Determination of Safe Distance Limit from Cellular base Station Radiation Exposure using SAR Analysis

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ABSTRACT
The remarkable growth of telecommunication industry resulted in boost in the number of cell-phone user everyday. Daily exposure to GSM-EMF has raised public concern of possible undesirable health effects to people living in the vicinity of base station (BS) antennas. The radiation exposure to EMF for a certain period of time will lead to health problem that is briefly explained in this paper. Presented here are measurements of incident electric field and obtained results are used for numerical prediction of Specific Absorption Rate (SAR) in order to check compliance for safety limits. This paper also presents the computed SAR in the human brain phantom model using measured field strengths from RF signals radiated by cellular BS operating in the 925 MHz band.

Keywords
Base station antennas, radiation hazards, Specific absorption rate, and Finite difference time domain

1. INTRODUCTION
Millions of people around the world use cellular phones as a communication device every day. Telecommunication towers or BSs are continuously being erected. An incredible amount of publicity generated in the mass media about ease of access to cellular phones has also caused great concern among members of the public [1]. We are living in both natural and man-made radiation world. Radiations broadly categorized in two parts like (a) Ionizing radiation - It contains enough energy to cause ionization. The electrons are stripped from atoms molecules known as Ionization. It can change the chemical reactions in the body that leads to damage in biological tissues including effects on DNA - the genetic material. Gamma rays and X-rays are the most significant forms of ionizing radiations. (b) Non-ionizing radiation - It does not have sufficient energy to cause ionization in living matter. It causes heating effect, but usually not enough to cause any kind of long term damage to tissues. RF energy, visible light and microwave radiation are non ionizing radiation. Scientist has known that this radiation might cause human biological damage through heating effects. International guidelines and standards established for limiting human exposure to electromagnetic fields are given in two categories: basic restrictions (SAR, induced power density) and reference levels (free space electric field intensity, power density and magnetic field intensity) [2]. Hutter et al. [3] presented the use of mobile phones before bed disturbs sleep which is important for full recuperation of brain and body. This study looked at the effects of phone tower radiation among people living near ten GSM phone antennas in Vienna and Carinthia. It established that, in homes with highest exposures, people reported more horrible symptoms including: (a) three times as many headaches, (b) 2.3 times the incidence of tremor, (c) 2.5 times the incidence of cold hands/feet and concentration problems, (d) 2.4 times the incidence of appetite loss,(e) twice as much exhaustion and (f) twice as much fatigue. Mild et al. [4] discovered that among people living closer than 300m away from the BS, there was an increased incidence of headache. Chou et al. [5] claimed to have evidence of altered nerve function in the skin of a mobile phone user, around the ear area. Andrzejak et al. [6] estimated the influence of the call with a mobile phone on heart rate variability (HRV) in young healthy people. Myung et al [7] discovered that the chances of developing tumor [8] are "significantly increased" for people who use cell phones for 10 years. They also found that a type of brain tumor/glioma is more likely in long-term mobile users. Table 1 depicts the different RF sources with range of operating frequency and transmitted power.

Table 1. Different RF sources with their operating frequency and transmitted power

Sl. No.	R. F Source	Operating Freq.	Transmission Power
1	AM/FM Tower	540 KHz – 108 MHz	1 KW-300 KW
2	TV Tower	48 MHz – 814 MHz	10-500 W
3	Wi-Fi	2.4 – 2.5 GHz	10-100 mW
4	Cell Towers	800, 900, 1800, 2450 MHz	20 W
5	Mobile Phones	GSM- 1800/CDMA GSM-900	1W, 2W

1.1 Biological Effects
Epidemiological studies deals with the symptoms like sleeping disruption, headache, depression discomfort, irritability, dizziness, appetite loss and many more [9]. All these are related due to changes in electrical activity of the brain. Different organs like heart, lungs, nervous system, eyes and thyroid gland have been shown to be especially susceptible to radio waves. In the last couple of decades, diseases like sleep, attention deficit and anxiety disorders,

asthma, epilepsy chronic fatigue syndrome, cataracts, hypothyroidism, diabetes, cancer, heart attacks and strokes in young people have increased remarkably. Radiation from cellular BS affects human skin like crawling, biting and stinging sensations, granules, and black speck-like materials on or beneath the skin and/or lesions (e.g., rashes or sores). EMFs degrade the immune system and stimulate various allergic and inflammatory responses.

1.2 Thermal Effect

This effect of cellular phone radiation comes from two aspects. First one when the user is using the cellular phone, the phone is transmitting and receiving by its antenna and the microwave exposure is partially absorbed by the user's head and other body tissues. Second, ions in the cells in human body which can be turned into electric current by giving required amount of frequency, this electric energy also gets into heat energy as the dielectric loss exists in human body.

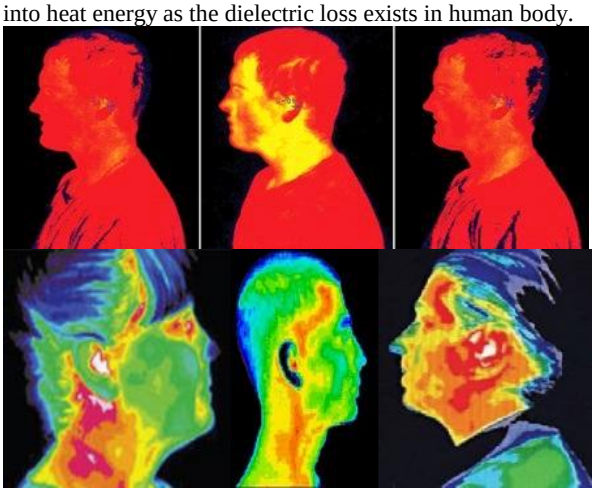

Fig 1: Thermal effect on human body [10]

The World health organization (WHO)/International Agency for Research on Cancer (IARC) has classified RF-EMFs as possibly carcinogenic to humans, based on an increased risk for glioma, a malignant type of brain cancer, associated with wireless phone use [11]. A group of German doctors found an increased incidence of cancer in patients living near mobile phone towers. The study found that after five years of exposure, people had three times the risk of developing cancer of those living further from the transmitter [12]. However, most of the people don't know that they are having the sleep disorder and concentration problems due to EMF radiation or the people are less aware of it. And being a heavily populated country, this study looked at the effects of phone tower radiation among people living near ten GSM-BS antennas.

Thus similar situation of our country motivates to calculate both the absorption of electromagnetic energy (SAR) in the human body and the resulting thermal effect. Since the large amount of general population is using the mobile phones, there is a need to determine the level of radiation in respect to the exposure standards. These small steps must mark the beginnings of a major march forwards.

2. OVERVIEW OF OPERATION

In principle, RF levels decrease rapidly when a person moves further away from the transmitting antenna. For each antenna, the RF level can be measured based on its electrical characteristics. The distance at which the RF level is always below the RF limit is known as compliance distance. The compliance distance may be based on the reference levels or an SAR evaluation; in either case it incorporates a substantial safety margin [13]. The occupational exposure limits for RF fields: Action values - external electric and magnetic field strength, induced body current and exposure limit values - Peak SAR (10g), whole body average SAR, induced current density (<10MHz). It is also possible to determine a 3D-compliance boundary around an antenna. The region inside the compliance boundary is often known as exclusion zone. The advantage of compliance boundary is that it specifies the compliance distance in all directions. Usually BS antennas are highly directional and therefore the RF level behind the antenna is much smaller than in front of it.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines [14] specify an averaging time of 6 min. for determining the exposure level. Therefore, an RF level exceeding the reference level for a short period does not necessarily mean that the RF limit has been exceeded. In practice, this means that even if people walk through a compliance boundary zone, they are unlikely to be subject to overexposure. However, the averaging time should only used with expert advice. In Fig. 2, the first boundary shows the danger zone, where the distance very near to the BS and distance from first boundary to second boundary is the occupational distance limit and distance beyond this is the safe zone for general people.

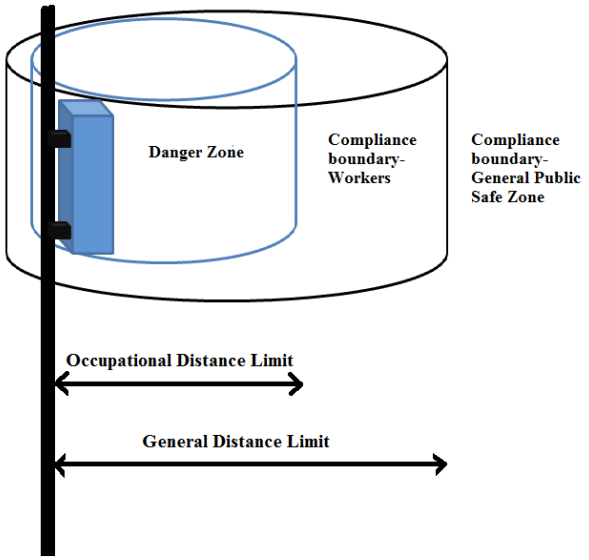

Fig 2: Proposed system model for safe limit identification

The primary and secondary dataset has been used in this study. The secondary data were collected from records of the ICNIRP and IEEE recommended guidelines while the primary data were collected via survey.

3. RESULTS AND ANALYSIS

Maxwell's equations are implemented using well-known computational electrodynamics modeling technique like finite-difference time domain (FDTD) numerical method for solving partial differential equations in both space and time domain [15] [16] to investigate the radiation effects in human body. Flat head Phantom model for human body has been proposed and implemented using incident electric fields and Perfect Matched Layers (PML) [17] boundary conditions due to the impossibility of simulating an infinite space. The electric field distribution and SAR are calculated for all

possible human organs using the measured electric field intensity at 925 MHz. The SAR effect has been predicted for brain with proposed model. It is observed that the effect is higher in higher frequencies and the organ affects worse is brain [18]. The SAR predicted by the proposed model for measured radiated fields at aforementioned frequencies are compared with safety guidelines given by the recognized body such as ANSI/IEEE, ICNIRP guidelines [19]. The power density and electric field over distance for GSM 925 MHz application compared to the limit for public exposures are obtained. The occupational range is 0.9 m. It is concluded that no transmission tower should be located near the populated area. It also be suggested that nobody should reach near 1.35 m to the cellular BS.

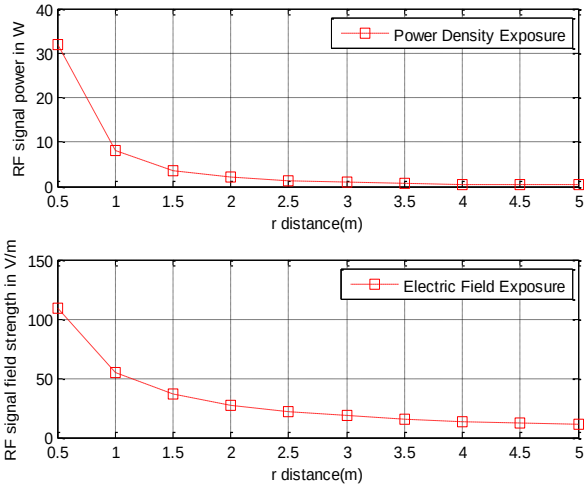

Fig 3: Power density and Electric field over distance for GSM 925 MHz application compared to the limit for public exposures

The ICNIRP recommended and IEEE recommended SAR limits are 2W/kg averaged over 10 gram and 1.6W/kg averaged over 1 gram of tissue respectively. SAR is defined as

$$SAR = (\sigma |E^2|)/\rho \quad (1)$$

where σ is the conductivity of body tissue, E is the root mean square of intensity of electrical field at considered point and ρ is the mass density of tissue at that point respectively.

Table 2. Indicator status display

Distance in between Cellular-BS & Phantom (*m*)	RF signal power density (*W*)	RF signal field strength (*V/m*)	Indicator status
0.5	31.83	109.52	Non Complaint - inside of danger zone
1	7.95	54.76	Usually Complaint - inside of severe exposure zone
1.5	3.53	36.50	Complaint - inside of the safety zone
2	1.98	27.38	Complaint - inside of the safety zone
2.5	1.27	21.90	Complaint - inside of the safety zone
3	0.88	18.25	Complaint - inside of the safety zone
3.5	0.64	15.64	Complaint - inside of the safety zone
4	0.49	13.69	Complaint - inside of the safety zone
4.5	0.39	12.16	Complaint - inside of the safety zone
5	0.31	10.95	Complaint - inside of the safety zone

SAR distributions inside the human head model (X, Y) plane and (X, Z) plane for distance (r) equals to 1 m at frequency of 925 MHz have been obtained with different time step in Fig.4. The grid resolution was chosen such that to provide at least 10 samples per wavelength up through 5 GHz, with the current source is located in the center of the grid. In Fig. 5 the SAR is obtained in the human head model at frequency 925 MHz for a set of r in range of 0.5 to 5 m. It has seen that the SAR is obtained in range 7.85W/Kg to 0.047 W/Kg. When r is less than 1m then SAR is above FCC and ICNIRP safety limits (2 W/Kg). For r is greater than and equal to 1m, the values of SAR remain below the upper safety limits. The SAR estimation and electric field variation has been developed as incident field using MATLAB code for proposed phantom model. The estimated SAR values in FDTD have been compared with safe guidelines given by recognized body such as ANSI/IEEE and ICNIRP.

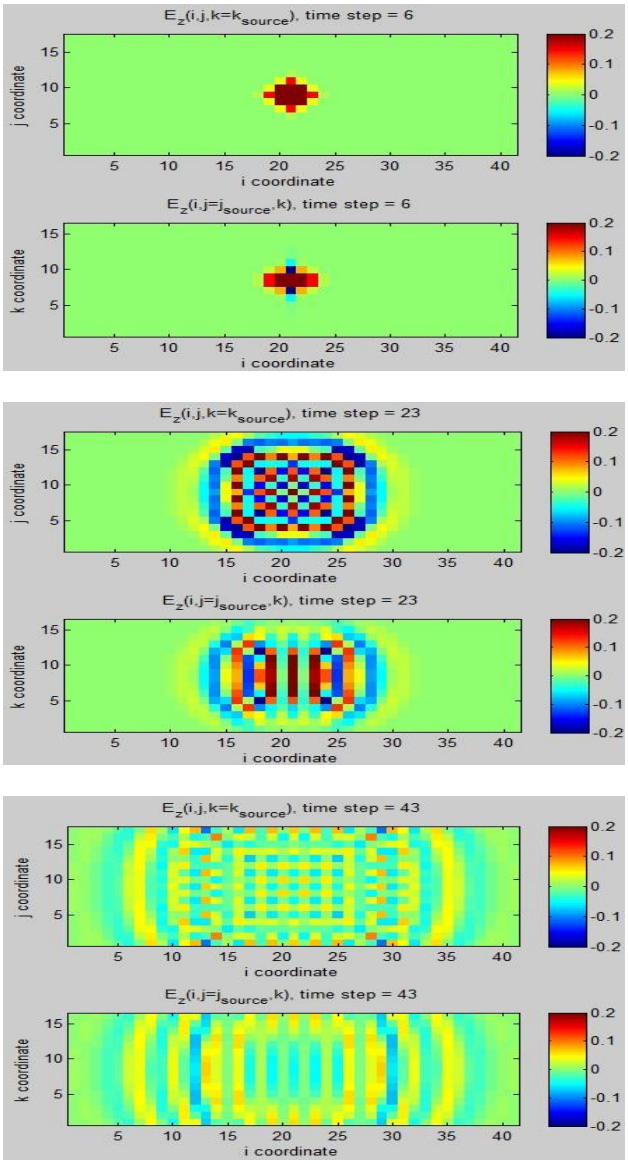

Fig 4: SAR distributions inside the human head model (X,Y) and (X,Z) plane

4. CONCLUSIONS

This analysis shows that the human body can absorb the thermal radiation from the cellular BSs easily, where temperature of the human body increase significantly as one moves in the vicinity of BS. Actually the whole body phantom is not considered, we used only head phantom model. So we can't say exactly it is safe but we can predict not deadly dangerous. In this work EMF, power density and SAR has been calculated in close proximity to BS by considering human head as a rectangular shaped, homogenous dielectric medium exposed to a 100 Watt GSM using FDTD combining Friss transmission formula. The calculated values of SAR have been compared and verified with standard limits given by ICNIRP guidelines. Numerical SAR simulations and FDTD method were proposed to generate compliance distances and to simplify the adherence process to calculate the either peak or average value of the SAR localized body. The variation of the SAR with the distance between the cellular BS and the human body has been observed.

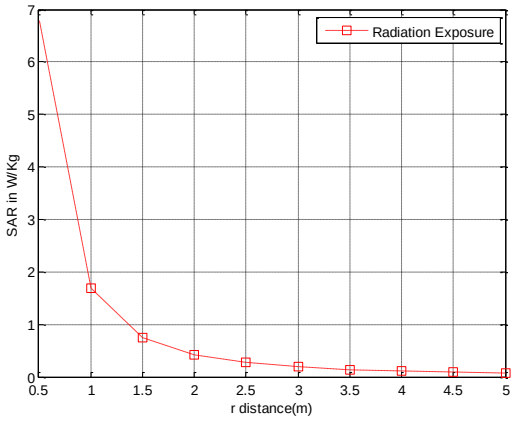

Fig 5: SAR vs. distance in human head model at frequency 925MHz

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