



## A Review of the Potential Health Hazards of Radio Frequency Radiation from Cellular Base Station

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### Authors' contributions

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

### Article Information

DOI: 10.9734/BJAST/2017/31737

#### Editor(s):

(1) Luigi Maxmilian Caligiuri, Faculty of Science, University of Calabria, Italy and Foundation of Physics Research Center (Director)- FoPRC, Italy.

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- Complete Peer review History: <http://www.sciencedomain.org/review-history/18767>

**Review Article**

**Received 22<sup>nd</sup> January 2017**  
**Accepted 16<sup>th</sup> April 2017**  
**Published 24<sup>th</sup> April 2017**

### ABSTRACT

Over the last decade, detrimental effects of human exposure to electromagnetic radiations have received widespread attention. With the increasing number of cellular communication system around the world, the number of base transceiver station is also increasing. This scenario is very common around us. When these base stations are located in a crowd place and even on the top side of the building, it can create some panic to the general public. The electromagnetic radiation from these base stations may cause serious health hazard. This paper takes into account the adverse health effects caused by radiated electromagnetic energy from typical base stations in different countries and the exposure level due to these base stations are compared to international guideline like ICNIRP and FCC.

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Keywords: Electromagnetic fields; base station; power density; exposure guideline.

**1. INTRODUCTION**

Electromagnetic wave plays a significant role to carry signals (voice, data and image) from a typical source to the wanted destination. In free space, this wave is propagating with the velocity of light. Therefore it can be regulated, channeled and received while carrying the necessary information. In this wave electric and magnetic fields are perpendicular with the direction of propagation as shown in Fig. 1 [1].

the orbit of an atom and turns into ionized atom that may cause hazard of health [1].

On the contrary, non-ionizing radiation contains energy in the lower frequencies. Some scientific evidence suggests that non-ionizing radiation may have sufficient energy to cause biological harm. For mobile communication in which radio frequency is used can be in the range 450-2200 MHz which is considered as part of the microwave range as shown in Fig. 2 [1,2].

As in Fig. 2 it is easily seen that in electromagnetic spectrum this waves have distinct frequencies. Every frequency can be distinguished from one another by their characteristics. Two broad categories of electromagnetic radiation are ionizing and non-ionizing radiation. Ionizing radiation possesses enough energy that can detach electrons from

**2. RADIATION FROM THE BASE STATION**

Cell tower antennas transmit in the frequency range of 869 to 890 MHz (CDMA), 935 to 960 MHz (GSM900), 1810 to 1880 MHz (GSM1800) and 2110 to 2170 MHz (3G). The directional antennas are climbed on the top of the building

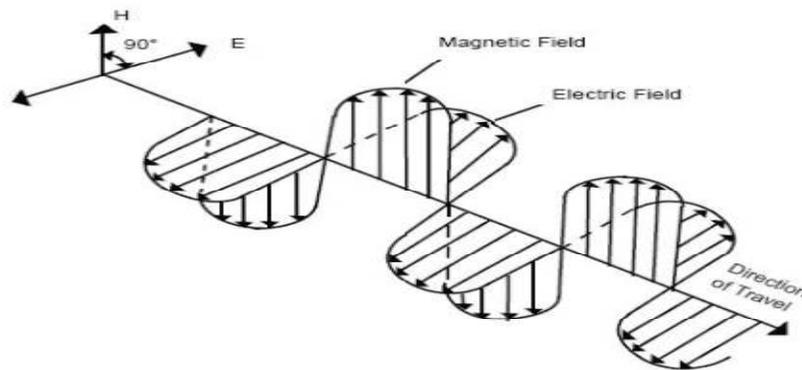


Fig. 1. The electromagnetic wave

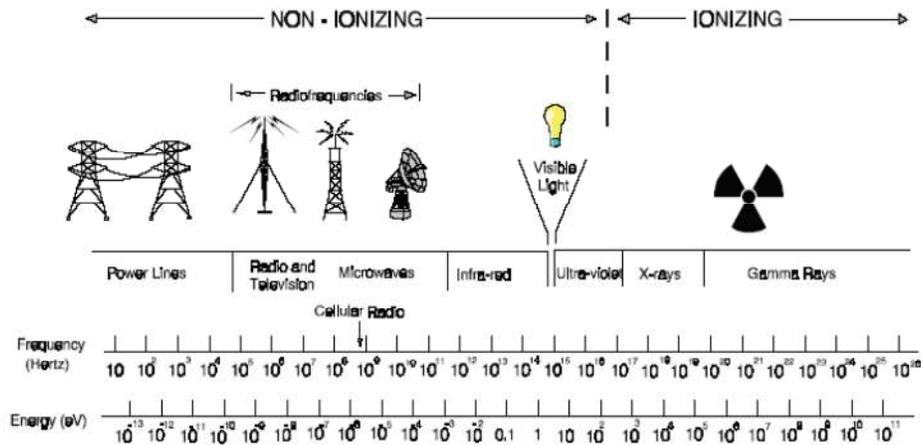


Fig. 2. The electromagnetic spectrum, energy and some applications

and on ground based towers. The signals from the antennas can be focused on ground by mechanical tilting. To provide a good coverage for users, a mentionable numbers of base stations are constructed around public places such as residential areas, schools, hospitals etc. These base stations transmit radiation twenty four hours in all the seven days, so people living near the towers receives many more times stronger signals than distant one [3,4].

A typical GSM900 base station antenna transmits in the frequency range of 935-960 MHz. This 25 MHz frequency band is split into several sub-bands, which are apportioned into various operators. If there are three to four mobile operators antenna on a single rooftop and each operator transmits 50 to 60 Watts of power then the transmitted power may be 150 to 250 Watt. Effectively several Kilowatts of power may be transmitted in the main beam direction [3,4].

### 3. INTERNATIONAL ORGANIZATIONS AND LIMITATIONS

The concern relating to RF exposure is not a new issue. Around sixty years ago some national and international organizations provided a regulations and recommendations regarding RF exposure for general public and the people who working with this fields. The recommendation given by different organizations and the threshold level of exposure are nearly same and they maintained a safety margin in order to protect people from health hazards [4].

Some of these standards were organized and developed by the following organizations:

- 1) World Health Organization (WHO) [5]
- 2) International Commission on Non-Ionizing Radiation Protection (ICNIRP)
- 3) Federal Communications Commission (FCC).
- 4) Institute of Electrical and Electronic Engineering (IEEE).
- 5) Environmental Protection Agency (EPA).
- 6) Food and Drug Administration (FDA).
- 7) American Cancer Society (ACS)
- 8) National Institute for Occupational Safety and Health (NIOSH).
- 9) Occupational safety and Health Administration (OSHA)
- 10) National Council of Radiation Protection and Measurements (NCRPM).
- 11) Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

The ICNIRP is considered as the most important organization specifying radio frequency EMF limits due to the following items [1,6];

- a) ICNIRP guidelines were published in 1998.
- b) Limits are based on all available scientific research and include large safety margins.
- c) Limits are set to protect all people from established adverse health effect from short and long term exposure.
- d) Specifies limits for both general public and occupational exposure.
- e) Endorsed by WHO.

When the distance of the people from radio transmitter is one meter then safety limits can be expressed as field strength. This field strength generally applied to exposure from base transceiver stations. An electromagnetic wave has electric and magnetic components and the former is measured in Volts per meter (V/m) and the later is Amperes per meter (A/m). A plane wave power density is another unit to characterize the electromagnetic field. The power density can be expressed as Watts per square meter ( $W/m^2$ ) [1,6].

The Maximum Permissible Exposure (MPE) limits adopted by FCC in 1996 for both occupational and general public exposure expressed in terms of electric field strength E (V/m) and magnetic field strength H (A/m) and power density S ( $W/m^2$ ) for a wide frequency range are given in Table 1. Similarly, the ICNIRP limits for frequencies up to 300 GHz are given in Table 2. The details of the MPE for both ICNIRP and FCC are given in [6] and [7] respectively.

It is clear from these recommendations that the Maximum Permissible Exposure (MPE) is a function of the operating frequency. Hence for 900 MHz the MPE for both FCC and ICNIRP is shown in Table 3.

### 4. RADIATED POWER DENSITY FROM THE CELL TOWER

Power density  $P_d$  at a distance  $R$  is given by

$$P_d \equiv \left( \frac{P_t \times G_t}{4\pi R^2} \right) \text{ Watt / m}^2$$

Where,  $P_t$  = Transmitter power in Watts

$G_t$  = Gain of transmitting antenna in dB

$R$  = Distance from the antenna in meters

Table 1. FCC Limits for maximum permissible exposure [7,8]

## (A) Limits for occupational/controlled exposure

Frequency range (MHz)	Electric field strength, E (V/m)	Magnetic field strength, H (A/m)	Power density, S (mW/cm <sup>2</sup> )	Averaging time in minutes
0.3-3.0	614	1.63	100	6
3.0-30	1842/f	4.89/f	900/f	6
30-300	61.4	0.163	1.0	6
<b>300-1500</b>	--	--	<b>f/300</b>	<b>6</b>
1500-100,000	--	--	5	6

## (B) Limits for general population/ uncontrolled exposure [8,9]

Frequency range (MHz)	Electric field strength, E (V/m)	Magnetic field strength, H (A/m)	Power density, S (mW/cm <sup>2</sup> )	Averaging time in minutes
0.3-3.0	614	1.63	100	30
3.0-30	824/f	2.19/f	180/f	30
30-300	27.5	0.073	0.2	30
<b>300-1500</b>	--	--	<b>f/1500</b>	<b>30</b>
1500-100,000	--	--	1.0	30

Table 2. ICNIRP reference levels for maximum permissible exposure

## (A) Limits for occupational/controlled exposure

Frequency range (MHz)	Electric field strength, E (V/m)	Magnetic field strength, H (A/m)	Power density, S (W/m <sup>2</sup> )
0.065-1.0	610	1.6/f	--
1.0-10	610/f	1.6/f	--
10-400	61	0.16	10
<b>400-2000</b>	<b>3f<sup>1/2</sup></b>	<b>0.008f<sup>1/2</sup></b>	<b>f/40</b>
2000-300000	137	0.36	50

## (B) Limits for general population/ uncontrolled exposure

Frequency range (MHz)	Electric field strength, E (V/m)	Magnetic field strength, H (A/m)	Power density, S (W/m <sup>2</sup> )
0.065-1.0	87	0.73/f	--
1.0-10	87/f <sup>1/2</sup>	0.73/f	--
10-400	28	0.073	2
<b>400-2000</b>	<b>1.375f<sup>1/2</sup></b>	<b>0.0037f<sup>1/2</sup></b>	<b>f/200</b>
2000-300000	61	0.16	10

Table 3. MPE for both FCC and ICNIRP at 900 MHz

	FCC (W/m <sup>2</sup> )	ICNIRP (W/m <sup>2</sup> )
General public exposure	6	4.5
Occupational exposure	30	22.5

In case of multi carriers and multiple towers are present on a typical building, power density values will increase many times compared to a single carrier and single operator. On the other hand, direction away from the primary beam, radiation intensity will gradually decrease. It would be better if people could determine the actual radiation pattern of antenna and

hence exact radiation intensity at a particular point [3].

According to ICNIRP guideline, safe power density is  $f/200$ , where  $f$  is the frequency in MHz. This organization state clearly that if there are multiple frequency fields for simultaneous exposure, all the field must be taken into account. Depending upon the total numbers of transmitters in that area, the radiation level can be surpassing manifolds. Generally old people, housewives and children are exposed 24 hours a day. Though ICNIRP considers only the thermal effect but scientists around the world found that non thermal effect also have significant health effect [3].

## **5. BIOLOGICAL EFFECTS OF CELL PHONE AND CELL TOWER RADIATION**

Human body absorbs radiation when it is exposed to electromagnetic wave because it consists of about two-third of liquid. It can be compared to cooking in the oven where the water portion of the food is heated first. The brain which consists of almost 90% of fluid absorbs a significant amount of microwave energy. In the areas where the movement of fluid is less (eyes, brain, joints, hearts), effects are more noticeable. The wavelength of the cell tower radiation is much lower than the human height. It also one cause for absorbing microwave radiation and consequently heating in the body. As a result fluid deficiency is observed in the above mentioned organs [3,4].

### **5.1 Danger for Pregnant Women and Children**

The negative impacts of cell phones and cell towers cause many more health problems. If radio frequency radiations continuously interact with the developing embryo and pregnant women then both are vulnerable. This radiation can damage the placental barrier which means that pregnant women should avoid the cell tower radiation. Also, children are more vulnerable due to less developed immune system [3,10].

### **5.2 Release of Calcium Ion**

Calcium ion plays an important role to the membrane of the living cells. When weak electromagnetic waves impose on those cells, it removes calcium ions, tear the membrane, makes irregular pores and leak. Metabolic

stimulant is one result of calcium ion release which results in accelerate growth of tumors. Calcium ion leakage in brain cells can cause pain and other neurological disorder for electro-sensitive individuals. Signal to noise ratio of the brain also degrades which results to respond with comparatively weak stimuli [3,11].

### **5.3 DNA Destruction**

Damage of DNA can be caused by cell phone frequency. Several studies showed that when microwave exposure is below the FCC guidelines, then single and double strands break in DNA occurs. Microwave exposure also interrupts the natural processes of DNA replication and repair by changing molecular orientation. This radiation is responsible for formation of free radicals inside the cell that results in DNA damage and which finally turns into carcinogenic [3,12].

### **5.4 Disturbance with Pace Makers**

Exposure from cell phone and base station antennas can affect patients who are carrying pacemakers. The signal from antennas interferes with pacemaker and prevents its proper functioning. The various functions of cell phone e.g., turning on and off, ringtone, incoming/outgoing calls containing low frequencies that can adversely interfere with pacemaker and can lead the death of the patient [3,13].

### **5.5 Impact on Stress Proteins**

The non-thermal effects of RF radiation gradually accumulate over time and after several years of exposure, risks became pronounced. Due to the body defensive mechanism during initial years, the adverse effects can't be seen and the total pressure is on the stress proteins of the body that is called heat shock proteins (HSP). Various stressful stimuli like metal poisoning and oxygen deprivation disrupts these heat shock proteins accumulation. HSP plays important role to survive with changing environment and other destructive conditions [3,14].

### **5.6 Impact on Skin**

Human skin is another area where cell tower radiation has adverse effect. Generally those people who often talk on cell phone have relatively greater concentration of transthyretin protein than those who do not. This protein is found in liver. The main purpose of this protein is

to transport vitamin A within body and plays a key role in nervous diseases such as Alzheimer's [3,15].

### 5.7 Neurodegenerative Diseases

Electromagnetic radiation has a connection with some diseases like Alzheimers, motor neuron disease and Parkinson. As a consequence of these diseases, generally referred to as neurodegenerative diseases specific neurons die. Also those people who are living close to the base stations can have a risk of some neuro-psychiatric problems such as nausea, tremors, dizziness, headache, memory loss, numbness, muscle pain etc. Sometimes it can be more severe includes seizures, paralysis and stroke [3,16].

## 6. EPIDEMIOLOGICAL STUDIES IN VARIOUS COUNTRIES

Some countries studied the epidemiological impact on people living near the base stations. Spain, Netherland, Israel, Germany, Egypt, Austria etc are some examples [17]. They have documented that the measured exposure was below the FCC or ICNIRP guidelines. Some of these studies are summarized below:

### France

In this report people who lived near the base station antennas had the maximum prone to the given disorder: sleep disturbances, fatigue, feeling of discomfort, and difficulty in concentrating, headaches, depression, memory loss, visual disruptions, hearing disruptions, skin problems, irritability, cardiovascular disorders, and dizziness.

These problems found more in women than men. This study taken place where people were near the base station and recommends that people should live more than 300m from the cellular base station [3,18].

### Germany

The research group studied that those people who lived within 400 meter from base station antennas during the past ten years suffer more cancer cases than those who lived further away from base station. They also found that the patients fell ill on average eight years earlier. The relative risk of cancer has increase three times

for the people who lived near the cell tower compared to those who were outside. Breast cancer was in the top lists. Besides, cancers of the pancreas, prostate, lungs and intestine also increased [3,19].

### Israel

The research group investigates medical records of people who had lived within 350 meters of a base station, showed a four times increased of cancers compared with the general people of Israel. These problems are most common and many folds in women compared with the other locality further from the tower [3,20].

### Spain

In Spain significant ill-health effects found among those living very closely to two cellular base stations. The most five problems were found such as depression, fatigue, insomnia, unable to concentration and cardiovascular problems. The scientists reported the following symptoms within 50 to 150 m of the cell phone antenna at an average power density of 1,100 to 1,900  $\mu\text{W}/\text{m}^2$ , which is considerably lower than ICNIRP guidelines of 4,700,000  $\mu\text{W}/\text{m}^2$ . This demonstrates that present guidelines do not protect the public from radio frequency radiation exposure. Among the 350 inhabitants of Pérez, near the town of Velez-Malaga, there have been 43 cases of cancer, 35 of which have resulted in death [3,21].

### Sweden

In terms of mobile connectivity, Sweden claims that they are the first who completes hundred percents of connectivity. A Swedish survey showed that about 3% of men and women out of total population are electro-hypersensitive and report distinct types of symptoms when kept in contact with electromagnetic sources. These symptoms includes- allergy, fall in memory, sleep disorder, headache, redness of skin, nausea, anxiety, visual impairment, heart problems, respiratory problems. More several problems like leukemia, brain cancer have also reported [3,22].

### United Kingdom (UK)

One of the houses in Bristol, UK that was five storied building and a mobile tower was erected on the top floor. It had been showed that people living on the top floor had cancer. In Warwickshire, 31 cancer patients were detected

on a single street and a quarter of 30 odd staff at a special school, within sight of 90 ft. high mast, developed brain tumors since 2000. The masts are being pulled down under growing protests of thousands of people [3,23].

### **Australia**

The top floors of a Melbourne office building were closed down and 100 people were evacuated after a seventh worker in seven years was diagnosed with a brain tumor. The Australian Health Research Institute indicates that due to billions of times more in volume electromagnetic radiation emitted by billions of mobile phones, internet, intranet and wireless communication data transmission, almost one-third of world population (about 2 billion) may suffer from Cell Phone Cancer beside other major body disorders like heart ailments, impotency, migraine, epilepsy by 2020 [3,24].

### **India**

Usha Kiran Building in Mumbai has reported 6 cancer cases in sequential floors as they were in the main beam of the transmitting tower antenna in the opposite building. In Andheri, 15 cancer cases have been reported due to heavy cluster of cell towers. Mr. Bhagwant Deshpande of Solapur has reported 9 deaths due to cancer living within 91m from the two towers [3].

### **Brazil**

It is reported in May 2011 that electromagnetic radiation emitted by transmitting cell phone antennas is linked to the occurrence of some types of cancer. Out of 4,924 cancer patients, nearly 80% of them lived within 500 m from one of the radiating towers [19].

## **7. CONCLUSION**

The seriousness of the health hazards due to radiation from the cell phones and cell towers has not been realized among the common man. Cell operators continue to claim that there are no health issues. Even organizations like WHO, ICNIRP, FCC, etc. have not recommended stricter safe radiation guidelines, whereas several countries have adopted radiation norms, which are much lower than of these values based on their studies [2]. As a result majority of

people are familiar to their own protection. Unluckily, ignorance and non-awareness are two reasons that are responsible to increase these sufferings by absorption of radiation like slow poison day by day.

On the other hand, in spite of knowing the adverse effect of cell tower radiation, they may not have any choice to go further away because the base stations not only from base stations, it also from another sources such as wireless are installed near the office or the top of the building. The uninterrupted radiation comes from phones, TV towers, Laptops, FM towers, microwave ovens etc. These radiations are additive in nature and we are exposed to radiation from all of these. Therefore, the policy makers should settled more strict radiation norms and it is the core responsibility of the government to take necessary steps to maintain it strictly. Finally, researchers/ entrepreneurs have to come out with potential solutions, which may be costly but never greater than the risk that is faced by human, animals, birds and environment.

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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*Peer-review history:*  
The peer review history for this paper can be accessed here:  
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