by WHO.

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