



Harmful Effects of Electromagnetic Field (EMF) Radiation from mobile towers and handsets on Humans: A Review

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Abstract: In the last decade, the Indian telecom sector in general and mobile telephony in particular has witnessed phenomenal growth. As on May 2014, of the 938 million connections in the country 910 million are wireless. [1] The popularity of the mobile phone has resulted in a proliferation of cell towers across the country. But there has been a growing public concern on the possible adverse health effects due to Electro-magnetic field (EMF) Radiation from mobile towers and mobile handsets. There have been several studies suggesting either the presence or absence of risk to human beings from EMF radiation. The main areas of concern are the radiations emitted by the base transceiver stations (BTS) and mobile handsets. These radiations are suspected to cause harmful thermal and non-thermal health effects. The effects of exposure to EMF have created an active scientific debate among the research agencies across the globe.

This paper focuses on the various technical aspects of radiation emanating from the BTS, the interaction of radiation with human body (SAR – Specific Absorption Rate) and the possible adverse health effects of such radiations by analyzing various studies published in this field.

Keywords: BTS (Base Transceiver Station), Electromagnetic field (EMF) radiation, health effects, research agencies, SAR (Specific Absorption Rate).

I. Introduction

EMF radiations are divided into two categories, ionizing and non-ionizing, depending on frequency and the power level.

Ionizing radiation is electromagnetic radiation whose waves contain energy sufficient to overcome the binding energy of electrons in atoms or molecules, thus creating ions. e.g. Ultraviolet rays, X-rays, gamma rays and cosmic rays.

Non-ionizing radiation refers to any type of electromagnetic radiation that does not carry enough energy to ionize atoms or molecules. e.g. low frequency radiations like radio waves, microwaves, and infrared radiations. EM emissions in the frequency range of 1 Hz to 1THz(1000 GHz) are termed as non-ionizing and do not have enough energy to change the chemical bonds of the human body. EMF health effects related to the non-ionizing radiation include tissue heating at levels above limits. Electromagnetic emissions at frequencies above 1 THz are termed as ionizing and have enough potential to alter the chemical bonds of human tissue resulting in serious genetic damage on prolonged exposure. [1]

Various studies researching the health effects of cell phone use have yielded mixed results. Some studies suggested a link between exposure to radiation from cell phones and an increased risk of acoustic neuronal- a tumor of the nerve connecting the ear to the brain. At radio frequency (RF), the main biological effect of EMFs is heating; the same principle that microwave ovens utilize. Existing data indicate that RF of relatively low intensity can affect the nervous system. Changes in blood-brain barrier, morphology, electrophysiology, neurotransmitter functions, cellular metabolism, and genetic effects have been reported in the brain of animals after exposure to RF. These changes can lead to functional changes in the nervous system. Behavioral changes in animals after exposure to RF have also been reported. [2]

II. Radiation from mobile BTS (Base Transceiver Stations)

For providing mobile services, telecom service providers establish base transceiver stations (BTSs), at suitable locations for proper coverage of the area and for meeting capacity requirements. Every antenna on a cell phone tower radiates electro-magnetic power. BTS also contain a number of transceivers or channels (TRXs) to handle more traffic and each of these has the same maximum output power. The outputs from the individual transmitters are then combined and fed via cables to the base station antenna, which is mounted at the top of a Ground Base Tower (GBT) or roofs or mobile stations like COW (Carrier on Wheels). Thus the Equivalent Isotropic Radiated Power (EIRP) is equal to the output power from the transmitters multiplied by the antenna gain minus the small loss that occurs in the combiner and connecting cables. It should be noted that all the transmitters are not operational continuously; this depends on the call traffic in each of the sectors. However the

level of exposure is maximum at the time of peak traffic when all the channels are utilized and hence sectors with higher call traffic carry the risk of having maximum EM exposure. Also a building may lie at an azimuth angle where regions of two sectors intersect and hence it receives relatively higher amount of radiation. This is known as the worst case. The calculation of EMF radiation (the EIRP value) is done for the worst case.

Hence, the transmission power levels and the gain of the antennas are the major technical parameters to be considered when dealing with exposure levels. Typical gains for the sector antennas used with base stations in India are in the range 15–17 dBi for GSM900 systems and 16–18 dBi for GSM1800 systems. Although the high gain antennas increase the efficiency and coverage, the risk of exposure for buildings in the close proximity and in the line of sight of the main beam of the antennas increases manifold.

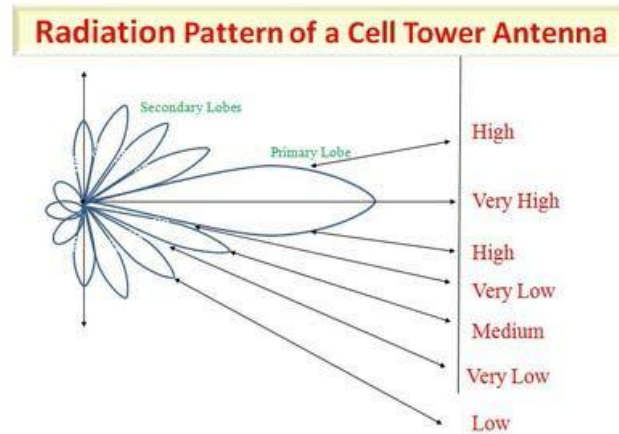


Figure 1.

Radiation will be highest from the primary lobes of the antenna in the horizontal direction. There is also radiation from secondary lobes which ranges from medium to very low when transmitting horizontally as seen in the figure 1 above. Hence, the direct exposure to the primary lobes along the line of antenna is the most severe of the exposed radiation. The radiation levels relatively decrease as one moves away from the line of the antenna to its side lobes. [1]

The amount of RF generated by cell phone usually depends on the number of base stations around the area, the cell phone network traffic, and on how far the cell phone from base stations. The amount of the power which sent from a base station could vary from one cell phone to another even within the same area, depending on the interference from obstacles such as buildings and trees. Although, cell phones are designed to operate at power levels below a threshold level for known thermal effects, radio frequency radiation could produce other kinds of effects, called biological effects.

To cater services to a wider geographical area, the telecom companies tend to increase the transmission power rather than putting another tower to minimize the costs. But this leads to increase in radiation level above the limits and hence should be avoided.

III. Specific Absorption Rate (SAR)

The quantity used to measure how much RF energy is actually absorbed by the body is called the Specific Absorption Rate or SAR. The SAR is a measure of the rate of absorption of RF energy. It is usually expressed in units of watts per kilogram (W/kg) or milliwatts per gram (mW/g). Generally, a part of the radio waves emitted by a mobile telephone handset are absorbed by the human head. The maximum power output from a mobile phone is regulated by the mobile phone standard it is following and by the regulatory agencies in each country. In India and USA, the SAR limit is 1.6 W/kg, averaged over a volume of 1 gram of tissue, for the head. In Europe, the limit is 2 W/kg, averaged over a volume of 10 grams of tissue. SAR values are heavily dependent on the size of the averaging volume. [3]

IV. Harmful effects of mobile phone/ tower radiations

1. Thermal effects

Any dielectric material (such as living tissue) could be heated by rotations of polar molecules induced by the electromagnetic field. As high frequency radiations (radio waves) penetrate the body, the exposed molecules move about and collide with one another and heat up due to friction. While using a mobile phone, most of the heating effect occurs at the surface of the head, causing its temperature to increase by a very nominal amount. This increase in temperature is far less as compared to the increase caused due to exposure to direct sunlight. The brain's blood circulation is capable of disposing of excess heat by increasing local blood flow. However, the cornea of the eye does not have this temperature regulation mechanism and any exposure for 2–3 hours duration

has been reported to produce cataracts in rabbits' eyes at SAR values from 100-140W/kg. Since the SAR value of 100-140W/kg is very high, therefore premature cataract cannot be linked with mobile phone use, possibly because of the lower power output of mobile phones. [1]

2. Cancer

In 2011, International Agency for Research on Cancer (IARC) classified mobile phone radiation as Group 2B - possibly carcinogenic (not Group 2A - probably carcinogenic - nor the dangerous Group 1). That means that there "could be some risk" of carcinogenicity, so additional research into the long-term, heavy use of mobile phones needs to be conducted which might take another 10-15 years since cancer and tumors cells take time to develop and multiply. [4]

3. Blood-brain barrier effects

Swedish researchers from Lund University (Salford, Brun, Persson, Eberhardt, and Malmgren) have studied the effects of microwave radiation on the rat brain. They found a leakage of albumin into the brain via a permeated blood-brain barrier. [5] This may lead to interaction of albumin with astrocytes resulting in epilepsy. Prof Leszczynski of Finland's radiation and nuclear safety authority found that, at the maximum legal limit for mobile radiation, one protein in particular, HSP 27, was affected. HSP 27 played a critical role in the integrity of the blood-brain barrier. [6]

4. Electromagnetic hypersensitivity

Some users of mobile handsets have reported feeling several unspecific symptoms during and after its use; ranging from burning and tingling sensations in the skin of the head, headaches, sleep disturbances, dizziness, loss of mental attention, reaction times and memory retentiveness, fatigue, malaise, tachycardia (heart palpitations), to disturbances of the digestive system. Reports have noted that all of these symptoms may even be attributed to stress and that current research is not at such an advanced stage that it may be able to distinguish between the symptoms. [3]

5. Genotoxic effects

In 1995, in the journal Bioelectromagnetics, Henry Lai and Narendra P. Singh reported damaged DNA after two hours of microwave radiation at levels deemed safe according to U.S. government standards. [3]

In December 2004, a pan-European study named REFLEX (Risk Evaluation of Potential Environmental Hazards from Low Energy Electromagnetic Field (EMF) Exposure Using Sensitive in vitro Methods), involving 12 collaborating laboratories in several countries showed some compelling evidence of DNA damage of cells in in-vitro cultures, when exposed between 0.3 to 2 watts/kg, whole-sample average. There were indications, but not rigorous evidence of other cell changes, including damage to chromosomes, alterations in the activity of certain genes and a boosted rate of cell division. [3]

Blank and Reba Goodman have pointed out that microwave has the chance to change the DNA molecule because the frequency of the EM fields radiated from the mobile phones is high and there are charges shuttling on the DNA double helix, and the interaction between the microwave and charges will disturb the genetic material, namely genes. Of course, their explanations barge up against difficulties, as Robert. K concludes that since the ingoing electromagnetic wave energy is too weak even far less than the energy of particle vibration, and therefore he states that the parlance about the direct interaction between the EM fields and DNA molecules is hard to come into existence. [7] However, the order of magnitude of DNA molecule is 10^{-8} m, and it is not a macroscopic object, so the classical theory is apparently not suitable. It naturally leads to unclear results when we use the classical electromagnetics to explain the microscopic phenomena in the order of magnitude of DNA molecules, but if we try to use quantum theory to solve this problem, it may lead to promising results.

6. Sleep and EEG effects

Sleep, EEG (Electroencephalography) and rCBF have been studied in relation to RF exposure for a decade now, and the majority of papers published to date have found some form of effect.

German research from 2006 found that statistically significant EEG changes could be consistently found, but only in a relatively low proportion of study participants (12 - 30%). [3]

7. Brain glucose consumption

A recent study showed that when people used a cell phone for a long period of time, brain tissues on the same side of the head as the phone's antenna metabolized more glucose than did tissues on the opposite side of the brain. The researchers noted that the results are preliminary, and possible health outcomes from this increase in glucose metabolism are still unknown.

A team led by Dr. Nora Volkow, head of the National Institute on Drug Abuse, used advanced imaging technology to monitor glucose consumed in the brain. They found that even weak cell phone radiation alters brain activity near cell phone antennas. [3]

8. Behavioral effects

A study on mice offspring suggested that cell phone use during pregnancy may cause behavioral problems that resemble the effects of ADHD (Attention Deficit Hyperactivity Disorder). [8]

9. Sperm count and sperm quality

A number of studies have shown relationships between mobile telephone use and reduced sperm count and sperm quality. The Environmental Working Group (EWG) has a web page entitled "Cell Phone Radiation Damages Sperm, Studies Show" published August 2013. The EWG page reviews and tabulates studies showing relationships between mobile phone use and low sperm count and sperm quality.

Australian research conducted in 2009, by subjecting in vitro samples of human spermatozoa to radio-frequency radiation at 1.8 GHz and specific absorption rates (SAR) of 0.4 to 27.5 W/kg showed a correlation between increasing SAR and decreased motility and vitality in sperm, increased oxidative stress and 8-Oxo-2'-deoxyguanosine markers, stimulating DNA base adduct formation and increased DNA fragmentation. [3]

10. Birds

There have been reports of harmful effects of EM radiation on birds, bees etc. Animals that depend on the natural electrical, magnetic and electromagnetic fields for their orientation and navigation through earth's atmosphere are confused by the much stronger and constantly changing artificial fields created by technology and fail to navigate back to their home environments. On this, the Agricultural Research Service, US Department of Agriculture has said that despite a great deal of attention, neither cell phones nor cell phone towers have any connection to Colony Collapse Disorder (CCD) or poor honey bee health. A study was conducted in Germany to find whether there is any connection between CCD and radiation effects. The study examined whether a particular type of base station for wireless phones could affect honey bee homing systems. The results showed that the base station has nothing to do with CCD. [1]

V. Safety standards

In order to protect the population living around base stations and users of mobile handsets, governments and regulatory bodies adopt safety standards, which translate to limits on exposure levels below a certain value. There are many proposed national and international standards, but that of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) is the most respected one, and has been adopted so far by more than 80 countries. For radio stations, ICNIRP proposes two safety levels: one for occupational exposure, another one for the general population. Currently there are efforts underway to harmonize the different standards in existence. As per the ICNIRP Guidelines, the levels of safety are:

Table 1.

Frequency Range	Power Density (W/Sq. m)
400MHz to 2000MHz	f/200
2GHz to 300GHz	10

EMF Radiation Norms in India for mobile towers (BTS):

In India, monitoring of the radiation emanating from the BTS is carried out by the Department of Telecommunications (DoT). The DoT has issued instructions regarding setting up of acceptable EMF radiation limits and the testing procedure to be followed. The Telecom Enforcement Resource & Monitoring (TERM) Cells, a unit of DOT, tests upto 10% of BTS sites selected randomly by them. Additionally, BTS sites, against which there are public complaints, are also tested by TERM Cells.

The DoT has set up an Inter-ministerial Committee (IMC) consisting of officers from DoT, Indian Council of Medical Research (Ministry of Health), Department of Biotechnology and Ministry of Environment and Forest to examine the effects of Electro Magnetic Field radiation from base stations and mobile phones. [1]

Table 2.

Frequency Range	E-Field Strength (Volt/Meter (V/m))	H-Field Strength (Amp/Meter (A/m))	Power Density (W/Sq. m)
400MHz to 2000MHz	0.434f ^{1/2}	0.0011f ^{1/2}	f/2000
2GHz to 300GHz	19.29	0.05	1

Consequent to this revision by DoT, Indian standards are now 10 times more stringent than many countries (like USA, Canada, Japan and Australia) in the world which follow ICNIRP guidelines.

Some of the local municipal bodies have even banned the erection of cell phone towers in residential areas and school and college campuses due to health reasons.

Example of Chandigarh, India: The Punjab and Haryana High Court gave a ruling banning the erection of BTS towers in residential areas in Chandigarh following a number of petitions by the local residents. The High Court held, "The mobile emit signals in the form of radio waves. It is feared that radio waves can cause changes to the cells in our brain. If the DNA in the brain cells gets damaged, they may become cancerous and cause brain tumors. It is also feared that radio waves can alter chemical and electrical reactions in our brain, changing, in effect, the way the brain cells communicate. Studies conducted have revealed that number of sparrows have declined in the most contaminated electromagnetic fields".

The Union Government's Department of Science and Technology, India, has given permission to 16 leading scientific institutions across India to conduct research on the effects of electromagnetic fields (EMF), particularly radiating from cell phone towers, on human health. The focus will be on the impact of EMF-related issues on the human body including dosimetry (study of radiation absorbed by the body), brain related effects, biochemical studies, effects on reproduction pattern, comparison of animal and human models, plant system, and remedial measures. [9]

VI. Conclusion

Much of the research work has provided evidences about the possible health hazards such as: brain tumor, blood brain barrier (BBB) permeability function, sleep problems, cognitive function, DNA damage, immunity system function and stress reaction to EMF radiation and negative biological effects. The conclusion on the risk, specially for brain tumors associated with the use of cell phone have been mostly with an insufficiently long latency period, however, the studies showed a somewhat increased risk for shorter latency periods. The biological effects are uncertain since some research studies indicated no clear association was found between the exposure to the EMF radiation and biological effects. The negative effects still cannot be ignored and hence appropriate safety standards should continue to be implemented by the Govt. authorities and adopted by Telecom companies.

VII. Future scope

Although, there have many evidences about the negative effect of the cell phone radiation on human health, but still there is need for more research work to confirm the evidence we have. Long-term experimental follow-up is needed to design proper rules to safeguard human health. Since there has been a rapid proliferation of cell phone towers only recently, hence it will take around 10-15 years for the radiation to cause any significant negative impact like cancer. Hence, a comprehensive research is needed to prove the adverse health effects of EMF radiation from cell phones and BTS towers so that a well defined strategy could be accordingly adopted to minimize or eliminate the threat to the health of people.

References

- [1] TRAI (Telecom Regulatory Authority of India), Information Paper on effects of EMF from mobile towers and handsets.
- [2] Effects of Electromagnetic Radiations from Cell Phones: A Critical Study, Sanjeev Dhawan, Kulvinder Singh Handa (2012), International Journal of Engineering, Business and Enterprise Applications (IJEBA), International Association of Scientific Innovation and Research (IASIR).
- [3] http://en.wikipedia.org/wiki/Mobile_phone_radiation_and_health/
- [4] "IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans" (PDF). World Health Organization press release N° 208 (Press release). International Agency for Research on Cancer. 31 May 2011.
- [5] Salford, Leif G.; Arne E. Brun, Jacob L. Eberhardt, Lars Malmgren, and Bertil R. R. Persson (June 2003). "Nerve Cell Damage in Mammalian Brain after Exposure to Microwaves from GSM Mobile Phones", Vol.111, No.7, Environmental Health Perspectives (United States: National Institute of Environmental Health Sciences).
- [6] <http://www.theguardian.com/uk/2002/jun/20/research.medicalscience>
- [7] The Research on the Harm of Biological Effect of Mobile Phone Radiation to Human Body, Yang Li and Guizhen Lu, Information Engineering School, Communication University of China, Progress in Electromagnetics Research Symposium, Beijing, China, March 23-27, 2009.
- [8] "Cell Phone Use in Pregnancy May Cause Behavioral Disorders in Offspring, Mouse Study Suggests". Science Daily. Retrieved 1 April 2012.
- [9] Article-"Mega Research on Mobile Tower Radiation gets nod", Times of India, 4 April 2015.