ANALYSIS OF MOBILE TOWER RADIATION AND ITS HEALTH EFFECTS IN CHAMPHAI AND LUNGLEI DISTRICTS OF MIZORAM

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ANALYSIS OF MOBILE TOWER RADIATION AND ITS HEALTH EFFECTS IN CHAMPHAI AD LUNGLEI DISTRICTS OF MIZORAM

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Certificate

This is to certify that the thesis entitled "*Analysis of RF Radiation and its Health Effects in Champhai and Lunglei Districts of Mizoram*" submitted by Shri Lallawmzuala, for the degree of Doctor of Philosophy of the Mizoram University, Aizawl, embodies the record of original investigations carried out by him under my supervision. The thesis presented is worthy of being considered for the award of the Ph. D. degree. This work has not been submitted for any degree to any other University.

(Prof. ZAITHANZAUVA PACHUAU)
Supervisor

Declaration

Mizoram University

OCTOBER, 2021

*I, **LALLAWMZUALA**, hereby declare that the subject matter of this thesis is the record of work done by me, that the content of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.*

This is being submitted to the Mizoram University for the degree of Doctor of Philosophy in Physics.

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Acknowledgement

After a long year gap of my master degree ,I have a desire to persue research specially in the field of Radiation Physics as I am working in Radiation field and make contribution to the scientific community and to the society as a whole. There are many people who encourages me to persue higher studies.Firstly, I would like to express my sincere thanks to Prof.Zaithanzauva Pachuau, Department of Physics, Mizoram University,for giving me this great opportunity to carry out my PhD research and who is always there to guide and help me.I would also like to extend my sincere gratitude to Dr. Lalrinthara Pachuau,Pachhung University College,for providing the instrument for my research work and for his invaluable contributions .I would also like to thank Prof. Diwaker, Dean, School of Physical Sciences , all faculty members and staffs of the Department of Physics for their kind support and encouragements during my entire research work.

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Sd/-

Dated Aizawl (LALLAWMZUALA)

The 29th October 2021 Regn No.MZU/PdD/ 21.4.2016

Preface

There has been many research works that has been carried out over the last two decades on the ill effects of Radio Frequency (RF) radiation emitted by Mobile Tower. Many people are unaware of the hazards and the possible measures to overcome the hazards. Some researchers have found that RF radiation produces biological effects. On the other hand, some authors did not find any biological effects of RF radiation.

This is the second time in Mizoram, the study of health effects of RF radiation has been carried out. Now a days, many people started to know the ill effects of RF radiation and therefore demands for more in depth study at the molecular level as well. In view of this, the present topic is chosen for the research work to have better understanding of the ill effects at the molecular level. It is expected that this study will provide the inhibitants near the mobile tower, in giving scientific information on regarding possible harmful effects of RF radiation on human health.

The thesis is divided into six (6) chapters which are followed by references. The topics in this thesis are arranged as follows:

In Chapter 1, Introduction and Review of Literature is presented.

In Chapter 2, a brief introduction of mobile communication and basic theory of interaction of RF radiation with biological tissues is discussed. The interaction of RF radiation with dielectric and biological tissues is followed by discussion on resonance absorption.

In Chapter 3, Methodology of the research work is presented.

In Chapter 4, we presented the details of power density measurements in the two Districts of Mizoram under the study area.

In Chapter 5, the detailed analysis of questionnaire surveys on thirteen different non specific health symptoms, *in situ* measurement of power density and comparison with power densities is presented, followed by assessment of biological effects of RF radiation at the molecular level.

In Chapter 6, conclusion of the thesis is presented which is followed by references.

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CHAPTER 1
INTRODUCTION

The rapid technological advances in Electronics, Electro-optics and Computer Science have profoundly affected our daily lives. They have also set the stage for an unprecedented drive towards the improvement of existing medical devices and the development of new ones. In particular, the advances in Radio Frequency (RF)/microwave technology and computation techniques, among others, have paved the way for exciting new therapeutic and diagnostic methods. Frequencies, from RF as low as 400 kHz to microwave frequencies as high as 10GHz are presently being investigated for therapeutic and diagnostic applications in areas such as cardiology, urology, surgery, ophthalmology and others (Andre Vander *et al*, 2006).

At the same time, safety concerns regarding the biological effects of electromagnetic (EM) radiation have been raised, in particular, at a low level of exposure. A variety of waves and signals have to be considered, from pure or almost pure sine waves to digital signals, such as in digital radio, digital television, and digital mobile phone systems. The field has become rather sophisticated, and establishing safety recommendations or rules and making adequate measurements require quite an expertise.

There has been an unprecedented growth in the global communication industry in recent years which has resulted in a dramatic increase in the number of wireless devices. Mobile services were launched in India in 1995 and it is one of the fastest growing industries in the world. According to the Telecom Regulatory Authority of India (TRAI, 2012), the composition of telephone subscribers using wireless form of communication in urban area is 63.27% and rural area is 33.20%. By 2013, it is estimated that more than one billion people will be having cell phone connection in India. This has led to the mushrooming of supporting infrastructure in the form of cell towers which provide the link to and from the mobile phone.

There has been growing public concern on possible adverse health effects due to Electro-magnetic field (EMF) radiation from mobile towers and mobile handsets. Over the past few years, a number of health activists and resident organisations have started opposing the erection of telecom towers on rooftops of houses and in densely populated areas, claiming that radiation from such installations causes serious health risks. 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 radiation emitted by the base transceiver stations (BTS) and mobile handsets. Concerns have also been raised that continuous exposure to EMF radiation emanating from telecom towers causes 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

The last two decades witnessed a magical revolution in the field of telecommunication as well as in data communication. The number of cell phones and cell towers are drastically increasing all over the world. The rapid developments in cell phone technology have made our life much more comfortable. Cell phone communicates in the range of radio frequency (RF), which is a low frequency non-ionising radiation. A mobile phone base station is designed in such a way that the cell phones coming under its coverage area should be able to transmit and receive enough signal which enables proper communication within a few kilometres. In order to establish more coverage, most of the towers are mounted near populated areas. People living nearer to the towers receive much more signal level than required for most of the times. In India, lakhs of people live in the high radiation zones. But most of the people are not concerned about the effects of radiations on health and possible safety measures to overcome the hazards. This demands the need for continuous studies on the effects of radiation on public health.

International Commission on Non–Ionizing Radiation Protection (ICNIRP) has published Guidelines (ICNIRP, 2009) for limiting EMF exposure that will provide protection against known health problems. According to the guidelines, the effects can be classified into two; direct effects result from the direct interaction of field with the body and indirect effects involving interaction of objects with a different potential from the body.

ICNIRP provides two classes of guidelines which are given below:

Basic Restrictions: These are restrictions on exposure to time varying electric, magnetic and electromagnetic fields. The physical quantities used to specify these restrictions are Current Density (J), Specific Absorption Rate (SAR) and Power Density (S). Among these, only power density in air can be measured outside the body.

Reference levels: These are levels given for practical exposure assessment to determine whether the basic restrictions have been violated or not.

Many scientists across the globe studied the harmful effects of mobile radiations on human health and living beings (Gandhi *et al*, 2005; Gulati *et al*., 2016). Several works are being carried out on the health issues of inhabitants living near mobile base stations. The RF radiations from mobile tower were studied based on power density measurements in residential areas close to cell tower sites (Singh, 2012; Urbinello *et al*, 2014; Eustatiu and Claudiu, 2016). In many countries, the standards on exposure limits to non-ionizing RF radiation are based on ICNIRP Guidelines (2009). The effect of RF radiation on inhabitants living within 15m near cell tower was studied by G. Kumar (2010). He concluded that, such people are exposed to 10,000 times stronger signal than required for mobile communication. Many other researchers also concluded that the existing ICNIRP recommendations are inadequate for the safe living of humans (IEGMP, 2000; SCENIHR, 2009; Interphone Study Group, 2010). The exposure limits in some countries like Russia is lower than the ICNIRP recommendations (Saeid, 2008).

Various studies have shown the ill-effects of RF electromagnetic field (RF-EMF) on bees, fruit flies, frogs, birds, bats and humans. But the long-term studies of such exposures are inconclusive and scarce, and almost non-existent in India (MOEF, 2010; DoT, 2010). In India, the invisible health hazard pollution (IHHP) is a relatively new environmental threat. The exposure to continuous RF-EMF radiation poses a greater risk to children, particularly due to their thinner skulls and rapid rate of growth. Also at risk are the elderly, the frail and pregnant women (Cherry, 2001). DNA damage via free radical formation inside cells has also been recorded (Lai and Singh, 1996). Free radicals kill cells by damaging macromolecules such as DNA, protein and membrane are carcinogenic. In fact, EMF radiation enhances free radical activity. Single and double-strand DNA breaks are seen in rat brain cells after acute exposure to RF-EMF radiation. Kane (2001) stated that RF-EMF radiations lead to tissue damage, DNA damage or chromosome mutations. The Austrian Department of Health, in 2008, found a higher risk of cancer among people living within 200 m of a mobile phone base station and that cancer risk rose with increasing exposure, reaching 8.5 times the norm for people who are most exposed. From a study on *in vitro* cell response to mobile phone radiation (900 MHz GSM signal) using two variants of human endothelial cell, it was suggested that the cell response to mobile phone radiation might be genome and proteome-dependent. Therefore, it is likely that different types of cells and from different species might respond differently to mobile phone radiation or might have different sensitivity to this weak stimulus (Nylund and Leszczynski, 2006).

Singh *et al.* (2016) investigated the RF-EMF radiation generated by mobile phone BSTs and its impact on the public health of people who lived close to the mobile phone BSTs. They reported that majority of the subjects who were living adjacent to the mobile phone BSTs complained about cardio-vascular and nervous system associated clinical symptoms including headache, sleep disturbances, dizziness, difficulties in concentration and high blood pressure, when compared to the control subjects. In agreement with the present study findings, researchers established a link between high exposure to RF-EMF and cognitive function (Calvente *et al.*, 2016). The study outcome demonstrated a positive link between exposure to RF-EMF and decline in cognitive function. Children who were exposed to high levels of RF-EMF had lower cognitive scores for verbal expression and comprehension in comparison to those living in areas with lower exposure. They also identified that exposure to RF-EMF radiation has a negative impact on cognitive and behavioral development in children

Health effects due to RF-EMF radiation can be divided in to two categories; short term effects and long term effects. The short term effects include brain electrical activity, heart rate, blood pressure, etc. The long term effects include tinnitus, headaches, joint pain, memory loss, muscle problem, cancers, tumours, etc. A recent study conducted in Aizawl have revealed an increased in micronuclei frequency after exposure to RF radiation, and also reported relatively lower levels of antioxidants; and higher level of lipid peroxidation among people in the vicinity of mobile base stations than control group indicating possibility of having oxidative stress .(Zothansiama *et al*., 2017).

1.1 Electro Magnetic field Radiation

Electromagnetic field (EMF) radiation is the flow of photons through space. Each photon contains a certain amount of energy, and the different types of radiations are defined by the amount of energy found in the photons. The electromagnetic spectrum is the range of all types of EM radiation. X-rays used in hospitals or the radio waves from a radio station are all part of this spectrum.

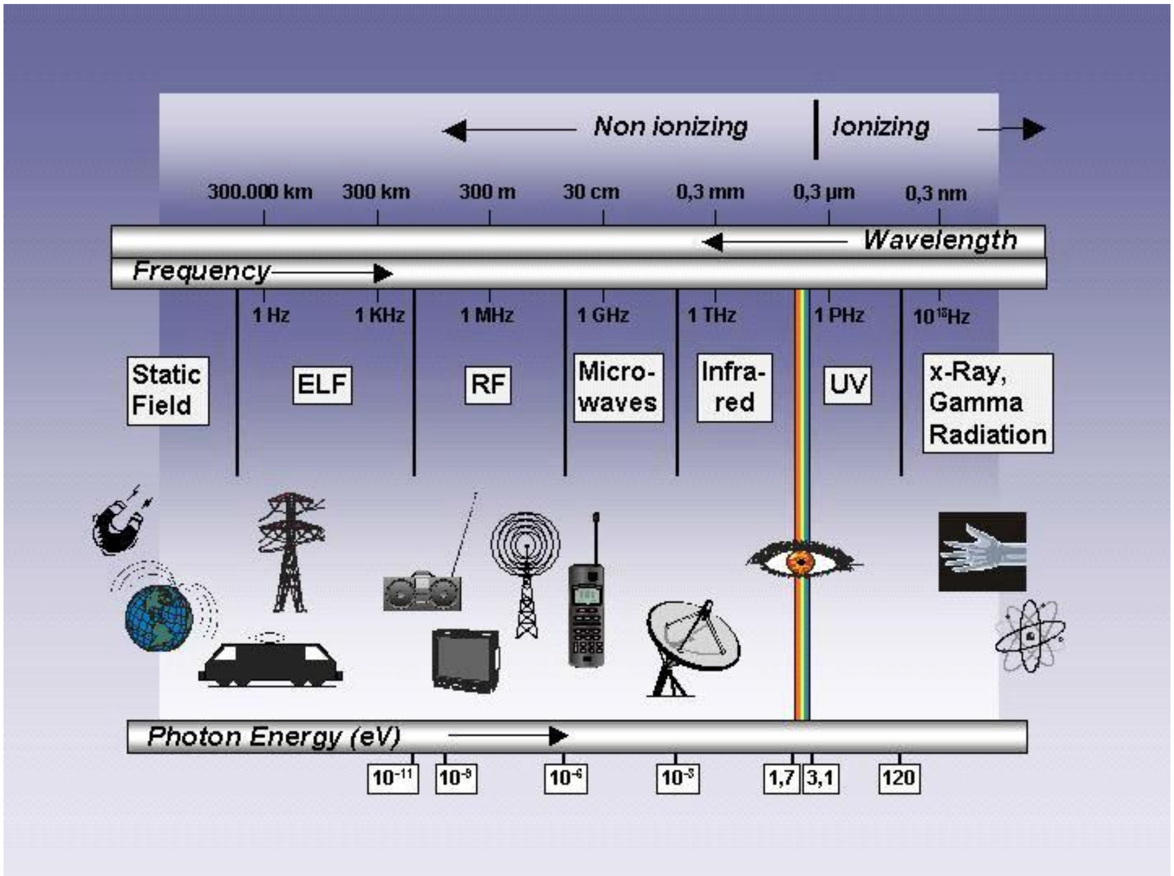

Figure 1.1: Electromagnetic Spectrum

1.2 Types of EMF radiation

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 as shown in Figure 1.1.

Non-ionizing radiation refers to any type of electromagnetic radiation that does not carry enough energy per quantum 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 alter the chemical bonds of the human body. EMF health effects related to the non-ionizing radiation include tissue heating at levels above limits. EM emissions at frequencies above 1 THz are termed as ionizing and have enough potential to alter the chemical bonds of human tissue and resulting in serious genetic damage on prolonged exposure.

1.3 Mobile Service and EMF Radiation

The EMF radiation in mobile services is primarily from two sources: radiations from BTS and radiation from mobile handsets – both of which are at the relatively low end of electromagnetic spectrum. The energy carried by them is unable to break chemical bonds in molecules. Thus, they fall under the non-ionizing radiation category.

Radiation from base transceiver stations (BTS)

For providing mobile services, telecom service providers establish BTSs at suitable locations, as per their Radio Frequency (RF) Network Planning for proper coverage of the area and for meeting capacity requirements. Every antenna on a cell phone tower radiates electro-magnetic power. A typical BTS site diagram is shown in Figure 1.2.

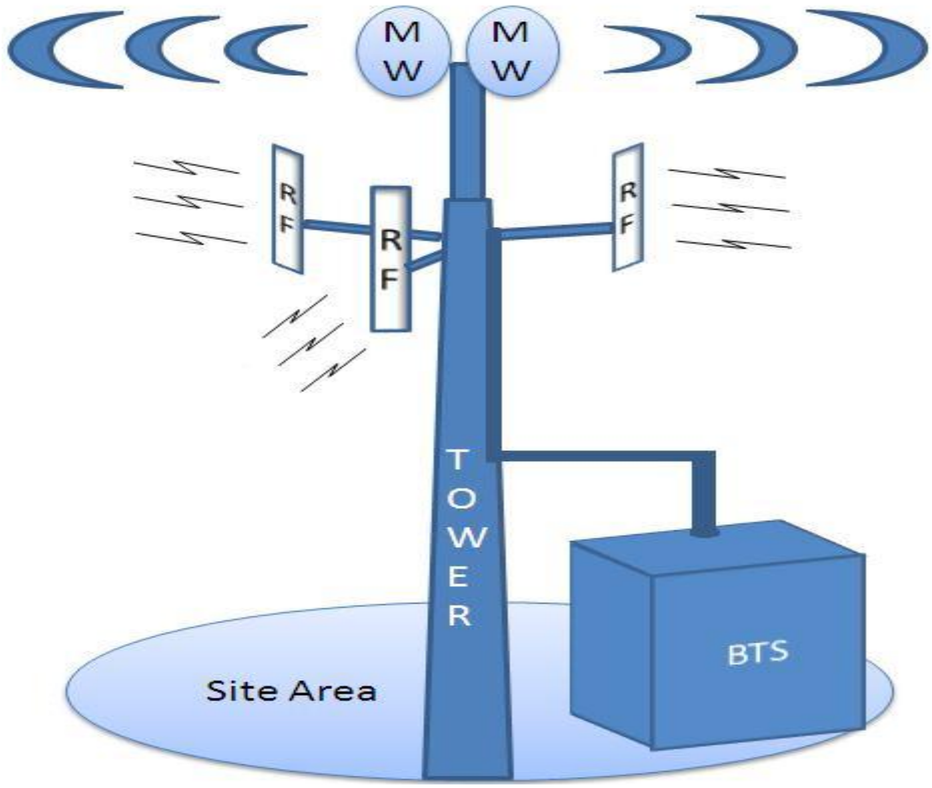

Figure 1.2: Typical BTS site

BTS also contain a number of radio transmitters 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 mast (or other suitable structure). Thus, the radiated power would ideally be equal to the sum of the output power from the transmitters except for a 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.

The transmission power levels and the gain of the antennas used for transmission are other major factors to be considered when dealing with exposure levels. Typical gains for the sector antennas used with macro-cellular base stations in India are in the range of 15–17 dBi for GSM900 systems and 16–18 dBi for GSM1800 systems. Omni directional antennas for macro-cellular base stations are much less common than sector antennas, but generally have gains in the range 8–10 dB. However, there are antennas with higher gain levels of 21 dB available recently in the market. Although the high gain antennas increase the efficiency and coverage, the risk of exposure for buildings in the close proximity of line of sight of the main beam of the antennas increases in multifold.

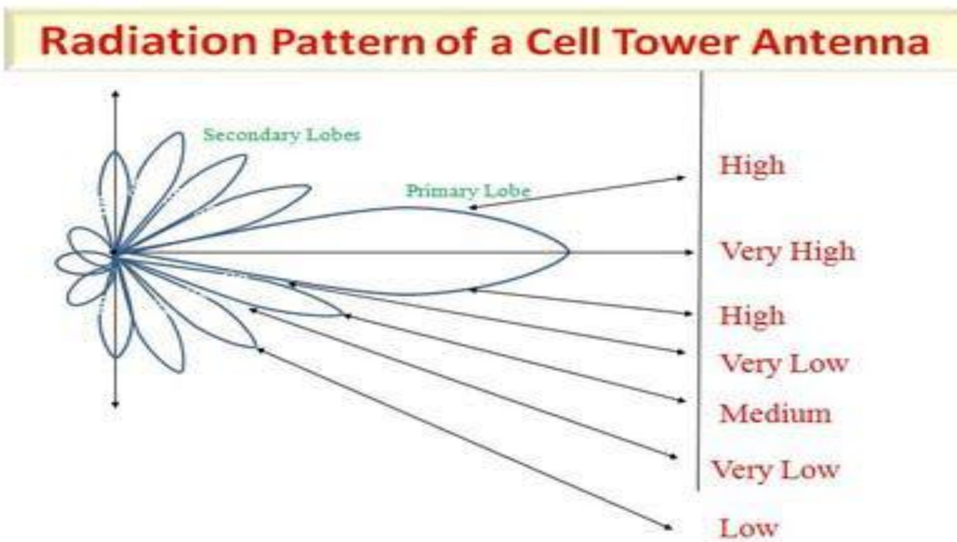

Figure 1.3: Radiation from mobile BTS

The real source of EM radiation is the transmitting antenna – not the transmitter itself, because the transmitting antenna is the main source that determines electromagnetic field distribution in the vicinity of a transmitting station. Radiation will be highest from the primary lobes 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 1.3 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. The distance from the source of radiation is another critical factor. The power density varies by ($1/R^2$), where R is the distance. As one moves away from the antenna, the less is the radiation.

Generally, a cell phone tower is shared by more than one operator to provide mobile services. The more the number of antennas, the greater is the power intensity in the nearby area. Power levels near towers are higher and reduce with distance. It is reduced to ¼ when the distance from antenna doubles, and 1/9 when distance is tripled and so on. The EMF power density varies with distance as shown in Figure 1.4 below. In addition, the safe distance from the tower also depends on the number of antennas served by the tower.

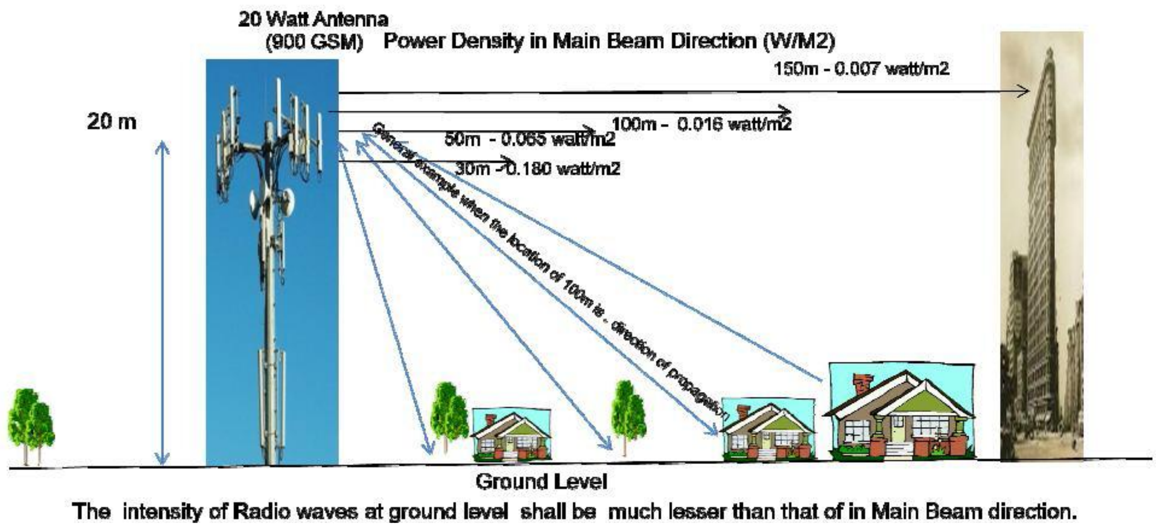

Figure 1.4: Power levels from the antenna

1.4 Radiation Exposure Standards – Current scenario for RF/MW

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an international commission specialized in non-ionizing radiation protection. The organization's activities include determining exposure limits for electromagnetic fields used by devices such as cellular phones.

ICNIRP is an independent non-profit scientific organization chartered in Germany. It was founded in 1992 by the International Radiation Protection Association (IRPA) to which it maintains close relations.

The mission of ICNIRP is to screen and evaluate scientific knowledge and recent findings toward providing protection guidance on non-ionizing radiation, i.e. radio, microwave, UV and infrared. The commission produces reviews of the current scientific knowledge and guidelines summarizing its evaluation. ICNIRP provides its science-based advice free of charge. In the past, national authorities in more than 50 countries and multinational authorities such as the European Union have adopted the ICNIRP guidelines and translated them into their own regulatory framework on protection of the public and of workers from established adverse health effects caused by exposure to non-ionizing radiation.

In India, we have adopted radiation norms given by ICNIRP Guidelines of 1998 for safe power density of $f/200$, where frequency (f) is in MHz. Hence, for GSM 900 transmitting band (935-960 MHz), power density is 4.7 W/m^2 and for GSM1800 transmitting band (1810-1880 MHz), it is 9.2 W/m^2. However, ICNIRP guidelines clearly stated that these are only for short term exposure (averaged over 6 minutes of time) and not for long term exposure (ICNIRP, 1998).

Type of exposure	Frequency range	Electric field	Magnetic field	Power density
General Public	400 – 2000 MHz	$1.375\ f^{1/2}$	$0.0037\ f^{1/2}$	$f/200$
	2 – 300 GHz	61	0.16	10

Table 1.1: ICNIRP Exposure standard of RF Radiation

The existing standards are based on thermal (heating) limits and do not address non-thermal (or low intensity) exposures which are reported to cause biological effects. The present ICNIRP/FCC limits are insufficiently protective of public health and require reconsideration (CCST, 2011).

Some countries have specified for their own radiation level keeping in view the environmental and physiological factors. In order to protect the population living around base stations and users of mobile handsets, established new, low intensity based exposure standards. The new exposure guidelines are hundreds or thousands of times lower than those of Institute of Electrical & Electronics Engineers (IEEE), USA and ICNIRP. The exposure limit for RF field of some of the countries including countries that have lowered their limit, in cell phone frequency range of 900 MHz and 1800 MHz for example are as given in Table 1.2 (Kumar, 2010).

Power Density (W/m^2)	**International Exposure limits adopted by various countries**
10	FCC (USA) OET-65, Public Exposure Guidelines at 1800 MHz
9.2	ICNIRP and EU recommendation 1998 – Adopted in India
3	Canada (Safety Code 6, 1997)
2	Australia
1.2	Belgium (ex Wallonia)
0. 5	New Zealand
0.24	Exposure limit in CSSR, Belgium, Luxembourg
0.1	Exposure limit in Poland, China, Italy , Paris
0.095	Exposure limit in Italy in areas with duration > 4hours
0.095	Exposure limit in Switzerland
0.09	ECOLOG 1998 (Germany) *Precaution recommendation only*
0.025	Exposure limit in Italy in sensitive areas
0.02	Exposure limit in Russia (since 1970), Bulgaria, Hungary
0.001	"Precautionary limit" in Austria, Salzburg City only
0.0009	BUND 1997 (Germany) *Precaution recommendation only*
0.00001	New South Wales, Australia

Table 1.2 : Exposure standard of some countries

However, since September 2012, India has adopted new guidelines, according to which maximum power density for GSM 900 is 450 mW/m2 and for GSM 1800 it is 900 mW/m2 (DOT, 2013). Other than the exposure limits given above, some organizations recommended the exposure limit as given in Table 1.3 (Haumann *et al*.,2002, Bioinitiave Report, 2012) :

Organization	**Exposure limit**
Bioinitiave Report 2012	0.5 mW/m^2
EU (STOA) 2001	0.1 mW/m^2
Salzburg resolution 2000	1 mW/m^2

Table 1.3: Exposure limit recommended by other organization

The BioInitiative Report is a report on the relationship between the electromagnetic fields (EMF) associated with power lines and wireless devices and health. It was self-published online, on 31 August 2007, by a group of scientists, researchers and public health policy professionals. They proposed safe limit of 1 mW/m^2 for outdoor, cumulative RF exposure and 0.1 mW/m^2 for indoor, cumulative RF exposure. The Bioinitiative Report states that it is an examination of the controversial health risks of electromagnetic fields and RF radiation. The 2012 version of the report was released on 7 January 2013. After thorough survey of the scientific literature, they concluded that the existing standards for public safety are inadequate to protect public health. They proposed that the safe limit for power density should be reduced by a factor of 3 from the 2012 recommendation of 1 mW/m^2 (Bioinitiative, 2012).

Salzburg Resolution is a compilation of what government, public health and environment organizations and officials, independent scientists, health advocacy groups and activists are advocating around the world in response to the proliferation of electromagnetic fields. One of such resolutions in 2000 has recommended 1 mW/m^2 as the safe limit of exposure to the RF radiation for public (Salzburg, 2000).

1.5 Specific Absorption Rate (SAR)

SAR is a measure to know the levels of exposure to electromagnetic fields from mobile handsets. It is the rate at which human body absorbs electromagnetic power radiated from mobile phones. India has adopted the following ICNIRP guidelines as standard for safety limits of exposure to radiofrequency energy produced by mobile handsets (ICNIRP Guidelines, 1998) :

General Public Exposure	Whole body average SAR (W/Kg)	Localized SAR head and trunk	Localized SAR limbs (W/Kg)
	0.08	2	4

Table 1.4 : Specific Absorption Rate for ICNIRP guideline

In the USA, the FCC has set a SAR limit of 1.6 watt per kg averaged over a volume of 1 gram of tissue, for the head. In Europe, the limit is 2 watt per kg, averaged over a volume of 10 gram of tissue. SAR values are heavily dependent on the size of the averaging volume. The cell phones and other wireless communication devices are regulated according to their emissions, which define the amount of power absorbed into the body. The metric for measurement is Specific Absorption Rate (SAR) expressed in Watts/ Kg of tissue. Each body has a characteristic resonant frequency, depending upon the length of the long axis. For the same level of incident exposure, the average SAR is dependent upon the length of the body. Thus, the average body SAR is size and frequency dependent.

The standards adopted in US are most stringent which is prescribed by the Federal Communication Commission (FCC) of United States. The permissible SAR levels at or below 1.6 W/kg taken over a volume containing a mass of 1 gm of tissue, whereas for general public exposure the localized SAR value as per ICNIRP guidelines standard adopted in India is 2 W/kg, averaged over a 6 minute period and use a 10 gm average mass. With higher SAR values of mobile handset, the public could potentially receive much higher RF exposure.

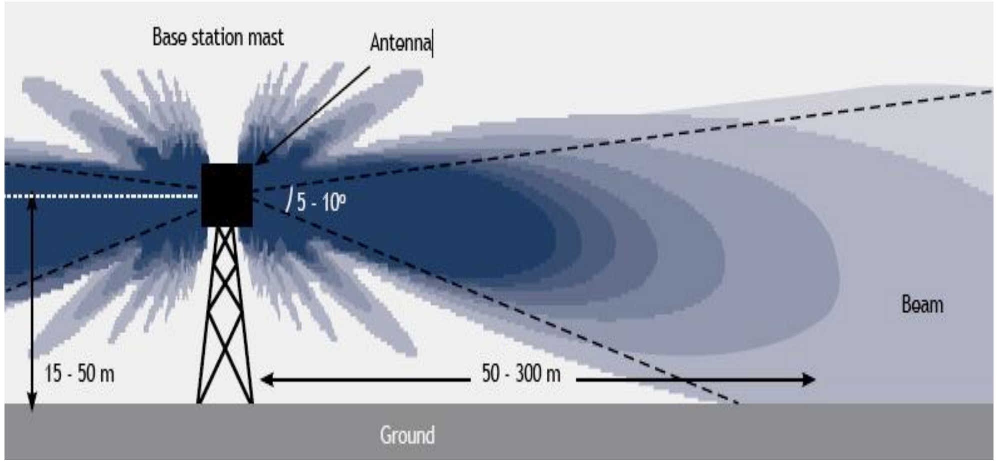

Fig. 1.5: Typical radiation pattern from a mobile tower

1.6 Effects of EMF exposure on human health

Effects of EMF radiation can be studied in two ways i.e. bio-effects and health effects:

1.6.1. Bio-effects are measureable responses to a stimulus or to a change in the atmosphere and are not necessarily harmful to our health. Biological effects can be two types i.e. Thermal and Non-Thermal effects.

Thermal Effects: It refers to the heat generated due to absorption of EMF radiation. While using a cell phone, most of the heating effect occurs at the surface of the head, causing its temperature to increase by a fraction of a degree. Prolonged thermal effect may lead to increase in body temperature.

Non-Thermal Effects: Non-thermal effects are attributed to the induced electromagnetic effects inside the biological cells of the body which is possibly more harmful.

1.6.2. Health effects are the changes which may be short term or long term. These effects stress the system and may be harmful to human health.

There are many reported biological effects to humans and animals that are exposed to RF/MW radiation. Mobile phones communicated by transmitting RF waves are electromagnetic fields, and unlike ionizing radiation such as X-rays or gamma rays, cannot break chemical bonds nor cause ionization in the human body. However, a number of studies have reported the link between exposure to RF radiation and occurrence of health disorder i.e. effect on cell growth, cell differentiation, DNA, immune system, hormonal effects, reproduction, neurological, cardiovascular systems, blood brain barrier, interference with gadgets, stress proteins, skin, sleep disorder etc. As these studies were not well designed and the numbers were not statistically significant, these observations have not been considered conclusive.

The electromagnetic wave spectrum is divided into ionizing radiation such as ultraviolet and X-rays, and non-ionizing radiation such as radiofrequency (RF), which includes Wi-Fi, Cell phones and smart meter wireless communication. It has long been recognized that ionizing radiation can have a negative impact on health. However, the effects of non-ionizing radiation on human health recently have been observed. Discussions and research on non-ionizing radiation effects were focussed on thermal and non-thermal effects. According to the FCC and other regulatory agencies, only thermal effects are relevant regarding health implications and consequently, exposure limits are based on thermal effects only (CCST, 2011). While it was practical to regulate thermal bio-effects, it was also stated that non-thermal effects are not well understood and no conclusive scientific evidence points to non-thermal based negative health effects (CCST, 2011).

Further arguments are made with respect to RF exposure from Wi-Fi, Cell towers and smart meters that due to distance, exposure to these wavelengths are negligible (EPRI, 2011). However, many *in vitro*, *in vivo* and epidemiological studies demonstrated that significant harmful biological effects occur from non-thermal RF exposure and satisfy Hill's criteria of causality (Hill, 1965). Genetic damage, reproductive defects, cancer, neurological degeneration and nervous system dysfunction, immune system dysfunction, cognitive effects, protein and peptide damage, kidney damage and developmental effects have all been reported in the peer-reviewed scientific literature.

Genotoxic effects from RF exposure, including studies of non-thermal levels of exposure, consistently and specifically show chromosomal instability, altered gene expression, gene mutations, DNA fragmentation and DNA structural breaks (Xu *et al*, 2010; Phillips *et al*, 2009; Ruediger, 2009; Zhao, 2007; Lee *et al*, 2005; Demsia *et al*, 2004; Lai, Singh, 2004; Mashevich, 2003). A statistically significant dose response effect was demonstrated by Maschevich *et al*. (2003), who reported a linear increase in aneuploidy as a function of the SAR value of RF exposure (Mashevich, 2003). Genotoxic effects are documented to occur in neurons, blood lymphocytes, sperm, red blood cells, epithelial cells, hematopoietic tissue, lung cells and bone marrow. Adverse developmental effects due to non-thermal RF exposure have been shown with decreased litter size in mice from RF exposure well below safety standards (Magras and Xenos, 1997). Cellular telephone use in rural areas was also shown to be associated with an increased risk for malignant brain tumors (Hardell *et al*, 2005).

The fact that RF exposure causes neurological damage has been documented repeatedly. Increased blood-brain barrier permeability and oxidative damage, which are associated with brain cancer and neurodegenerative diseases, have been found (Xu *et al*, 2010; Zhao, 2007; Nittby, 2009; Awad, 2008; Leszczynski and Joenvaara, 2002). Nittby *et al* (2009) demonstrated a statistically significant dose-response effect between non-thermal RF exposure and occurrence of albumin leak across the blood-brain barrier. Changes associated with degenerative neurological diseases such as Alzheimer’s, Parkinson’s and Amyotrophic Lateral Sclerosis (ALS) has been reported (Xu *et al,* 2010; Lai and Singh, 2004). Other neurological and cognitive disorders such as headaches, dizziness, tremors, decreased memory and attention, autonomic nervous system dysfunction, decreased reaction times, sleep disturbances and visual disruption have been reported to be statistically significant in multiple epidemiological studies with RF exposure occurring non-locally (Santini *et al*., 2002; Abdel-Rassoul *et al.*, 2007; Hutter *et al*., 2006; Kolodynski *et al*., 1996).

Nephrotoxic effects from RF exposure also have been reported. A dose response effect was observed in which RF exposure resulted in mild to extensive degenerative changes in chick embryo kidneys based on duration of RF exposure (Ingole and Ghosh, 2006). RF emissions have also been shown to cause isomeric changes in amino acids that can result in nephrotoxicity as well as hepatotoxicity (Lubec *et al*., 1998).

Electromagnetic field (EMF) hypersensitivity has been documented in controlled and double blind studies with exposure to various EMF frequencies. Rea *et al*. (1991) demonstrated that under double blind placebo controlled conditions, 100% of subjects showed reproducible reactions to that frequency to which they were most sensitive. Pulsed electromagnetic frequencies were shown to consistently provoke neurological symptoms in a blinded subject while exposure to continuous frequencies did not (Mc Carty *et al*., 2011).

Although these studies clearly show causality and disprove the claim that health effects from RF exposure are uncertain, there is another mechanism that proves electromagnetic frequencies, including RFs, can negatively impact human health. Government agencies and industry set safety standards based on the narrow scope of Newtonian or Classical Physics reasoning that the effects of atoms and molecules are confined in space and time. This model supports the theory that a mechanical force acts on a physical object and thus, long-range exposure to EMF and RF cannot have an impact on health if no significant heating occurs. However, this is an incomplete model. A quantum physics model is necessary to fully understand and appreciate how and why EMF and RF fields are harmful to humans (Smith, 2004, 2008). In quantum physics, matter can behave as a particle or as a wave with wave-like properties. Matter and electromagnetic fields encompass quantum fields that fluctuate in space and time. These interactions can have long-range effects which cannot be shielded, are non-linear and by their quantum nature have uncertainty. Living systems, including the human body, interact with the magnetic vector potential component of an electromagnetic field such as the field near a toroidal coil (Smith, 2004; Del Giudice *et al*., 1989; Tonomura, 1986). The magnetic vector potential is the coupling pathway between biological systems and electromagnetic fields (Smith, 2004; Smith, 2008). Once a patient's specific threshold of intensity has been exceeded, it is the frequency which triggers the patient's reactions.

Long range EMF or RF forces can act over large distances setting a biological system oscillating in phase with the frequency of the electromagnetic field so it adapts with consequences to other body systems. This also may produce an EMF imprint into the living system that can be long lasting (Smith, 2004; Smith, 2008; Del Giudice *et al*., 2005). Research using objective instrumentation has shown that even passive resonant circuits can imprint a frequency into water and biological systems (Cardella *et al*., 2001). These quantum electrodynamic effects do exist and may explain the adverse health effects seen with EMF and RF exposure. These EMF and RF quantum effects have not been adequately studied and are not fully understood regarding human health.

Cleary *et al.* (1990) carried out series of experiments on cell proliferation and cell kinetic studies under continuous wave RF Radiation (RFR) exposures and reported increased proliferation. They also observed similar effects in human peripheral lymphocytes (Cleary, 1990). RF Radiation has been shown to down–regulate gap-junction intercellular communication, which plays an essential role in regulation of cell growth, differentiation and wound healing (Chiang, 1998).

RF Radiation have been reported to affect a variety of ion channel properties such as decreased rates channel protein formation, decreased frequency of single channel opening and increased rates of rapid burst–like firing (Chiang, 1998). Even Ca^{2+} release from cell membrane has been reported (Bawin *et al.*, 1975;Dutta *et al.*, 1984). An increase in calcium dependent protein kinase C has been noted in developing rat brain indicating that this type of radiation could affect membrane bound enzymes associated with cell signalling, proliferation and differentiations (Paulraj and Behari, 2004).

In experimental animals, an increase in the blood brain barrier permeability in response to exposure to RF Radiation has been reported in a number of studies (Albert, 1977; Oscar and Hawkins, 1977; Fritze *et al.*, 1997).

Resting BP has been reported to increase during exposure to RF Radiation emitted from cell phones (Braune, 1998).

DNA rearrangement in cells from brain and testis were reported under RF Radiation exposure at low intensity in mice (Verma, *et al.*, 1976; Sarkar *et al.*, 1994). Increased dominant lethal mutations in the offspring of exposed male mice and abnormal sperm were also reported in mice (Verma *et al*, 1976; Verma and Traboulay,1976; Goud *et al.*, 1982) but such effects were not seen in rats (Berman *et al.*, 1980) and C3H mice (Saunders *et al.*, 1983; Saunders *et al.*, 1983). While increased chromosomal aberrations have been reported in large number of studies (Yao and Jiles, 1970; Chen *et al.*, 1974; Garaj Vrhovac *et al.*, 1991; Garaj Vrhovac *et al.*, 1992, Khalil *et al.*, 1993; Maes *et al.*, 1993a; Maes *et al*, 1993b), some other studies did not find such aberrations (Meltz *et al*, 1987; Kerbacher *et al*, 1990). Occurrence of increased micronuclei, which is another indirect indicator of DNA damage, has been reported in large number of studies (Antipenko and Koveshinkova, 1987; Haider *et al.*, 1994; Balode, 1996; Garaj Vrhovac *et al.*, 1992).

Hardell *et al*. (2009) conducted number of epidemiological studies as well as case control studies on use of mobile phones for more than 10 years. They reported that the use of mobile phones for more than 10 years give a consistent pattern of increased risk for acoustic neuroma and gliaoma. The risk is highest for ipsilateral exposure. They further reported that longer follow-up is needed and an increased risk for other type of brain tumor cannot be ruled out. Goldoni (1990) compared the haematological finding in 25 male air traffic control technicians working at a distance from microwave sources and reported that radar exposed workers had significantly lower levels of leukemia and red cells than the electronic technician.

Santini *et al*. (2002) reported significant health effects on people living within 300 meters of mobile phone base stations in Paris particularly, in relation to depressive tendency, fatigue, sleeping disorder and difficulty in concentration. Netherlands Organization for Applied Scientific Research, TNO (2003) studied the effects of Global Communications System (GSM) RF Fields on well being and cognitive function of human subjects with and without subjective complaints and reported significant effects on wellbeing of the people i.e., headaches, muscle fatigue/pain, dizziness etc from 3G mast emissions. Those who had previously been noted as 'electro-sensitive' under a scheme in that country were shown to have more pronounced ill-effects, though others were also shown to experience significant effects.

Wolf and Wolf (2004) from Israel, based on medical records of people living within 350 meters of a long established phone mast, reported a fourfold increased incidence of cancer in comparison with the general population. They also reported a tenfold increase specifically among women, compared with the surrounding locality further from the mast. In Germany (2004), the bases of the data used for the survey were PC files of the 1000 patient's case histories between the years 1994 and 2004. The authors reported that the proportion of newly developing cancer cases was significantly higher among those patients who had lived during the past ten years at a distance of up to 400 meters from the cellular transmitter site, which has been in operation since 1993, compared to those patients living further away, and that the patients fell ill on average 8 years earlier. In Austria(2005), when electro-sensitive men (3) and women (9) were exposed to RF Radiation emitted from a shielded cell phone base station in phase manner, all of them reported symptoms like buzzing in the head, palpitations of the heart, unwellness, lightheadedness, anxiety, breathlessness, respiratory problems etc. This study shows significant changes of the electrical currents in the brain by a cell phone base station at a distance of 80 meters.

Most of the laboratory studies were unable to find a direct link between exposure to RF Radiation and the incidence of cancer. However, growing scientific evidences of bio effects and adverse health effects like DNA rearrangement in cells or chromosomal damage is reported (Sarkar, 1997). Even the biological effects could not be established as caused by RF Radiation, due to complex interaction of the different exposure parameters i.e. mass, shape and size of the body (age, gender, activity level, body insulation etc.) and the environmental conditions (ambient temperature, air velocity, humidity).

Many of the biological effects resulting from mobile phone use were relatively well-known and were similar to those described in RF sickness (Mild *et al*., 1998; Santini *et a1*., 2002; Pachuau *et al.,* 2015). The frequency of non specific health symptoms such as nausea, loss of appetite, visual disturbance, irritability, and depression were found to be significantly higher in the population living close (within 100m) to mobile phone base stations as compared to those living away from these stations (Santini *et al*., 2002, 2003). It is possible that RF radiation may change the fidelity of DNA as the increased incidence of cancer has been reported already (Hardell *et al*., 1999; Bortkiewicz *et al*., 2004; Wolf and Wolf, 2004; Hutter *et al.*, 2006; Abdel-Rassonl *et al*., 2007). Any form of damage to DNA is subsequently converted into DNA strand breaks, especially after DNA repair and it will be expressed in the form of chromosome breaks (Ensminger *et al*., 2014). Chromosomal abnormalities are thought to be important in the development and progression of cancer pathology (Mitelman *et al*., 1997).

A number of studies have reported an increase in the DNA damage/micronuclei in different study systems. The human peripheral blood lymphocytes exposed to RF radiation have shown an increased frequency of micronuclei earlier (Garaj-Vrhovac *et al*., 1992, Zotti-Martelli *et al*., 2000; d'Ambrosio *et al*., 2002; Tice *et al*., 2002; El-Abd and Eltoweissy, 2012). Various studies conducted in other systems have revealed an increased micronuclei frequency after exposure to RF radiation (Balode, 1996; Trosic *et al*., 2002, 2004; Busljeta *et al*., 2004; Gandhi and Singh, 2005).

Many environmental pollutants are shown to initiate oxidative damage, for example heavy metals, polycyclic aromatic hydrocarbons, pesticides, polychlorinated biphenyls, dioxins, and other xenobiotics (Livingstone, 2001). Exposure to electromagnetic radiation may exert an oxidative stress on human cells as evidenced by the increase in the concentration of the superoxide radical anion released in the saliva of cell phone users (Abu Khadra, 2014). Also, RF electromagnetic waves emitted from cell phones led to oxidative stress in human semen (Agarwal, 2009). Biochemical changes associated with a prolonged exposure to electromagnetic fields and its relationship to the activity of antioxidant system have been reported in rat (Achudume *et al*., 2010; Atasoy *et al.*, 2012).

Studies conducted in Guru Nanak Dev University, Amritsar has found correlation between mobile phone use (exposure to RF radiations) and DNA and chromosomal damage in lymphocytes of individuals using mobile phones which may have long term consequences in terms of neoplasia and/or age related changes (Gandhi, 2007). Exposure to RF radiations has been reported to affect physiological, neurological, cognitive and behavioral changes (Gandhi and Singh, 2005). A recent study conducted in Aizawl have revealed an increased in micronuclei frequency after exposure to RF Radiation, and also reported relatively lower levels of antioxidants and higher level of lipid peroxidation among people in the vicinity of mobile base stations, than control group indicating possibility of having oxidative stress (Zothansiama *et al.*, 2017).

Indian Council of Medical Research (ICMR) supported an animal study under Prof. J. Behari, School of Environmental Sciences, Jawaharlal Nehru University, New Delhi (2005-08). Anti-oxidative changes were noticed in reproductive pattern of male rats and increase in the level of CAT activity. The result obtained showed that the chronic exposure to these radiations cause double strand DNA breaks in sperm cells. This study also shows that the microwave radiation exposure can cause statistically significant decrease in the sperm count and testes weight.

To study the adverse effects of cell phone, the ICMR has just initiated (2010) a study in Delhi to examine whether use of cell phone create risk of neurological disorders and reproductive dysfunctions. Measurement of SAR from various types of cell phones and power density, wave length and frequency of RF radiation emitted from cell phone towers is also under study. These physical characteristics of RF Radiation will be correlated with the clinical and laboratory findings.

CHAPTER 2
INTERACTION OF RF RADIATION WITH BIOLOGICAL TISSUES

2.1 : Mobile communication

This chapter deals with exposure of RF radiation from Mobile/Cell tower. A brief introduction of mobile communication system is given first before discussing the interaction of RF radiation with biological tissues.

GSM (Global System for Mobile Communication) is a digital mobile telephony system that is widely used in Europe and other parts of the world. Mobile services based on GSM technology were first launched in Finland in 1991 (Huurdeman, 2003).

GSM uses a variation of time division multiple access (TDMA) and is the most widely used of the three digital wireless telephony technologies (TDMA, GSM, and CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1800 MHz frequency band.

A cell phone transmits 1 to 2 Watt of power in the frequency range of 824 - 849 MHz (CDMA), 890 - 915 MHz (GSM900) and 1710 – 1780 MHz (GSM1800) to the base station. Cell tower antennas transmit in the frequency range of 869 - 894 MHz (CDMA), 935 - 960 MHz (GSM900) and 1810 – 1880 MHz (GSM1800). Also, 3G has been deployed in a few cities, in which base station antenna transmits in the frequency range of 2110 – 2170 MHz.

The antennas connected to the base station tend to be mounted high above ground level because the radio signals would be blocked by buildings etc if the antennas were nearer the ground. Antennas used with macro-cellular base stations are generally placed between 15 and 50 m above ground level because they are designed to provide communications over distances of several kilometres. However, micro-cellular base stations have their antennas mounted nearer ground level as communications are only carried out over distances of a few hundred metres. Antennas tend to be mounted directly on existing structures, such as buildings, when this is convenient, but ground based lattice towers, shorter masts mounted on roofs, and lamp-post type systems are also used.

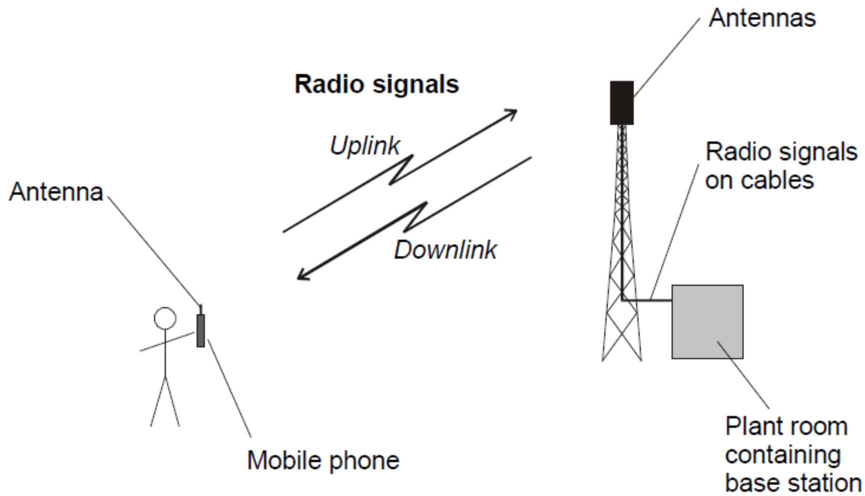

Figure 2.1: Block diagram of Mobile phone communication system

Mobile phone operators divide a region in large number of cells, and each cell is divided into number of sectors. The base stations are normally configured to transmit different signals into each of these sectors. In general, there may be three sectors with equal angular coverage of 120 degrees in the horizontal direction as this is a convenient way to divide a hexagonal cell. If number of users is distributed unevenly in the surrounding area, then the sectors may be uneven. These base stations are normally connected to directional antennas that are mounted on the roofs of buildings or on free-standing masts. The antennas may have electrical or mechanical down-tilt, so that the signals are directed towards ground level. The figure shows how the area covered

by each base station can be regarded as a hexagon if there is a fixed distance between neighbouring base stations. In practice, the location of base stations is influenced by many factors so cells vary in shape and size.

CHAPTER 2 INTERACTION OF RF RADIATION WITH BIOLOGICAL TISSUES

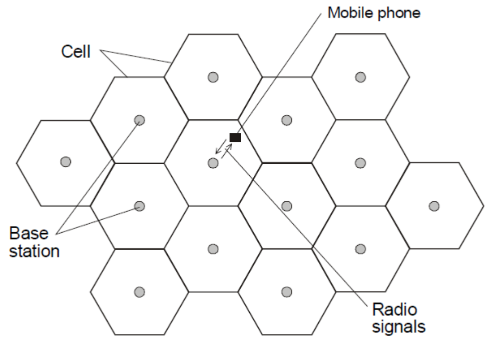

Figure 2.2: Diagram showing division of cells by service provider

2.2 Effects of RF/MW radiation on Biological Tissues

The effects of the interaction of RF and Microwave radiation with biological tissues can be considered as the result of three phenomena:

1. The penetration of EM waves into the living system and their propagation into it.
2. The primary interaction of the waves with biological tissues.
3. The possible secondary effects induced by the primary interaction.

Living systems have a large capacity for compensating for the effects induced by external influences, in particular EM sources. This is very often overlooked while it is one main reason for which conclusions derived from models have to be taken with precaution. The radiation mechanism considered consists of a source that emits EM energy. Part of the incident energy is absorbed and transformed within the biological system. Hence, there is the sequence source–radiation–target. The physical laws of EM field theory, reflection, diffraction, dispersion, interference, optics, and quantum effects, must be applied to investigate and explain the observed phenomena. This is true in general, for the whole spectrum of EM radiation. Before starting any interpretation of the results obtained, however, it is necessary to survey the basic phenomena involved in the interaction of RF and Microwave radiation with living systems.

The first step is to review basic bioelectricity (Reilly *et al.*1993). Natural bioelectric processes are responsible for nerve and muscle function. Externally applied electric currents can excite nerve and muscle cells. The nervous system is concerned with the rapid transfer of information through the body in the form of electrical signals. It is conveniently divided into the central nervous system (CNS) and the peripheral nervous system. Muscles can be stimulated directly or indirectly through the nerves that enervate the muscle. Thresholds of stimulation of nerve are generally well below thresholds for direct stimulation of a muscle. Hence, an understanding of neuro-electric principles is a valuable foundation for investigating both sensory and muscular responses to electrical stimulation.

2.2.1 Bioelectric Phenomena

All living cells exhibit bioelectric phenomena. However, a small variety only produce potential changes that reveal their physiological function. There are familiar bioelectric recordings. The three most prominent bioelectric effects, those of heart, skeletal muscle, and brain, are recorded by the following: the electrocardiogram (ECG), reflecting the excitation and recovery of the whole heart; the electromyogram (EMG), reflecting the activity of skeletal muscle; and the electroencephalogram (EEG), reflecting the activity of the outer layers of the brain, the cortex. In these cases, the action potentials are used for diagnostic purposes, and extracellular electrodes are used that are both large and distant from the population of cells that become active and recover. The depolarization and repolarization processes send small currents through the conducting environmental tissues and fluids, resulting in a time-varying potential field. Appropriately placed electrodes can record the electrical activity of the bioelectric generators. However, the waveforms of such recordings are vastly different from those of the transmembrane action potentials. It has been shown by Geddes and Baker that such extracellular recordings resemble the second derivative of the excursion in the transmembrane potential (Geddes *et.al*, 1989). Despite the difference in waveform, extracellular recordings identify the excitation and recovery processes very well (Reilly *et.al.*, 1993). Furthermore the eye, ear, sweat glands, and many types of smooth muscles also produce action potentials that are used for their diagnostic value (Geddes *et.al* 1989).

CHAPTER 2 INTERACTION OF RF RADIATION WITH BIOLOGICAL TISSUES

Bioelectricity is extremely important in a living body. It has long been shown that direct application of an externally generated voltage may have an effect on bone and cartilage repair. Considerable animal and in vitro experimentation suggests the clinical usefulness of electric currents for soft tissue repair and possibly to enhance repair of nerve fibers that have sustained crush or transsection injury (Reilly *et.al.,* 1993). There is no doubt that bioelectricity has to be taken into account seriously when investigating possible medical applications of RFs and microwaves as well as when wondering about possible hazards on human beings and animals due to RF or microwave exposure.

2.3: Dielectric Properties and Polarisation of RF Radiation

There are three relaxation processes which are mainly responsible for the dielectric properties of tissues: dipolar orientation, interfacial polarization, and ionic diffusion. The theories summarized below apply to linear responses to weak fields. As the field intensity is increased, at some level the response will no longer be linear. The threshold at which nonlinearity becomes noticeable depends on the system and the investigated dielectric effect.

2.3.1 Dipolar Orientation: The basic theory is macroscopic and does not strictly apply to molecular systems. It applies poorly to liquids, especially to water. In tissues, several dipolar effects may be anticipated. Globular proteins typically exhibit total dielectric increments of the order of 1–10 per gram of protein per 100 g of solution, with relaxation frequencies in the range 1–10 MHz. Polar side chains on protein relax at some higher frequencies. However, these are likely to be relatively small effects in tissues at RFs and below for which charging phenomena or counterion effects dominate the dielectric properties. Water is the major constituent in most tissues, and in several respects the dielectric properties of tissues reflect those of water. At RFs, the conductivity of tissue is essentially that of its intracellular and extracellular fluids. At microwave frequencies the dielectric dispersion arises from the dipolar relaxation of the bulk tissue water. Dipolar relaxation of water is a dominant effect in tissues at microwave frequencies. Pure water undergoes nearly single time constant relaxation centered at 20 GHz at room temperature and 25 GHz at 37°C. Water associated with protein surfaces has a lower relaxation frequency than that of the bulk liquid, and this water fraction contributes noticeably to the dielectric dispersion at frequencies near 1 GHz.

2.3.2 Interfacial Relaxation : If a material is electrically heterogeneous, charges do appear at the interfaces within the material because of boundary conditions at the interfaces. Interfacial effects typically dominate the dielectric properties of colloids and emulsions. Evaluating the effect of interfaces within a material is a classical EM problem, in particular for evaluating the transmission and reflection of EM waves. Simple models can easily be analyzed. Cartesian configurations are most easy to evaluate, for instance two semi-infinite media in contact with each other, one slab of a given thickness inserted into an infinite medium separated in two parts by the slab, two slabs in contact with each other, and so on. The bulk permittivity and conductivity of the composite material can easily be calculated. When the bulk material properties of the constituent phases vary with frequency, the frequency dependence of the heterogeneous material can no longer be characterized by a single relaxation time.

2.3.3 Ionic Diffusion: Counter-ion phenomena are due to ionic diffusion in the electrical double layers adjacent to charged surfaces. Counter-ion polarization effects have been reported in a variety of systems containing charged surfaces: emulsions, suspensions of charged polystyrene spheres, micro-organisms and long-chain macromolecular poly-ions such as DNA. The time constants for such effects are of the form L^2/D, where L is the length over which diffusion occurs and D is a diffusion coefficient. In contrast, the time constant for the Maxwell–Wagner effect is of the form of RC or $\frac{\varepsilon\varepsilon_0}{\sigma}$, where R (or $1/\sigma$) is a resistance and C (or $\varepsilon\varepsilon_0$) a capacitance. Counter-ion effects contribute to the alpha dispersion that is found in tissues at low frequencies. They are dominant in biological systems at KiloHertz frequencies and below: Suspensions of sub-micrometer sized polystyrene spheres have permittivity values approaching 104 with relaxation frequencies in the KiloHertz range.

CHAPTER 2 INTERACTION OF RF RADIATION WITH BIOLOGICAL TISSUES

When a material is submitted to an applied electric field, it becomes polarized, the amount of which is called the polarization vector. This is due to the fact that, in many circumstances, electric dipoles are created or transformed into the material, which corresponds to what is called the dielectric properties of the material. Hence, the polarization is the electric dipole moment per unit volume, in Coulombs per square meter. The total electric field in a dielectric material is the sum of the applied electric field and of an induced electric field, resulting from the polarization of the material. As a simple example, a perfect electric conductor is defined as an equipotential material. If the points in the material are at the same electric potential, then the electric field must be zero and there can be no electric charges in the material. When a perfect electric conductor is submitted to an applied field, this applied field exists in all points of the material. To have a vanishing total electric field, the material must develop an induced electric field such that the sum of the applied field and the induced field vanishes in all points of the material. The induced field is calculated by taking into account the geometry of the problem and the boundary conditions, which can of course be complicated. As another example, a human body placed in an applied electric field develops an induced electric field such that the sum of the applied field and the induced field satisfies the boundary conditions at the surface of the body. The total field in the body is the sum of the applied field and of the induced field. A new vector field is then defined, known as the displacement flux density or the electric flux density, in Coulombs per square meter similarly to the polarization, defined as

$$\vec{D} = \varepsilon_0 \vec{E} + \vec{P} \ \text{Cm}^{-2} \qquad (2.1)$$

This definition is totally general, applying to all materials, in particular to all biological materials. The dipolar polarization, resulting from the alignment of the molecule dipolar moment due to an applied field, is a rather slow phenomenon. It is correctly described by a first-order equation, called after Debye (B. Frankenhaeuser *et.al* 1964): The dipolar polarization reaches its saturation value only after some time, measured by a time constant called relaxation time τ . The ability to polarize, called the polarizability, is measured by the parameter

$$\alpha_d = \frac{\alpha_0}{1 + j\omega\tau} + C \tag{2.2}$$

where constant C takes into account the non-zero value of the polarizability at infinite frequency. The relative permittivity related to this phenomenon is

$$\varepsilon_r = \varepsilon'_r - j\varepsilon''_r \tag{2.3}$$

It should be observed that the permittivity is a complex quantity with real and imaginary parts. If ε_{r0} and $\varepsilon_{r\infty}$ are the values of the real part of the relative permittivity at frequencies zero and infinity, respectively, one can easily verify that the equations can be written as

$$\varepsilon_r' = \frac{\varepsilon_{r0} - \varepsilon_{r\infty}}{1 + \omega^2\tau^2} + \varepsilon_{r\infty} \tag{2.4}$$

$$\varepsilon_r'' = \left(\frac{\varepsilon_{r0} - \varepsilon_{r\infty}}{1 + \omega^2\tau^2} \right)\omega\tau \tag{2.5}$$

The parameter $\varepsilon_{r\infty}$ is in most cases the value at optical frequencies. It is often called the optical dielectric constant. Dipolar polarization is dominant in the case of water, much present on earth and an essential element of living systems. The relative permittivity of water at 0°C is

$$\varepsilon_r = 5 + \frac{83}{1 + j0.113 f(GHz)} \tag{2.6}$$

with 1/t = 8.84 GHz. The real part of the relative permittivity is usually called the dielectric constant, while the imaginary part is a measure of the dielectric losses. These are often expressed also as the tangent of the loss angle:

$$\tan\delta_r = \frac{\varepsilon''}{\varepsilon'} \tag{2.7}$$

2.4: Skin depth

When a conductive material is exposed to an electromagnetic field, it is submitted to a current density caused by moving charges. In solids, the current is limited by the collision of electrons moving in a network of positive ions. Good conductors such as gold, silver, and copper are those in which the density of free charges is negligible, the conduction current is proportional to the electric field through the conductivity, and the displacement current is negligible with respect to the conduction current. The propagation of an EM wave inside such a material is governed by the diffusion equation, to which Maxwell's equations reduce in this case. Biological materials are not good conductors. They do conduct a current, however, because the losses can be significant; they cannot be considered as lossless. The depth of penetration of electromagnetic wave inside conductor or dielectric can be obtained by using Maxwell's electromagnetic equations.

We have Maxwell's equations in material medium given by

$$\vec{\nabla} \times \vec{H} = \sigma\vec{E} + \varepsilon\frac{\partial\vec{E}}{\partial t} \tag{2.8}$$

$$\vec{\nabla} \times \vec{E} = -\mu\frac{\partial\vec{H}}{\partial t} \tag{2.9}$$

Where σ is electric conductivity of the medium, ε is electric permittivity of the medium, μ is magnetic permeability of the medium.

Taking curl on both sides in equations (2.8) & (2.9), we get

$$\nabla^2\vec{H} - \mu\sigma\frac{\partial\vec{H}}{\partial t} - \mu\varepsilon\frac{\partial^2\vec{H}}{\partial t^2} = 0 \tag{2.10}$$

$$\nabla^2\vec{E} - \mu\sigma\frac{\partial\vec{E}}{\partial t} - \mu\varepsilon\frac{\partial^2\vec{E}}{\partial t^2} = 0 \tag{2.11}$$

CHAPTER 2 INTERACTION OF RF RADIATION WITH BIOLOGICAL TISSUES

Electric field of the plane wave is given by

$$\vec{E}(\vec{r}, t) = \vec{E}_o(\vec{r}, t)\, e^{i(\vec{k}.\vec{r} - \omega t)} \qquad (2.12)$$

Since equation (2.12) is solution of equation (2.10), substituting equation (2.12) in equation (2.10),

$$-k^2\vec{E} - i\sigma\mu\omega\vec{E} - \mu\varepsilon\omega^2\vec{E} = 0$$

$$\text{or ,}\quad k^2 = \mu\varepsilon\omega^2 + i\sigma\mu\omega \qquad (2.13)$$

Where k is propagation vector, it is a complex quantity. Let us write

$$k = \alpha + i\beta \qquad (2.14)$$

$$\text{or}\quad k^2 = \alpha^2 - \beta^2 + 2\alpha\beta \qquad (2.15)$$

Comparing equation (2.13) & (2.15) we get,

$$\alpha^2 - \beta^2 = \mu\varepsilon\omega^2 \qquad (2.16)$$

$$\&\quad 2\alpha\beta = \sigma\mu\omega \qquad (2.17)$$

Solving equations (2.16) & (2.17), we get

$$\alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}}\left[1 + \left\{1 + \left(\frac{\sigma}{\varepsilon\omega}\right)^2\right\}^{1/2}\right]^{1/2} \qquad (2.18)$$

$$\beta = \omega\sqrt{\frac{\mu\varepsilon}{2}}\left[-1 + \left\{1 + \left(\frac{\sigma}{\varepsilon\omega}\right)^2\right\}^{1/2}\right]^{1/2} \qquad (2.19)$$

For low frequency, the quantity $\frac{\sigma}{\varepsilon\omega} >> 1$. In that case both the equations (2.18) & (2.19) reduces to

$$\alpha = \beta = \sqrt{\frac{\mu\sigma\omega}{2}} \tag{2.20}$$

Equation (2.20) is valid mainly for good conductors, where the conduction current is large with respect to the displacement current, it shows that the amplitude of the fields decays exponentially inside of the material.

The parameter δ is called skin depth. It is equal to the distance within the material at which the field reduces to 36.8% of the value they have at the surface. It is found that the skin depth decreases when the frequency increases, being inversely proportional to the square root of frequency. It also decreases when the conductivity increases: The skin depth is smaller in a good conductor that in another material. Furthermore, it can be shown that the fields have a phase lag equal to $\frac{z}{\delta}$ at depth z.

For most biological tissues, the displacement current is of the order of the c expression should then be used instead of (2.20) (Jordan, 1950)

$$\delta = \omega\sqrt{\frac{\mu\varepsilon}{2}}\left[-1+\left\{1+\left(\frac{\sigma}{\varepsilon\omega}\right)^2\right\}^{1/2}\right]^{1/2} \tag{2.21}$$

The following important observations can be deduced from Eqn. (2.20):

1. The fields exist in every point of the material.
2. The field amplitude decays exponentially when the depth increases.
3. The skin depth decreases when the frequency, the permeability, and the conductivity of the material increase. For instance, the skin depth of copper is about 10 mm at 50 Hz, 3 mm at 1 kHz, and 3 μm at 1 GHz. It is equal to 1.5 cm at 900 MHz and of the order of 1 mm at 100 GHz in living tissues.

These results are strictly valid for solids limited by plane boundaries. They are applicable to materials limited by curved boundaries when the curvature radius is more than five (5) times larger than the skin depth. In the other cases, a correction has to be applied. The phenomenon just described is the *skin effect*: Fields, currents, and charges concentrate near the surface of a conducting material. This is the reason why materials which are simultaneously magnetic and conducting, such as mumetal, are used for low-frequency shielding. In practice, the skin effect becomes significant for humans and larger vertebrates at frequencies above 10 MHz.

Shielding is much easier to achieve at higher frequencies. The skin effect implies that ,when using microwaves for a medical application, the higher the frequency,, the smaller the penetration, which may lower the efficiency of the application. Hence, the choice of frequency is important. It also implies that if a human being, for instance, is submitted to a microwave field, the internal organs are more protected at higher than at lower frequencies. As an example, the skin depth is three times smaller at 900 MHz, a mobile telephony frequency, than at 100 MHz, an FM radio frequency, which means that the fields are three times more concentrated near the surface of the body at 900 MHz than at 100 MHz. It also means that internal organs of the body are submitted to higher fields at lower frequency than at higher frequency at lower frequency than at higher frequency.

The skin effect is also characterized by the *intrinsic* (or *internal* or *metal*) *impedance*, obtained by dividing the electric field at the surface by the current per unit width (I_x) flowing into the material (Vander Vorst *et al.*, 2009):

$$Z_m = \frac{E_o}{I_x} = (1+j)\sigma\delta = \sqrt{\frac{j\omega}{\sigma}} \qquad (2.22)$$

The impedance is useful for calculating the (complex) power dissipation in the material. A property of the exponential curve is that its integration yields a result equal to the initial value times the skin depth. In other words, the intrinsic resistance of the material in which the fields decay exponentially would be the same if the current was uniformly distributed over depth δ. Hence, the total power dissipated in the material under an exponentially decaying field is equal to the power dissipated in depth δ under a field constant and equal to the value at the surface.

Table 2.1 summarizes some skin depth values for human tissues at some frequencies. The EM properties of the tissues as well as their variation as a function of frequency have been taken into account.

Parameter	**Radio**	**TV**	**Telephony**	**Telephony**
Frequency (MHz)	100	450	900	1800
Skin depth (cm)	3	1.5	1	0.7
Depth at which power reduces to 1% (cm)	9	4.5	3	2

Table 2.1 : Typical skin depths in Human Tissue (Vander Vorst *et al*., 2009)

Figure 2.3 shows the variation of the power absorbed inside a human body as a function of the penetration depth at several microwave frequencies (Vander Vorst *et al*., 2009): We are less and less transparent to non ionizing EM radiation when the frequency increases. In the optical range, skin depth is extremely small i.e. not transparent anymore. Variation of the dielectric constant as a function of frequency was taken into account in this figure

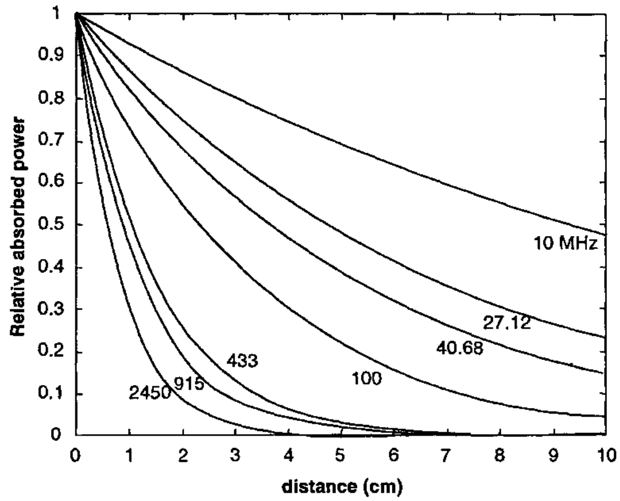

Figure 2.3 : Power absorbed in muscles as function of skin depths at various frequencies

There is a tendency to believe that RFs and microwaves exert more significant biological effects at low and extremely low frequencies. This is not necessarily true: The dielectric constant of living materials is about 10,000 times larger at ELF than at microwaves. The dielectric constant is important because it is the link between the source field and the electric flux density (also called the displacement field). A dielectric constant 10,000 times larger implies the possibility of an electric flux density of a given value with a source field 10,000 times smaller. Figure 2.4 shows the dielectric constant of living material (muscle) as a function of frequency (Gerin *et al.*, 1999). There is a level of about 1,000,000 at ELF up to 100 Hz, then a second level of about 100,000 from 100 Hz to 10 kHz, and, after some slow decrease, a third level of about 70–80 from 100 MHz to some GHz. This last value is that of the dielectric constant of water at microwaves. One of the main constituents of human tissues is water. Hence, we have about the same microwave properties as water.

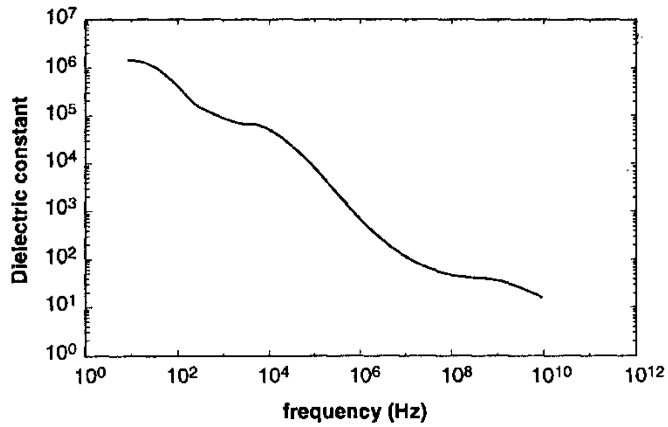

Figure 2.4 : Dielectric constant of living material as a function of frequency.

However, as mentioned earlier microwaves are in the frequency range in which the wavelength is of the order of the size of objects of common use - meter, decimeter, centimeter and millimeter - depending of course on the material in which it is measured. Hence such wavelengths can excite resonance in biological tissues and systems.

CHAPTER 3
METHODOLOGY

The research work mainly consist of measurements of power densities and frequency spectrum and questionnaire surveys on 13 non specific health symptoms which are supposed to be associated with exposure to RF/MW radiation. The questionnaires collected were analyzed with SPSS software version 16.0 to test the significance by performing *t*-test.

The objectives of the research work are:

1. To ensure that the RF radiation from the base transceiver stations comply with the guidelines set by ICNIRP recommendation 1998 and the current Indian standard for human exposure to RF.
2. To understand the status of electromagnetic radiation (RF radiation) level among general public in Champhai and Lunglei districts of Mizoram.
3. To study the health hazards faced by the inhabitants near the base transceiver stations.
4. To study the relationship between health complaints and the corresponding power density.

3.1 Questionnaire survey

To study the health hazards and problems faced by the inhabitants living close to the base transceiver station, questionnaire surveys were conducted on 13 different non specific health symptoms. The questionnaire was similar to that developed for the study on mobile phone users by Santini *et al.* (2002). The surveys were conducted in four different localities in Champhai city, two towns –Khawzawl and Kawlkulh within Champhai District, a total of six different sites of studies in Champhai district. Survey was also conducted in eight different localities in Lunglei District. The level of complaints for the studied symptoms was expressed by using a scale of: 0 = never, 1= sometimes, 2 = often, 3 = very often. Details of the different levels are given in table 3.1.

	Indication	**Frequency of complaints**
0	Never	-
1	Sometimes	Once a week
2	Often	2 or 3 times a week
3	Very often	More than 3 times a week

Table 3.1 : Details of the different levels of health complaints.

In Champhai District, the survey was done first in Champhai Kanaan, a locality in the outskirt of Champhai. A total of 50 persons (24 male, 26 female) in the age group of 15-60 years from different parts of the locality willingly participated in the questionnaire. As there was no mobile tower in Champhai Kanaan (the nearest tower from Champhai Kanaan is located about 500m away at another locality), the average power density was very low (0.0088 mW/m^2 for GSM 900, 0.0754 mW/m^2 for GSM 1800, net average value of 0.042 mW/m^2), which is within the safe limit of RF/MW exposure recommended by any organization. Practically, they can be considered not exposed to RF/MW radiation. Due to this reason, the questionnaire responses from Champhai Kanaan were used as the reference (for not exposed inhabitants, i.e. control group) for comparison of questionnaires with all the other sites of study within Champhai District.

In the other sites of study, the same number of questionnaires i.e. 50 (24 male, 26 female) was distributed in order to achieve uniformity in the comparison. The inhabitants were requested to participate in the questionnaire. As mentioned earlier, questionnaire responses of each other locality was compared with that of Champhai Kanaan by doing statistical analysis using independent *t*- sample test. Comparison between questionnaire responses of male and female were done for each locality using independent *t*-test.

In Lunglei District, the survey was done first in Zohnuai, a locality where there is no mobile tower (the nearest tower is located at 1 km. from Zohnuai). As there was no mobile tower in Zohnuai, the average power density was very low(0.015mw/m^2 for

GSM900, 0.150 mW/m^2 for GSM1800, net average value of 0.083mW/m^2), which is within the safe limit of RF/MW exposure recommended by any organization. Practically, they can also be considered not exposed to RF/MW radiation. Due to this reason, the questionnaire responses from Zohnuai were used as the reference (for not exposed inhabitants, i.e. control group) for comparison of questionnaires with all the other sites of study within Lunglei District.

Again, in the other sites of study, the same number of questionnaires i.e. 50 (24 male, 26 female) was distributed in order to achieve uniformity in the comparison. The inhabitants were requested to participate in the questionnaire. As mentioned earlier, questionnaire responses of each other locality was compared with that of Zohnuai by doing statistical analysis using independent *t*-sample test. Comparison between questionnaire responses of male and female were done for each locality using independent *t*-test.

Sl. No.	**Symptom**	**Scale**			
		0	**1**	**2**	**3**
1.	Fatigue				
2.	Nausea				
3.	Sleep disruption				
4.	Feeling of discomfort				
5.	Headache				
6.	Cramp				
7.	Difficulty in concentration				
8.	Memory loss				
9.	Skin problem				
10.	Visual disruption				
11.	Hearing problem				
12.	Dizziness				
13.	Muscle pain				

Table 3.2: The questionnaire format used in the study (Santini *et al.* 2002)

3.2 Power density measurement

Power density measurements were carried out at different houses and public places in each site of study. In each locality, power densities were measured at 10-12 different places, the average of those measurements were calculated. At the same time, absolute power (in dBm) was measured at each measurement site. The average value of each locality was compared with the recommendations given by various organizations like International Commission on Non Ionizing Radiation Protection (ICNIRP 1998), Bioinitiative Report 2012, Salzburg 2001 and the current Indian national limit. No mobile phone was turned on in the vicinity while taking readings. The main purpose of the measurement is to ensure that RF/MW field emission from each site does not exceed the safe public limits and to find whether there is relationship between the health complaints and the measured power densities.

All the measurements were done with the instrument HF-60105V4, manufactured by Aaronia, Germany. The HF-60105 V4 is a high-frequency RF spectrum analyzer that provides simplified measurement of RF signals for Interference and exposure applications. Find radiation sources, find their respective frequencies and signal strengths, including direct display of exposure limits. The highly complex calculations required for exposure limit calculations are performed automatically by a high-performance DSP (Digital Signal Performance).

HF 60105 V4 features :

- Frequency range : 1MHz to 9.4GHz
- Input connector : SMA(f) 50 ohms
- Display : dBm, V/m, A/m, dBiV, W/m2
- Exposure limits with percentage display
- RBW : 200Hz to 50MHz
- Maximum Level : +40dBm with external attenuator
- Option 020 internal 15dB RF preamplifier
- Extended full ICNIRP range (with external attenuator)
- Internal data logger

- Time-slot analyzer
- Internal speaker and audio output (internal AM/FM demodulation)
- Configurable antenna and cable calibration data

Figure 3.1 : Recording frequency spectrum with HF 60105V4

Different scientific organizations have recommended maximum power density exposure from RF/MW radiation for the safe limit.

The amount of energy passing through unit area per unit time is called Power density (P_d). If the transmitter is isotropic, it radiates energy uniformly in all directions. The power of a transmitter that is radiated from an isotropic antenna will have a uniform power density in all directions. The power density at any distance (R) from an isotropic antenna is the transmitter power divided by the surface area of a sphere ($4\pi R^2$) at that distance. The surface area increases by the square of the radius, therefore power density decreases by the square of the radius.

Power density form an isotropic antenna is given by (Nahas and Simsim, 2011)

$$P_d = \frac{P_t}{4\pi R^2} \qquad (3.1)$$

where P_t = Transmitter power (peak or average depending on how Pd is to be specified), R = radius of the sphere.

If G be gain of the antenna which is the ratio of power radiated in the desired direction as compared to the power radiated from the antenna, and let n be the number transmitter, we have (Nahas and Simsim, 2011)

$$P_d = \frac{nP_tG}{4\pi R^2} \qquad (3.2)$$

If the antenna gain is given in dB rather than dimensionless number, it can be converted back to dimensionless number by using the formula

$$G = [10]^{\left(\frac{x}{10}\right)} \qquad (3.3)$$

where x is the antenna gain given in dB, G is the antenna gain expressed in dimensionless number.

3.3 Frequency spectrum

Frequency spectrum of the RF radiation was taken at each site. The frequency peak for each measurement was recorded. The same instrument HF-60105V4, manufactured by Aaronia, Germany was used to analyse frequency spectrum. The instrument is capable of measuring non-ionizing radiation for frequency in the range of 1 MHz - 9.4 GHz. In the selected site, other than RF radiation, the other electromagnetic signals present were of TV and radio, which lie outside the GSM-900 frequency range. Hence, it has been assumed that the peaks observed were of RF radiation from the tower only.

3.4 Statistical analysis

The questionnaire responded were statistically analysed using independent *t*-sample test, as given in SPSS ver.16.0. SPSS is a widely used program for statistical analysis in social science.

Statistics included in the base software are: *Descriptive statistics:* Cross tabulation, Frequencies, Descriptives, Explore, Descriptive Ratio Statistics. *Bivariate statistics:* Means, *t*-test, ANOVA, Correlation (bivariate, partial, distances), Nonparametric tests, *Prediction for numerical outcomes:* Linear regression *Prediction for identifying groups:* Factor analysis, cluster analysis (two-step, K-means, hierarchical), Discriminant.

The main objective of the analysis is to find out whether is there any significant health complaints by using 95% confidence interval, i.e. significant value (*p*-value) less than 0.05. Those comparisons having *p*-value less than 0.05 only were considered to be significant. The analysis were done in three different ways –

1) Based on exposure to RF radiation: Comparison of the responses from inhabitants of Champhai Kanaan or Zohnuai and each other locality/village. In this case, inhabitants of Champhai Kanaan or Zohnuai were assumed to be not exposed to the RF radiation as power density was very low in this locality. This comparison was treated as inhabitants exposed to RF radiation versus those inhabitants who were not exposed to the same.

(2) Based on sex: Comparison of responses between male and female in each locality except that of Champhai Kanaan or Zohnuai. Male and female from each locality were exposed to the same RF radiation. The objective of this comparison was to find out who is having more health complaints between male and female.

CHAPTER 4

EXPERIMENTAL MEASUREMENT OF POWER DENSITY AND FREQUENCY SPECTRUM

Power densities were measured in each locality at different places selected randomly within 50 m and outside 50 m from the given base transceiver station (BST). The measurement was carried out in 4 localities in Champhai town and 2 villages outside Champhai town within Champhai District, eight (8) different localities in Lunglei District; a total of 14 different localities and villages. At the same time, frequency spectrum was taken for both GSM 900 and GSM 1800 for each locality. Measurements were done within 100 m from the tower except where there was no base transceiver station. In most of the places, particularly in Champhai and Lunglei town, taking measurements outside 100 m from a given BST was not practicable as the next tower comes within 100 m. The measured average power density of each locality was compared with safety limit recommendations of some organizations like ICNIRP (4700 mW/m^2), Indian standard (450 mW/m^2), Bioinitiavive 2012 (0.5 mW/m^2), Salzburg resolution 2000 (1 mW/m^2).

4.1. Power density measurements in different localities in Champhai District:

Power density measurement was carried out first in the locality called Champhai Kanaan, in the outskirt of Champhai town. There was no mobile tower in the locality, the nearest tower was located at another locality called Maubawk which is about 500 m away. Being the locality with no mobile tower, power density was very low compared to that of the safe limit recommendations of any organization and to that of other localities under study. Due to this reason, measurements and responses from inhabitants of Champhai Kanaan were used as the Control group. Details of the measurements at all the study sites were given in the following tables.

CHAPTER 4 EXPERIMENTAL MEASUREMENT OF POWER DENSITY AND FREQUENCY SPECTRUM

4.1.1. Champhai Kanaan

Sl. No.	Distance from tower (in m)	GSM 900		GSM 1800	
		Power density (mW/m^2)	Power (dBm)	Power density (mW/m^2)	Power (dBm)
1.	Site - 1	0.019	-38	0.180	-34
2.	Site – 2	0.009	-41	0.118	-36
3.	Site – 3	0.003	-46	0.006	-49
4.	Site – 4	0.008	-42	0.150	-35
5.	Site – 5	0.003	-46	0.008	-47
6.	Site – 6	0.002	-48	0.003	-53
7.	Site – 7	0.001	-52	0.005	-50
8.	Site – 8	0.007	-43	0.175	-34
9.	Site – 9	0.022	-37	0.056	-39
10.	Site – 10	0.002	-48	0.032	-41
11.	Site - 11	0.021	-38	0.096	-37
Average power		**0.0088**		**0.0754**	
Total Average power density for GSM 900 &				**0.0421 mW/m^2**	

Table 4.1: Power density measurement at Champhai Kanaan.

There was no mobile tower in Champhai Kanaan, the nearest tower is located more than 500m away. All the measuments were done outside 500 m. The measured power densities were much lower than the recommendation given by any scientific body; as such the inhabitants were supposed to be not-exposed to the RF radiation. The questionnaires they responded were taken as reference for comparing with that other localities.

4.1.2. Champhai Vengsang Tower 1:

Sl.No.	Distance from tower (m)	GSM900		GSM1800	
		Power Density (mW/m^2)	Power (dBm)	Power Density (mW/m^2)	Power (dBm)
Less than 50m					
1	15	0.424	-26	0.145	-35
2	20	0.182	-28	0.166	-34
3	30	0.172	-29	0.370	-31
4	35	0.159	-29	1.46	-24
5	40	0.662	-23	0.770	-28
Average Power Density		**0.298**		0.582	
Average Power Density of GSM900 & GSM1800 for < 50m = 0.440					
More than 50m					
6	60	0.304	-26	0.862	-33
7	70	0.639	-33	0.619	-39
8	75	0.072	-32	0.514	-39
9	80	0.097	-31	0.07	-38
10	90	0.245	-27	0.045	-40
Average Power Density		**0.199**		0.457	
Average Power Density of GSM900 & GSM1800 for > 50m = 0.328					
Net Average Density		**(a) = 0.248**		**(b) = 0.519**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**0.383**	

Table 4.2: Power density measurement at Champhai Vengsang Tower 1.

4.1.3. Champhai Vengsang Tower 2:

		GSM900		GSM1800	
Sl.No.	**Distance from tower (m)**	**Power Density (mW/m^2)**	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	10	0.236	-27	0.496	-30
2	20	0.395	-25	0.121	-36
3	30	0.42	-25	0.188	-37
4	40	0.099	-31	0.185	-34
5	45	0.024	-37	0.029	-42
Average Power Density		**0.234**		0.203	
Average Power Density of GSM900 & GSM1800 for < 50m = 0.218					
More than 50m					
6	55	0.044	-20	0.019	-41
7	60	0.229	-29	0.022	-44
8	70	0.289	-29	0.814	-47
9	80	0.245	-24	0.01	-49
10	90	0.071	-24	0.047	-42
Average Power Density		**0.175**		0.107	
Average Power Density of GSM900 & GSM1800 for > 50m = 0.107					
Net Average Density		**(a) = 0.204**		**(b) = 0.122**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**0.163**	

Table 4.3: Power density measurement at Champhai Vengsang Tower 2.

4.1.4.Champhai Vengsang Tower 3:

Sl.No	**Distance from tower (m)**	**GSM900**		**GSM1800**	
		Power Density (mW/m^2)	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	15	0.100	-31	0.371	-31
2	20	0.165	-29	1.60	-24
3	30	0.112	-30	0.372	-31
4	35	0.150	-29	0.269	-32
5	45	0.414	-25	0.043	-40
Average Power Density		**0.188**		0.531	
Average Power Density of GSM900 & GSM1800 for < 50m = 0.359					
More than 50m					
6	70	5.49	-14	3.59	-21
7	80	1.79	-18	1.85	-24
8	90	0.929	-21	0.076	-38
9	95	1.11	-20	7.46	-18
10	100	1.24	-20	0.364	-31
Average Power Density		**2.112**		2.668	
Average Power Density of GSM900 & GSM1800 for > 50m = 2.390					
Net Average Density		**(a) = 1.150**		**(b) = 1.599**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**1.374**	

Table 4.4: Power density measurement at Champhai Vengsang Tower 3.

4.1.5.Champhai Vengthlang :

		GSM900		**GSM1800**	
Sl.No	**Distance from tower (m)**	**Power Density (mW/m^2)**	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	10	0.166	-29	0.266	-33
2	15	0.43	-24	0.136	-35
3	30	0.354	-25	1.69	-24
4	40	0.42	-25	0.527	-30
5	45	1.19	-20	10.41	-16
Average Power Density		**0.512**		2.605	
Average Power Density of GSM900 & GSM1800 for < 50m = 1.558					
More than 50m					
6	60	0.784	-22	1.63	-24
7	65	0.169	-28	0.295	-32
8	70	0.163	-25	0.432	-30
9	90	1.79	-18	0.098	-37
10	100	7.15	-12	0.091	-37
Average Power Density		**2.011**		0.509	
Average Power Density of GSM900 & GSM1800 for > 50m = 1.26					
Net Average Density		**(a) = 1.261**		**(b) = 1.557**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**1.409**	

Table 4.5: Power density measurement at Champhai Vengthlang.

4.1.6.Kawlkulh :

Sl.No	Distance from tower (m)	GSM900		GSM1800	
		Power Density (mW/m^2)	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	15	0.82	-22	0.722	-28
2	20	0.509	-24	0.383	-31
3	30	0.15	-29	10.01	-17
4	35	0.087	-32	0.235	-33
5	40	0.131	-30	0.01	-47
Average Power Density		**0.36**		1.91	
Average Power Density of GSM900 & GSM1800 for < 50m = 1.135					
More than 50m					
6	55	0.183	-28	0.853	-28
7	65	0.088	-32	0.038	-41
8	70	0.014	-40	0.014	-45
9	90	0.003	-46	0.02	-43
10	95	0.001	-50	0.021	-43
Average Power Density		**0.078**		0.29	
Average Power Density of GSM900 & GSM1800 for > 50m = 0.184					
Net Average Density		**(a) = 0.218**		**(b) = 1.14**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**0.679**	

Table 4.6: Power density measurement at Kawlkulh.

4.1.7.Khawzawl :

		GSM900		GSM1800	
Sl.No	**Distance from tower (m)**	**Power Density (mW/m^2)**	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	15	0.066	-33	0.038	-41
2	20	0.127	-30	0.457	-30
3	30	0.339	-26	0.086	-38
4	40	0.147	-29	0.153	-35
5	45	0.047	-34	0.039	-91
Average Power Density		**0.131**		0.135	
Average Power Density of GSM900 & GSM1800 for < 50m = 0.133					
More than 50m					
6	55	0.167	-29	0.182	-34
7	60	0.03	-36	0.032	-41
8	70	0.1	-31	0.113	-36
9	80	0.124	-30	0.122	-36
10	100	0.014	-39	0.013	-46
Average Power Density		**0.1**		0.068	
Average Power Density of GSM900 & GSM1800 for > 50m = 0.084					
Net Average Density		**(a) = 0.114**		**(b) = 0.08**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**0.097**	

Table 4.7: Power density measurement at Khawzawl.

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4.2. Mobile tower Photographs of some selected locations:

Photographs of some selected towers within Champhai District were given in the following figures.

Fig. 4.2.1: Location of Champhai Vengsang Tower 1, 2 and 3.

Fig. 4.2.2: Location of mobile tower at Champhai Vengthlang.

Fig. 4.2.3: Location of tower at Khawzawl.

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Fig. 4.2.4: Location of tower at Kawlkulh.

4.3 Result and discussion on the measurements:

It has been observed that average power densities of all the localities were very low (within safe limit) compared to the recommendations of ICNIRP (1998) and that of the current Indian Standard (2012). However, in two localities –Champhai Vengsang (Tower 1) and Champhai Vengthlang (Tower 4), the average power densities were higher than that of the recommendation of Salzburg resolution 2000 (1 mW/m^2), and in Kawlkulh, the average power density was higher than the recommendation given by Bioinitiative 2012 (0.5 mW/m^2).

In Champhai District, the highest power density was observed in Champhai Vengthlang locality (10.41 mW/m^2) in Champhai town. The lowest value was observed in Kawlkulh village (0.001 mW/m^2).

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Sl.No	Locality	Average Power Density (mW/m2)
1	Champhai vengsang1	0.384
2	Champhai vengsang2	0.163
3	Champhai Vengsang3	1.374
4	Champhai Vengthalang	1.409
5	Kawlkulh	0.679
6	Khawzawl	0.007
7	Champhai Kanaan	0.042

Table 4.8: Average power density of each locality in Champhai District.

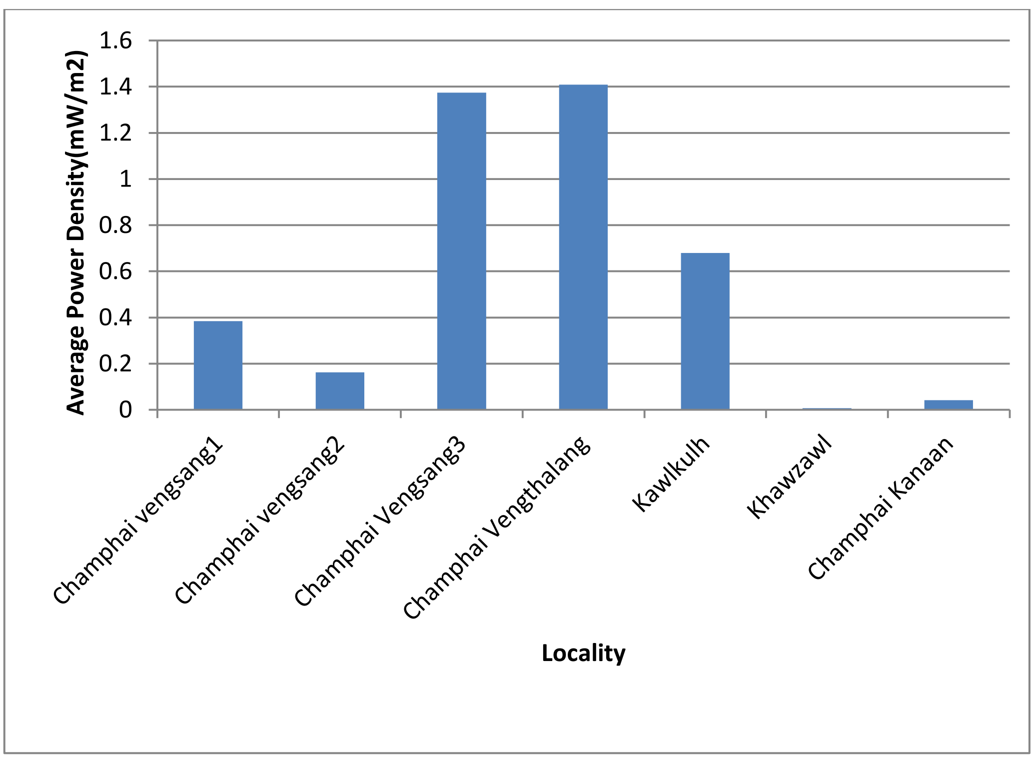

Fig 4.3.1 Graph showing variation of Power Density with different localities.

Sl.No	Locality	Average Power Density (mW/m2) <50m	Average Power density (mW/m2) >50m
1	Champhai vengsang1	0.44	0.328
2	Champhai vengsang2	0.218	0.107
3	Champhai vengsang3	0.359	2.39
4	Champhai vengthlang	1.558	1.26
5	Kawlkulh	1.138	0.184
6	Khawzawl	0.133	0.084

Table 4.9 : Average power density of each locality within and outside 50m in Champhai dstrict.

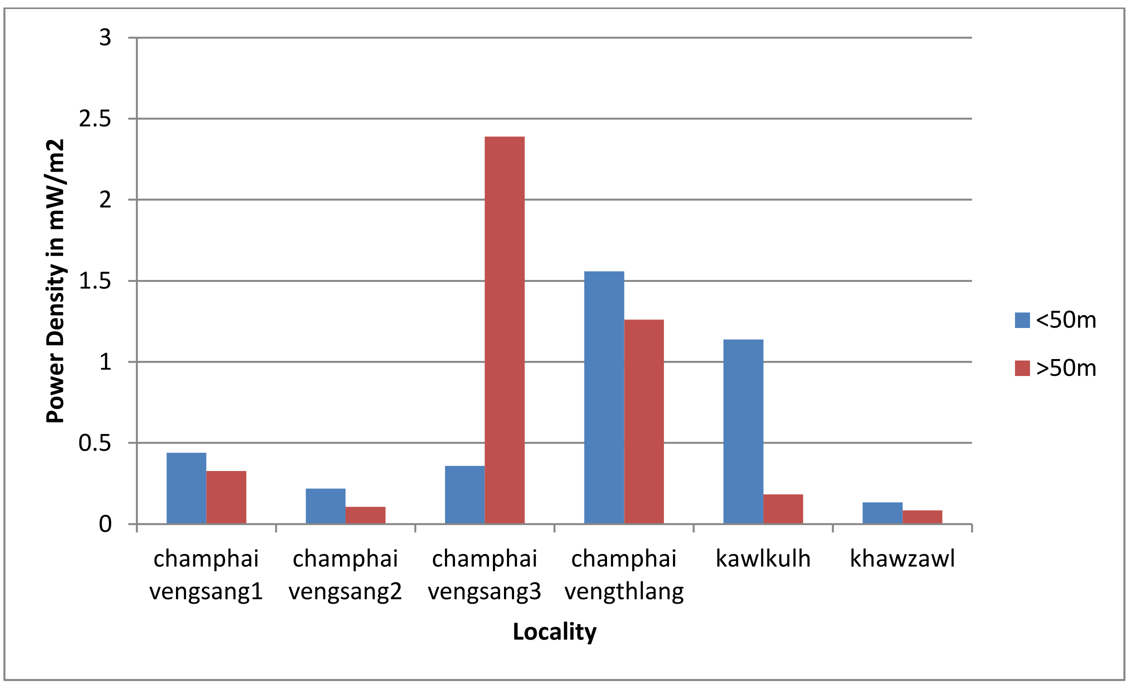

Fig 4.3.2 Graph showing variation of Power density within and outside 50m in each locality.

Dist.(m)	Tower1	Tower2	Tower3	Tower4	Tower5	Tower6	Mean (mW/m2)
10	0.424	0.236	0.1	0.166	0.82	0.066	0.302
20	0.182	0.395	0.165	0.43	0.509	0.127	0.301333333
30	0.172	0.42	0.112	0.354	0.15	0.339	0.257833333
40	0.159	0.099	0.15	0.42	0.087	0.147	0.177
50	0.662	0.024	0.414	1.19	0.131	0.047	0.411333333
60	0.304	0.044	5.49	0.784	0.183	0.167	1.162
70	0.639	0.229	1.79	0.169	0.088	0.03	0.490833333
80	0.072	0.289	0.929	0.163	0.014	0.1	0.261166667
90	0.097	0.245	1.11	1.79	0.003	0.124	0.5615
100	0.245	0.071	1.24	7.15	0.001	0.014	1.4535

Table 4.10: Mean power density within and beyond 50m for different towers in Champhai town.

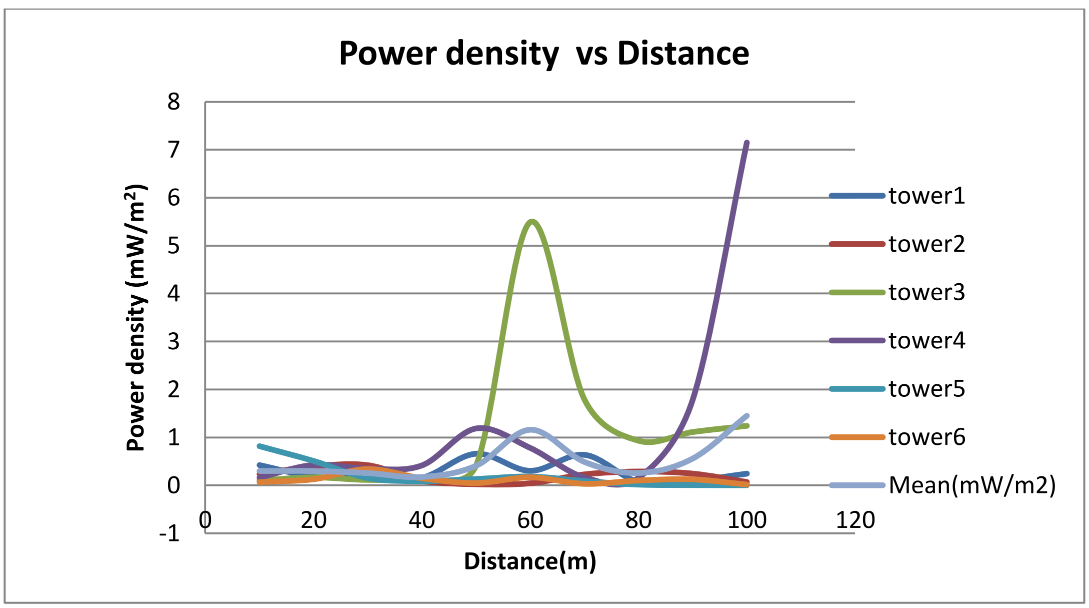

Fig .4.3.3: Graph showing variation of power density with distance in different towers in Champhai town.

Distance(m)	Mean (mW/m2)
10	0.302
20	0.301333333
30	0.257833333
40	0.177
50	0.411333333
60	1.162
70	0.490833333
80	0.261166667
90	0.5615
100	1.4535

Table 4.11 : Mean power Density within and beyond 50m for different towers.

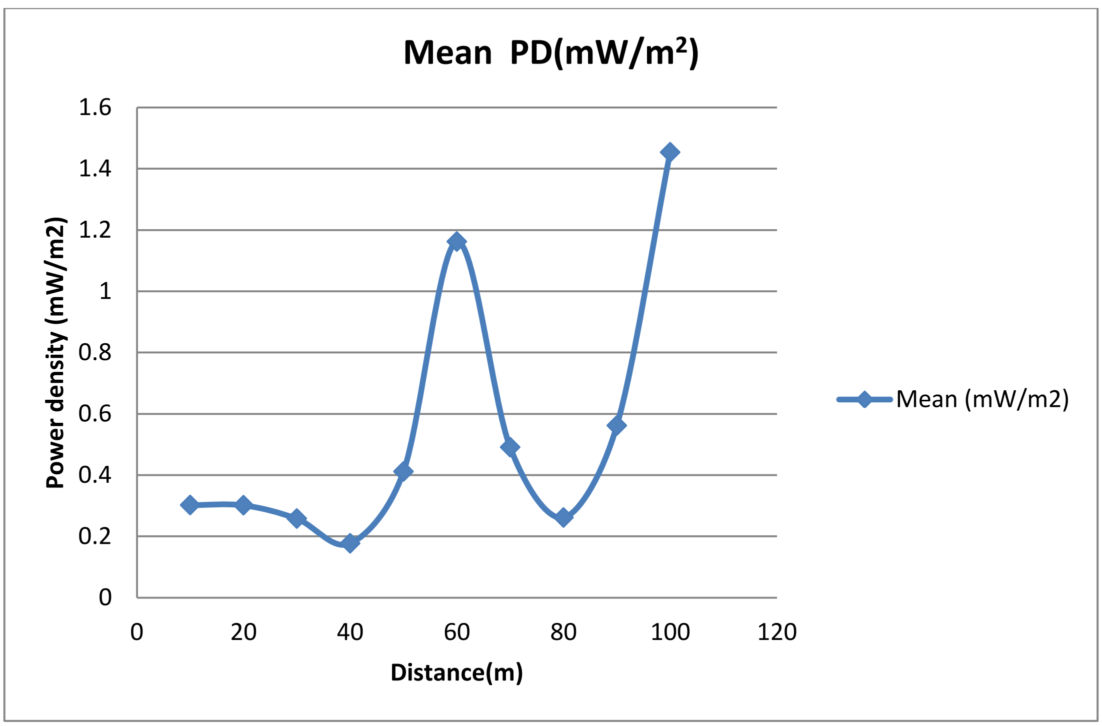

Fig .4.3.4: Graph showing variation of mean power density with distance in Champhai town.

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Power density measurements were taken at different towers located at different localities where the inhabitants are close to the base stations in Champhai town. The mean power density was plotted against distance as in Fig. 4.3.4. It has been observed that power densities were not necessarily higher close to the base stations. This may be due to the topography of Champhai as it is a hilly region and there were obstructions like buildings, walls, etc. Also, the site of measurement at 60m may be directly facing the primary lobe along the line of antenna of the tower. Therefore,it has been observed that power density does not necessarily decrease with distance in a hilly region as compared to plain areas where it decreases with distance Therefore, we can conclude that distance alone seems to be insignificant on regarding health complaints. Hence, it is the power density which determines the health complaints.

Locality	**No. of measurements**	**Average Power Density (mW/m^2)**		**wrt Champhai Kanaan GSM900**	**%wrt ICNRIP GSM900**	**%wrt Indian Standard GSM900**	%wrt Bioinitiative 2012 GSM900	%wrt Salzburg Resolution GSM900
		GSM900	**GSM1800**					
Champhai Kanaan	10	0.0088	0.092	1	0.00018	0.0019	1.76	0.88
Champhai Vengsang 1	10	0.298	0.582	33.86	0.0063	0.0662	59.6	29.8
Champhai Vengsang 2	10	0.204	0.122	23.18	0.0043	0.045	40.8	20.4
Champhai Vengsang 3	10	1.15	1.599	130.68	0.0244	0.255	230	115
Champhai Vengthlang	10	1.261	1.557	143.29	0.0268	0.2802	252.2	126.1
Kawlkulh	10	0.218	1.14	24.77	0.0046	0.0484	43.6	21.8
Khawzawl	10	0.114	0.08	12.95	0.003	0.032	28.8	11.4

Table 4.12 : Summary of power density measurements from all the localities and villages in Champhai District.

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Sl.no	Locality	No.of measure ments	Average power density of GSM900 and GSM1800 (mW/m^2)		Net Average power density of the locality(mW/m^2)
			Less than 50 m	More than 50 m	
1	Champhai Kanaan	10	0.05	0.03	0.042
2	Champhai Vengsang1	10	0.44	0.328	0.383
3	Champhai Vengsang2	10	0.218	0.107	0.163
4	Champhai Vengsang3	10	0.359	2.39	1.374
5	Champhai Vengthlang	10	1.558	1.26	1.409
6	Kawlkulh	10	1.135	0.184	0.679
7	Khawzawl	10	0.133	0.084	0.097

Table 4.13: Comparison of power density measurements between less than and more than 50 m from the mobile tower from all the localities and villages.

Power densities were measured within and outside 50 m from the tower in each locality/village. The net average values of GSM 900 and GSM 1800 were calculated for each locality within and outside 50 m. When the two measurements (i.e. within and outside 50 m from the tower) were compared for each locality, it was found that there was no appreciable difference based solely on distance. Out of the seven localities, power density was found to be higher outside 50m than within 50m in Champhai Vengsang3, whereas in other six localities power density was found to be higher within 50m than outside 50 m. There were many factors on which power density depend other than the distance alone. It largely depends on obstructions from any objects like walls, buildings etc. Power density is largely affected by direct exposure from the mobile tower. The site of measurement may be much farther than the others, it can still be possible to obtain higher power density if the site is directly exposed from the tower. Due to these factors discussed above, power densities were not necessarily found higher within 50 m. Comparison of power density within and outside 50 m from the tower in each locality in given in Figure 4.3.1

In Kawlkulh and Khawzawl towns, there were few towers as the population were thin. Power density measurements were done from one tower each where the inhabitants are residing close to the base station, the remaining towers were located 500m away and as such measurements were not possible.

4.4 Power density measurements in different localities in Lunglei District:

Measurement of power density was first carried out in Zohnuai locality in Lunglei District, where there is no mobile tower. As there is no mobile tower in this locality, the measured power density was very low compared to the safety limit recommended by any organization and to that of the other localities under study. Due to this reason, measurements and responses from inhabitants of Zohnuai were used as the Control group. Details of the measurements at all the study sites were given in the following tables.

1.Zohnuai :

Sl. No.	Distance from tower (in m)	GSM 900		GSM 1800	
		Power density (mW/m^2)	Power (dBm)	Power density (mW/m^2)	Power (dBm)
1.	Site - 1	0.019	-38	0.030	-42
2.	Site – 2	0.004	-45	0.039	-41
3.	Site – 3	0.009	-41	0.073	-38
4.	Site – 4	0.008	-42	0.442	-30
5.	Site – 5	0.007	-42	0.040	-41
6.	Site – 6	0.034	-36	0.555	-29
7.	Site – 7	0.004	-45	0.027	-42
8.	Site – 8	0.031	-36	0.061	-39
9.	Site – 9	0.003	-42	0.019	-44
10.	Site – 10	0.023	-37	0.209	-34
Average power		**0.015 mW/m^2**		**0.150 mW/m^2**	
Total Average power density for GSM 900 & GSM				**0.083 mW/m^2**	

Table 4.14: Power density measurement at Zohnuai locality.

There was no mobile tower in Zohnuai, the nearest tower is located more than 300 m away. All the measurements were done outside 300 m. The measured power densities were much lower than the recommendation given by any scientific body; as such the inhabitants were supposed to be not-exposed to the RF radiation. The questionnaires they responded were taken as reference for comparing with that other localities.

2.Zotlang

Sl.No	Distance from tower (m)	Power Density (mW/m^2)	Power (dBm)	Power Density (mW/m^2)	Power (dBm)
Less than 50m					
1	10	0.168	-29	0.371	-31
2	20	0.307	-26	0.427	-30
3	30	0.536	-24	5.45	-19
4	40	0.187	-28	7.25	-18
5	50	0.416	-25	0.998	-27
Average Power Density		**0.323**		2.899	
Average Power Density of GSM900 & GSM1800 for < 50m = 1.611					
More than 50m					
6	55	0.52	-24	1.28	-26
7	60	0.223	-28	0.541	-29
8	65	0.147	-29	0.651	-28
9	70	0.056	-34	0.154	-35
10	75	0.036	-35	1.01	-27
Average Power		**0.196**		0.457	

Density				
Average Power Density of GSM900 & GSM1800 for > 50m = 0.462				
Net Average Density	**(a) = 0.259**		**(b) = 1.813**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2			**1.036**	

Table 4.15: Power density measurements at Zotlang.

3.Bazar Veng

Sl.No	**Distance from tower (m)**	**GSM900**		**GSM1800**	
		Power Density (mW/m^2)	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	10	0.114	-30	0.692	-28
2	20	0.2	-28	0.115	-36
3	30	0.104	-31	0.778	-29
4	40	0.157	-29	0.081	-38
5	50	0.255	-27	0.031	-42
Average Power Density		**0.166**		0.339	
Average Power Density of GSM900 & GSM1800 for < 50m = 0.253					
More than 50m					
6	60	0.149	-29	0.041	-26

7	65	0.95	-21	0.027	-29
8	70	0.114	-30	0.079	-28
9	75	0.073	-32	0.054	-35
10	80	0.045	-34	0.025	-27
Average Power Density		**0.266**		0.045	
Average Power Density of GSM900 & GSM1800 for > 50m = 0.156					
Net Average Density		**(a) = 0.196**		**(b) = 0.192**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**0.194**	

Table 4.16: Power density measurements at Bazar Veng.

4.Ramzotlang

Sl.No	**Distance from tower (m)**	**GSM900**		**GSM1800**	
		Power Density (mW/m^2)	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	10	0.141	-29	0.355	-31
2	20	0.267	-27	0.304	-32
3	30	0.69	-23	2.17	-23
4	40	1.08	-21	6.11	-19
5	50	0.895	-22	11.75	-16
Average Power Density		**0.615**		4.138	
Average Power Density of GSM900 & GSM1800 for < 50m =					

2.377					
More than 50m					
6	60	1.22	-20	15.48	-15
7	65	0.862	-22	7.44	-18
8	70	0.51	-24	3.09	-22
9	75	1.61	-19	7.85	-17
10	80	0.889	-21	10.92	-16
Average Power Density		**1.018**		8.956	
Average Power Density of GSM900 & GSM1800 for > 50m = 4.987					
Net Average Density		**(a) = 0.817**		**(b) = 6.547**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**3.682**	

Table 4.17: Power density measurements at Ramzotlang.

5.Lunglawn

Sl.No	Distance from tower (m)	Power Density (mW/m^2)	Power (dBm)	Power Density (mW/m^2)	Power (dBm)
Less than 50m					
1	10	0.423	-25	0.212	-33
2	20	0.194	-28	1.75	-24
3	30	0.785	-22	0.508	-30
4	40	0.38	-26	0.103	-36
5	50	0.825	-22	0.862	-27

Average Power Density		**0.521**		0.687	
Average Power Density of GSM900 & GSM1800 for < 50m = 0.604					
More than 50m					
6	60	0.326	-26	0.129	-36
7	65	0.721	-22	0.105	-37
8	70	0.142	-29	0.124	-36
9	75	0.217	-28	0.218	-33
10	80	0.444	-25	0.344	-31
Average Power Density		**0.37**		0.184	
Average Power Density of GSM900 & GSM1800 for > 50m = 0.277					
Net Average Density		**(a) = 0.446**		**(b) = 0.436**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**0.441**	

Table 4.18: Power density measurements at Lunglawn.

6.Lunglei Venglai

		GSM900		GSM1800	
Sl.No	**Distance from tower (m)**	**Power Density (mW/m^2)**	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	10	0.365	-25	2.35	-33

2	20	0.448	-24	28.93	-24
3	30	0.339	-26	15.81	-30
4	40	0.375	-25	106.98	-36
5	50	0.289	-27	24.33	-27
Average Power Density		**0.363**		35.68	
Average Power Density of GSM900 & GSM1800 for < 50m = 18.022					
More than 50m					
6	60	0.482	-24	1.11	-36
7	65	0.745	-22	3.3	-37
8	70	0.658	-23	11.57	-36
9	75	0.699	-23	6.18	-33
10	80	0.244	-27	0.774	-31
Average Power Density		**0.566**		4.587	
Average Power Density of GSM900 & GSM1800 for > 50m = 2.577					
Net Average Density		**(a) = 0.465**		**(b) = 20.134**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**10.300**	

Table 4.19: Power density measurements at Venglai.

7.Pukpui

Sl.No	**Distance from tower (m)**	**GSM900**		**GSM1800**	
		Power Density	**Power (dBm)**	**Power Density**	**Power (dBm)**

		(mW/m^2)		**(mW/m^2)**	
Less than 50m					
1	10	0.102	-31	0.124	-36
2	20	0.19	-28	0.015	-45
3	30	0.158	-29	0.007	-48
4	40	0.426	-25	0.002	-55
5	50	0.115	-30	0.004	-51
Average Power Density		**0.198**		0.03	
Average Power Density of GSM900 & GSM1800 for < 50m = 0.114					
More than 50m					
6	60	0.158	-29	0.003	-36
7	65	0.43	-25	0.004	-37
8	70	0.521	-24	0.007	-36
9	75	0.366	-26	0.006	-33
10	80	0.433	-25	0.003	-31
Average Power Density		**0.382**		0.005	
Average Power Density of GSM900 & GSM1800 for > 50m = 0.194					
Net Average Density		**(a) = 0.29**		**(b) = 0.018**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**0.154**	

Table 4.20: Power density measurements at Pukpui.

8.Serkawn

There are two towers in Serkawn Venglai locality owned by Airtel and BSNL respectively, measurements were performed separately for the two towers.

Sl.No	Distance from tower (m)	GSM900		GSM1800	
		Power Density (mW/m^2)	**Power (dBm)**	**Power Density (mW/m^2)**	**Power (dBm)**
Less than 50m					
1	10	0.141	-30	0.247	-33
2	20	0.545	-24	0.433	-30
3	30	3.55	-15	1.83	-24
4	40	0.611	-23	1.39	-25
5	50	1.26	-20	1.02	-27
Average Power Density		**1.221**		0.984	
Average Power Density of GSM900 & GSM1800 for < 50m = 1.103					
More than 50m					
6	60	4.05	-15	0.11	-36
7	65	7.69	-12	0.399	-31
8	70	6.1	-13	0.214	-33
9	75	1.59	-19	0.372	-31
10	80	2.47	-17	3.82	-21
Average Power Density		**4.38**		0.983	
Average Power Density of GSM900 & GSM1800 for > 50m = 2.682					
Net Average Density		**(a) = 2.801**		**(b) = 0.984**	
Total Average power density of GSM900 & GSM1800 = [(a)+(b)]/2				**1.893**	

Table 4.21: Power density measurements at Serkawn.

CHAPTER 4 EXPERIMENTAL MEASUREMENT OF POWER DENSITY AND FREQUENCY SPECTRUM

4.5 Frequency spectrum of selected localities

Frequency spectrum of some of the selected locations in Champhai were given in the following figures.

4.5.1 Frequency spectrum at Champhai Kanaan.

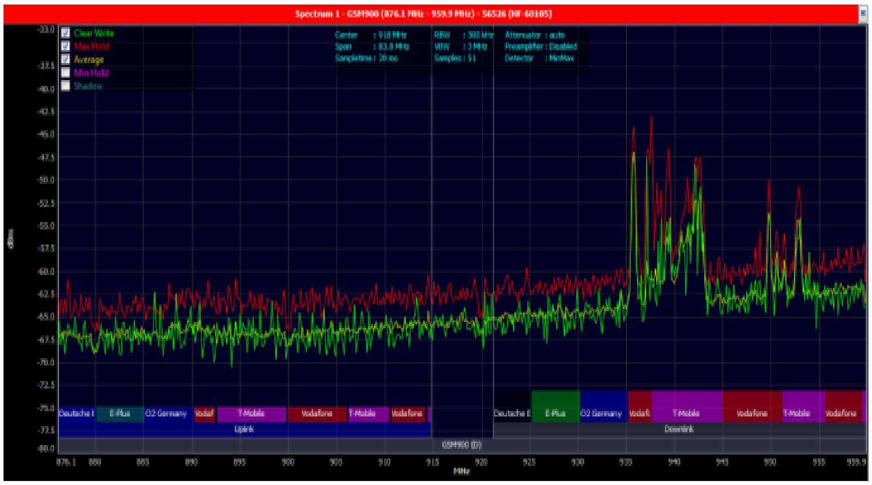

Fig. 4.5.1(a): Frequency spectrum of of GSM 900 at Champhai Kanaan

Fig. 4.5.1(b): Frequency spectrum of GSM 1800 at Champhai Kanaan

4.5.2 Frequency spectrum at Champhai Vengsang.

Fig. 4.5.2(a): Frequency spectrum of GSM 900 at Champhai Vengsang.

Fig. 4.5.2(b): Frequency spectrum of of GSM 1800 at Champhai Vengsang.

4.5.3 Frequency spectrum at Champhai Vengthlang.

Fig. 4.5.3 (a) : Frequency spectrum of of GSM 900 at Champhai Vengthlang.

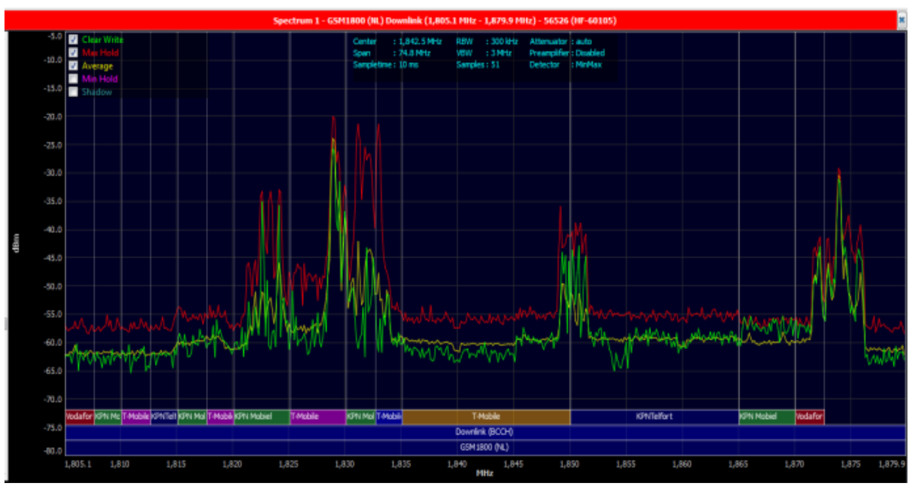

Fig. 4.5.3 (b) : Frequency spectrum of GSM 1800 at Champhai Vengthlang .

4.5.4 Frequency spectrum at Zotlang.

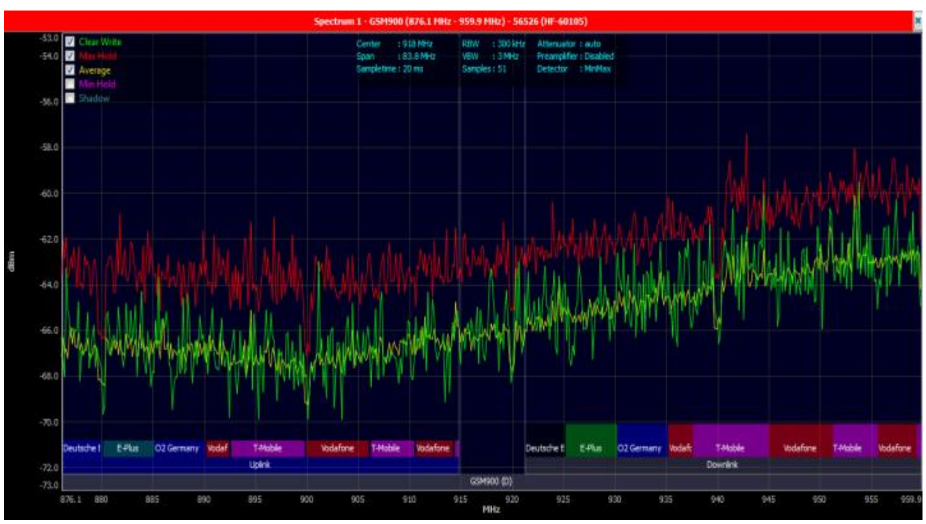

Fig. 4.5.4 (a) : Frequency spectrum of GSM 900 at Zotlang

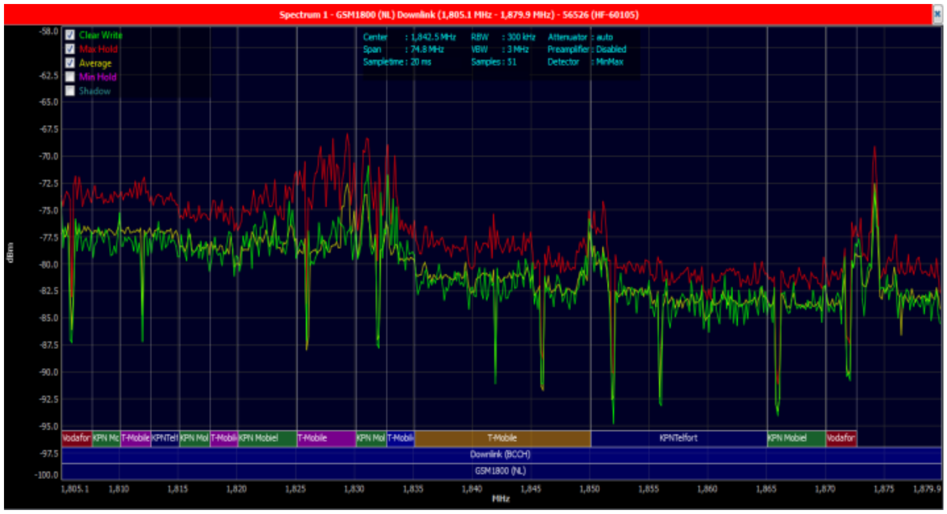

Fig. 4.5.4 (b) : Frequency spectrum of GSM 1800 at Zotlang.

4.5.5. Frequency spectrum at Lunglei Venglai

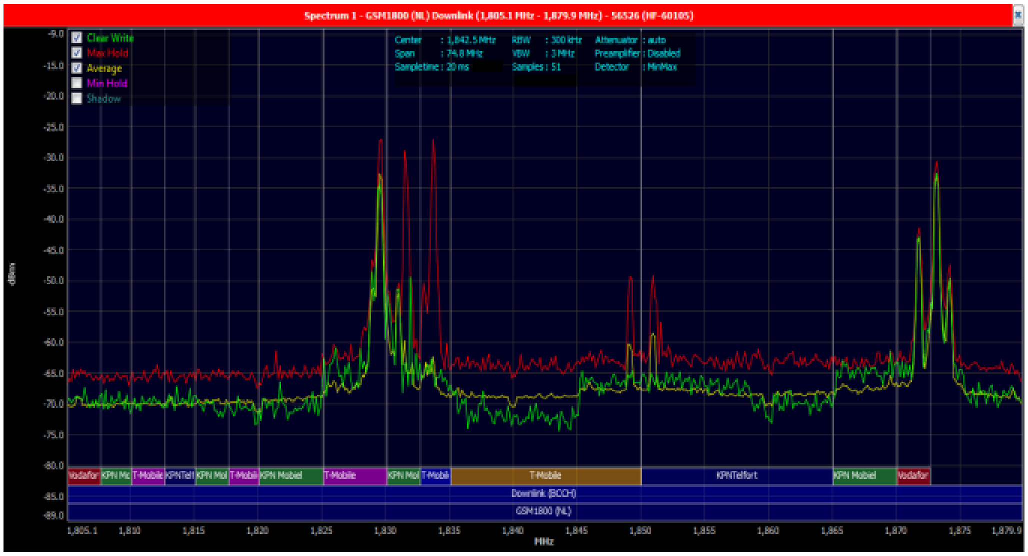

Fig. 4.5.5(a) : Frequency spectrum of GSM 900 at Lunglei Venglai.

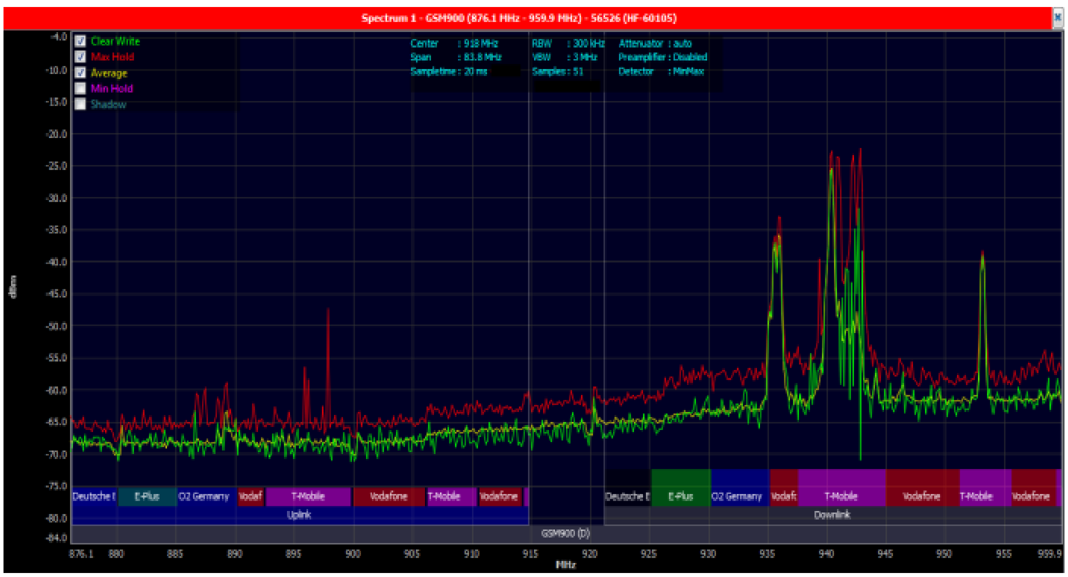

Fig. 4.5.5 (b) : Frequency spectrum of GSM 1800 at Lunglei Venglai

4.5.6. Frequency spectrum at Ramzotlang.

Fig. 4.5.6(a) : Frequency spectrum of GSM 900 at Ramzotlang

Fig. 4.5.6 (b) : Frequency spectrum of GSM 1800 at Ramzotlang.

4.5.7. Frequency spectrum at Lunglawn.

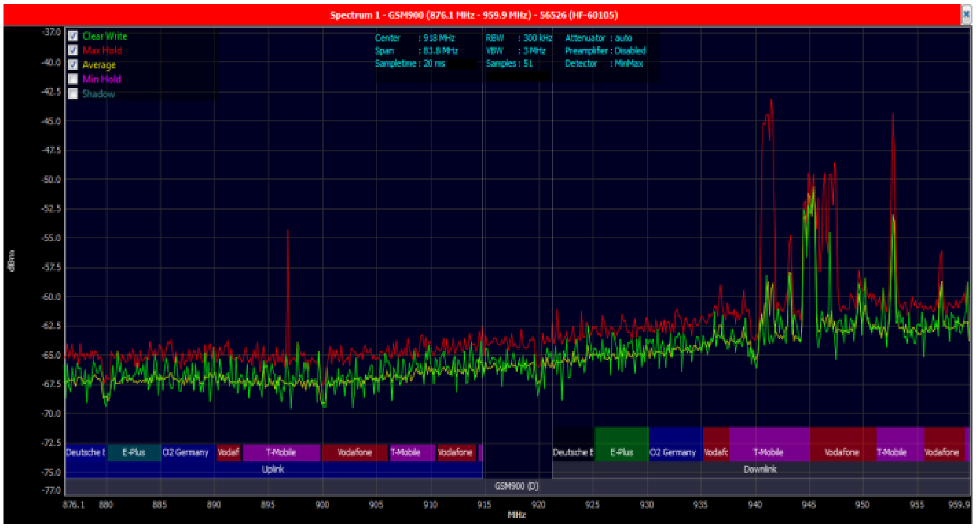

Fig. 4.5.7(a) : Frequency spectrum of of GSM 900 at Lunglawn.

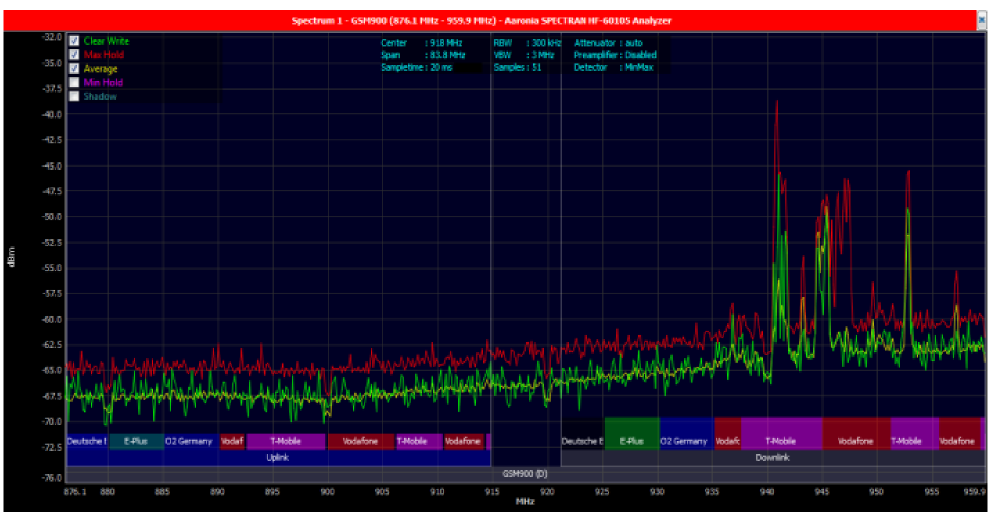

Fig. 4.5.7 (b) : Frequency spectrum of GSM 1800 at Lunglawn.

CHAPTER 4 EXPERIMENTAL MEASUREMENT OF POWER DENSITY AND FREQUENCY SPECTRUM

4.6.Mobile tower Photographs of some selected locations :

Photographs of some selected towers in Lunglei District were given in the following figures.

Fig. 4.6.1: Tower at Lunglei Bazar Veng (BSNL).

Fig. 4.6.2: Tower at Lunglei Venglai.

Fig.4.6.3: Tower at Lunglawn.

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Fig.4.6.4: Tower at Zotlang.

4.7 Result and discussion on the measurements:

From the power density measurements conducted in Lunglei city, it has been observed that average power densities of all the localities were very low (within safe limit) compared to the recommendations of ICNIRP(1998) and that of the current Indian Standard (2012).However, in four localities –Zotlang, Ramzotlang and two towers in Lunglei Venglai, the average power densities were higher than that of the recommendation of Salzburg resolution 2000 ($1mW/m^2$), the recommendation given by Bioinitiative 2012 ($0.5mW/m^2$).

In Lunglei District, the highest power density was observed in Lunglei Venglai ($10.300mW/m^2$) in Lunglei city. The lowest value was observed in Zohnuai (0.083 mW/m^2).

Sl.No	Locality	Average Power Density (mW/m2)
1	Zotlang	1.036
2	Bazar Veng	0.194
3	Ramzotlang	3.682
4	Lunglawn	0.441
5	Venglai	10.3
6	Pukpui	0.154
7	Zohnuai	0.083
8	Venglai(BSNL)	1.893

Table 4.22: The average power density of each locality in Lunglei District.

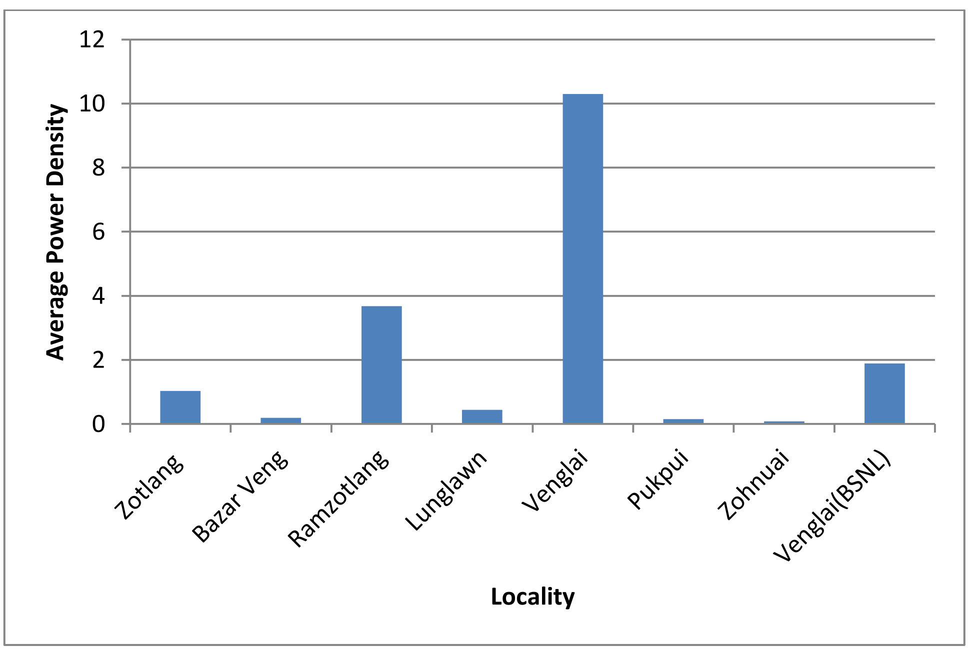

Fig 4.7.1: Graph showing variation of Power density with different localities in Lunglei District.

Sl.No	Locality	Average Power Density(mW/m2) <50m	Average Power Density (mW/m2) >50m
1	Zotlang	0.259	1.813
2	Bazar Veng	0.216	0.192
3	Ramzotlang	0.956	6.547
4	Lunglawn	0.445	0.435
5	Venglai	0.464	10.133
6	Pukpui	0.29	0.0175
7	Zohnuai	0.015	0.15
8	Venglai(BSNL)	2.8	0.983

Table 4.23: Average power density of each locality within and outside 50m in Lunglei District.

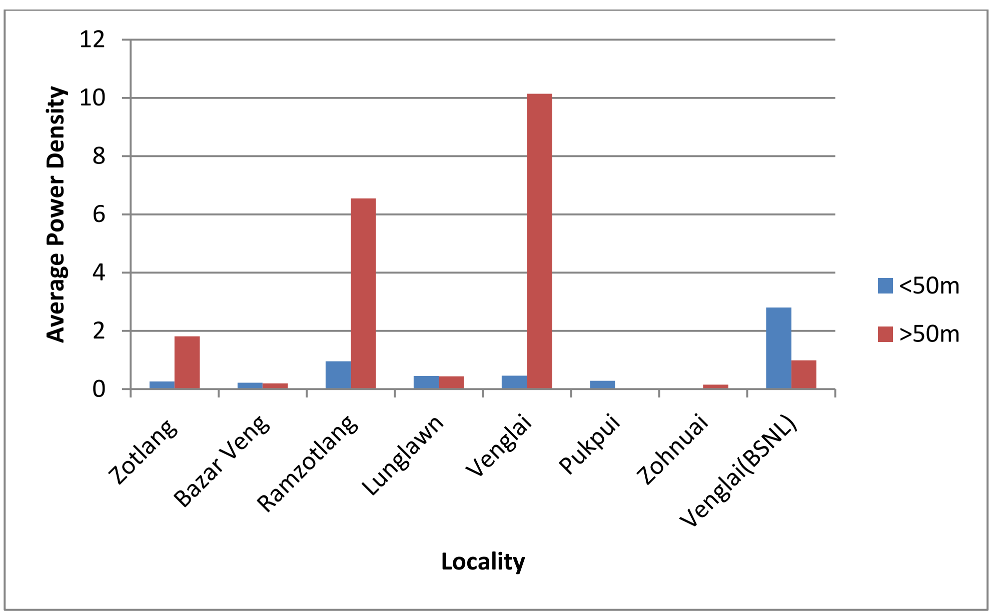

Fig.4.7.2: Graphs showing variation of power density within and outside 50m in each locality in Lunglei District

	Power Density im mW/m^2						
Distance	Tower1	Tower2	Tower3	Tower4	Tower5	Tower6	Mean
10	0.423	0.365	0.141	0.168	0.114	0.141	0.193143
20	0.194	0.448	0.545	0.307	0.2	0.267	0.280143
30	0.785	0.339	3.55	0.536	0.104	0.69	0.857714
40	0.38	0.375	0.611	0.187	0.157	1.08	0.398571
50	0.825	0.289	1.26	0.417	0.255	0.895	0.563
60	0.326	0.482	4.05	0.223	0.149	1.22	0.921429
65	0.721	0.745	7.69	0.147	0.95	0.862	1.587857
70	0.142	0.658	6.1	0.056	0.114	0.51	1.082857
75	0.217	0.699	1.59	0.036	0.073	1.61	0.603571
80	0.444	0.244	2.47	0.52	0.045	0.889	0.658857
300	0.019	0.004	0.009	0.008	0.007	0.034	0.011571

Table 4.24: Power density within and beyond 50m for different towers in Lunglei District.

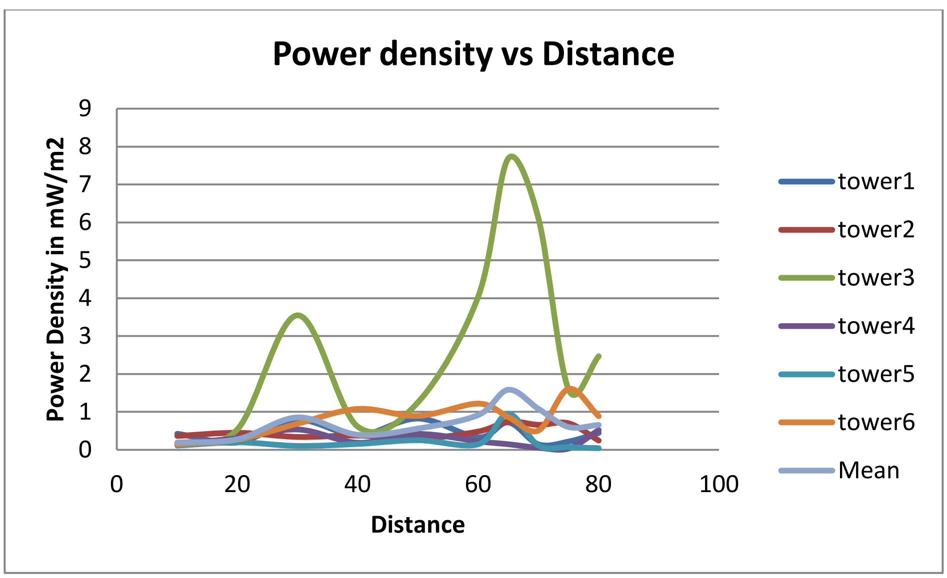

Fig. 4.7.3: Graph showing variation of power density with distance in different towers in Lunglei District.

Distance (m)	Mean Power Density (mW/m^2)
10	0.193142857
20	0.280142857
30	0.857714286
40	0.398571429
50	0.563
60	0.921428571
65	1.587857143
70	1.082857143
75	0.603571429
80	0.658857143

Table 4.25: Mean Power density within and outside 50m in Lunglei District.

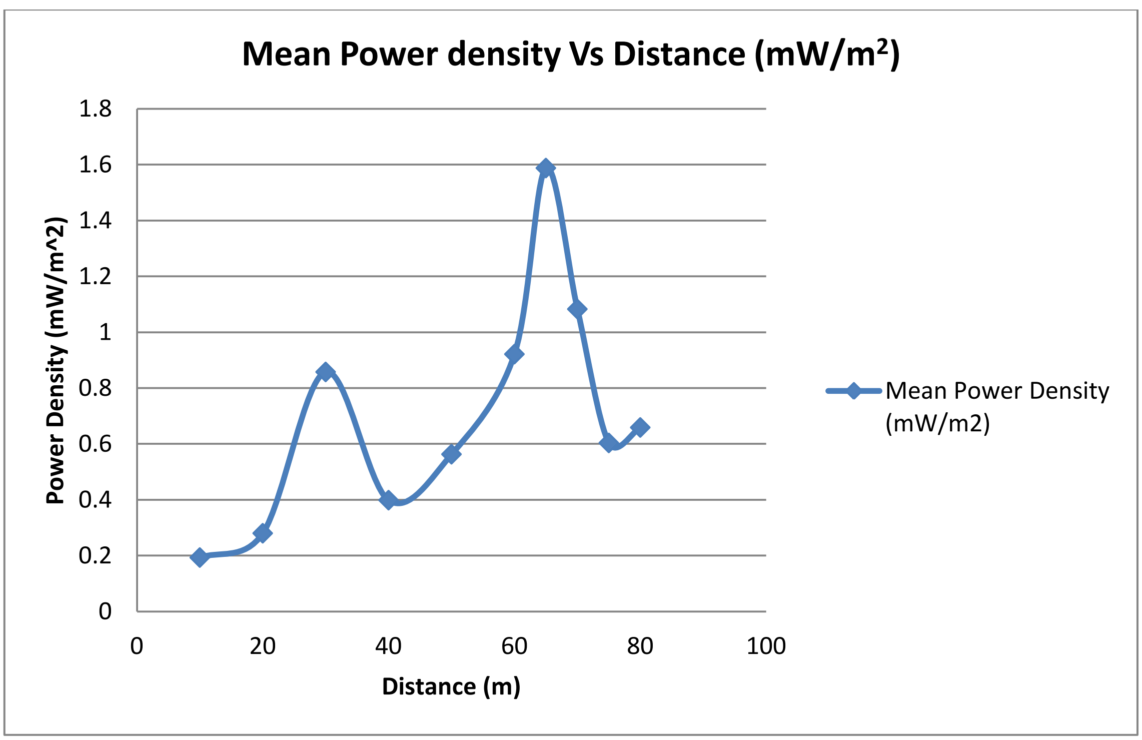

Fig.4.7.4: Graph showing variation of Mean Power density with distance in Lunglei District.

Power density measurements were taken at different towers located at different localities in Lunglei District, where the inhabitants are close to the base stations. The mean power density was plotted against distance as in Fig.4.7.4. It has been observed that power densities were not necessarily higher close to the base stations. The power density increases rapidly from 20m and peak occurs at 30m and 70m and then rapidly falls down as in fig 4.7.4 This may be due to the topography of Lunglei as it is a hilly region and there were obstructions like buildings, walls, etc. Also,the site of measurement at 30m and 70m may be directly facing the primary lobe along the line of antenna of the tower. Therefore,it has been observed that power density does not necessarily decrease with distance in a hilly region as compared to plain areas where it decreases with distance. Therefore, we can conclude that distance alone seems to be insignificant on regarding health complaints. Rather, it is the power density which determines the health complaints.

Locality	**No.of measurements**	**Average Power Density (mW/m^2)**		**wrt Zohnuai GSM900**	**%wrt ICNRIP GSM900**	**%wrt Indian Standard GSM900**	**%wrt Bioinitiative 2012 GSM900**	**%wrt Salzburg Resolution GSM900**
		GSM 900	**GSM 1800**					
Zohnuai	10	0.015	0.15	1	0.0003	0.0033	3	1.5
Zotlang	10	0.259	1.813	17.26	0.0055	0.0575	51.8	25.9
Bazar Veng	10	0.196	0.192	13.06	0.0041	0.0435	39.2	19.6
Ramzotlang	10	0.817	6.547	54.466	0.0173	0.1815	163.4	81.7
Lunglawn	10	0.446	0.436	29.73	0.0094	0.0991	89.2	44.6
Venglai	10	0.465	20.13	31	0.0098	0.1033	93	46.5

			4					
Pukpui	10	0.29	0.018	19.33	0.0061	0.064	58	29
Venglai (BSNL)	10	2.801	0.984	186.73	0.0595	0.6224	560.2	280.1

Table 4.26: Summary of power density measurements from all the localities and villages in Lunglei District.

Sl.no	Locality	No. of measurements	Average power density of GSM900 and GSM1800 (mW/m^2)		Net Average power density of the locality(mW/m^2)
			Less than 50m	More than 50m	
1	Zohnuai	10	0.0825	0.0825	0.083
2	Bazar Veng	10	0.253	0.156	0.194
3	Zotlang	10	1.611	0.462	1.036
4	Ramzotlang	10	2.377	4.987	3.682
5	Lunglawn	10	0.604	0.277	0.441
6	Venglai	10	18.022	2.577	10.3
7	Pukpui	10	0.114	0.194	0.154
8	Venglai (BSNL)	10	1.103	2.682	1.893

Table 4.27: Comparison of power density measurements between less than and more than 50 m from the mobile tower from all the localities and villages in Lunglei District.

Power densities were measured within and outside 50 m from the tower in each locality/village. The net average values of GSM 900 and GSM 1800 were calculated for each locality within and outside 50 m. When the two measurements (i.e. within and outside 50 m from the tower) were compared for each locality, it was found that there was no appreciable difference based solely on distance. Out of the eight localities where the study was carried out, power density was found to be higher within 50m than outside 50m in four localities- Bazar Veng, Zotlang, Lunglawn and Venglai whereas in three localities – Ramzotlang, Pukpui and Venglai (BSNL), power density was found to be higher outside 50m than within 50m.

There were many factors on which power density depend other than distance alone. It largely depends on obstructions from any objects like walls, buildings etc. Power density is largely affected by direct exposure from the mobile tower. The site of measurement may be much farther than the others, it can still be possible to obtain higher power density if the site is directly exposed from the tower. Due to these factors discussed above, power densities were not necessarily found higher within 50 m. Comparison of power density within and outside 50 m from the tower in each locality in given in Figure 4.3.1

In Champhai town, there were four towers lying close to each other on top of a hill in one of the localities where the study was carried out. Therefore, it was practically impossible to measure power density from a single tower. The power density measured at this site did not come from a single source, the site received many RF radiations from other towers locating outside the selected site of study. This could be the reason why power densities were relatively higher in this Champhai town than Khawzawl and Kawlkulh. In fact, the interest was in the accumulated power density from all directions at the site of measurement.

There were large variations in power densities in the studied localities. When average power densities were calculated for – Champhai town, villages outside Champhai town within Champhai District, and Lunglei District, it was observed that power density was highest in Lunglei city.

Sl.no	District	Mean (mW/m^2)	Highest (mW/m^2)	Lowest (mW/m^2)
1	Champhai town	0.832	10.41	0.022
2	Villages outside Champhai town	0.343	10.01	0.001

3	Champhai District	0.587	10.41	0.001
4	Lunglei District	2.22	28.93	0.002
	Overall	0.9955		

Table 4.28 : Mean, maximum and minimum power density of the two districts.

Power densities were found to be higher in Champhai town than outside Champhai town since there were more number of towers. Correspondingly, there were more significant health complaints in Champhai town than other villages within Champhai District. Lunglei city which is more populated and with more number of towers have higher power densities than Champhai town. Again, it was found that there were more number of significant health complaints in Lunglei District compared to Champhai District.

CHAPTER 5
ANALYSIS OF RESULTS AND DISCUSSION

5.1 Champhai District

Questionnaire surveys on health complaints on 13 non specific health symptoms were conducted on each of the localities in Champhai District. The questionnaire was similar to the same used by Santini *et al.* (2002). Questionnaire was surveyed first in Champhai Kanaan locality, 26 female and 24 males, a total of 50 adult persons participated in the survey. Accordingly, in all other localities, 50 persons were selected for the survey with 26 females and 24 males selected randomly. The questionnaire responses were classified into four (4) different levels: 0 = never, 1 = sometimes, 2 = often, 3 = very often. The responses of questionnaire were analysed by using independent *t*-test in SPSS version 16.0. Being positive responses, scales 2 and 3 are considered for the statistical analyses. The details of questionnaire and their analyses are given in the following tables.

As there was no mobile tower in Champhai Kanaan, and as it is located in the outskirt of Champhai city, the questionnaire from Champhai Kanaan was used as reference (for locality with no RF/MW exposure, i.e. control group) for all other localities of studies for comparison.

5.2 Details of questionnaire responses from each locality

1. Champhai Kanaan

Measured average power density of GSM 900 and GSM 1800 = 0.0421 mW/m^2

Sl no.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	8	13	6	1	0	1	1	0
2	Nausea	12	12	3	2	0	1	0	0
3	Sleep disruption	5	7	6	5	2	3	2	0
4	Feeling of discomfort	9	13	5	1	1	1	0	0
5	Headache	9	9	3	5	0	1	3	0
6	Cramp	6	6	3	2	4	7	2	0
7	Difficulty in concentration	12	7	1	8	1	0	1	0
8	Memory loss	3	6	2	1	6	6	4	2
9	Skin problem	9	10	4	3	2	1	0	1
10	Visual disruption	6	7	3	3	2	3	4	2
11	Hearing problem	11	11	1	3	2	1	1	0
12	Dizziness	9	11	4	3	2	1	0	0
13	Muscle pain	8	7	0	1	5	5	2	2

Table 5.2.1: Questionnaire responses from Champhai Kanaan

2. Champhai Vengsang1 (CK = Champhai Kanaan, VS1= Champhai Vengsang1)

Measured average power density of GSM 900 and GSM 1800 = 0.383 mW/m^2

Sl no.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	9	6	4	6	1	3	1	0
2	Nausea	6	7	9	5	0	3	0	0
3	Sleep disruption	7	5	2	4	6	3	1	3
4	Feeling of discomfort	9	4	4	8	2	3	0	0
5	Headache	5	3	5	5	4	5	1	2
6	Cramp	6	6	7	6	2	3	0	0
7	Difficulty in concentration	11	7	1	4	2	3	0	1
8	Memory loss	5	4	4	4	3	5	3	2
9	Skin problem	4	5	2	4	9	4	0	1
10	Visual disruption	10	6	1	7	3	2	0	0
11	Hearing problem	12	9	2	3	2	2	0	1
12	Dizziness	3	1	5	10	3	3	1	1
13	Muscle pain	5	3	4	8	3	3	1	1

Table 5.2.2: Questionnaire responses from Champhai Vengsang locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Sl.No.	Symptoms	Scale 2		Scale 3	
		CHK	VS1	CHK	VS2
1	Fatique	1	4	1	1
2	Nausea	1	3	1	0
3	Sleep disruption	5	9	0	4
4	Feeling of discomfort	5	5	4	0
5	Headache	1	9	2	3
6	Cramp	1	5	1	0
7	Difficulty in concentration	1	5	5	1
8	Memory loss	3	8	1	5
9	Skin problem	8	13	0	1
10	Visual disruption	5	5	2	0
11	Hearing problem	2	4	1	1
12	Dizziness	3	6	3	2
13	Muscle pain	6	6	1	2

Table 5.2.3: Comparison of Questionnaire responses between Champhai Kanaan and Champhai Vengsang1 on scales 2 and 3.

3. Champhai Vengsang2 (CK = Champhai Kanaan, VS2 = Champhai Vengsang2)

Measured average power density of GSM 900 and GSM 1800 = 0.163 mW/m^2

	0		1		2		3	
Symptoms	M	F	M	F	M	F	M	F
Fatique	11	7	3	7	0	1	0	0
Nausea	8	8	4	7	1	0	0	0
Sleep disruption	7	7	4	5	3	3	1	0
Feeling of discomfort	10	9	5	4	2	2	0	0
Headache	4	4	6	1	2	10	1	0
Cramp	6	8	5	4	1	3	1	0
Difficulty in concentration	10	9	3	5	1	0	0	1
Memory loss	3	3	5	4	5	5	1	3
Skin problem	6	7	7	3	1	3	0	2
Visual disruption	8	6	3	4	2	4	0	1
Hearing problem	9	10	3	4	2	1	0	0
Dizziness	6	3	2	8	4	3	1	0
Muscle pain	5	7	2	2	5	6	3	0

Table 5.2.4 : Questionnaire responses from Champhai Vengsang2 locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

		Scale 2		Scale 3	
Sl.No.	**Symptoms**	**CHK**	**VS2**	**CHK**	**VS2**
1	Fatique	1	1	1	0
2	Nausea	1	1	1	0
3	Sleep disruption	5	6	0	1
4	Feeling of discomfort	5	4	4	0
5	Headache	1	12	2	1
6	Cramp	1	4	1	1
7	Difficulty in concentration	1	1	5	1
8	Memory loss	3	10	1	4
9	Skin problem	8	4	0	2
10	Visual disruption	5	6	2	1
11	Hearing problem	2	3	1	0
12	Dizziness	3	7	3	1
13	Muscle pain	6	11	1	3

Table 5.2.5: Comparison of Questionnaire responses between Champhai Kanaan and Champhai Vengsang2 on scales 2 and 3.

4. Champhai Vengsang3(CK = Champhai Kanaan, VS3 = Champhai Vengsang3)

Measured average power density of GSM 900 and GSM 1800 = 1.374 mW/m^2

Symptoms	0		1		2		3	
	M	F	M	F	M	F	M	F
Fatique	8	13	6	1	0	1	1	0
Nausea	12	12	3	2	0	1	0	0
Sleep disruption	5	7	6	5	2	3	2	0
Feeling of discomfort	9	13	5	1	1	1	0	0
Headache	9	9	3	5	0	1	3	0
Cramp	6	6	3	2	4	7	2	0
Difficulty in concentration	12	7	1	8	1	0	1	0
Memory loss	3	6	2	1	6	6	4	2
Skin problem	9	10	4	3	2	1	0	1
Visual disruption	6	7	3	3	2	3	4	2
Hearing problem	11	11	1	3	2	1	1	0
Dizziness	9	11	4	3	2	1	0	0

Muscle pain	8	7	0	1	5	5	2	2

Table 5.2.6: Questionnaire responses from Chaamphai vengsang3 locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Sl.No.	Symptoms	Scale2		Scale3	
		CHK	VS3	CHK	VS3
1	Fatique	1	1	1	1
2	Nausea	1	1	1	0
3	Sleep disruption	5	5	0	2
4	Feeling of discomfort	5	2	4	0
5	Headache	1	1	2	3
6	Cramp	1	11	1	2
7	Difficulty in concentration	1	1	5	1
8	Memory loss	3	12	1	6
9	Skin problem	8	3	0	1
10	Visual disruption	5	5	2	6
11	Hearing problem	2	3	1	1
12	Dizziness	3	3	3	0
13	Muscle pain	6	10	1	4

Table 5.2.7: Comparison of Questionnaire responses between Champhai Kanaan and Champhai Vengsang3 on scales 2 and 3.

5. Champhai Vengthlang(CK = Champhai Kanaan, VTH = Champhai Vengthlang)

Measured average power density of GSM 900 and GSM 1800 = 1.409 mW/m^2

Symptoms	0		1		2		3	
	M	F	M	F	M	F	M	F
Fatique	9	7	6	6	0	3	2	2
Nausea	12	8	4	9	2	3	0	0
Sleep disruption	7	8	5	5	3	4	1	2
Feeling of discomfort	10	9	6	5	1	1	0	3
Headache	7	1	7	12	3	5	0	2
Cramp	6	5	8	8	2	5	1	2
Difficulty in concentration	6	6	8	4	2	6	1	3
Memory loss	6	5	4	3	5	4	2	8
Skin problem	11	12	4	2	1	2	1	4
Visual disruption	11	9	4	6	1	2	1	3
Hearing problem	14	12	2	7	0	0	1	1

Dizziness	4	4	10	9	3	5	0	2
Muscle pain	8	13	4	4	3	1	2	2

Table 5.2.8 : Questionnaire responses from Chaamphai Vengthlang locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Sl.No.	Symptoms	Scale2		Scale3	
		CHK	VTH	CHK	VTH
1	Fatique	1	3	1	4
2	Nausea	1	5	1	0
3	Sleep disruption	5	7	0	3
4	Feeling of discomfort	5	2	4	3
5	Headache	1	8	2	2
6	Cramp	1	7	1	3
7	Difficulty in concentration	1	8	5	4
8	Memory loss	3	9	1	10
9	Skin problem	8	3	0	5
10	Visual disruption	5	3	2	4
11	Hearing problem	2	0	1	2
12	Dizziness	3	8	3	2
13	Muscle pain	6	4	1	4

Table 5.2.9: Comparison of Questionnaire responses between Champhai Kanaan and Champhai Vengthlang on scales 2 and 3.

6. **Kawlkulh (CK = Champhai Kanaan, KK = Kawlkulh)**

Measured average power density of GSM 900 and GSM 1800 = 0.679 mW/m^2

Symptoms	0		1		2		3	
	M	F	M	F	M	F	M	F
Fatique	1	1	4	2	3	3	0	0
Nausea	1	3	1	3	4	2	1	1
Sleep disruption	1	1	4	3	2	3	2	1
Feeling of discomfort	0	0	4	3	2	0	1	1
Headache	0	0	2	1	2	0	4	3
Cramp	1	0	2	2	3	1	2	2
Difficulty in concentration	0	0	5	4	1	0	1	1
Memory loss	1	2	1	2	2	0	4	1
Skin problem	1	1	1	4	2	1	4	0
Visual disruption	2	1	1	1	2	2	3	2

Hearing problem	1	0	3	5	3	0	1	0
Dizziness	1	1	4	1	2	1	1	2
Muscle pain	0	1	0	2	0	1	7	2

Table 5.2.10 : Questionnaire responses from Kawlkulh village from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Sl.No.	Symptoms	Scale2		Scale3	
		CHK	KK	CHK	KK
1	Fatique	1	6	1	0
2	Nausea	1	6	1	2
3	Sleep disruption	5	5	0	3
4	Feeling of discomfort	5	2	4	2
5	Headache	1	2	2	7
6	Cramp	1	4	1	4
7	Difficulty in concentration	1	1	5	2
8	Memory loss	3	2	1	5
9	Skin problem	8	3	0	4
10	Visual disruption	5	4	2	5
11	Hearing problem	2	3	1	1
12	Dizziness	3	3	3	3
13	Muscle pain	6	1	1	9

Table 5.2.11: Comparison of Questionnaire responses between Champhai Kanaan and Kawlkulh on scales 2 and 3.

7.Khawzawl (CK = Champhai Kanaan, KHZ =Khawzawl)

Measured average power density of GSM 900 and GSM 1800 = 0.007 mW/m^2

Symptoms	0		1		2		3	
	M	F	M	F	M	F	M	F
Fatique	2	7	4	0	2	0	0	0
Nausea	6	7	6	2	7	1	0	0
Sleep disruption	7	8	4	3	6	4	2	2
Feeling of discomfort	10	9	5	7	3	5	1	1
Headache	4	5	1	6	4	6	0	0
Cramp	7	6	5	5	8	7	2	0
Difficulty in concentration	6	9	4	4	6	4	4	3
Memory loss	9	4	4	3	5	4	6	4

Skin problem	4	5	3	7	4	3	5	2
Visual disruption	9	7	5	1	2	2	1	1
Hearing problem	9	10	6	4	3	5	0	1
Dizziness	6	2	7	4	6	3	1	0
Muscle pain	5	7	3	2	5	6	3	0

Table 5.2.12 : Questionnaire responses from Khawzawl village from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Sl.No.	Symptoms	CHK	KHZ	CHK	KHZ
1	Fatique	1	2	1	0
2	Nausea	1	8	1	0
3	Sleep disruption	5	10	0	4
4	Feeling of discomfort	5	8	4	2
5	Headache	1	10	2	0
6	Cramp	1	15	1	2
7	Difficulty in concentration	1	10	5	7
8	Memory loss	3	9	1	10
9	Skin problem	8	7	0	7
10	Visual disruption	5	4	2	2
11	Hearing problem	2	8	1	1
12	Dizziness	3	9	3	1
13	Muscle pain	6	11	1	3

Table 5.2.13: Comparison of Questionnaire responses between Champhai Kanaan and Khawzawl on scales 2 and 3.

5.3 Analysis of the Questionnaires

The questionnaires responded were statistically analysed using independent *t*-sample test. The main objective of the analysis was to find out is there any significant health complaints by using 95% confidence interval, i.e. significance value (*p*-value) less than 0.05. Those comparisons having *p* value less than 0.05 only were considered to be significant. The analysis were done in two different ways –

1) Based on exposure to RF radiation: Comparison of the responses from inhabitants of Champhai Kanaan and each other locality / village. In this case, inhabitants of Champhai Kanaan were assumed to be not exposed to the RF radiation as power density was very low in the locality. This comparison was treated as

inhabitants exposed to RF radiation versus those inhabitants who were not exposed to the same.

2) Based on sex: Comparison of responses between male and female in each locality except that of Champhai Kanaan. Male and female from each locality were exposed to the same RF radiation. The objective of this comparison was to find out who is having more health complaints between male and female.

The following tables give the results of comparison for each of the two cases discussed above.

5.3.1: Results of comparison based on exposure (*mark indicates significant health complaints)

Sl. No.	Symptom	1		2		3		4		5		6		7		8		9		10		11		12		13	
		Fatique		Nausea		Sleep Disruption		Feeling of discomfort		Headache		Cramp		Difficulty in concentration		Memory loss		Skin problem		Visual Disruption		Hearing Problem		Dizziness		Muscle Pain	
	Scale	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3
1	Champhai Kanaan																										
2	Champhai Vengsang1						*		*	*						*											
3	Champhai Vengsang2								*	*						*										*	
4	Champhai Vengsang3							*	*			*					*	*								*	
5	Champhai Venfthlang									*		*		*		*	*	*						*			
6	Khawzawl															*	*		*							*	
7	Kawlkulh	*		*							*															*	*

Table 5.3.1: Statistical comparison of responses from Champhai Kanaan versus other localities.

5.3.2 : Results of comparison based on sex (* mark indicate significant health complaints)

Sl. No	Symptom	1		2		3		4		5		6		7		8		9		10		11		12		13	
		Fatique		Nausea		Sleep Disruption		Feeling of discomfort		Headache		Cramp		Difficulty in concentration		Memory loss		Skin problem		Visual Disruption		Hearing Problem		Dizziness		Muscle Pain	
	Scale	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3
1	Champhai Kanaan																										
2	Champhai Vengsang1						*											*									
3	Champhai Vengsang2									*																	*
4	Champhai Vengsang3										*	*									*						
5	Champhai Vengthlang									*				*			*		*					*			
6	Khawzawl			*																							
7	Kawlkulh																		*								*

Table 5.3.2: Statistical comparison of responses of male and female from each locality.

When questionnaire responses from Champhai Kannan (who were considered not exposed to RF radiation)were compared with all other localities, significant health complaints were observed in all the six(6) localities where average power density was considerably higher. The most common complaints were Headache, Memory loss and Muscle pain (all significant in 4 different localities in scale 2 or 3 or both the scales) which is the same as that found out and published by Pachuau *et al*. (2014). The second one is Skin problem and Feeling of discomfort (significant in 3 localities in scale 2 or 3). All the significant health complaints were in favour of other localities i.e. other localities other than Champhai Kanan where power densities of RF radiation from mobile tower were higher than Champhai Kanan.

When male versus female questionnaire responses from each locality were compared and analysed, significant health complaints were found in all the six (6) localities. It was also observed that females were more affected than males, i.e. all the significant health complaints being in favour of female. The most common complaint was headache (significant in three different localities in scale 2 and 3) and skin problem (significant in three different localities in scale 2 and 3), the second one is muscle pain (significant in two different localities in scale 2).There was only one health complaint on nausea, sleep disruption, cramp, difficulty in concentration, memory loss, visual disruption and dizziness from one locality each (significant in scale 2 or 3) whereas there was no health complaints on fatique, feeling of discomfort and hearing problem.

5.4: Summary of Power density versus Health complaints based on exposure

Sl. No.	Locality	Average Power Density (mw/m^2)		Mean value of average power density of GSM 900 & GSM 1800	Health Complaints significant in			Total no. of significant health complaints
		GSM 900	GSM 1800		Scale 2 only	Scale 3 only	Both the Scale 2 & 3	
1	Champhai Kanaan	0.007	0.073	0.042				
2	Champhai Vengsang1	0.249	0.319	0.383	Headache, memory loss	Sleep disruption, feeling of discomfort	-	4
3	Champhai Vengsang II	0.204	0.122	0.163	Headache, memory loss, muscle pain	Feeling of discomfort	-	4
4	Champhai Vengsang III	1.18	1.822	1.374	Cramp, skin problem, muscle pain	Memory loss	Feeling of discomf ort	5

5	Champhai Vengthlang	1.281	1.887	1.409	Headache, cramp, difficulty in concentration, memory loss, skin problem, dizziness	Memory loss	Memory loss	7
6	Khawzawl	0.114	0.06	0.377	Muscle pain	Skin problem	Memory loss	3
7	Kawlkulh	0.218	1.14	0.679	Fatigue, nausea	Headache	Muscle pain	4

Table 5.4.1: Power density versus health complaints based on exposure

In this comparison, maximum number of significant health complaints were observed in Champhai Vengthlang within Champhai town with seven different health symptoms being significant. Significant health complaints appeared only when the average power density was more than was 0.163 mW/m2 which was observed in Kawlkulh. This level is more or less comparable with the same given by Bio-initiative 2012 (0.5 mW/m^2), Salzburg resolution 2000(1 mW/m^2).

5.5: Summary of Power density versus Health complaints based on sex (male versus female)

Sl. No	Locality	Average Power Density(mW/m2)		Mean value of average power density of GSM 900 & GSM 1800(mW/m2)	Health Complaints significant in			Total no. of significant health complaints
		GSM 900	GSM 1800		Scale 2 only	Scale 3 only	Both the Scale 2 & 3	
1	Champhai Kanaan	0.007	0.073	0.042	-	-	-	
2	Champhai Vengsang I	0.249	0.319	0.383	Skin problem	Sleep disruption	-	2
3	Champhai Vengsang II	0.204	0.122	0.163	Headache	Muscle pain	-	2
4	Champhai Vengsang III	1.18	1.822	1.374	Cramp	Visual disruption, headache	-	3

5	Champhai Vengthlang	1.281	1.887	1.409	Dzziness, difficulty in concentration	Memory loss, skin problem	Headache	5
6	Khawzawl	0.114	0.06	0.377	Nausea	-	-	1
7	Kawlkulh	0.218	1.14	0.679	-	Skin problem, muscle pain	-	2

Table 5.5.1: Power density versus health complaints based on sex.

Again in this comparison, maximum number of significant health complaints were found in Champhai Vengthlang within Champhai town, with five different health symptoms being significant. All the significant health complaints were in favour of female, i.e. female can be considered more affected than male by the RF radiation. The same trend was observed by Santini *et al.* (2002) and Pachuau *et al* (2015).

5.6 Frequency of significance of health complaints

The tables given below summarises the number of localities where significant health complaints for each health symptom studied were observed.

5.6.1: For comparison based on exposure, i.e. responses from Champhai Kanaan versus other localities

Sl.no	Symptom	No. of localities		
		Scale 2 only	Scale 3 only	Both the scales
1	Fatique	1	0	0
2	Nausea	1	0	0
3	Sleep disruption	1	0	0
4	Feeling of discomfort	1	3	1
5	Headache	3	1	0
6	Cramp	2	0	0
7	Difficulty in concentration	1	0	0

8	Memory loss	4	3	2
9	Skin problem	2	1	0
10	Visual disruption	0	0	1
11	Hearing problem	0	0	0
12	Dizziness	1	0	0
13	Muscle pain	4	1	1

Table 5.6.1: Frequency of occurrences of the symptoms studied based on exposure

5.6.2: For comparison based on sex, i.e. responses from male and female from each locality

Sl.no	Symptom	No.of localities		
		Scale 2 only	Scale 3 only	Both the scales
1	Fatique	0	0	0
2	Nausea	1	0	0
3	Sleep disruption	0	1	0
4	Feeling of discomfort	0	0	0
5	Headache	2	2	1
6	Cramp	1	0	0
7	Difficulty in concentration	1	0	0
8	Memory loss	0	1	0
9	Skin problem	1	2	0
10	Visual disruption	0	1	0
11	Hearing problem	0	0	0
12	Dizziness	1	0	0
13	Muscle pain	0	2	0

Table 5.6.2: Frequency of occurrences of the symptoms studied based on sex

From the discussions above, it was observed that the most common significant health complaint were muscle pain, headache and memory loss which were significant in four (4) different localities out of the thirty seven (7) localities which were compared with that of Champhai Kanaan where there was no mobile tower. The other common significant health complaints were skin problem and feeling of discomfort. Although the measured power densities were much lower than the safe limit of exposure recommended by ICNIRP (4700 mW/m^2 for GSM 900) and the current Indian National standard (450 mW/m^2 for GSM 900), significant health complaints were still observed in many health symptoms. The lowest average value of power density where significant health complaints appeared was 0.163mW/m^2., which is almost same with the value as suggested by Bio-initiative report - 2012 and Salzburg resolution 2000 and hence, we suggest 0.163 mW/m^2 to be the safe limit of exposure.

5.7: Correlation between Power density and Significant health complaints

The bivariate correlation graphs between significant health complaints and power density is plotted in Figures 5.71 and 5.72. When responses from Champhai Kanaan (control group) versus all other localities (test groups) are plotted, R squared value of 0.925 was obtained. From comparison of male and female responses from each locality, R squared value of 0.758 was obtained. Both the results show strong positive correlation between power density and complaints on non specific health symptoms, i.e. more is power density more is the number of significant health complaints.

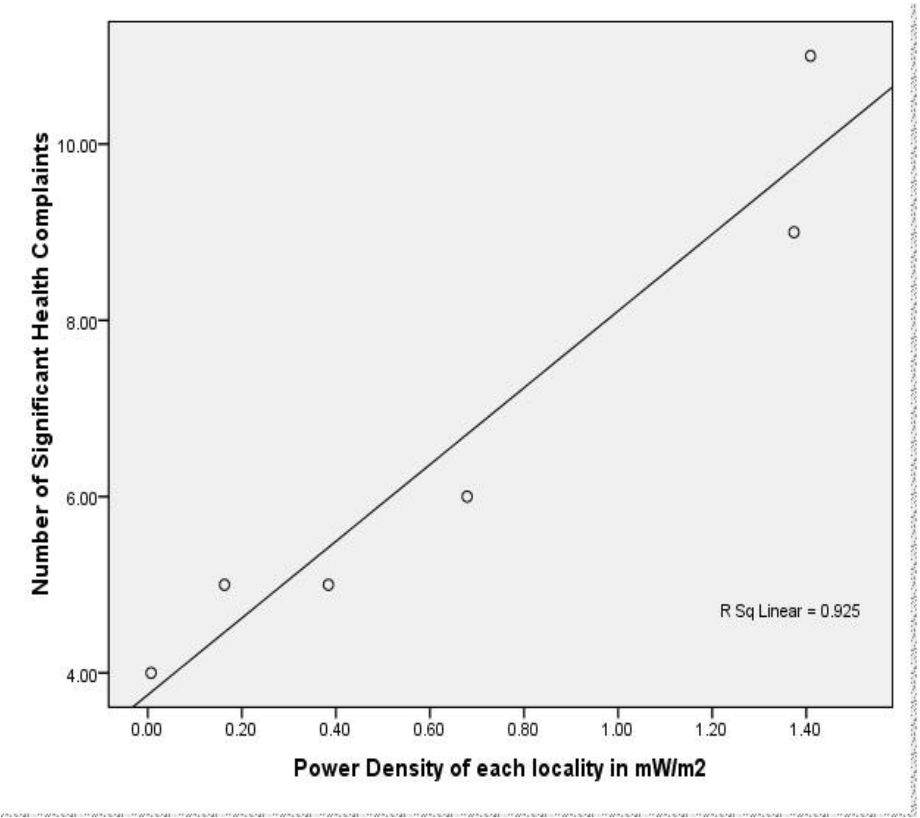

Fig 5.7.1: The correlation graph showing Number of significant health complaints versus average power density from each locality.The graph is plotted from the comparison of responses from Champhai Kanan and that of other localities.

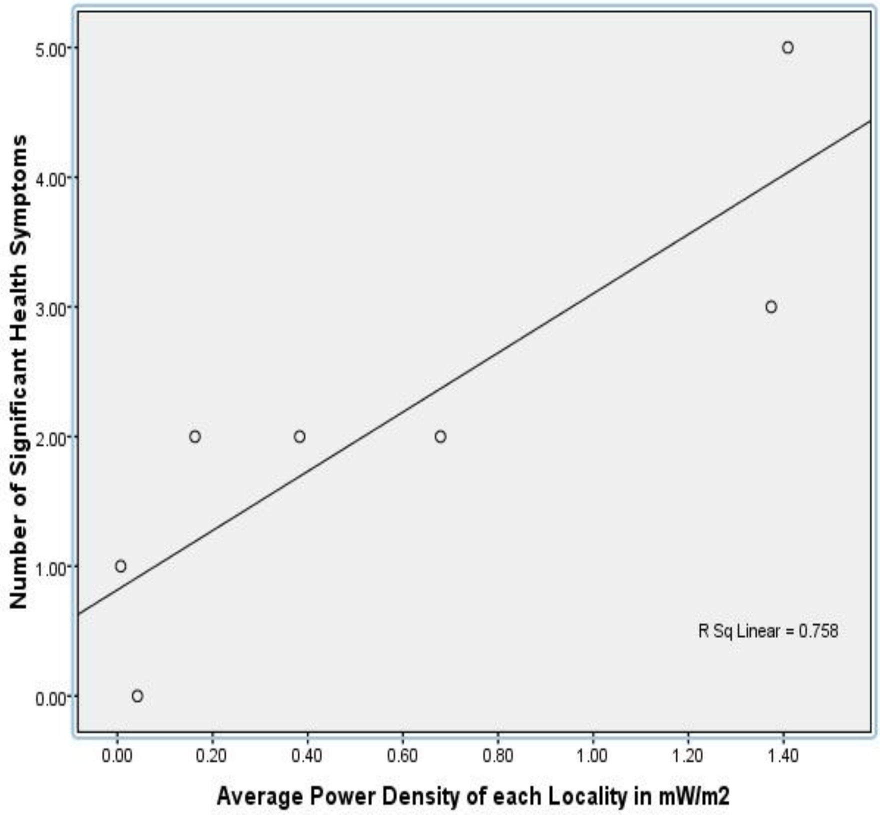

Figure 5.7.2 : The correlation graph showing number of significant health complaints versus average power density from each locality.The graph is plotted from comparison of responses from male and female in each locality.

As described earlier, when male and female responses were compared and statistically analysed using independent *t*-sample test, it was observed that female were having more complaints than male. The correlation graph (Figure 5.7.2) shows the fact that, female are having more significant health complaints than male is strongly positively correlated (R squared value = 0.758). The same trend was also observed by Santini *et al*. (2002), Pachuau *et al* (2015) when the same kind of study was conducted in France and Aizawl respectively.

The observed more health complaints on female than male may be attributed to the fact that majority of the female participated in the survey were housewife. They spent their maximum time in their own houses, as such they were exposed to the RF Radiation from the respective Cell tower the whole day and night.

A recent study (Zothansiama *et al*, 2017) conducted in Aizawl city in the same cohorts of the population of the present study also recorded relatively lower levels of antioxidants, and higher level of lipid peroxidation among people inhabiting close to mobile base stations than control group indicating possibility of having oxidative stress. They also recorded that continuous exposure of humans to RF radiation emitted by mobile phone base stations induced significant DNA damage and this damage was positively correlated with the power density of RF radiation.

All these findings support our results where we found the strong positive correlation between power density and health complaints.

5.8 Lunglei District

Questionnaire surveys on health complaints on 13 non specific health symptoms were conducted on each of the localities. The questionnaire was similar to the same used by Santini *et al.* (2002). Questionnaire was surveyed first in Zohnuai locality, 26 female and 24 males, a total of 50 adult persons participated in the survey. Accordingly, in all other localities, 50 persons were selected for the survey with 26 females and 24 males selected randomly. The questionnaire responses were classified into four (4) different levels : 0 = never, 1= sometimes, 2= often, 3 = very often. The responses of questionnaire were analysed by using independent *t*-test in SPSS version 16.0. Being positive responses, scales 2 and 3 are considered for the statistical analyses. The details of questionnaire and their analyses are given in the following tables.

As there was no mobile tower in Zohnuai and as it is located beyond 500m from the nearest tower, the questionnaire from Zohnuai was used as reference (for locality with no RF/MW exposure, i.e. control group) for all other localities of studies for comparison.

5.8 Details of questionairre responses from each locality

1. Zohnuai

Measured average power density of GSM 900 and GSM 1800 = 0.083 mW/m^2

Sl No.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	13	23	3	16	2	0	0	0
2	Nausea	14	27	4	9	0	3	0	0
3	Sleep disruption	10	21	7	13	0	5	1	0
4	Feeling of discomfort	13	31	4	6	1	2	0	0
5	Headache	13	23	4	11	2	2	0	0
6	Cramp	7	21	8	11	1	4	1	2
7	Difficulty in concentration	13	28	3	10	1	2	0	0
8	Memory loss	12	20	5	13	1	4	0	0
9	Skin problem	11	26	3	7	3	4	0	2
10	Visual disruption	12	20	4	10	2	8	0	0
11	Hearing problem	14	34	3	4	1	1	0	0
12	Dizziness	10	20	5	13	0	3	2	1
13	Muscle pain	14	33	3	3	0	3	1	0

Table 5.8.1 : Questionnaire response from Zohnuai

2. Zotlang (ZH = Zohnuai, ZT = Zotlang)

Measured average power density of GSM 900 and GSM 1800 = 1.036 mW/m^2

Sl No.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	4	3	10	12	6	8	4	3
2	Nausea	10	11	10	8	3	4	0	1
3	Sleep disruption	8	4	6	8	8	8	2	6
4	Feeling of discomfort	13	10	4	1	5	8	2	5
5	Headache	4	3	11	8	7	11	2	4
6	Cramp	3	4	12	7	7	10	3	6
7	Difficulty in concentration	8	9	6	2	5	7	4	7
8	Memory loss	4	6	4	5	8	10	7	6
9	Skin problem	3	4	10	9	6	8	3	4
10	Visual disruption	12	8	3	7	4	8	5	4
11	Hearing problem	13	11	4	7	4	6	3	3
12	Dizziness	5	2	10	9	7	13	2	3
13	Muscle pain	7	9	5	7	4	6	7	5

Table 5.8.2: Questionnaire responses from Zotlang locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Sl.No	Symptoms	Scale 2		Scale 3	
		ZH	ZT	ZH	ZT
1	Fatique	3	14	0	8
2	Nausea	3	7	0	1
3	Sleep Disruption	6	18	1	9
4	Feeling Of Discomfort	3	13	0	7
5	Headache	6	19	0	6
6	Cramp	6	17	3	9
7	Difficulty In Concentration	2	11	0	11
8	Memory Loss	7	19	1	13
9	Skin Problem	7	14	2	8
10	Visual Disruption	11	10	1	9
11	Hearing Problem	2	10	0	6
12	Dizziness	2	21	3	5
13	Muscle Pain	3	11	2	11

Table 5.8.3: Comparison of Questionnaire responses between Zohnuai and Zotlang on scales 2 and 3.

3. Bazar Veng (ZH=Zohnuai, Bazar Veng = BZV)

Measured average power density of GSM 900 and GSM 1800 = 0.194 mW/m^2

Sl No.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	19	27	3	10	6	7	1	0
2	Nausea	19	33	4	3	6	6	0	2
3	Sleep disruption	17	23	5	8	6	8	0	0
4	Feeling of discomfort	21	30	4	7	4	5	0	1
5	Headache	17	20	3	12	6	5	0	3
6	Cramp	16	21	6	13	6	6	1	2
7	Difficulty in concentration	16	28	4	11	6	4	1	0
8	Memory loss	11	24	10	11	8	7	0	1
9	Skin problem	15	32	5	7	6	4	3	2
10	Visual disruption	15	25	9	8	4	5	1	3
11	Hearing problem	21	30	1	9	5	4	2	0
12	Dizziness	18	25	4	12	7	4	0	1
13	Muscle pain	19	26	1	8	6	5	2	2

Table 5.8.4: Questionnaire responses from Bazar Veng locality from all inhabitants, including male versus female responses. Note: M = Male, F = Female.

Sl.No.	Symptoms	Scale 2		Scale 3	
		ZH	BZV	ZH	BZV
1	*Fatique*	3	11	0	1
2	Nausea	3	12	0	3
3	Sleep Disruption	6	12	1	1
4	Feeling Of Discomfort	3	9	0	2
5	Headache	6	13	0	3
6	Cramp	6	13	3	2
7	Difficulty In Concentration	2	10	0	1
8	Memory Loss	7	14	1	1
9	Skin Problem	7	11	2	5
10	Visual Disruption	11	8	1	4
11	Hearing Problem	2	9	0	2
12	Dizziness	2	12	3	1
13	Muscle Pain	3	11	2	3

Table 5.8.5 : Comparison of Questionnaire responses between Zohnuai and Bazar Veng on scales 2 and 3.

4. Ramzotlang (ZH=Zohnuai, RZT = Ramzotlang)

Measured average power density of GSM 900 and GSM 1800 = 3.682 mW/m^2

Sl No.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	9	13	6	6	0	3	0	0
2	Nausea	14	19	0	2	1	4	0	0
3	Sleep disruption	3	7	3	9	5	5	4	4
4	Feeling of discomfort	14	15	1	6	0	1	0	2
5	Headache	6	8	7	12	2	1	0	3
6	Cramp	4	11	7	9	5	3	0	1
7	Difficulty in concentration	10	12	4	8	1	2	0	1
8	Memory loss	6	5	6	12	2	6	1	1
9	Skin problem	7	8	4	9	3	4	1	4
10	Visual disruption	8	11	1	6	4	6	2	1
11	Hearing problem	9	17	1	4	3	4	1	0
12	Dizziness	12	9	10	10	3	3	0	2
13	Muscle pain	6	13	4	4	5	6	0	3

Table 5.8.6 : Questionnaire responses from Ramzotlang locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Table 5.8.7 : Comparison of Questionnaire responses between Zohnuai and Ramzotlang on scales 2 and 3.

Sl.No	Symptoms	Scale 2		Scale 3	
		ZH	RZT	ZH	RZT
1	Fatique	3	3	0	0
2	Nausea	3	2	0	0
3	Sleep Disruption	6	9	1	6
4	Feeling of Discomfort	3	0	0	1
5	Headache	6	3	0	1
6	Cramp	6	7	3	1
7	Difficulty In Concentration	2	3	0	1
8	Memory Loss	7	8	1	2
9	Skin Problem	7	6	2	4
10	Visual Disruption	11	9	1	3
11	Hearing Problem	2	7	0	1
12	Dizziness	2	4	3	2
13	Muscle Pain	3	11	2	1

5. Lunglawn(ZH=Zohnuai, LLN= Lunglawn)

Measured average power density of GSM 900 and GSM 1800 = 0.441 mW/m^2

Sl No.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	15	15	9	11	0	2	1	3
2	Nausea	19	13	6	13	0	1	0	4
3	Sleep disruption	7	7	11	13	4	7	4	2
4	Feeling of discomfort	21	22	4	6	1	3	0	0
5	Headache	8	6	14	19	1	4	2	2
6	Cramp	10	9	10	14	5	6	0	3
7	Difficulty in concentration	18	22	7	2	2	5	0	0
8	Memory loss	15	13	6	7	5	7	0	2
9	Skin problem	15	18	9	9	3	4	0	0
10	Visual disruption	14	23	5	5	6	3	1	1
11	Hearing problem	18	24	5	4	2	4	1	0
12	Dizziness	15	13	6	10	2	5	2	2
13	Muscle pain	13	7	2	8	6	9	5	3

Table 5.8.8 : Questionnaire responses from Lunglawn locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female

Sl.No	Symptoms	ZH	LLN	ZH	LLN
1	Fatique	3	2	0	4
2	Nausea	3	2	0	4
3	Sleep Disruption	6	11	1	6
4	Feeling Of Discomfort	3	4	0	0
5	Headache	6	5	0	4
6	Cramp	6	11	3	4
7	Difficulty In Concentration	2	7	0	1
8	Memory Loss	7	12	1	2
9	Skin Problem	7	7	2	0
10	Visual Disruption	11	9	1	1
11	Hearing Problem	2	6	0	1
12	Dizziness	2	7	3	4
13	Muscle Pain	3	15	2	8

Table 5.8.9 : Comparison of Questionnaire responses between Zohnuai and Lunglawn on scales 2 and 3.

6.Venglai(ZH=Zohnuai, VNG= Venglai)

Measured average power density of GSM 900 and GSM 1800 = 10.30 mW/m^2

Sl No.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	10	6	12	17	1	1	2	0
2	Nausea	10	7	9	14	5	3	1	0
3	Sleep disruption	7	6	10	15	5	4	1	0
4	Feeling of discomfort	12	9	9	12	3	3	0	1
5	Headache	4	3	11	17	6	3	3	1
6	Cramp	6	5	11	12	7	6	1	1
7	Difficulty in concentration	11	7	10	13	2	5	0	0
8	Memory loss	11	8	10	10	3	5	0	1
9	Skin problem	14	9	11	11	1	4	0	0
10	Visual disruption	16	9	6	11	3	3	0	1
11	Hearing problem	19	16	4	6	0	0	1	1
12	Dizziness	9	9	11	12	4	3	1	0

13	Muscle pain	13	11	9	9	3	4	0	1

Table 5.8.10 : Questionnaire responses from Venglai locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Table 5.8.11 : Comparison of Questionnaire responses between Zohnuai and Venglai on scales 2 and 3.

SL.No.	Symptoms	Scale 2		Scale 3	
		ZH	VL	ZH	VL
1	Fatique	3	22	0	2
2	Nausea	3	11	0	1
3	Sleep Disruption	6	14	1	1
4	Feeling Of Discomfort	3	10	0	4
5	Headache	6	10	0	7
6	Cramp	6	18	3	3
7	Difficulty In Concentration	2	7	0	3
8	Memory Loss	7	9	1	3
9	Skin Problem	7	5	2	0
10	Visual Disruption	11	9	1	1
11	Hearing Problem	2	0	0	2
12	Dizziness	2	8	3	4
13	Muscle Pain	3	7	2	1

Table 5.8.10 : Questionnaire responses from Venglai locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

7 Serkawn(ZH=Zohnuai, SK= Serkawn)

Measured average power density of GSM 900 and GSM 1800 = 1.893 mW/m^2

Sl No.	Symptoms	0		1		2		3	
		M	F	M	F	M	F	M	F
1	Fatique	10	1	5	4	0	1	0	0
2	Nausea	11	1	5	3	0	2	0	0
3	Sleep disruption	8	0	2	3	3	2	2	1
4	Feeling of discomfort	14	2	0	2	1	1	0	1
5	Headache	10	1	4	3	0	0	2	2
6	Cramp	11	1	3	4	2	1	0	0
7	Difficulty in concentration	10	1	5	5	0	0	1	0
8	Memory loss	10	1	3	5	1	0	2	0
9	Skin problem	12	1	1	2	1	1	2	2
10	Visual disruption	11	3	2	2	2	1	1	0
11	Hearing problem	12	4	0	2	1	0	2	0
12	Dizziness	9	0	3	4	3	2	1	0
13	Muscle pain	9	4	5	0	0	0	2	2

Table 5.8.12 : Questionnaire responses from Serkawn locality from all inhabitants, including male versus female responses. Note : M = Male, F = Female.

Sl.No.	Symptoms	Scale2		Scale 3	
		ZH	SK	ZH	SK
1	Fatique	3	2	0	1
2	Nausea	3	2	0	0
3	Sleep Disruption	6	5	1	3
4	Feeling Of Discomfort	3	2	0	1
5	Headache	6	0	0	4
6	Cramp	6	3	3	0
7	Difficulty In Concentration	2	0	0	1
8	Memory Loss	7	1	1	2
9	Skin Problem	7	2	2	4
10	Visual Disruption	11	3	1	1
11	Hearing Problem	2	1	0	2
12	Dizziness	2	5	3	1
13	Muscle Pain	3	0	2	4

Table 5.8.13 : Comparison of Questionnaire responses between Zohnuai and Serkawn on scales 2 and 3.

5.9 Results of Questionnaire analysis

The questionnaire responded were statistically analysed using independent *t*-sample test. The main objective of the analysis was to find out is there any significant health complaints by using 95% confidence interval, i.e. significance value (*p*-value) less than 0.05. Those comparisons having *p* value less than 0.05 only were considered to be significant. The analysis were done in two different ways –

(1) Based on exposure to RF radiation: Comparison of the responses from inhabitants of Zohnuai and each other locality/village. In this case, inhabitants of Zohnuai were assumed to be not exposed to the RF radiation as power density was very low in the locality. This comparison was treated as inhabitants exposed to RF radiation versus those inhabitants who were not exposed to the same.

(2) Based on sex: Comparison of responses between male and female in each locality except that of Zohnuai. Male and female from each locality were exposed to the same RF radiation. The objective of this comparison was to find out who is having more health complaints between male and female.

5.9.1: Results of comparison based on exposure (*mark indicates significant health complaints)

Sl. No	Symptom	1		2		3		4		5		6		7		8		9		10		11		12		13	
		Fatique		Nausea		Sleep Disruption		Feeling of discomfort		Headache		Cramp		Difficulty in concentration		Memory loss		Skin problem		Visual Disruption		Hearing Problem		Dizziness		Muscle Pain	
	Scale	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3
1	Zohnuai																										
2	Zotlang	*	*							*	*	*	*											*		*	*
3	Ramzotlang						*			*			*			*		*	*			*		*		*	*
4	Serkawn									*	*					*		*		*					*		
5	Bazar Veng											*												*		*	
6	Venglai	*		*		*		*		*		*		*		*	*	*	*					*		*	
7	Lunglawn		*									*												*		*	

Table 5.9.1: Statistical comparison of reponses from Zohnuai versus other localities

5.9.2 : Results of comparison based on sex (* mark indicates significant health complaints)

Sl. o	Symptom	1		2		3		4		5		6		7		8		9		10		11		12		13	
		Fatique		Nausea		Sleep Disruption		Feeling of discomfort		Headache		Cramp		Difficulty in concentration		Memory loss		Skin problem		Visual Disruption		Hearing Problem		Dizziness		Muscle Pain	
	Scale	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3
1	Zohnuai																										
2	Zotlang						*				*	*	*														*
3	Ramzotlang	*		*				*		*	*					*									*	*	*
4	Serkawn			*					*								*				*	*					
5	Bazar Veng	*	*																							*	
6	Venglai		*		*		*		*	*	*			*			*	*							*	*	*
7	Lunglawn			*																						*	

Table 5.9.2: Statistical comparison of responses of male and female from each locality

When questionnaire responses from Zohnuai (who were considered not exposed to RF radiation) were compared with all other localities, it was found that out of the six (6) other localities compared with that of Zohnuai locality, significant health complaints were observed in all the six localities, where average power density was considerably high. The most common complaint was dizziness (significant in 6 different localities in scale 2 or 3 or both the scales), the second one is muscle pain and cramp (significant in 5 different localities in scale 2 or 3 or both the scales). The third one is Headache (Significant in 4 different localities) followed by skin problem and memory loss(significant in 3 localities in scale 2 or 3 or both),there was no complaints on nausea and difficulty in concentration. All the significant health complaints were in favour of other localities, i.e. other localities other than Zohnuai where power densities of RF radiation from mobile tower were higher than Zohnuai.

When male versus female questionnaire responses from each locality were compared and analysed, significant health complaints were found in six (6) localities, all of them were in Lunglei town. It was also observed that females were more affected than males, i.e. all the significant health complaints being in favour of female. The most common complaint was muscle pain (significant in 5 different localities in scale 2 or 3 or both the scales), the second one is fatique (significant in 4 different localities in scale 2 or 3 or both the scales), the third one is headache (significant in 3 different localities in scale 2 or 3), which is comparable with that found by Pachuau *et al* (2014).

5.10: Summary of Power density versus Health complaints based on exposure

Sl. No	Locality	Average Power Density (mW/m^2)		Mean value of average power density of GSM 900 & GSM 1800	Health Complaints significant in			Total no. of significant health complaints
		GSM 900	GSM 1800		Scale 2 only	Scale 3 only	Both the Scale 2 & 3	
1	Zohnuai	0.015	0.15	0.083				0
2	Zotlang	0.259	1.813	1.036	Headache, fatique,cramp,diziness, muscle pain	fatique,headache,cramp,muscle pain	fatique,headache, cramp,muscle pain	5
3	Ramzotlang	0.817	6.547	3.682	Headache, memory loss, muscle pain,skin problem,dizziness,hearing problem	sleep disruption, muscle pain,skin problem,cramp	muscle pain,skin problem	8

4	Serkawn	2.801	0.984	1.893	headache, skin problem, memory loss,visual disruption	headache,dizziness	headache	5
5	Bazar Veng	0.196	0.192	0.194	muscle pain, cramp, dizziness			3
6	Venglai	0.465	20.13	10.300	Muscle pain, fatique,nausea,sleep disruption,feeling of discomfort,headache,difficulty in conc,memory loss,skin problemcramp, dizziness	Skin problem,memory loss	Memory loss,skin problem	11
7	Lunglawn	0.446	0,436	0.441	cramp,dizziness,muscle pain	fatique	-	4

Table 5.10.1: Power density versus health complaints based on exposure.

In this comparison, maximum number of significant health complaints were found in Lunglei Venglai, Lunglei town with eleven (11) different health symptoms being significant. Significant health complaints appeared only when the average power density was more than 0.194 mW/m^2 which is still less than that observed in Champhai District (0.377mW/m^2) above which only significant health complaints were observed. This level is more or less comparable with the same given by Bio-initiative 2012 (0.5 mW/m^2), Salzburg resolution 2000(1 mW/m^2).

5.11: Summary of Power density versus Health complaints based on sex (male versus female)

Sl. No.	Locality	Average Power Density (mW/m^2)		Mean value of average power density of GSM 900 & GSM 1800	Health Complaints significant in			Total no. of significant health complaints
		GSM 900	GSM 1800		Scale 2 only	Scale 3 only	Both the Scale 2 & 3	
1	Zohnuai	0.015	0.15	0.083				0
2	Zotlang	0.259	1.813	1.036	Headache, cramp	Cramp,sleep disruption,muscle pain	cramp	4

3	Ramzotlang	0.817	6.547	3.682	fatique,nausea,feeling of discomfort, Headache, memory loss, muscle pain	headache,muscle pain,dizziness	muscle pain,headache	7
4	Serkawn	2.801	0.984	1.893	nausea,hearing problem	feeling of discomfort,memory loss,visual disruption,		5
5	Bazar Veng	0.196	0.192	0.194	fatique,muscle pain	fatique		2
6	Venglai	0.465	20.13	10.300	headache,difficulty in concentration,skin problem,muscle pain	fatique,nausea,sleep disruption,feeling of discomfort,headache,memory loss,skin problem,dizziness,muscle pain	headache,muscle pain	10
7	Lunglawn	0.446	0,436	0.441	muscle pain,	nausea	-	2

Table 5.11.1 : Power density versus health complaints based on sex.

In this comparison, maximum number of significant health complaints were found again in Venglai, Lunglei town where the average power density was highest within Lunglai District. All the significant health complaints were in favour of female, i.e. female can be considered more affected than male by the RF radiation. The same trend was observed by Santini *et al.* (2002) and Pachuau *et al* (2014).

5.12 Frequency of significance of health complaints

The tables given below summarised the number of localities where significant health complaints for each health symptom studied were observed.

5.12.1: For comparison based on exposure, i.e. responses from Zohnuai versus other localities

Sl.No	Symptom	No. of localities		
		Scale 2 only	Scale 3 only	Both the scales
1	Fatique	2	3	1
2	Nausea	1	0	0
3	Sleep disruption	1	1	0
4	Feeling of discomfort	1	0	0
5	Headache	4	2	2
6	Cramp	4	2	1
7	Difficulty in concentration	1	0	0
8	Memory loss	3	1	1
9	Skin problem	3	2	2
10	Visual disruption	1	0	0
11	Hearing problem	1	0	0
12	Dizziness	5	1	0
13	Muscle pain	5	2	2

Table 5.12.1: Frequency of occurrences of the symptoms studied based on exposure

5.12.2: For comparison based on sex, i.e. responses from male and female from each locality

Sl No.	Symptoms	No. of localities		
		Scale 2 only	Scale 3 only	Both the scales
1	Fatique	2	2	1
2	Nausea	2	2	0
3	Sleep disruption	0	2	0
4	Feeling of discomfort	1	2	0
5	Headache	3	2	2
6	Cramp	1	1	0
7	Difficulty in concentration	1	0	0

8	Memory loss	1	2	0
9	Skin problem	1	0	0
10	Visual disruption	0	1	0
11	Hearing problem	1	0	0
12	Dizziness	0	2	0
13	Muscle pain	4	3	2

Table 5.12.2: Frequency of occurrences of the symptoms studied based on sex.

From the discussions above, it was observed that the most common significant health complaint were muscle pain, fatique and headache which were significant in four (4) different localities out of the seven (7) localities which were compared with that of Zohnuai where there was no mobile tower. The other common significant health complaints were skin problem and feeling of discomfort. Although the measured power densities were much lower than the safe limit of exposure recommended by ICNIRP (4700 mW/m^2 for GSM 900) and the current Indian National standard (450 mW/m^2 for GSM 900), significant health complaints were still observed in many health symptoms. The lowest average value of power density where significant health complaints appeared was 0.194mW/m^2., which is almost same with the value suggested by Bio-initiative report - 2012 and Salzburg resolution 2000 and hence, we suggest 0.194mW/m^2 to be the safe limit of exposure.

5.13: Correlation between Power density and Significant health complaints in Lunglei District

The bivariate correlation graphs between significant health complaints and power density is plotted in figures 5.71 and 5.72. When responses from Lunglei Zohnuai (control group) versus all other localities (test groups) are plotted, R squared value of 0.795 was obtained. From comparison of male and female responses from each locality, R squared value of 0.833 was obtained. Both the results show strong positive correlation between power density and complaints on non specific health symptoms, i.e. more is power density more is the number of significant health complaints.

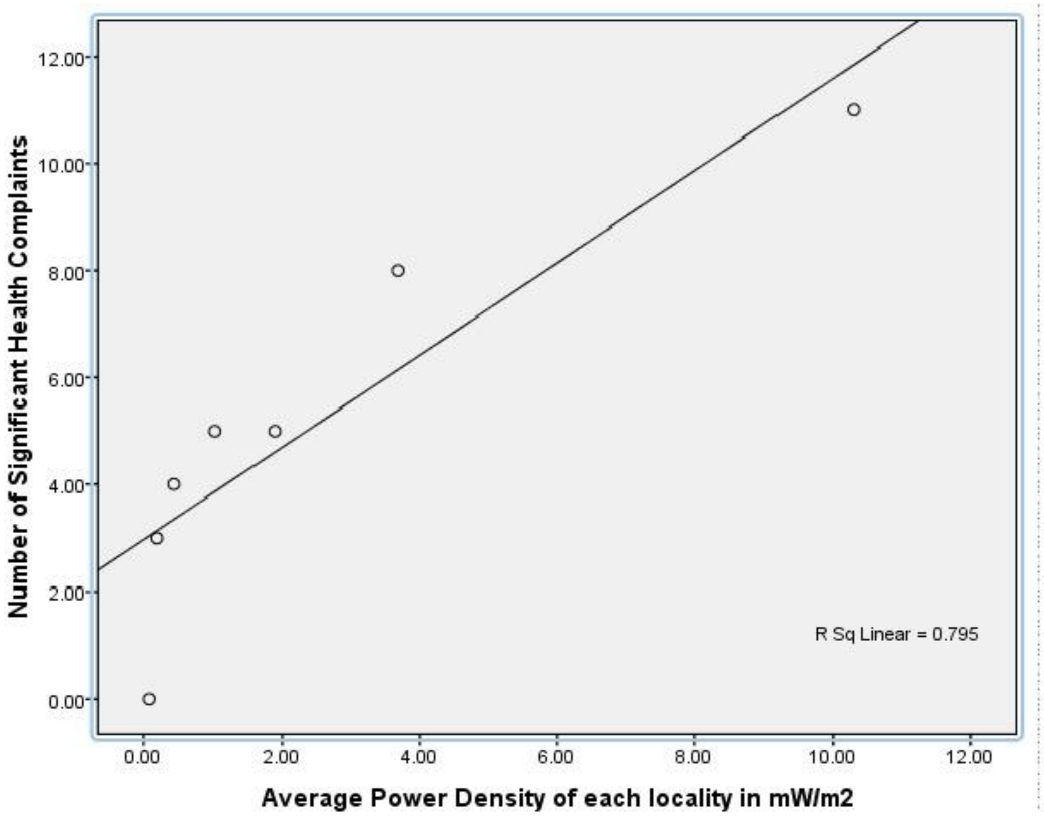

Figure 5.13.1: The correlation graph showing Number of significant health complaints versus average power density from each locality. The graph is plotted from the comparison of responses from Zohnuai and that of other localities.

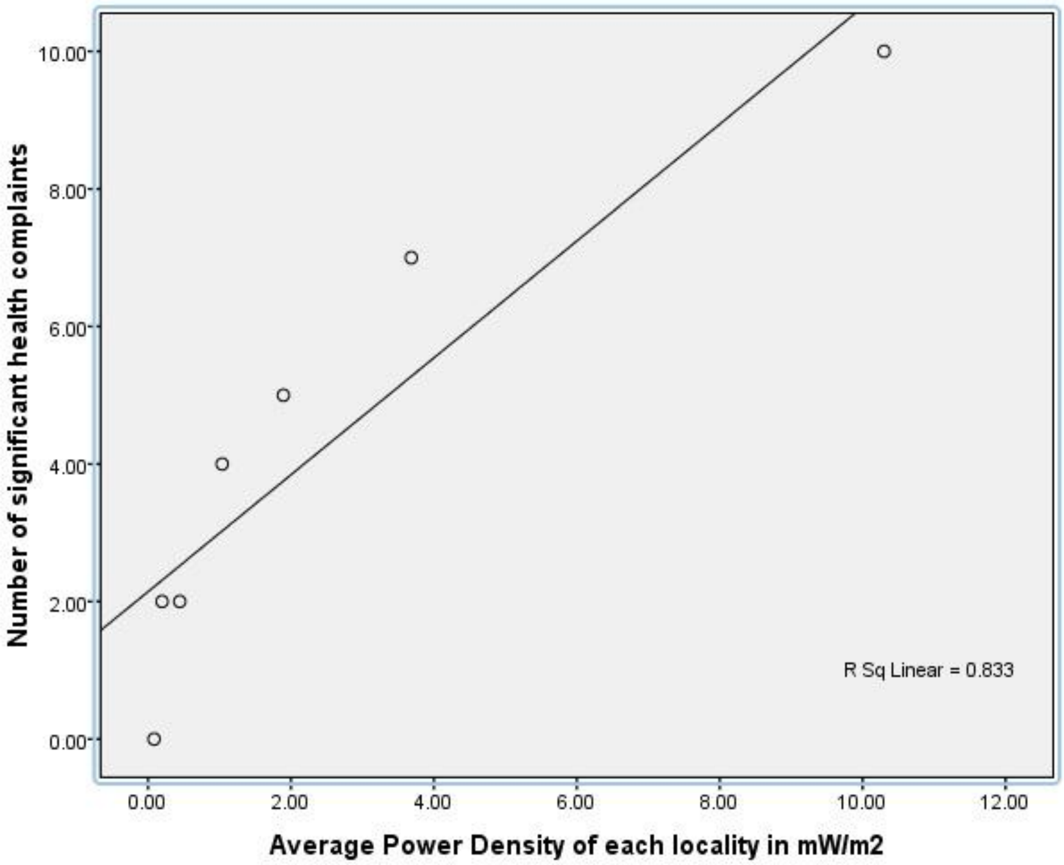

Figure 5.13.2: The correlation graph showing Number of significant health complaints versus average power density from each locality. The graph is plotted from comparison of responses from male and female in each locality.

In the same manner as in Champhai District, when male – female responses were compared and statistically analysed using independent *t*-sample test, it was observed that female were having more complaints than male. The correlation graph (Figure 5.72) shows that the fact that female are having more significant health complaints than male is strongly positively correlated (R squared value = 0.81). The same trend was also observed by Santini *et al.* (2002) and Pachuau *et al* (2015) when the same kind of study was conducted in France and Aizawl respectively.

Most of the females those who participated in the survey were housewife. They spent their maximum time in their own houses and as such they were continuously exposed to RF radiation from the respective tower the whole day and night. This may be attributed to the fact that females were having more health complaints than males.

5.14 Assesment of Effects of RF Radiation at the Molecular Level.

A. Materials and Methods

In this study, two mobile base stations were selected in Aizawl city where inhabitants are nearby station and have frequent health complaints. The two locations selected were Zemabawk (23.7357ºN, 92.7499ºE) and Ramhlun North (23.74.75ºN, 92.72.59ºE) both towers were erected in 2007. The present study was carried out in 2019 considering that inhabitants were exposed to RF radiation for a period of more than ten (10) years.

B. Power density measurement

Power density measurement was carried out randomly at different sites in close proximity to the base station. At the same time, absolute power (in dBm) was measured at each site. The average value of power density of each locality was compared with the recommendation given by various organizations like International Commission on Non Ionizing Radiation Protection(ICNIRP,1998), Bioinitiative Report (2012), Salzburg resolution (2001) and the current Indian national limit. The main purpose of the measurement was to ensure that RF Radiation from each site did not exceed the safe public limits and to find whether there is correlation between health complaints and the measured power densities. The power density measurement was done with the instrument HF-60105V4, manufactured by Aaronia, Germany.

Sl. No.	Distance from tower (in m)	GSM 900		GSM 1800	
		Power density (mW/m^2)	Power (dBm)	Power density (mW/m^2)	Power (dBm)
	Less than 50 m				
1.	29	1.2	-20	2.2	-23
2.	21	1.6	-19	3.5	-21
3.	33	6.6	-13	1.3	-26
4.	39	20.6	-5	11.5	-16
5.	44	31.7	-4	13.1	-15
6.	48	109	-1	11.1	-16
Average power density		**28.45 mW/m^2**		**7.12 mW/m^2**	
Average power density of GSM 900 & GSM 1800				**17.785**	
	More than 50 m				
7.	56	1.6	-19	0.65	-29
8.	76	1.4	-19	0.035	-41
9.	89	1.2	-20	0.05	-39
10.	91	1.5	-19	0.22	-33
11.	117	10.7	-11	0.95	-27
12.	65	2.2	-18	0.45	-30
13.	81	1.3	-20	0.56	-29
Average power density		**2.84 mW/m^2**		**0.416 mW/m^2**	
Average power density of GSM 900 & GSM 1800				**1.628 mW/m^2**	
Net Average power		**14.67 mW/m^2**		**3.5 mW/m^2 (b)**	
Total Average power density of GSM 900 & GSM 1800= [(a)				**9.085 mW/m^2**	

Table 5.14.1: Power Density measurement at Ramhlun North.

Sl. No.	Distance from tower (in m)	GSM 900		GSM 1800	
		Power density (mW/m^2)	Power (dBm)	Power density (mW/m^2)	Power (dBm)
	Less than 50 m				
1.	21	11.77	-10	0.396	-31
2.	19	0.002	-7	0.067	-39
3.	25	1.17	-20	0.240	-33
4.	29	1.62	-19	0.095	-37
5.	37	1.81	-18	0.110	-36
6.	45	0.374	-31	0.287	-32
7.	31	1.14	-20	0.720	-28
8.	19	5.34	-14	1.27	-26
9.	22	1.05	-21	0.243	-33
10.	41	0.308	-26	0.129	-36
Average power density		**2.46 mW/m^2**		**0.35 mW/m^2**	
Average power density of GSM 900 & GSM 1800 for < 50 m				**1.45 mW/m^2**	
	More than 50 m				
11.	67	0.657	-23	0.157	-35
12.	68	0.337	-16	0.001	-26
13.	92	0.034	-36	0.067	-38
14.	57	0.326	-26	0.249	-33
15.	81	0.129	-30	0.118	-36
16.	77	0.288	-26	0.32	-92
17.	60	0.141	-30	0.117	-36
18.	51	0.021	-38	0.866	-28
19.	88	0.003	-46	0.68	-39
20.	103	15.40	-9	159	-5
21.	79	0.126	-30	0.001	-25
Average power density		**1.59 mW/m^2**		**14.69 mW/m^2**	
Average power density of GSM 900 & GSM 1800 for > 50 m				**8.14 mW/m^2**	
Net Average power		**2.002 mW/m^2**		**7.86 mW/m^2**	
Total Average power density of GSM 900 & GSM 1800= [(a)				**4.93 mW/m^2**	

Table 5.14.2: Power Density measurement at Zemabawk.

5.15 Blood sample collection

Within 50 meter radius of the mobile towers, blood samples were collected from randomly candidate individuals among Mizo inhabitants from Aizawl, Mizoram, India. **Subject**: **Test** (12 individuals who were residing within 50 meter radius of the nearest Mobile tower and considered exposed consistently for not less than 10 years) and **Control** (3 individuals residing >300 meter away from the nearest tower). The study was approved by the Institutional Human Ethics Committee of the Mizoram University, Aizawl, Mizoram: India vide letter No. MZU/IHEC/2020/002.

5.16 Biochemical Assay

The biochemical parameters such as total serum protein, cholesterol and glutathione were estimated from blood according to the standard protocols.

a)DNA extraction and PCR amplification from the blood sample

The whole blood were lysed and Genomic DNA extraction was performed (Qiagen Mini Blood Kit) followed by PCR amplification using mtD-loop, ALDH2, CDH1 and TP53 genes (mtD-loopF:5'-TCCACACAGACATCAATAACA-3', mtD-loopR: 5'-AAAGTG CATACCGCCAAAG-3'; ALDH2E5.6 F:5'-CTACACACGCCATGAACCTG-3', ALDH2E5.6 R: 5'-AAATGGGACGGAGAAGGAG-3', CDH1F: 5'- GCAGAACTGTCC CTGTCCCAG-3', CDH1R: 5'- GAACAGCACGTACACAGCCCT-3';-TP53E3.4 F: 5'-GACCTA GG AA TG GA TG -3', TP53E3.4 R: 5'-GGGTGTGATGGGATGGATAAA-3'

b) Sanger sequencing

Sanger sequencing was performed for mitochondrial genome variation with the fifteen DNA samples from Mizo inhabitants. PCR was performed using a thermal cycler as follows: 35 cycles of 1 min at 95°C for denaturation, 50 *s* at specific annealing temperatures, and 1 min at 72°C for extension. Final extension was performed at 72°C for 10 min. The PCR products were electrophoresed on an 2% *agarose gel* and stained with *ethidium bromide* to confirm the size of the bands. The amplified product was purified and sequenced by gold standard Sanger sequencer (AB3500 DNA Analyzer, Thermofisher). All products were sequenced from the opposite directions to ensure reading accuracy. The sequences were compared with latest version of Revised Cambridge Reference Sequence [rCRS] of the Human Mitochondrial DNA [NC_012920] and analysed the variation of sequences by Mutation taster, Polyphen2, HOPE and Swift.

Power density of the RF radiation from the selected towers were measured at different selected sites in Zemabawk and Ramhlun North in Aizawl District. The lowest measured value was 0.002 mW/m^2 in Zemabawk (at 19m), highest measured value was 109 mW/m^2 (at 48m) Ramhlun North. In Zemabawk, at twelve (12) different points of measurement from the tower within and outside 50m, the measured power densities were found to be less than that of the safety limits recommended by Bioinitiative Report 2012 (0.5 mW/m^2), Salzburg Resolution 2000 (1mW/m^2) and at nine(9) different points of measurement, it was found to be greater. However, all the measured values were quite below the current ICNIRP safe level (4700mW/m2) and the current Indian Standard (450 mW/m^2).

In Ramhlun North, all the measured values are higher than that of the safety limits recommended by Bioinitiative Report 2012 (0.5 mW/m^2) and Salzburg Resolution 2000 (1mW/m^2). Similar to Zemabawk, all the measured values were quite below the current ICNIRP safe level (4700mW/m^2) and the current Indian Standard (450 mW/m^2).

The average power density measurement in Zemabawk and Ramhlun North were 4.93 mW/m^2 and 9.085 mW/m^2 respectively which were below the current ICNIRP safe level (4700mW/m2) and the current Indian Standard (450 mW/m^2).

The biochemical assays such as total serum protein, cholesterol and glutathione were also estimated as shown in Table 5.16.1. The result showed no significant changes in the serum protein (within normal range). However, there is a significant change in the **S1** for cholesterol and GSH levels. This change may be incorporated with personal history for further analysis.

In the mutational analysis using Direct Sanger sequencing consisting of 15 (RF exposure) samples, we have assessed 4 genes: Mitochondrial D-loop, ALDH2, CDH1 and TP53. From this study, we observed no significant sequenced alterations. However, 2 polymorphisms: intronic region of ALDH2 and TP53 (exon 4) were observed as shown in Table 5.16.2. Our result corresponded with Fang (2002) that P72R (rs1042522) TP53 Codon 72 polymorphisms might cause cancer risk.

The power density, biochemical and molecular studies revealed that there was no significant damage caused by RF radiation at the molecular level. However, the polymorphism was detected in ALDH2 gene (83.3% G>A, intronic region, novel) and TP53 (exon 4,G>C, P72R 0.08%), found in Mizo inhabitants in Aizawl city.

Table 5.16.1: Biochemical parameters such as total serum protein, glutathion (GSH) content and total cholesterol level in the participants blood samples.

S. No	**Sample Code**	**Cholesterol (mg/dl)**	**Protein (g/dl)**	**GSH** (mg/dl)
1	CR1	161	6.16±0.51	4.55±0.64
2	CR2	181	6.00±0.84	3.65±0.82
3	CR3	125	6.22±0.82	3.44±0.47
4	S1	509	3.89±0.64	16.22±1.45
5	S2	176	5.05±0.61	3.09±0.55
6	S3	156	6.37±0.59	2.97±0.58
7	S4	262	6.37±0.24	2.57±0.84
8	S5	153	3.23±0.68	3.37±0.93
9	S6	169	3.29±0.57	4.40±0.95
10	S7	202	3.41±0.88	4.05±0.87
11	S8	165	5.24±0.94	4.18±0.69
12	S9	186	3.62±0.87	3.88±0.87
13	S10	183	6.05±0.56	4.10±0.25
14	S11	146	5.78±0.79	4.38±0.97
15	S12	200	5.91±0.54	6.18±0.17

The data expressed as Mean ± SD.

CR1-CR3, control sample; S1,S12…- Test samples.

Table 5.16.2: Mutation types observed in the amplified sequences of mtDNA D-loop, ALDH2, CDH1and TP53 in 12 radio frequency exposure samples.

S. No	**Gene**	**Genomic Sequence alteration**	**Amino acid change**	**Mutation Taster/** PolyPhen-2/ HOPE	**Frequency**	**Prediction problem splicing**	**Status**
1	mtDNA D-loop	No alteration	-	-	-		-
2	ALDH2	G/A	Intronic	Polymorphism	83.33%	affected	Novel
3	CDH1	No alteration	-	-	-		-
4	TP53	G/C	P72R	Polymorphism	**00.08%**		Reported (rs1042522)

Fig.5.16.3(a)

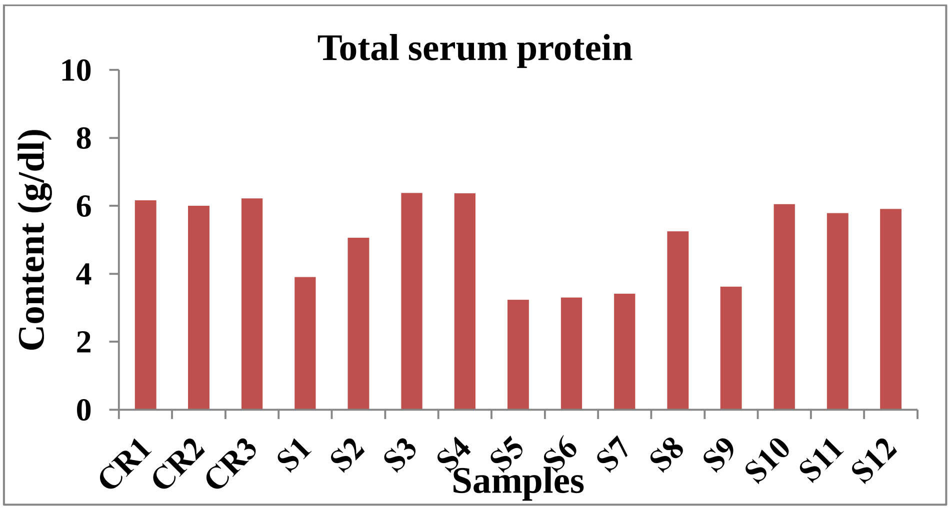

Fig. 5.16.3(b)

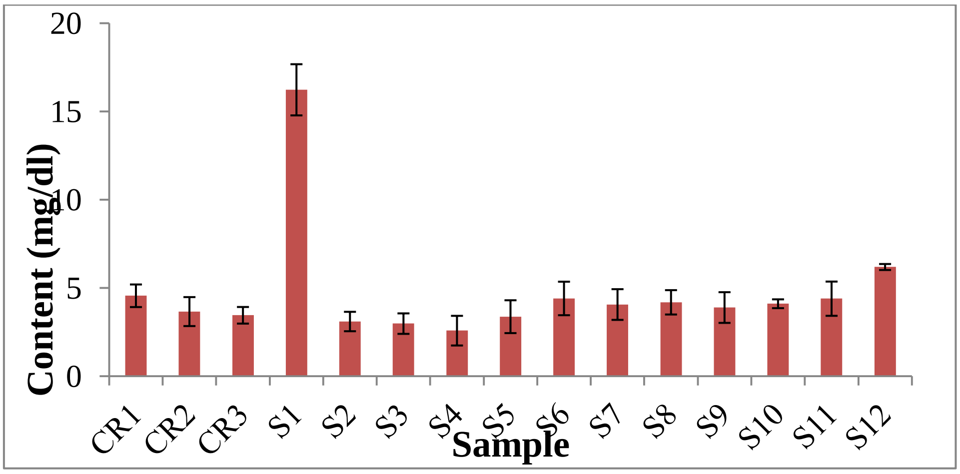

Fig.5.16.3(c)

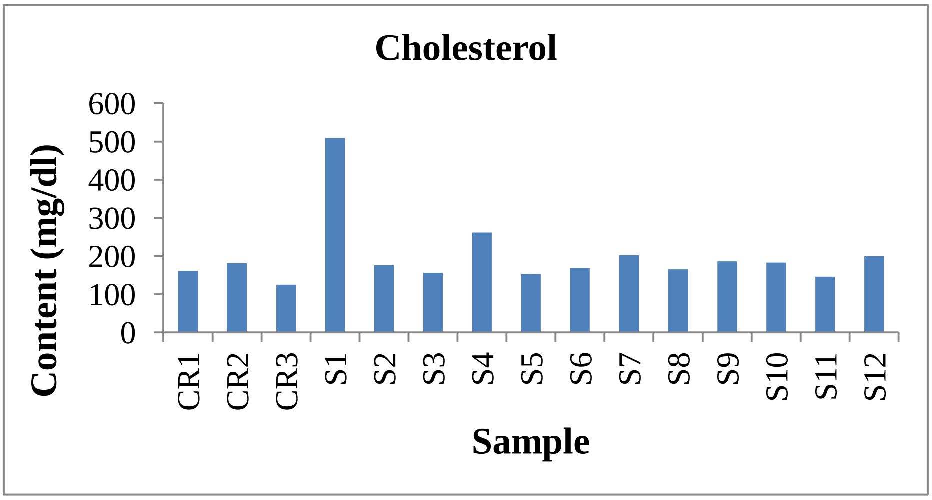

Figure 5.16.3: Biochemical parameters of participants blood samples.

(a). Total serum protein level in the blood (b). Glutathion (GSH) content in the blood, (c). Total cholesterol level in the blood. The data expressed as Mean ± SD. *CR1-CR3, control sample; S1,S12…- Test samples.*

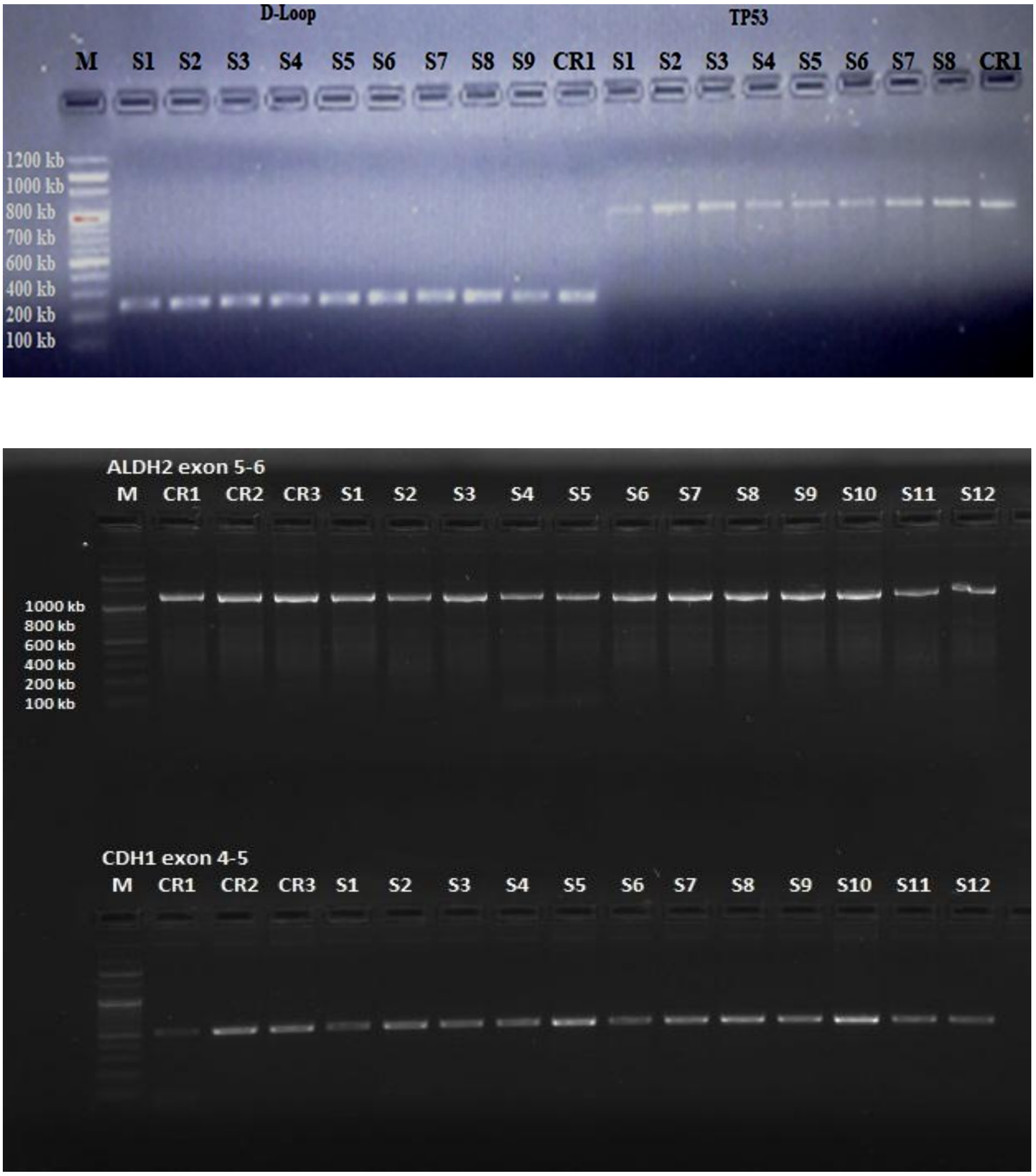

Figure 5.16.4: Amplification of mt-Dloop, TP53 exon 4, ALDH2 exon 5-6 and CHD1 exon 4-5 genes.

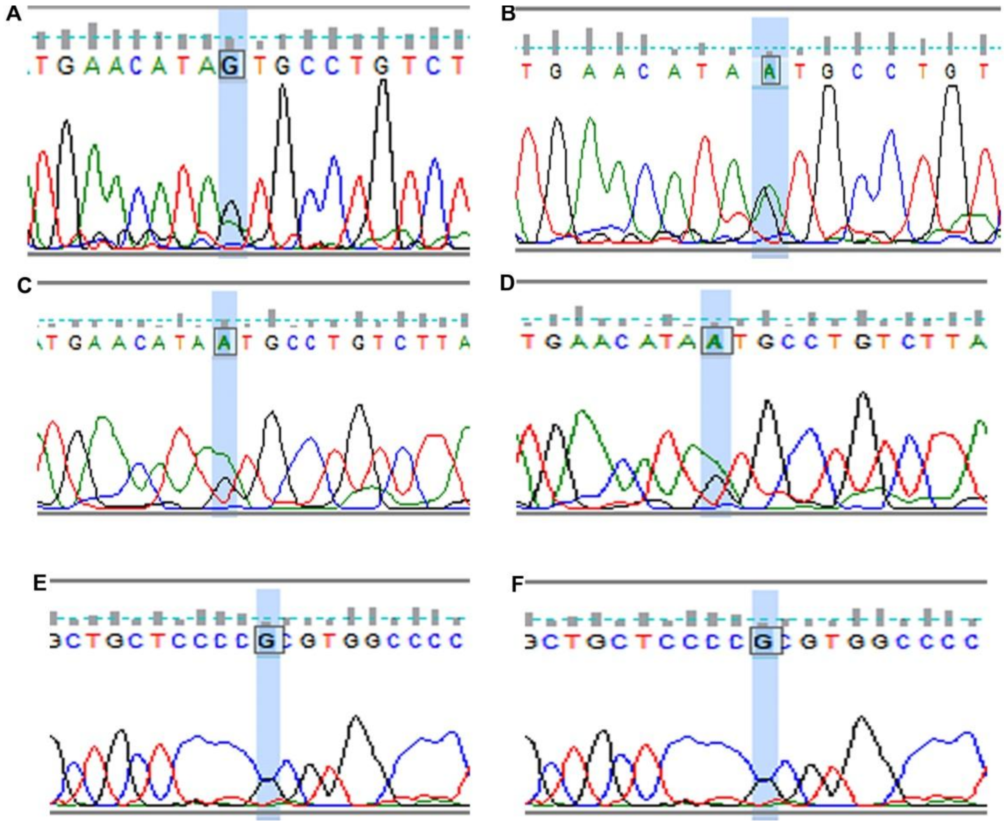

Figure 5.16.5: Detection of polymorphism in ALDH2 gene and TP53 exon 4.
a) Control ALDH2, (b) ALDH2 Sample No 1, (c)ALDH2 Sample No 2, (d) ALDH2 Sample No 4, (e) Control Tp53 Exon 4, (f) Tp53 Exon 4 Sample 9

5.17 Discussions and Results

Mobile phone base stations have become an integral part of telecommunication, which use RF Radiation to transmit the signals. Although RF Radiations are non-ionizing electromagnetic radiations, yet there has been a great concern about their deleterious effects on the human body as it is assumed that RF Radiation could produce some of the biological effects akin to those produced by ionizing radiations such as X or γ-rays. Because of its adverse health effects reported worldwide, the presence of mobile base stations in the residential areas could be an electromagnetic threat, which is silently creeping in the lives of residents staying near the mobile base stations. We have therefore, attempted to obtain an insight into the adverse effects of RF Radiation in the inhabitants residing in the vicinity of mobile base stations emitting RF Radiation for mobile connectivity.

The frequency of nonspecific health symptoms such as nausea, loss of appetite, visual disturbance, irritability and depression were found to be significantly higher in the population living close (within 100 m) to mobile phone base stations as compared to those living away from these stations (Santini *et al*., 2002, 2003). In the earlier study (Pachuau *et al*., 2015), it was also reported that the frequency of nonspecific health symptoms such as fatique, headaches, dizziness and muscle pain were significantly higher in the population close to the base stations, inspite of the fact that the power density in the selected site of studies were much below the public safe limits recommended by ICNRIP (1998) and the Indian standard. A number of studies have reported an increase in the DNA damage/micronuclei in different study systems. The human PBLs exposed to RFR have shown an increased frequency of micronuclei earlier (d'Ambrosio et al., 2002; Garaj-Vrhovac *et al*., 1992; El-Abd and Eltoweissy, 2012; Tice *et al*., 2002;Zotti-Martelli *et al*., 2000). Various studies conducted in other systems have also revealed an increased micronuclei frequency after exposure to RF Radiation (Balode, 1996; Busljeta *et al*., 2004; Gandhi and Singh, 2005; Trosic *et al*., 2002, 2004). However, some of the studies did not find any increase in the MN frequency after RF Radiation exposure both *in vitro* and *in vivo*(Bisht *et al*., 2002; Scarfi *et al*., 2006; Vijayalaxmi *et al*.,1997, 1999, 2001; Zeni *et al*., 2003, 2008).In a recent study (Zothansiama *et al*, 2017) conducted in Aizawl, it was found that there was a significant increase in MN frequency and decreased antioxidants among inhabitants residing close to the base station/s when compared to controls whereas our result showed that the power density, biochemical and molecular studies does not produce significant damage by RF Radiation at the molecular level. However, the polymorphism was detected in ALDH2 gene (83.3% G>A, intronic region, novel) and TP53 (exon 4, G>C, P72R 0.08%), found in Mizo inhabitants.

From the present study, it was found that RF Radiation from base station did not cause mutation and therefore, does not produce significant damage at the molecular level, although it produces polymorphism to some extent, to those inhabitants residing in the proximity of the base stations.

CHAPTER 6

CONCLUSION

It has been observed that all the measured values of power density in all the 15 localities of Champhai and Lunglei Districts were lower than the safe limit recommendations of ICNIRP(1998) and the Department of Telecommunications, Government of India. However, in seven (7) different localities, the average values of the measured power densities were higher than the recommendations of Bioinitiative report 2012 (0.5 mW/m^2). In six (6) localities, the average values of the measured power densities were higher than the recommendation of Salzburg resolution, 2000 (1 mW/m^2). The highest average value of power density for GSM 900 was observed in Champhai Vengthlang locality in Champhai town (7.15 mW/m^2), and the lowest value for GSM 900 was observed in Kawlkulh village in Champhai District (0.001 mW/m^2). For GSM 1800, the highest power density was observed in Lunglei Venglai locality Lunglei town (106.98 mW/m^2), the lowest value was observed in Pukpui in Lunglei town (0.003 mW/m^2). For the average value of GSM 900 and GSM 1800, the highest value was observed in Lunglei Venglai locality (10.300 mW/m^2) whereas the lowest value was observed in Khawzawl village (0.007 mW/m^2).

Although the measured power densities were very low when compared to the recommendations of ICNIRP (1998) and the current Indian standard, it has been observed that many inhabitants were still having significant health complaints on many non specific health symptoms since the erection of the towers. It has also been observed that females were having more health complaints than males (Santini *et al* 2002; Pachuau *et al*, 2015).

From the comparison of Champhai Kanaan and Zohnuai with other localities in Champhai and Lunglei Districts, health complaints were found to be significant in all the localities and villages within Champhai and Lunglei Districts. In all the fifteen (15) different localities within Champhai and Lunglei Districts, comparison of the questionnaire responses on health complaints were found to be significant at least in one (1) symptom in scale 2 only or scale 3 only or in both the scales 2 and 3. In comparison with Champhai Kanaan and Zohnuai, the most common complaints were muscle pain (which is significant in 9 localities), headache (which is significant in 8 localities) and dizziness (which is significant in 6 localities). In all the significant comparison, health complaints were more in other localities than in Champhai Kanaan and Zohnuai. The same trend of more significant health complaints by individuals living in the vicinity of RF Radiation was also observed (Wolf and Wolf 2004 ; Santini *et al,* 2002; Pachuau *et .al*, 2014).

From the comparison of health complaints of male and female from each locality, it was observed that females were having more complaints than male. The comparisons were significant in twelve (12) different symptoms viz., fatigue, sleep disruption, headache, cramp, dizziness, muscle pain, nausea, feeling of discomfort, memory loss, hearing problem, visual disruption, difficulty in concentration and skin problem. In all the symptoms, females were having more complaints than male. The most common complaint was muscle pain, which was significant in seven (7) different localities. The same trend of complaint was also observed by Santini *et al.* (2002) and Pachuau *et al*. (2014).

By comparing the measured average power densities and health complaints of each locality, a particular trend has been observed in the two districts where significant health complaint was observed only when the average power density was above a certain limit. In comparison between Champhai Kanaan and other localities in Champhai District, significant health complaint starts to occur when average power density was more than 0.163 mW/m^2. If lower than this value, no significant health complaint was observed between Champhai Kanaan and other localities. Similarly in comparison between Zohnuai and other localities in Lunglei District, significant health complaint starts to occur when average power density was more than 0.194 mW/m^2. When it was lower than this value, no significant health complaint was observed between Zohnuai and other localities. It has also been observed that only when the average power density was more than 0.178 mW/m^2, health comparison between male and female becomes significant. If lower than this value, no significant health complaint was observed between male and female. We suggest power density of 0.18 mW/m^2 to be the safe limit of exposure to RF

Radiation which is in line with Bio-initiative Report(0.0005W/m^2). Based on our studies, we can conclude that the current Indian standard (0.45W/m^2) for mobile tower exposure is inadequate for the safe living.

Due to the geographical location as Lunglei and Champhai Districts are hilly region, the power densities were not necessarily higher close to the base stations. But in plain areas, power density seems to be higher close to the base stations than which are further away and people are more affected with health symptoms (Premlal *et al,* 2017). Therefore, distance alone seems to be insignificant on regarding health complaints; rather, it is the power density which determines the health complaints. There is direct relationship between power density and significant health complaints, i.e. power density and health complaints are strongly positively correlated. In recent study conducted by Zothansiama *et al* (2017), it was found that continuous exposure of human to RF Radiation emitted by mobile tower induced significant micronuclei formation and this damage was positively correlated with the power density of RF radiation. These findings supported our results of strong positive correlation between power density and health complaints.

However, there are many other factors which could contribute to the health complaints other than RF Radiation. It is not wise to conclude that all the observed health complaints were due to the radiation alone. Further, it has been observed that more is power density, more is health complaints. The study of the effect of RF Radiation on human body at the molecular level was carried out and a significant result was obtained.

It has also been found that from the power density, biochemical and molecular studies, it does not produce significant damage by RF Radiation at the molecular level. However, polymorphism was detected in the Mizo inhabitants in Aizawl city. Therefore, we may conclude that at the molecular level, RF Radiation from base station did not cause mutation and not produce significant damage, although it produces polymorphism to some extent to those inhabitants residing in the proximity of the base stations.

The number of Mobile phone towers are expected to grow as more smart devices grow and the need for bandwidth among consumers keeps escalating. However, the growth of this RF based systems could lead to increased exposure to users within the high level coverage area, which may lead to health effects associated with these radiations. It is thus important that radiation coverage in this area is properly analyzed to help people in deciding where to operate businesses and live in. A system developed based on this model is expected to attain this and together with a tailored app, it can help people find safe areas as far as RF radiation is concerned.

Exposure of the general population to RF Radiation from wireless communication devices and transmission towers should be kept to a minimum and should follow the ‘‘As Low As Reasonably Achievable (ALARA)” principle. One of the possible solutions to reduce the health effects of cell tower radiation is to have more number of cell towers with lesser transmitted power. When transmitted power is reduced, heating effect will be reduced and lesser cooling or no cooling will be required; all of this will reduce power requirement. Also, radiation measurements must be monitored continuously so that operators should not increase the transmitted power during the peak period and also to check whether it exceeds permissible limit.

In modern world, since it is almost impossible to live without wireless telecommunication systems, we have to be aware of its health impacts and as such stricter rules and regulations on Mobile/Cell tower erection should be enforced as prescribed by Telecom Regulatory Authority of India (TRAI). It is highly recommended that children are limited to use of mobile phone and be shielded from continuous exposure from RF Radiation and minimizing cell phone use for long duration, and to avoid continuous exposure to the public as a whole, which can be achieved by maintaining time, distance and shielding.

Future Scope of Study:

Five districts of Mizoram- Aizawl, Kolasib, Serchhip, Champhai and Lunglei Districts were covered by the researchers. For future studies of the work, the research can be carried out in the remaining districts like Saiha, Lawngtlai and Mamit Districts in order to have a road map for studying the health effects of RF Radiation from Mobile base stations. More in depth study may be taken at the Cellular level to find if there is any association between leukaemia, brain tumour, cancer and RF Radiation.

RESEARCH PUBLICATIONS

1. **Journal Papers :**

1**. Lallawmzuala**, Lalrinthara Pachuau, Zaithanzauva Pachuau (2019), Analysis of Mobile Tower Radiation and its health effects in Champhai District of Mizoram, *Science and Technology Journal*, **6(2**):29-32. **ISSN: 2321-3388**.

2. **Lallawmzuala**, Lalrinthara Pachuau, Zaithanzauva Pachuau (2020), Analysis of Mobile Tower Radiation and its health effects in Lunglei District of Mizoram, *Science and Technology Journal*, **9(1)**:1-7, ISSN: 2321-3388

2. CONFERENCE PAPERS

1. **Lallawmzuala**, Lalrinthara Pachuau, Zaithanzauva Pachuau (2019), Analysis of Mobile Tower Radiation and its health effects in Champhai District of Mizoram, *International Conference on Chemistry and Environmental Sustainability(ICCES-2019)* during February 19-22,2019, *Mizoram University*, Mizoram (**Oral Presentation**)

2. **Lallawmzuala**, Lalrinthara Pachuau, Zaithanzauva Pachuau (2019), Analysis of Mobile Tower Radiation and its health effects in Champhai District of Mizoram, *URSI Asia-Pacific Radio Science Conference (AP-RASC-2019*) during 9-15 March, New Delhi **(Oral Presentation)**

3. Lallawmzuala, Lalrinthara Pachuau, Zaithanzauva Pachuau (2020), Analysis of Mobile Tower Radiation and its health effects in Lunglei District of Mizoram, *2^nd^ Annual Convention of North East(India) Academy of Science and Technology (NEAST) & International Seminar on Recent Advances in Science and Technology(ISRAST)* during 16-18 November, Mizoram University, Mizoram (India).

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1	HSLC	Distn	86	1993	MBSE
2	PU (Science)	First	73.66	1995	NEHU
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REFERENCES :

Abdel-Rassoul G., Abou El-Fatech O., Abou Salem M., Michael A., Farahat F., El-Batanouny M., Salem E. (2007), Neurobehavioral effects among inhabitants around mobile phone base stations. *Neurotoxicology* **28**(2):434-440.

Abu Khadra, Khalil AM, Aljaberi AM, Gagaa MH, Issa HS, (2014), Assessment of oxidant/antioxidant status in saliva of cell phone users. *Electromagn. Biol. Med.* **33**(2):92-7.

Achudume Albert, Onibere Bill, Aina Funso, Tchokossa Paschal (2010), Induction of Oxidative Stress in Male RatsSubchronically Exposed to Electromagnetic Fields at Non-Thermal Intensities, *J. Electromagnetic Analysis and Applications*, **2:** 482-487.

Advisory Guidelines for State Governments for Issue of clearance for installation of Mobile Towers, Department of Telecommunications, Govt. of India, 2013, http://www.dot.gov.in/access-services/journey-emf

Agarwal A., Desai N.R., Makker K., Varghese A., Mouradi R., Sabanegh E., Sharma R. (2009), Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study, *Fertil. Steril.* **92(4):**1318-25.

Albert E.N. (1977). Light and electron microscope observation on blood brain barrier after microwave radiation. In symposium on Biological Effect and Measurement of Radio Frequency Microwaves, Washington DC : DHEW (HEW Publications), FDA **77**: 8026, pp 2943

Andre Vander Vorst, Arye Rosen ,Youji Kotsuka (2006) , RF/Microwave Interaction with Biological Tissues,1

Antipenko E.N. and Koveshinkova I.V. (1987). Cytogenetic effects of microwaves of nonthermal intensity in mammals. *Dokl. Akad. Nauk.* SSSR **296:** 724-726.

Atasoy HI, Gunal MY, Atasoy P, Elgun S, Bugdayci G (2012), Immuno-histopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices, *J. Pediatr. Urol.* **9**(2):223-9.

Awad SM, Hassan NS (2008). Health Risks of electromagnetic radiation from mobile phone on brain of rats., *J. Appl. Sci. Res.*, **4**(12): 1994-2000.

Aweda MA, Gbenebitse S, Meidinyo RO, (2003), Effects of 2.45 GHz microwave exposures on the peroxidation status in Wistar rats, *Niger Postgrad. Med. J*, **10** (4): 243-246.

Balode Z. (1996), Assessment of radio-frequency electromagnetic radiation by the micronucleus test in bovine peripheral erythrocytes. *Sci. Total Environ.* **180 (1):**81–85.

Bawin SM, Kaczmarek LK, Adey WR (1975), Effects of modulated VHF fields on the central nervous system, *Ann NY Acad. Sci.*, **247:**74-81.

bees, Government of India. http://www.indiaenvironmentportal.org.in/_ les/_ le/_ nal_mobile_

Berman E, Carter H.B, House D., (*1980*). Tests for mutagenesis and reproduction in male rats exposed to 2450 MHz (CW) microwaves. *Bioelectromagnetics* **1:** 65-76.

Bioinitiative 2012, A Rationale for Biologically-based Exposure Standards for Low Intensity Electromagnetic Radiation, www.**bioinitiative**.org/conclusions.

Bisht, K. S., Moros, E. G., Straube, W. L., et al. (2002). The effect of 835.62 MHz FDMA or 847.74 MHz CDMA modulated radiofrequency radiation on the induction of micronuclei in C3H 10T½ Cells. Radiat. Res. 157:506–515.

Bortkiewicz A, Zmyslony M, Szyjkowska A, Gadzicka E. (2004). Subjective symptoms reported by people living in the vicinity of cellular phone base stations. *Med. Pr.* **55:**345-351.

Braune S, Wrocklage C, Raczek J, Gailus T, Lücking CH. (1998). Resting blood pressure increase during exposure to a radiofrequency electromagnetic field. *Lancet* **351:**18571858.

Busljeta I, Trosic I, Milkovic-Kraus S. 2004. Erythropoietic changes in rats after 2.45 GJz nonthermal irradiation. *Int. J. Hyg. Environ. Health*, 207 (6):549–554.

California Council on Science and Technology (2011), Health Impacts of Radiofrequency Exposure from Smart Meters.

http://www.ccst.us/publications/2011/2011smartA.pdf

Calvente, I., Perez-Lobato, R., Nunez, M. I., Ramos, R.,Guxens, M., Villalba, J., Fernandez, M. F. (2016). Does exposure to environmental radiofrequency electromagnetic fields cause cognitive and behavioral effects in 10-yearold boys? Bioelectromagnetics, 37(1), 25–36. doi:10.1002/bem.21951

Cardella C, de Magistris L, Florio E, Smith C (2001), Permanent changes in the physic-chemical properties of water following exposure to resonant circuits, *Journal of Scientific Exploration*, 2001; **15(4):** 501-518.

Chen KM, Samuel A and Hoopingarnerner R. (1974), Chromosomal aberration of living cells induced by microwave radiation, *Environ. Lett.,* **6:** 37-46.

Cherry N, 2001. Evidence that electromagnetic radiation is genotoxic: the implications for the

Chia S.E, Chia H.P, Tan J.S (2000), Prevalence of headache among handheld cellular telephone users in Singapore: A community study, *Environ. Health Perspect,* **108** (11)**:** 1059-1062.

Chiang H. (1998). Microwave and ELE electromagnetic field effects on the intracellular communication, *Proceedings of 20th Annual Intl. Conf. of IEEE Engineering in Medicine and Biology Society* **20:** 2798-2801.

Cleary S.F, Liu LM, Merchant RE. (1990). Glioma proliferation modulated *in vitro* by isothermal radiofrequency electromagnetic radiation exposure. *Radiat. Res.* **121:** 38-45.

Cleary S.F, Liu LM, Merchant RE. (1990), *In vitro* lymphocyte proliferation induced by radiofrequency electromagnetic radiation under isothermal condition. *Bioelectromagnetics* **11:**47-56.

d'Ambrosio G, Massa R, Scarfi MR, Zeni O. (2002). Cytogenetic damage in human lymphocytes following GMSK phase modulated microwave exposure. *Bioelectromagnetics* **23:**7–13.

Damiano Urbinello et.al, "Radio-frequency electromagnetic field (RF-EMF) exposure levels in different European outdoor environment in comparison with regulatory limits," *Environment International*, vol. **68**, 2014.

Del Giudice E, De Ninno A, Fleischmann, Giuliano Mengoli, Marziale Milani, Getullio Talpo, Giuseppe Vitiello (2005) Coherent quantum electrodynamics in living matter. Electromagn. *Biol. Med.* **24:** 199-210.

Del Giudice E, Doglia S, Milani M, C. W. Smith C.W, Vitiello G (1989), Magnetic flux quantization and Josephson behavior in living systems. *Physica Scripta*, **40:** 786-791.

Demsia G, Vlastos D, Matthopoulos DP (2004), Effect of 910-MHz electromagnetic field on rat bone marrow. *The Scientific World Journal.* **4**(S2): 48-54.

Dutta SK, Subramoniam A, Ghosh B, Parshad R. (1984). Microwave radiation induced calcium ion efflux from human neuroblastoma cells in culture. *Bioelectromagnetics*, **5:**71-76.

El-Abd SF, Eltoweissy MY. (2012), Cytogenetic alterations in human lymphocyte culture following exposure to radiofrequency field of mobile phone. *J. App. Pharm. Sci*. **2**(2)**:**16-20.

Electric Power Research Institute (2011), Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model. https://www.nvenergy.com/NVEnergize/documents/EPRI_1022270_case Study.pf

Ensminger M, Iloff L, Ebel C, Nikolova T, Kaina B, Löbrich M. (2014), DNA breaks and chromosomal aberrations arise when replication meets base excision repair. *J. Cell Biol.* **206**(1):29–43.

epidemiology of cancer and cardiac, neurological, and reproductive effects. http://www.neilcherry.com/documents/90_m2_EMR_Evidence_That_EMR-EMF_is_genotoxic.pdf

Foster K.R, Schepps J.L, Schwan H.P.(1977), Microwave Dielectric Relaxation in Muscle : A second look, *Biophys. J.*, **17**(2) : 193-197.

Foster K.R, Schepps J.L, Stoy R.D, Schwan H.P. (1979), Dielectric properties of brain tissue between 0.01 and 10 GHz, *Phys. Med. Biol.*, **24**(6) : 1177-87.

Foster K.R, Schepps J.L, Stoy R.D, Schwan H.P. (1979), Dielectric properties of brain tissue between 0.01 and 10 GHz, *Phys. Med. Biol.*, **24**(6) : 1177-87.

REFERENCES

Frankenhaeuser B., A. F. Huxley, "The action potential in the myelinated nerve fiber of *Xenopus laevis* as computed on the basis of voltage clamp data," *J. Physiol.,*Vol. 171, pp. 302–315, 1964.

Fritze K, Wiessner C, Kuster N, Sommer C, Gass P, Hermann DM, Kiessling M, Hossmann KA. (1997a), Effect of global system for mobile communication microwave exposure on the genomic response of the rat brain. *Neuroscience* **81:**627-639.

Gandhi G., Singh P. (2005), Cytogenic damage in Mobile Phone Users : Preliminary data, *Int. J. Hum. Genetic,* **5** (4) **:** 259-265.

Gandhi G., Singh P. (2007), Genetic damage in Mobile Phone Users : Preliminary Findings, *Int. J. Hum. Genetic,* **11** (2) : 99-104.

Garaj Vrhovac V., Fucic A., Horvat D. (1992). The correlation between the frequency of micronuclei and specific chromosome aberrations in human lymphocytes exposed to microwave radiation in vitro. *Mutat. Res.* **281**(3):181–186.

Garaj Vrhovac V., Horvat D., Koren Z. (1991). The relationship between colonyforming ability, chromosome aberrations and incidence of micronuclei in V79 Chinese hamster cells exposed to microwave radiation. *Mutation Res.* **263**:143– 149.

.

Gerin A., Stockbroeckx B., Vander Vorst A. (1999), Champs Micro-ondes et Sante, Louvain-la-Neuve: EMIC-UCL.

Geddes L. A., Baker L. E., *Principles of Applied Biomedical Instrumentation*, 3rd ed., New York:Wiley, 1989.

Goldoni J. (1990). Hematological change in peripheral blood of workers occupationally exposed to microwave radiation. *Health Physics **58***: 205-207.

Goud S.N., Usha Rani M.V., Reddy P.P., Reddi O.S., Rao M.S. and Sexena V.K. (1982), Genetics effect of microwave radiation in mice. *Mutat. Res.* **103**: 39-42.

REFERENCES

Gulati, S., Yadav A., Kumar, N., et al., "Effect of GSTM1 and GSTT1 Polymorphisms on Genetic Damage in Humans Populations Exposed to Radiation From Mobile Towers," *Arch Environ Contam Toxicol.,* vol.**70**, 2016.

Gursatej Gandhi, Gurpreet Kaur and Uzma Nisar, "A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station", *Electromagn Biol Med*., vol. **34**(8), 2015.

Hagmann M.J, Gandhi O.P, D'Andrea I.A, and Chatterjee I (1979), Head Resonance: Numerical Solutions and Experimental Results, *IEEE Transactions Microwave Theory and Techniques,* **27**: 809-813.

Haider. T, knasmueller S, Kundi M and Haider M. (1994). Clastogenic effects of radiofrequency radiations on chromosomes of Tradescantia. *Mutat. Res.* **324**:65-68

Hardell L, Carlberg M, Hansson Mild K (2005), Use of cellular telephones and brain tumour risk in urban and rural areas. *Occup. Environ. Med.* **62**: 390-394.

Hardell L, Carlberg M, Hansson Mild K (2005), Use of cellular telephones and brain tumour risk in urban and rural areas. *Occup. Environ. Med.* **62**: 390-394.

Hardell L, Nasman A, Pahlson A, Hallquist A, Hansson MK. (1999). Use of cellular telephones and the risk for brain tumours: a case-control study. *Int. J. Oncol.* **15:**113-116.

Hardell Lennart, Carlberg Michael, Hansonn Mild K (2009), Epidemiological evidence for an association between use of wireless phones and tumour diseases, *Pathophisiology*,**16** (2-3) : 113-122.

Hardell Lennart, Carlberg Michael, Hansonn Mild K (2009), Epidemiological evidence for an association between use of wireless phones and tumour diseases, *Pathophisiology*,**16** (2-3) : 113-122.

Haumann Thomas, Uwe Munzenberg, Maes Wolfgang, Sierck Peter (2002), HF radiation levels of GSM cellular phone towers in residential areas, *hbelc.org/pdf/memdocs/cellularphoneradiation.pdf*.

Hill, AB. The Environment and Disease (1965), Association or Causation?

Proceedings of the Royal Society of Medicine, **58**: 295-300.

Hutter HP, Moshammer H, Wallner P, Kundi M. (2006), Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. *Occup. Environ. Med.* **63** : 307-313.

Huurdeman Anton A. (2003), *The Worldwide History of Telecommunications,* John Wiley & Sons.

ICNIRP – International Commission on Non-Ionizing Radiation Protection, "Statement on the Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz)", Health Phys (Germany), vol. **97**, pp. 257-258, Sep. 2009.

ICNIRP Guidelines For Limiting Exposure to Time Varying Electric, Magnetic and Electromagnetic Fields (1998), *Health Physics* **74** (4): 494 - 522.

Independent Expert Group on Mobile Phones. Mobile phones and healths (IEGMP, Chilton), 2000.

Information paper on Effects of Electromagnetic Fields Radiations from Mobile Towers and Handsets(TRAI), pp 3-14 , July 2014

Ingole IV, Ghosh SK (2006). Cell phone radiation and developing tissues in chick embryo – a light microscopic study of kidneys. *J. Anat. Soc. India*, **55** (2): 19-23.

Interphone Study Group (IST), "Brain tumour risk in relation to mobile telephone use: Results of the Interphone international case-control study", *Int J Epidemiol (UK),*Vol. **39**, 2010.

Ioan EustatiuMarinescu and ClaudiuPoparlan, "Assessment of GSM HF-Radiation Impact Levels within the Residential Area of Craiova City," *Procedia Environmental Sciences*, vol. **32**, 2016. Available [online] https://doi.org/ 10.1016/ j.proenv.2016.03.022

Kane RC, 2001. Cellular telephone russian roulette – a historical and scienti_ c perspective. New York:Vantage Press.

Kerbacher J.J, Meltz M.L, Erwin D.N. (1990). Influence of radiofrequency radiation on chromosome aberrations in CHO cells and its interaction with DNA damaging agents. *Radiation Res.* **123:** 311-319.

Kerman, Memduh; Senol, Nilgun (2012), Oxidative stress in hippocampus induced by 900 MHz electromagnetic field emitting mobile phone: Protection by melatonin, *Biomedical Research*, **23**(1):147.

Khalil A.M, Qassem W.F, Sukeiman M.M. (1993). A preliminary study on the radiofrequency field induced cytogenetic effects in cultured human lymphocytes. *Dirasat* **20:**121-130.

Kolodynski AA, Kolodynska VV(1996), Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia. *Sci. Total Environ*, **180:** 87-93.

Kumar G (2010), Report on Cell Tower Radiation, Submitted to Secretary, DOT, Govt. of India.

Kumar, G., “Cell Tower Radiation”, Electrical Engineering Department, IIT Bombay Tech. Rep., Dec. 2010.

Lai H, Singh NP (2004), Magnetic-field-induced DNA strand breaks in brain cells of the rat. , *Environmental Health Perspectives*, **112**(6)**:** 687-694.

Lai H, Singh NP, 1996. Single- and double-strand DNA breaks in rat brain cells after acute exposure to radiofrequency electromagnetic radiation. International Journal of Radiation Biology, 69: 513–521.

Lalrinthara Pachuau , Zaithanzauva Pachuau (2014) , Study of Cell Tower Radiation and its Health Hazards on human body. *IOSR Journal of Applied Physics (IOSR-JAP) e-ISSN: 2278-4861.Volume 6, Issue 1 Ver. I (Jan. 2014), PP 01-06 www.iosrjournals.org*

Lee S, Johnson D, Dunbar K (2005), 2.45 GHz radiofrequency fields alter gene expression on cultured human cells. *FEBS Letters*. **579:** 4829-4836.

Leszczynski D, Joenvaara S (2002). Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: Molecular mechanism for cancer - and blood-brain barrier

– related effects. Differentiation. **70:** 120-129.

Livingstone (2001), Contaminant-stimulated reactive oxygen species production and oxidative damage in aquatic organisms, *Mar. Pollut. Bull.*, **42(8):** 656-66.

Lubec G., Wolf C., Bartosch B. (1998). Amino acid isomerisation and microwave exposure. *Lancet.***334:** 1392-1393.

Maes A, Verschaeve L, Arroyo A, De Wagter C, Vercruyssen L. (1993), *In vitro* cytogenetic effects of 2450 MHz waves on human peripheral blood lymphocytes. *Bioelectromagnetics,* **14**: 495–501.

Magras IN, Xenos TD (1997). RF radiation-induced changes in the prenatal development of mice. *Bioelectromagnetics*, **18**: 455-461.

Mashevich M, Foldman D, Kesar A, Barbul A, Korenstein R, Jerby E, Avivi L (2003). Exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability. *Bioelectromagnetics*, **24**(2) **:** 82-90.

Mc Carty DE, Carrubba S, Chesson AL, Frilot C, Gonzalez-Toledo E, Marino AA (2011). Electromagnetic hypersensitivity: Evidence for a novel neurological syndrome. *Int. J. Neurosci.* **121**(12): 670-676.

Meltz M.L, Walker K.A (1987), Radiofrequency microwave radiation exposure on mammalian cells during UV induced DNA repair synthesis. *Radiation Res*. **110:** 255–266.

Mild KH, Oftedal G, Sandstrôms M, Wilen J, Tynes T, Haugsdal B. (1998), Comparison of symptoms experienced by users of analogue and digital mobile phones. *Arbetslisrapp* **23:** l-4l.

Mitelman F, Johansson B, Mandahl N, Mertens F (1997). Clinical significance of cytogenetic findings in solid tumors. *Cancer Genet. Cytogenet.***, 95:**1-8.

MOEF, 2010. Report on possible impacts of communication towers on wildlife, including birds and

Nahas M, Mohammed T. Simsim (2011), Safety Measurements of Electromagnetic Fields Radiated form Mobile Base Stations in the Western Region of Saudi Arabia, *Wireless Engineering Technology,* **2:** 221-229.

Nittby H., Brun A., Eberhardt J. Malmgren L, Persson BR, Salford LG (2009), Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. *Pathophysiology*, **16:** 103-112.

Nylund R, Leszczynski D, 2006. Mobile phone radiationcauses changes in gene and protein expression in human endothelial cell lines and the response seems to be genome- and proteome-dependent. Proteomics, 6: 4769–4780.

Oftedal G., Wilen G., Sandstrom M., Mild K.H. (2000), Symptoms experienced in connection with mobile phone use, *Occup. Med.*, **50** (4) : 237-245.

Oscar K.J. and Hawkins T.D. (1977), Microwave alteration of the blood brain barrier system of rats. *Brain Res.***126**(2) **:** 281-293.

Pachuau L., Pachuau Z., Zothansiama (2015), Comparisons of Non specific Health Symptoms Faced by Inhabitants Exposed to High and Low Power Density from Mobile Phone tower, *Int. J. Recent Innov. Trends Comp. Commun.*, **3:** 94-98.

Paulraj R., Behari J. (2004) Radiofrequency radiation effect on protein kinase C activity in rats brain, *Mutation Research*, **585:** 127-131.

Phillips J.L., Singh N.P., Lai H. (2009), Electromagnetic fields and DNA damage. *Pathophysiology*. **16:** 79-88.

Premlal P.D.,Eldhose N.V (2017), Mobile Tower Radiation-An Assessment of Radiation Level and its Health Implications in the Residential Areas of Western Ghats in Idukki, Kerala, *Int.J. of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 20 (2017) pp.* 9548-9554.

Rea WJ, Pan Y, Fenyves EJ (1991). Electromagnetic field sensitivity. *Journal of Bioelectricity*, **10**(1, 2): 243-256.

J. P. Reilly, *Electrical Stimulation and Electropathology*, New York: Cambridge University Press, 1992.

J. P. Reilly, L. A. Geddes, C. Polk, "Bioelectricity," in R. C. Dorff (Ed.), *The Electrical Engineering Handbook*, Boca Raton, FL: CRC Press, 1993.

Ruediger H. W. (2009), Genotoxic effects of radiofrequency electromagnetic fields.

Pathophysiology, **16**(2): 89-102.

Saeid, H. S., "Calculation of the Mobile Phone Radiation Level in Respect to the Exposure Standards", *Journal of Science & Technology, University of Science and Technology, Yemen*, Vol. **13**(1), 2008.

Salzburg (2000), Resolution on Mobile Telecommunication Base Stations. *International Conference on Cell Tower Siting. Linking Science and Public Health.*

Santini R., Santini P., Danze J.M., Le Ruz P. (2002), Study of the Health of People living in the vicinity of mobile phone base stations : I. Influences of distance and sex, *Pathol. Biol.* **50 :** 369-373.

Santini R., Santini P., Danze J.M., Le Ruz P., Seigne M. (2003). Symptoms experienced by people in vicinity of base stations: II. Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors. *Pathol. Biol.* **51**:412-415. Sarkar N. (1997), Polyadenylation of mRNA in prokaryotes, *Ann. Rev. Biochem*. **66**: 173-97.

Sarkar S., Ali S., Thelma B.K. and Behari J. (1996), Study of the mutagenic potential of low power microwaves by direct DNA analysis. *Proc. Int. Conf. on Radiation Protection*, **3**: 565-567.

Sarkar S, Ali S, Behari J. (1994). Effect of low power microwave on the mouse genome: a direct DNA analysis. *Mutat. Res.*, **320** (12):141-147.

Saunders R.D., Darby S.C. and Kowalczuk Cl (1983), Dominant lethal studies in male mice after exposure to 2450 MHz microwave radiation. *Mutat. Res.* **117:** 345-356.

Scarfi, M. R., Fresegna, A. M., Villani, P., et al. (2006). Exposure to radiofrequency radiation (900 MHz, GSM signal) does not affect micronucleus frequency and cell proliferation in human peripheral blood lymphocytes: an interlaboratory study. Radiat. Res. 165:655–663.

Schwan H.P., Li K. (1953), Capacity and conductivity of body tissues at ultra high frequencies, *Proc. IRE*, **41:** 1735 – 1740.

Scientific Committee on Emerging and Newly Identified Health Risks, Health effects of EMF, (SCENIHR), EC, Brussels, 2009.

Singh, K., Nagaraj, A., Yousuf, A., Ganta, S., Pareek, S., & Vishnani, P. (2016). Effect of electromagnetic radiations from mobile phone base stations on general health and salivary function. Journal of International Society of Preventive and Community Dentistry, 6(1), 54–59. doi:10.4103/2231-0762.175413

Singh, R.K., "Assessment of electromagnetic radiation from base station antennas," *Indian J. of Radio and Space Physics*, vol. **41**, 2012.

Smith C.W. (2004), Quanta and coherence effects in water and living systems. *Journal of Alternative and Complimentary Medicine,* **10**(1): 69-78.

Smith C.W. (2008), Fröhlich's Interpretation of Biology through Theoretical Physics. In: Hyland GJ and Rowlands P (Eds.) Herbert Fröhlich FRS: *A Physicist Ahead of His Time*, Liverpool: University of Liverpool, 2nd Edition,107-154.

The Peculiar Circumstances of the IARC Working Group on Radio- Frequency Electromagnetic Fields and Cellular Telephones *IEEE Antennas and Propagation Magazine,* Vol. **53**(3), 2011

Tice RR, Hook GG, Donner M, McRee DI, Guy AW (2002), Genotoxicity of radiofrequency signals. I. Investigation of DNA damage and micronuclei induction in cultured human blood cells. *Bioelectromagnetics*, **23**(2):113–126.

Tice RR, Hook GG, Donner M, McRee DI, Guy AW (2002), Genotoxicity of radiofrequency signals. I. Investigation of DNA damage and micronuclei induction in cultured human blood cells. *Bioelectromagnetics*, **23**(2):113–126.

Tonomura A, Osakabe N, Matsuda T, Takeshi Kawasaki, Junji Endo, Shinichiro Yano, and Hiroji Yamada (1986). Evidence for Aharonov-Bohm effect with magnetic field completely shielded from electron wave. *Phys. Rev. Lett.* **56**(8): 792-75.

towers_report.pdf

Trosic I., Busljeta I., Kasuba V., Rozgaj R. (2002), Micronucleus induction after whole-body microwave irradiation of rats. *Mutat. Res.* **521**(1–2): 73–79.

REFERENCES

Trosic I., Busljeta I., Modlic B. (2004), Investigation of the genotoxic effect of microwave irradiation in rat bone marrow cells: *in vivo* exposure. *Mutagenesis* **19**(5): 361–364.

Vander Vorst A., Arye Rosen, Youji Kotsuka (2009), *RF/Microwave Interaction with Biological Tissues*, John Wiley & Sons.

Verma M.M. and Traboulay E.A. Jr. (1995), Evaluation of dominant lethal test and DNA studies in measuring mutagenicity causes by non- ionizing radiation. In: Johnson C.C., Shore M. (Eds.): *Biological Effects of Electromagnetic Waves*, Washington, DG: US Food and Drug Administration (FDA), (USNC/URSI) Annual Meeting Selected papers, Oct. 20-23, 1995, Boulder, Co **1**:386-396.

Verma M.M., Dage E.L. and Joshi S.R. (1995), Mutagenicity induced by non-ionizing radiation in swiss male mice, In: C.C. Johnson, M. Shore (Eds.). *Biological Effects of Electromagnetic Waves.* Vol. 1. Food and Drug Administration. US (FDA), Washington, DC. USNC/URSI Annual Meeting –selected papers, Oct. 20-23, 1995, Boulder, Co, pp. **1**: 397-405.

Vijayalaxmi Mohan, N., Meltz, M. L., et al. (1997). Proliferation and cytogenetic studies in human blood lymphocytes exposed in vitro to 2450 MHz radiofrequency radiation. Int. J. Radiat. Biol. 72:751–757.

Vijayalaxmi Seaman, R. L., Belt, M. L., et al. (1999). Frequency of micronuclei in the blood and bone marrow cells of mice exposed to ultra-wideband electromagnetic radiation. Int. J. Radiat. Biol. 75(1):115–120.

Vijayalaxmi, Pickard, W. F., Bisht, K. S., et al. (2001). Cytogenetic studies in human blood lymphocyte exposed in vitro to radiofrequency radiation at a cellular telephone frequency (835.62 MHz, FDMA). Radat. Res. 155:113–121.

Wolf R., Wolf D. (2004). Increased Incidence of Cancer near a Cell-Phone Transmitter Station. *Int. J. Cancer Prev.*, **1**(2): 1-19.

Wolf R., Wolf D. (2004). Increased Incidence of Cancer near a Cell-Phone Transmitter Station. *Int. J. Cancer Prev.*, **1**(2): 1-19.

.

Xu S., Zhou Z., Zhang L., Yu Z, Zhang W, Wang Y, Wang X, Li M, Chen Y, Chen C, He M, Zhang G, Zhong M (2010), Exposure to 1800 MHZ radiofrequency radiation induces oxidative damage to mitochondrial DNA in primary cultured neurons. *Brain Research*, **1311**: 189-196.

Yao K.T.S. and Jiles M.M. (1970), Effects of 2450 MHz microwave radiation on cultivated rat kangaroo cells. In Biological effects and Health Implications of Microwave Radiation (Cleary S.F., Ed.) Proceedings of Medical College of Virginia Symposium,1969. Richmond VA, Department of Health, Education and Welfare, Public Health Service, Environmental Health Service, *Bureau of Radiology*, 123-133.

Yoshikawa Toshikazu and Naito Yuji (2002), What Is Oxidative Stress? *Japan Medical Association Journal* **45**(7): 271–276.

Zeni, O., Schiavoni, A., Perrottam, A., et al. (2008). Evaluation of genotoxic effects in human leukocytes after in vitro exposure to 1950 MHz UMTS radiofrequency field. Bioelectromagnetics. 29:177–184.

Zeni, O., Schiavoni, A., Sannino, A., et al. (2003). Lack of genotoxic effects (micronucleus induction) in human lymphocytes exposed in vitro to 900 MHz electromagnetic fields. Radiat. Res. 160:152–158.

Zhao T., Zou S., Knapp P. (2007). Exposure to cell phone radiation up-regulates apoptosis genes in primary cultures of neurons and astrocytes. *Neurosci. Lett.*, **412**(1): 34-38.

Zothansiama, Mary Zosangzuali, Miriam Lalramdinpuii, and Ganesh Chandra Jagetia (2017) Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. *J.Electromag. Biol. and Med.*,pp.1-11, doi.org/10.1080/15368378.2017.1350584

Zotti-Martelli L., Peccatori M., Scarpato R., Migliore L. (2000). Induction of micronuclei in human lymphocytes exposed in vitro to microwave radiation. *Mutat. Res.* **472**(1–2):51–58.