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Effects of Electromagnetic Radiations from Cell Phones: A Critical Study

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Abstract: The increasing use of mobile phones has resulted in larger human exposure to radio frequency electromagnetic fields. Although the electromagnetic fields from mobile phones are weak, the high number of exposed persons, together with some stimulating but inconclusive scientific results, has raised concerns about possible health hazards. Most of the biological studies showed that radio frequency modulated electromagnetic fields (like Global System for Mobile Communications (GSM 900 MHz and 1800 MHz)) induced a stress response in the cells, which can potentially change the blood-brain barrier. The potential health effects of human-made electromagnetic fields (EMFs) have been a topic of scientific interest since the late 1800s, particularly in the last twenty years. Electromagnetic fields are natural phenomena that have always been present on earth. However, during the twentieth century, environmental exposure to human-made EMFs increased steadily, predominantly due to increased electricity and wireless technology use. Nearly all people are exposed to a complex mix of different types of weak electric and magnetic fields, both at home and at work. Electrical currents exist naturally in the human body and are an essential part of normal body function. Nerves relay signals by transmitting electric impulses, and most biochemical reactions, from those associated with digestion to those involved in brain activity, proceed by means of rearranging charged particles. This present paper shows the possible effects of electromagnetic radiations emitted from cellular phones on human and living organisms. Therefore, a complete study has been carried out to discuss the serious worries of using mobile phones. The paper has been divided into four parts: part I gives the basis introduction and related studies of cell phones, part II presents the technology behind the cellular networks, part III discusses the basic hazards of using mobile phones, and danger of cellular phone and their prolonged effects, and part IV gives the conclusions and precautions, which should be taken into account while using the cell phones to avoid any serious health related risks.

Keywords: Cellular networks, cell phone, electromagnetic fields, health hazards, specific absorption rate.

I. Introduction

Due to rapid change in Information and Communication Technology (ICT), the expansion in telecommunications and other sectors have led to considerable increases in the use of radio frequencies. Today the equipment employing with microwave or radio waves are widely used not only in broadcasting and communication networks, but also in the health care industry, the food industry, and in a host of other industries in a wide range of applications. Equipment employing microwave and radio waves is today widely used not just in broadcasting and communications, but also in the health care industry, the food industry, and in a host of other industries in a wide range of applications. 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 effect that microwave ovens utilize. EMFs can be broadly divided into two categories: extremely low frequency electric and magnetic fields (ELF EMFs), common sources of which include power lines, household electrical appliances, and computers; and high-frequency or radio frequency (RF) and EMFs, of which the main sources are telecommunications and broadcast facilities, and mobile telephones and their base stations. ELF EMFs influence the human body just as they would any other substance consisting of conducting materials and charged particles. ELF EMFs may induce circulating currents within the human body. The strength of these induced currents depends on the intensity of the outside magnetic field and the size of the loop through which the current flows. When sufficiently large, these currents can cause neural and muscular stimulation (among other biological effects). However, at the EMF exposure levels normally found in the environment, the currents induced in the body by ELF EMFs are much weaker than those occurring in the body naturally [1] [2] [3]. The levels of RF EMFs to which people are normally exposed are far lower than those needed to produce significant heating. When the radio frequency radiation penetrates the body, the tissue or skin will be heated or burned. The issue is primarily heat. According to the Occupational Safety and Health Department of the Communication Workers of America (CWA), "As high frequency radio frequency radiations penetrates the body, the exposed molecules move about and collide with one another causing friction and, thus, heat. If the radiation is powerful enough, the tissue or skin will be heated or burned." According to CWA, "there is substantial scientific data that establishes negative health effects associated with microwave radiation." CWA cites cataracts as one possible negative health effect from prolonged exposure, as well as nervous system

damage and even reproductive problems in both males and females. However, there are some more environmental effects of electromagnetic radiation emitting from Cell phones. *It is very well said by Beverly Filip: "Could our health be negatively affected by all the radio frequencies being bandied about by cell phones and cell phone towers, wireless pagers and Internet systems, and other uses of radio frequency and microwave radiation"?*

II. Related Studies and Initiatives

One of the most widely publicized cases of electro-sensitivity is that of former Norwegian Prime Minister and former Director-General of World Health Organization Director-General Dr. Gro Harlem Brundtland, who is also a medical doctor by profession. Brundtland said that she is electrically sensitive to cell phones and computers and does not own a mobile phone but says that there is not yet enough scientific evidence to prove the devices are dangerous. She said that she has never owned a mobile phone herself and that there now is reason to be cautious about the technology, told Dagbladet's: "In the beginning I felt a local warmth around my ear. But the problem grew worse, and turned into a strong discomfort and headaches every time I used a mobile phone." In Spain, a judge ordered 49 cell phone antennas removed from a rooftop in downtown Valladolid, the second time a Spanish court has ruled antennas should be removed for health reasons. "This time the fight was led by parents of children at Garcia Quintana Primary School, where three children had contracted acute lymphoblastic leukemia and one Hodgkin's lymphoma since the antennas were installed," reported one of the popular newsletters. Indeed, reported Arturo Soria y Puig, who provided information for both the Taskforce and Spain's influential El Mundo newspaper: "The popular response to the rapid and chaotic installation of some 30,000 mobile phone antennas in Spain has been impressive. Because of judicial rulings (in a few cases) and because of pressure on municipal authorities (in the majority of cases) the mobile phone providers have had to disconnect and dismantle 2,000 already-installed antennas." In Switzerland, an initiative to amend the Swiss Constitution and called "Moratorium on Mobile Telephone Antennas" would stop the construction of antennas particularly for "mobile telephony" as long as "the harmlessness of pulsed non-ionizing radiation, and of pulsed magnetic or electromagnetic fields, taking into account their non-thermal effects, has not been demonstrated." In France, Dr. Robert Santini, a veteran researcher in "bioelectromagnetics" said he had been forbidden by the director of the government laboratory with which he has long been associated from speaking to journalists, politicians and other researchers about "cellular phone and base station bioeffects." Some scientists who work on the problem of the biological effects of cell phones and relay stations have recently been made the object, following these pressures, of discriminatory measures on the part of their institutions: firing, professional change, change of research topic, blockage of career, loss of collaborators, ban on speaking." In Sweden, a group of victims of electromagnetic sensitivity asked the prime minister and the prestigious Karolinska Institute not to proceed with threats to close down Karolinska's Unit for Experimental Dermatology, whose Prof. Olle Johansson has produced some of the most exciting scientific questioning of the safety of cell phones and related devices. In Germany, veteran medical physicist and researcher Dr. Lebrecht von Klitzing of the Medical University of Lubeck was forbidden by the University dean to address the German Bundestag (parliament) on the medical effects of cell phones, claiming such a presentation would damage the university's reputation. The Task Force reported that von Klitzing, forbidden to do any more research on his own, resigned from the university in March in order to continue his research. In England, Dr. Gerald Hyland, University of Warwick, took early retirement following high-level pressures against his research into the biocompatibility of magnetic fields with the human organism. In Bangkok, Thailand, the English language Nation newspaper reported on the near-ubiquity of mobile phones among Thai teenagers ("many teens today are utterly devoted to their mobiles, even to the extent that they regard them as an extra limb").

In another research Czerska *et al.* [4] using a waveform identical to that used in digital cellular phones at a power level within our current standards (Specific Absorption Rate (SAR) of 1.6 W/Kg, the maximum spatial peak exposure level recommended for the general population in the ANSI C95.1-1991 standard) found increases in cellular proliferation in human glioblastoma cells. This shows that acceptable levels of radiation can cause human cancer cells to multiply faster. The authors note that "because of reported associations between cellular phone exposure and the occurrence of a brain tumor, glioblastoma, a human glioblastoma cell line was used" in their research. Dr. Michael Repacholi took one hundred transgenic mice and exposed some to radiation for two 30-minute periods a day for up to 18 months. He found that the exposed mice developed lymphomas (a type of cancer) at twice the rate of the unexposed mice. While telecommunications industry spokespersons criticized the experiment for using mice with a mutation, which predisposed them to cancer (transgenic) the researchers pointed out that "some individuals inherit mutations in other genes that predispose them to develop cancer, and these individuals may comprise a subpopulation at special risk from agents that would pose an otherwise insignificant risk of cancer [5]". In 1996 Dr. Ross Adey found what appeared to be a protective effect in rats exposed to the type of radiation used in digital cellular phones. The rats were exposed to an SAR of 0.58-0.75 W/Kg 836 MHz pulsed radiation of the TDMA type two hours a day, four days a week for 23 months, with the signals turned on and off every 7.5 minutes, so total exposure was 4 hours a week. Interestingly this effect was not present when a non-digital, analog signal was used. Rats exposed developed cancer less often. This study shows that low power fields of the digital cellular frequency can influence cancer development. Whether they would protect or promote in our children is a question for further study [6] [7]. Dr. Stanislaw Szmigielski has studied many thousands of Polish soldiers. He has found that those exposed to radio frequency and microwave radiation had more than

double the cancer rate of the unexposed servicemen analyzing data from 1971-1985. He has presented further data suggesting a dose-response relationship with soldiers exposed to 100-200 W/cm² suffering 1.69 times as many cancers as the unexposed, and those exposed to 600-1000 W/cm² suffering 4.63 times as many cancers. 1000 W/cm² is the level considered safe for the public according to FCC regulations. Occupational exposure up to 5000 W/cm² is allowed [8]. Dr. Bruce Hocking found an association between increased childhood leukemia incidence and mortality in the proximity of television towers. The power density ranged from 0.2-8.0 W/cm² nearer and 0.02 W/cm² farther from the towers [9]. Henry Lai's review of the literature concerning neurological effects of RF: 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 calcium efflux, 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 been reported. Even a temporary change in neural functions after RF exposure could lead to adverse consequences. For example, a transient loss of memory function or concentration could result in an accident when a person is driving. Loss of short term working memory has indeed been observed in rats after acute exposure to RF [10]. Seitz *et al.* [11] conclude in their studies on mobile phone radiation and health-related quality of life. Moreover, the results are contradictory and the greater part of these studies is not able to address the issue of causality between exposure and outcome. One of the first studies dealing with radio frequency electromagnetic field exposure was about the shutdown of the Swiss Schwarzenburg short-wave radio transmitter. While this took place back in 1998, a recently published paper [12] reports of measurements in the change in the melatonin produced by 54 volunteers living in the vicinity. The measurements showed that in the week after the shutdown, sleep quality improved and melatonin excretion increased by 15 percent, on average. (Melatonin plays an important role in regulating sleep-wake cycles because its production is inhibited by light and permitted by darkness. Melatonin is sometimes prescribed when suffering from jetlag.). Meanwhile, the REFLEX study under Professor F. Adlkofer, was making measurements on isolated cells to see if these were effected by a high or low-frequency (power-line frequency) EMF (electro-magnetic field). "The main goal of the REFLEX project was to investigate the effects of EMF on single cells in vitro at the molecular level below the energy density reflected by the present safety levels." The study showed that in certain human cell types there was indeed a significant increase in the number of single- and double-strand breaks in the DNA as a result of high and extremely low frequency electromagnetic fields [13].

These studies are accompanied with the following recitation of health risks known to be associated with the omnipresent gadgets:

- A study published in the UK suggested mobile phone use might be as addictive for teenagers as smoking.
- A recent British study reported that phone driving is more dangerous than drunk driving. The Transport Research Laboratory found reaction times for those driving on the phone was 30 percent slower than those driving drunk and nearly 50 percent worse than someone sober and not using a cell phone.
- In 2000, a study by Action on Smoking and Health in London found a number of common traits, including the desire to rebel, prevalent among smokers as well as young cell-phone users.
- The Thai Ministry of Public Health in 2001 recommended that people under 12 should not use a mobile phone, while studies on health risks – particularly the links to brain cancer – are underway by the World Health Organization.
- A recent study by the Physicists Association in Japan warned of the harm of using mobile phones in passenger trains. The researchers said, "Passengers might be harmed by microwaves emitted from phones, which reflect on the train's metal structure and accumulate on the passengers." The researchers suggested there should be a ban on the use of mobile phones in trains, busses and elevators [14].

III. Technologies Behind Cellular Networks

There are three common technologies used by cell phone networks for transmitting information: (i) Frequency Division Multiple Access (FDMA), (ii) Time Division Multiple Access (TDMA), and (iii) Code Division Multiple Access (CDMA).

The first technique tells you what the access method is and the second technique lets you know that it splits calls based on that access method. FDMA puts each call on a separate frequency, TDMA assigns each call a certain portion of time on a designated frequency, and CDMA gives a unique code to each call and spreads it over the available frequencies. The last part of each name is multiple access. This simply means that more than one user (multiple) can use (access) each cell. FDMA separates the spectrum into distinct voice channels by splitting it into uniform chunks of bandwidth. To better understand FDMA, think of radio stations. Each station sends its signal at a different frequency within the available band. FDMA is used mainly for analog transmission. While it is certainly capable of carrying digital information, FDMA is not considered to be an efficient method for digital transmission.

IV. Radiofrequency Energy and Health Hazards

Radiofrequency (RF) energy is another name for radio waves. It is one form of electromagnetic energy that makes up the electromagnetic spectrum. Some of the other forms of energy in the electromagnetic spectrum are

gamma rays, x-rays and light. Electromagnetic energy (or electromagnetic radiation) consists of waves of electric and magnetic energy moving together (radiating) through space. The area where these waves are found is called an electromagnetic field. RF energy includes waves with frequencies ranging from about 3000 waves per second (3 kHz) to 300 billion waves per second (300 GHz). Microwaves are a subset of radio waves that have frequencies ranging from around 300 million waves per second (300 MHz) to three billion waves per second (3 GHz). 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 radio waves emitted by a GSM handset, can have a peak power of 2 watts, and a US analog phone had a maximum transmit power of 3.6 watts. Other digital mobile technologies, such as CDMA and TDMA, use lower output power, typically below 1 watt. 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. The rate at which radiation is absorbed by the human body is measured by the SAR, and its maximum levels for modern handsets have been set by governmental regulating agencies in many countries. In the USA, the FCC has set a SAR limit of 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 [15].

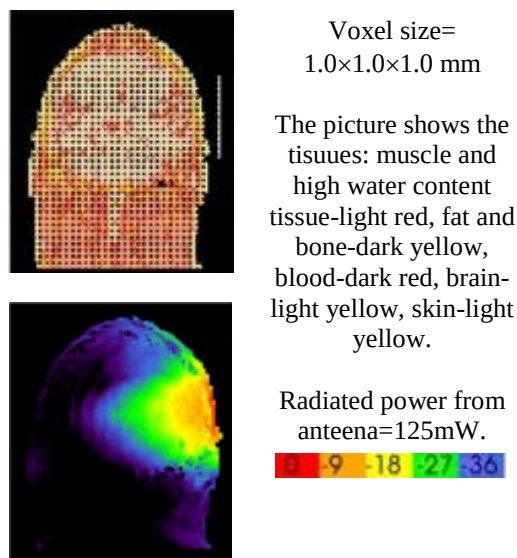


Figure 1 shows the geometry of top and SAR distribution in phantom human head model exposed to 1900 MHz dipole antenna [15].

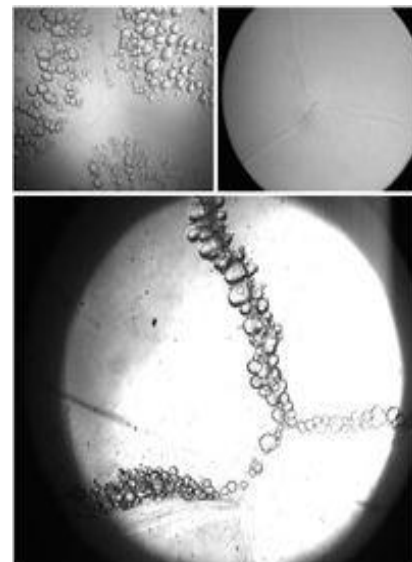


Figure 2 shows the microscope photographs of lenses incubated in organ culture conditions for 12 days [15].

In figure 1 the calculated SAR distribution in an anatomical model of head next to a 125 mW dipole antenna. Peak SAR is 9.5 W/kg over 1 mg, whole head average is 0.008 W/kg. (USAF/AFRL). In figure 2 shows the microscope photographs of lenses incubated in organ culture conditions for 12 days. Right frame shows control lens with no damage. Bottom frame demonstrates the effect of microwave radiation on bovine lens sutures for a total exposure of 192 cycles (1.1 GHz, 2.22 mW). Each cycle lasts 50 min followed by 10 min pause. In the absence of microwave radiation, the bubbles are generated by temperature increase to 39.5 °C during 4 h [16].

A. Effects of microwave radiation

In an observational study, researchers from Cleveland, Mumbai, and New Orleans found that the number of hours in a day that a man uses his cell phone can affect all aspects of his sperm profile. Three hundred and sixty-one men undergoing evaluation for infertility were classified into four groups according to their cell phone usage. Among the men in the group with a normal sperm count, those who did not use a cell phone at all had sperm counts averaging 86 million per milliliter, with 68% motility, and 40% normal forms. Men who use a cell phone more than four hours a day had an average count of 50 million sperm per milliliter with 45% motility and 18% normal forms. The effect of cell phones on sperm parameters may be due to the electromagnetic radiation the devices emit or to the heat they generate. The researchers note that further studies will be necessary to identify the mechanism involved in the reduction of sperm quality due to cell phones [17]. The link between cell phones and low sperm quality suggests that the radiation emitting from mobile phones may be potentially dangerous and should be considered as such.

B. Thermal effects

One well-understood effect of microwave radiation is dielectric heating, in which any dielectric material (such as living tissue) is heated by rotations of polar molecules induced by the electromagnetic field. In the case of a

person using a cell phone, most of the heating effect will occur at the surface of the head, causing its temperature to increase by a fraction of a degree. In this case, the level of temperature increase is an order of magnitude less than that obtained during the exposure of the head 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. Premature cataracts are known as an occupational disease of engineers who work on high power radio transmitters at similar frequencies. Premature cataracts however, have not been linked with cell phone use, possibly because of the lower power output of mobile phones. It has been claimed that some parts of the human head are more sensitive to damage from increases in temperature, particularly in anatomical structures with poor vasculature, such as nerve fibers. More recent results from a Swedish scientific team at the Karolinska Institute have suggested that continuous use of a mobile phone for a decade or longer can lead to a small increase in the probability of getting acoustic neuroma, a type of brain tumor.

C. Non-thermal effects

The communications protocols used by mobile phones often result in low frequency pulsing of the carrier signal. Some researchers have argued that so-called "non-thermal effects" could be reinterpreted as a normal cellular response to an increase in temperature. Swedish researchers from the University Lund, Salford, Brun, Perrson, Eberhardt and Malmgren, have studied the effects of microwave radiation on the rat brain. They found a leakage of albumin into brain via a permeated blood-brain barrier.

D. Genotoxic effects

It has been found a direct causal relationship between mobile phone radiation and DNA damage. 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.

V. Danger of cellular phone and their effects

Mobile phones create a radio-frequency electromagnetic field around them when in use, the effects of which on brain physiology in humans are not well known. The health effects from exposure to magnetic fields from electric power distribution lines or the use of hand held cell phones are based on fear, not fact. There is a robust and ongoing controversy over many aspects of RF health effects. While no one disagrees that serious health hazards occur when living cells in the body are heated, as happens with high intensity RF exposure (just like in a microwave oven). The scientists are currently still investigating the health hazards of low intensity exposure. Low intensity exposure is exposure, which does not raise the temperature of the living cells in the body. The telecommunications industry claims cellular antennas are safe because the radiation they produce is too weak to cause heating, a "thermal effect." They point to "safety standards" from groups such as ANSI/IEEE or ICNIRP to support their claims. But these groups have explicitly stated that their claims of "safe levels of exposure" are based on thermal levels. Thus the claim that the RF exposure is harmless rests on the fact that it is too weak to produce a rise in temperature, a "thermal effect." There is a large body of internationally accepted scientific evidence which points to the existence of non-thermal effects of microwave radiation. The issue at the present time is not whether such evidence exists, but rather what weight to give it.



Our dependence on and investment in cell phones rise steadily. The annual sale of cell phones will reach to 5 billion units by year 2010. Is the result of all the accompanying electromagnetic radiation going to have an effect on our health? Almost everyone has heard some 'anecdotal evidence' where there have been some undesirable effects on people: headache, concentration problems, irritability, insomnia, etc. Ideally, in a cold, scientific experiment, one should find a group of humans, some of whom would be subjected to the electromagnetic radiation produced by cell phones and their base stations for several years and some of whom in the group would not be exposed. All of them would be blind to exposure and they would not differ in terms of other factors

influencing their health. One could carefully measure their health status and their well being, distinguishing between those exposed and those not exposed. Obviously this has not been done nor will it be done in the future. Since the introduction of mobile phones, concerns have been raised about the potential health impacts from regular use.

A. Environmental impacts of cell phones

Internationally acknowledged experts in the field of RF research have shown that RF of the type used in digital cellular antennas and phones can have critical effects on cell cultures, animals, and people in laboratories and have also found epidemiological evidence (studies of communities, not in the laboratory) of serious health effects at "non-thermal levels," where the intensity of the radiation was too low to cause heating. Like all high structures, cellular antenna masts pose a hazard to low flying aircraft. Towers over a certain height or towers that are close to airports or heliports are normally required to have warning lights. There have been reports that warning lights on cellular masts, TV-towers and other high structures can attract and confuse birds. Migrating birds have been known to fly right into cell phone and other communications towers. Some blame the radiation emanating from such towers for disorienting the birds and undermining their navigational abilities. US authorities estimate that millions of birds are killed near communication towers in the country each year. Others chalk such incidents up to poor visibility associated with bad weather and nothing more. Some farmers have observed that cows grazing near cell towers are more likely to experience still births, spontaneous abortions, birth deformities and behavioral problems, not to mention general declines in overall health. Moving cattle herds away from such towers has reportedly led to immediate health improvements [18].

VI. Conclusions and Precautions

The results of radiation from the cell phones increases cell growth of brain cancer cells, increase the rate of lymphoma, changes in tumor growth, increases breaks in double and single stranded DNA, more childhood leukemia in children, changes in sleep patterns, headaches caused by RF exposure, neurologic changes including changes in the blood-brain-barrier, changes in cellular morphology (results in cell death), changes in neural electro physiology, change in neurotransmitters, metabolic variations, cytogenetic effects (which can affect cancer, Alzheimer's, neurodegenerative diseases), decreased memory, attention, and slower reaction time in school children, increases blood pressure in healthy men, damage to eye cells when combined with commonly used glaucoma medications, affected to pregnant women, newly born babies. Furthermore, it also affects the levels of TLC- Total leucocyte count: it reflects normal number of white blood cells in your blood. White blood cells fight infection normal 4000-11000. They are increased in bacterial infections. Decreased in Viral and Typhoid, and DLC - Differential leucocyte count tells you about different type of white blood cells you have. To overcome the problems the possible recommendations are to use hands-free to decrease the radiation to the head, keep the mobile phone away from the body, don't telephone in a car without an external antenna. It is also advised that don't place your mobile phone in your close proximity especially when you switched on the alarm. Another alternative is to use the Bluetooth. Basically, the Bluetooth also uses the microwave frequency spectrum in the range of 2.4 GHz to 2.4835 GHz. The radiated output power of Bluetooth devices varies between 1 and 100 mW, and can operate continuously or sporadically (on demand), so total exposure to EMF radiation is quite variable. Bluetooth devices have not been linked with any health issues [19] [20] [21]. In conclusion, we now know that EMF does have some effects on humans and human cells. Since we still do not know that up to what degree it affects our health and well being. Moreover, due to recent launch of 3G networks, the effects of radiations will have more peculiar health dangers. Likewise, the 3G or WiMAX technologies are having a strong relationship. Both can be used for broadband visions in terms of making video calls, data on demand, online mobile TV, watch live sports, financial updates, or headlines whenever you want and wherever you are. But, besides these exciting features both the technologies are having the serious health issues, which can be taken into account by the concerned authorities. So, the government regulatory authorities in the area of mobile communication networks should give their views in this area to maintain a good future for the human being concerning humanity without any prejudice or any diversion to a particular sector of highly financially sound people in this field. Today, when the people are taking about global warming (but 2-3 years before no one was aware of it) and the citizens are serious about this issue, and many funding projects are running by the different organization to overcome global warming. Therefore, the steep steps should also be taken in the field of mobile communication towards the use of cellular phones. Ultimately the technology is good if it benefits to its target users without any serious setbacks. Finally, it's my personal observation that "*When I am close to LCD screen to read what is on the screen it feels as I get an electric shock up through my fingers*".

VII. References

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