A Study on Effects of Telecom Electromagnetic Radiations on Eco-System of the Region using Geo-Information Technology

Naveenchandra, B., [1] **Lokesh, K. N.,** [2] **Usha**[3] **and Gangadhara, B. H.**[4]
[1]Information Telecom Project Circle, Data Centre, Pune, India, E-mail: naveensde@gmail.com
[2]Department of Geology, NITK; Surathkal, 575 025, India, E-mail: knlokesh@nitk.ac.in
[3]Govt. P.U. College for Girls, Udupi-576101, India, E-mail: unchnadra@yahoo.co.in
[4]Mangalore University, Mangalore-574199, India, E-mail: gangadharab@yahoo.com

Abstract
Our environment is subjected to exposure to microwave and radio electromagnetic irradiations because of widespread use of wireless telecommunication services. The electromagnetic radiations like radio waves, microwaves and Infrared rays emitted from the multiple telecom sites also contributing large amounts of environment harming to natural eco systems and causing climate change. A potentially constant exposure has caused an alert in public and governments about the so-called environmental electromagnetic pollution. Assessment of the RF EMF impact on plants is of great importance because plants have an important role in the living world as main primary producers of organic compounds and oxygen. Plants are continuously exposed to various environmental stresses and display a wide spectrum of developmental and biochemical responses contributing to stress adaptation. Their physiological responses can be evoked by a great variety of external stimuli, including mobile phone radiation. The adverse effects of electromagnetic radiation from mobile phones and communication towers on health of human beings are well documented today. However, exact correlation between radiation of communication towers and eco-system, are not yet very well established. In this context, there is need to carry out the scientific investigations to understand the effects of RF radiation on plants. The main objective of this research is to measurement of signal strength and power emitted by the tower and to establish guidelines for limiting EMF exposure that will provide protection against known adverse effects on eco-systems will be studied using Geo-Informatics techniques in Udupi District, Karnataka State. The advancement in the recent years in the field of Geo-Informatics has enabled us to get the required spatial information of the environment in a better way.

1. Introduction

Rapid developments in various fields of science and technology in recent years have intensified the human interference into the natural environment and associated physical, biological and ecological systems resulting in various unintended and undesirable negative impacts on environment. With economic, social and scientific development, increasingly fresh avenues for environmental pollution are being thrown open in recent times. Pharmaceutical, genetic, nano-particulates and electro-magnetic pollutions are the prominent ones among them which were in the limelight in recent times for all the negative reasons. The intensity of manmade electromagnetic radiation has become so ubiquitous and it is now increasingly being recognized as a form of unseen and insidious pollution that might perniciously be affecting life forms in multiple ways (Balmori, 2005). The electro-magnetic fields (EMF) as a pollution called 'electro-smog' is unique in many ways. Unlike most other known pollutants, the electro-magnetic radiations (EMR) are not readily perceivable to human sense organs and hence not easily detectable. However, their impacts are likely to be insidious and chronic in nature. However, it is possible that other living beings are likely to perceive these fields and get disturbed or sometimes fatally misguided. Because the EMR pollution being relatively recent in origin and lately being recognized as a pollutant coupled with its expected long-term impacts and lack of data on its effect on organisms, the real impacts of these pollutants are not yet fully documented in the scientific literature (Okumara et al., 1968). The electromagnetic radiations (EMR) are extensively used in modern communication and technology. The first mobile telephone service started on the non-commercial basis on 15 August 1995 in Delhi. During the last 16 years, India has seen exponential growth of mobile telephoning. With this growth, a number of private and government players are coming in to this lucrative and growing sector. At present nearly 800 million Indians have mobile phones, making it the second largest mobile subscribers in the world after China. At present, there are nearly 15 companies providing mobile telephoning. However, necessary regulatory policies and their implementation mechanism have not kept pace with the growth of mobile telephoning.

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Moreover, there have been not enough scientific studies on the impact of mobile phone towers on human health or its environmental impacts. According to the Telecom Regulatory Authority of India, 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. With no regulation on the placement of cell towers, they are being placed haphazardly closer to schools, creches, public playgrounds, on commercial buildings, hospitals, college campuses, and terraces of densely populated urban residential areas. Hence, the public is being exposed to continuous, low intensity radiations from these towers. Since the electromagnetic radiations, also known as electro smog cannot be seen, smelt or felt, one would not realize their potential harm over long periods of exposure until they manifest in the form of biological disorders. Various studies have shown the ill-effects of radio-frequency 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 (Neskovi et al., 2002). Cancer, diabetes, asthma, infectious diseases, infertility, neurodegenerative disorders, and even suicides are on the rise in India. This invisible health hazard pollution (IHHP) is a relatively new environmental threat. When energy is released from a source of electromagnetic radiation like radio frequency (RF), infrared light (IR), visible light (VL), ultra-violet light (UV) or x-rays and gamma rays, it is referred to as radiation of energy (Bi et al., 2001). Although all listed forms of radiation carry energy it is only the high frequency portion of electromagnetic radiation (above $3x10^8$Hz or 300GHz) like x-rays and gamma rays that carry enough energy to cause ionisation. Radiation may be ionising or non-ionising. In the case of ionising radiation the radiation carries plenty of energy along. This energy is so powerful that when colliding with an atom of another particle it can bounce electrons off the aforementioned particle. In such a case the mentioned atom will lose/gain electrons due to the collision and this atom will now become ionised (Bulligton, 2006). Further to this, ionising radiation may occur in two forms namely wave or particle. Wave types like visible light and radio waves carries wave packets of photons while in particle type there are atomic particles that contain huge quantities of kinetic energy.

Non-ionizing radiation is similar to ionising radiation as it also contains the electromagnetic spectrum of light but now more towards a different set of frequency ranges like ultraviolet (UV), visible light, infrared (IR), microwave (MW), radio frequency (RF), and extremely low frequency (ELF). The problem with non-ionizing radiation is that it still poses health risks because it can interact with the biological systems of workers and the public if not properly controlled. When an object or a sample of an object is subjected to radio frequency (RF) then such sample will absorb some of this applied energy. This energy referred to may only be labelled as non-ionising energy when the energy does not cause ionisation to samples of living matter (plant, animal or human tissue) but it will cause a heating effect in such sample which would be detrimental to the sample of living matter (Figure 1). Cell phone technology has several advantages and has grown rapidly in the last decade. In India, there are nearly 80 crores cell phone subscribers and around 4.5 lakhs cell phone towers (Figure 2). Number of cell phones and cell towers are increasing without considering its disadvantages. The purpose of a cell tower is to enable cell phone to receive adequate signal for its proper operation. A mobile phone shows full strength at -69 dBm input power and works satisfactorily in the received power range of -80 to -100 dBm. In comparison with -80 dBm level, the measured power level at several places is at least 50 to 80 dB higher, which translates to 100,000 to 100,000,000 times stronger signal than a mobile phone requires (Wagen and Rizk, 2002). There are millions of people who live near these cell towers and absorbing this radiation 24x7. The measured received power values are comparable to the theoretical values in the direction of main beam. Measured values are much lesser than the theoretical values in the directions other than main beam of radiation because of reduction in the gain in that direction. Hence, it is important to know the radiation pattern of the antenna to know the exact radiation density at a given location. The generic radio wave propagation prediction algorithms based on computer databases or empirical results give only approximate coverage, which are not suitable for detailed network design. The efficiency of radio wave propagation prediction system can be improved greatly, with powerful capability of handling geo-spatial data through Remote Sensing and GIS techniques (Naveenchandra et al., 2012). Signal strength predicted by integration of NDVI methodology and view shed analysis taken into account for factors like terrain height, building height and distance from tower which will be compared with field measurements for validation.

The variation in signal strength depends upon many factors, such as the type of trees, trunks, leaves, branches, their densities, and their heights relative to the antenna heights. When the signal strikes the surface of a building, it may be diffracted or absorbed. Foliage loss is caused by propagation of the radio signal over vegetation, principally forests. Foliage loss depends on the signal frequency and varies according to the season. According to this quantitative analysis, RS/GIS oriented signal strength prediction method using NDVI found significantly improve the prediction quality compared to the theoretical free space model which does not take into account any local terrain feature effects for the assessment of the impacts of radiations in a given location. The multi spectral and stereo satellite data in conjunction with GIS/GPS techniques can be utilised to formulate suitable plans and strategies for an effective prediction and measurement of signal strength and power density for the assessment of impacts on eco-system (Naveenchandra et al., 2011).

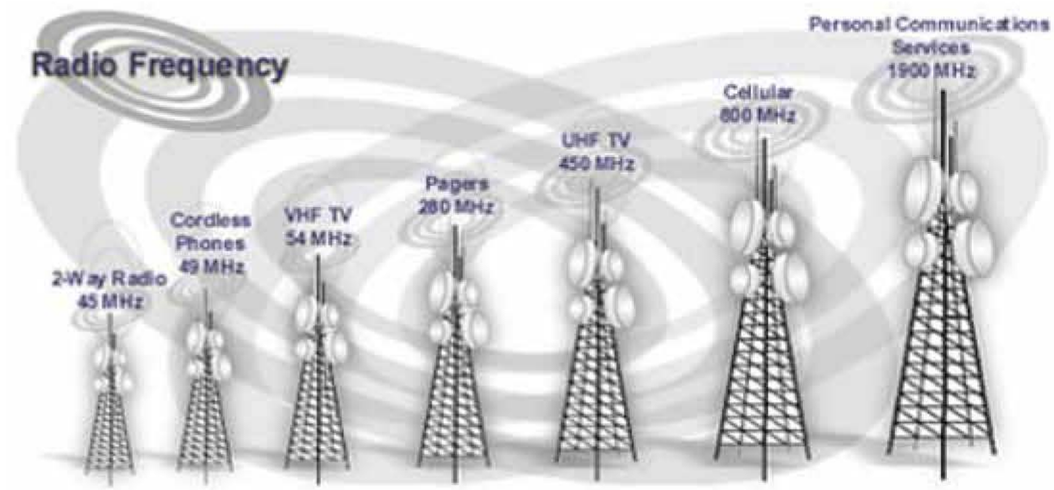

Figure 1: Various wireless communication technologies

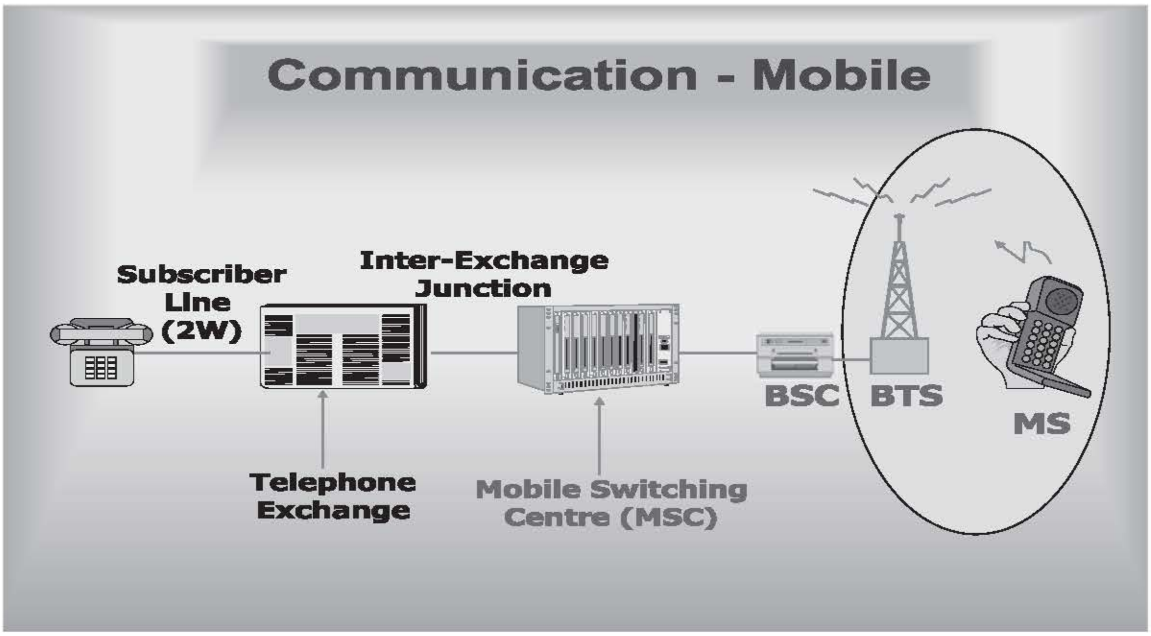

Figure 2: The architecture of mobile communication system

Accelerated and widespread use of different communication systems and modern electronic equipment has increased exposure to radio frequency electromagnetic fields (RF EMF) and has raised serious concerns about the biological and health-related effects of RF radiation. Numerous studies have documented various biological effects of RF radiation. Most of them concern health, brain and DNA effects. However, most of these findings derived from epidemiological, animal and *in vitro* studies while only a few investigated effects of RF radiation on plants. Assessment of the RF EMF impact on plants is of great importance because plants have an important role in the living world as main primary producers of organic compounds and oxygen. Plants are continuously exposed to various environmental stresses and display a wide spectrum of developmental and biochemical responses contributing to stress adaptation. Their physiological responses can be evoked by a great variety of external stimuli, including mobile phone radiation. Propagation is very complex and diverse. First, because of the separation between the receiver and the transmitter, attenuation (reduction or loss) of the signal strength occurs. In addition, the signal propagates in different manners, known as diffraction, scattering, reflection, transmission and refraction. Approximately 70 percent of the Earth's land surface is covered with vegetation. Furthermore, vegetation is one of the most important components of ecosystems. Knowledge about variations in vegetation species and community distribution patterns, alterations in vegetation phonological (growth) cycles, and modifications in the plant physiology and morphology provide valuable insight into the climatic, edaphic, geologic and physiographic characteristics and area (Rubinstein, 1998). Trees singly or in a group can be found in cells of land mobile systems as well as in fixed access systems. The trees act as obstacles in the radio path causing both absorption and scatter of radio signals. The scattering and absorption need to be accounted for in radio planning tools to improve their accuracy, with improved co-ordination of radio links and optimum use of the radio spectrum. Foliage loss is caused by propagation of the radio signal over vegetation, mainly forests. The variation in signal strength depends upon many factors, such as the type of trees, trunks, leaves, branches, their densities, and their heights relative to the antenna heights. Foliage loss depends on the signal frequency and varies according to the season. This loss can be as high at 20dB in GSM 800 systems (Figure 3).

2. Study Area

The coastal district Udupi of Karnataka state is chosen as study area which falls along the west coast of peninsular India and is separated from the rest of peninsula by towering high Western Ghats. The district lies between 13°04′ and 13°59′ N latitude and 74°35′ and 75°12′ E longitude and covers an area of 3575 sq. Km. It is about 88 km in length and about 80 km in the widest part and is bound by Uttara Kannada district in the north, Shivamogga and Chikamagalur district in the east and Dakshina Kannada district in the south. The district is carved out of South Kanara District during 1991. The district comprises of administrative subdivision; Kundapura, Udupi and Karkala Taluks. This coastal district of Karnataka is blessed with various endowments of nature. The population as per 2001 census was 11, 12,243 of which 18.55% were urban. The area is almost plain towards west with an undulating topography towards northeast. The general elevation of the area ranges from 20m to 100m above mean sea level. Density of population is 536 per sq.km. The Literacy rate of the district is 78.87%. The area has an excellent communication system. National Highway (N.H)-66 and Konkan railway are passing through the area, almost parallel to the west coast. Villages and habitations are connected with metalled and unmetalled roads with a network of private and public transport systems. In the past few years, tremendous progress has also been made in the field of telecommunication especially in the mobile communication. At present there are around 410 cell sites operated by different operator.

3. Materials and Methods

The research was carried out by health survey of the household members who are residing within the radius of 300 meters from the Mobile Towers. A pre-structure questionnaire was designed in which information related to socio-economic status, health problems like headache, disturbance in sleep, depression, fatigue, dizziness, palpitation of heart, visual problems, irritability, nausea, feeling of discomfort etc. In Udupi urban there are 21 spots where mobile towers are placed, among then 4 spots was selected, in Kundapur and Karkala 2 spots was selected. Household members who are staying close to these spots (within the radius) of 500 meters was interviewed to understand health problems and also their exposure to radiations was measured. For external measurements there are essentially three methods that are used to measure electric and magnetic fields and these are portable survey instrumentation, spectrum analyzers and personal exposure monitors.

Portable RF measurement instrumentation provide a relatively simple and convenient means for measuring electric and magnetic field strengths to assess compliance with exposure guidelines. In most cases only instruments with shaped frequency response should be used for that purpose. Extensive field survey has been conducted from each BTS towards 500 meter distance for the study impacts of radiation on living and non-living of the eco system (Figure 4). 10 % of total towers in Udupi District (345) towers was classified in to high, medium and low radiation (more than two providers, two providers and single provider) and 3500 households (100 from each tower area) was selected based on population and households having livestock as per census 2011 in urban , semi urban and rural areas of Udupi District. The study mainly involves the applications of remote sensing and GIS techniques. A major part of the work has been carried out by making use of the satellite data (both hard copies and digital data), SOI topographical maps and other thematic maps.

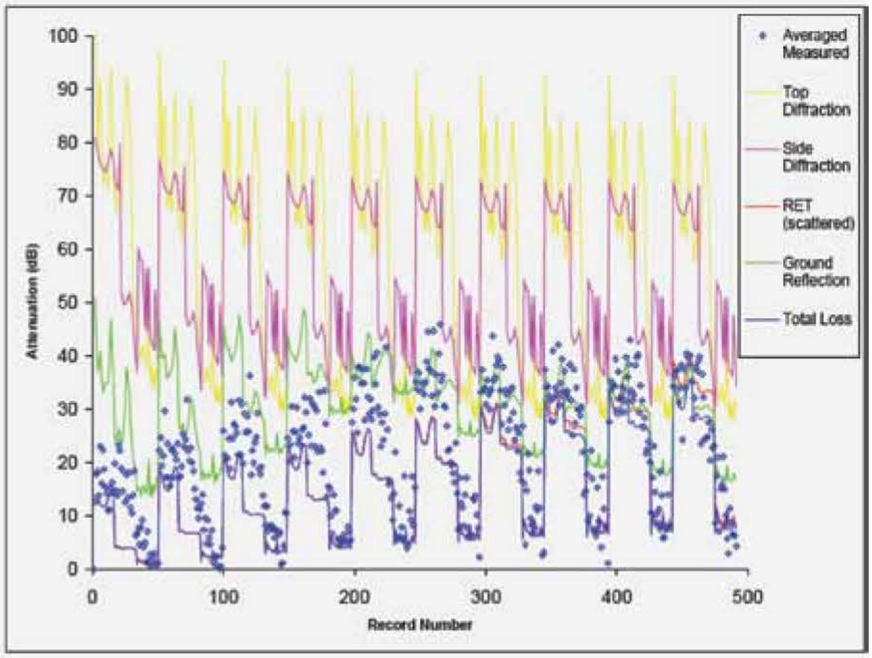

Figure 3: Signal frequency effects on Vegetation eco-system

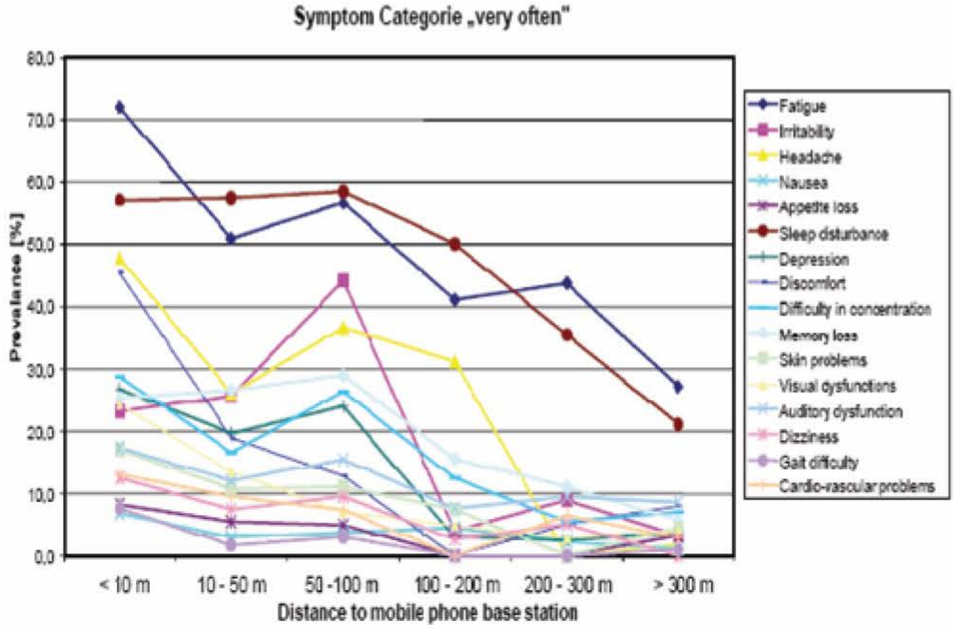

Figure 4: Health impacts of EMF on human bio-system

Digital mapping constitutes an integral component of the process of managing land resources, and mapped information is the common product of analysis of remotely sensed data. High-resolution space-borne remote sensing image data show a high level of detail and provide opportunities to be integrated into mapping applications (Usha, 2014). The demand for accurate and up-to-date spatial information is increasing and its availability is becoming more important for a variety of tasks. The successful launch of IRS-1C satellite with the availability of high spatial resolution data in 5.8m in single panchromatic band (0.5-0.75μm) and 23m (LISS) resolution data in four multispectral bands along with stereo and revisit capability, it would now be possible to explore its potential either singularly or in combination in different areas of telecom survey and planning, wireless radio coverage, landscape design, base map preparation etc. The monitoring of land cover involves the computation of vegetation indices. Vegetation indices help in mapping the regions under vegetation and non-vegetation (soil and water). Among all techniques of land cover mapping Normalised difference Vegetation Index (NDVI) is most widely accepted and applied (Naveenchandra et al., 2010). The land cover analysis was done using NDVI (Normalized Difference Vegetation Index). Calculation of NDVI for Multi-temporal data is advantageous in areas where vegetation changes rapidly. NDVI is based on the principle of spectral difference based on strong vegetation absorbance in the red and strong reflectance in the near-infrared part of the spectrum. NDVI is computed using visible Red and Near Infra-Red (NIR) bands of the data. Healthy vegetation absorbs most of the visible light and reflects a large portion of the near-infrared light. Sparse vegetation reflects more visible light and less near-infrared light. Morphology correction for the various morphology classes has been considered. The radio path to each measurement and prediction point was analyzed and the morphology classes traversed noted. The distance covered by each morphology class was recorded and then taken as a ratio of the total path distance. Another class considered was the foliage due to trees in the area. All these LU/LC factors accounted for a morphological correction factor and together with the terrain height, slope and environmental type correction factors yielded has been be derived. The performance analysis is based on the calculation of received signal strength, path loss between the base station and mobile from the propagation model.

4. Results and Discussions

As mobile technology progresses, the data demands on mobile network increases, coupled with lower costs, their use has increased dramatically and the overall levels of exposure of the population as a whole had increased drastically. Every living being is tuned into the earth's electromagnetism and uses it for various purposes. The purpose of a cell tower is to enable cell phone to receive adequate signal for its proper operation. A mobile phone shows full strength at -69 dBm input power and works satisfactorily in the received power range of -80 to -100 dBm. In comparison with -80 dBm level, the measured power level at several places is at least 50 to 80 dB higher, which translates to 100,000 to 100,000,000 times stronger signal than a mobile phone requires. There are millions of people who live near these cell towers and absorbing this radiation 24x7. Figure 5 shows the multi towers installed in Manipal city of Udupi District by many service providers transmitting multiple radiations in the study area where haphazard type of installations observed.

Figure 5: Multi towers installed in Manipal city of Udupi District by many service providers transmitting multiple radiations

The measured received power values are comparable to the theoretical values in the direction of main beam. Measured values are much lesser than the theoretical values in the directions other than main beam of radiation because of reduction in the gain in that direction. Hence, it is important to know the radiation pattern of the antenna to know the exact radiation density at a given location. Various studies have shown that even at low levels of this radiation, there is evidence of damage to cell tissue and DNA, and it has been linked to brain tumours, cancer, suppressed immune function, neuroendocrine disruption, chronic fatigue syndrome, and depression. Across many species and groups of organisms, compelling evidence exists that the physical basis of this response is tiny crystals of single-domain magnetite (Fe_3O_4). All magnetic field sensitivity in living organisms, including elasmobranch fishes, is the result of a highly evolved, finely-tuned sensory system based on single-domain, ferromagnetic crystals (Sandu et al., 2004). Animals that depend on the natural electrical, magnetic, and electromagnetic fields for their orientation and navigation through earth's atmosphere are confused by the much stronger and constantly changing artificial fields created by technology and fail to navigate back to their home environments. When a human body is exposed to the electromagnetic radiation, it absorbs radiation, because human body consists of 70% liquid. It is similar to that of cooking in the microwave oven where the water in the food content is heated first. Microwave absorption effect is much more significant by the body parts, which contain more fluid (water, blood, etc.), like the brain which consists of about 90% water. Effect is more pronounced where the movement of the fluid is less, for example, eyes, brain, joints, heart, abdomen, etc. Also, human height is much greater than the wavelength of the cell tower transmitting frequencies, so there are multiple resonances in the body, which creates localized heating inside the body. This results in boils, drying up of the fluids around eyes, brain, joints, heart, abdomen, etc. It is found that 0.05 V/m was the level at which symptoms start to show. This is shown graphically below. Though the numbers involved in the study were small, they point out that where the signal strength is less than 0.06 V/m, 70% of people did not experience adverse health effects, whereas in levels of 0.2 V/m and above only 5-6% of the population did not experience health effects. It is important to remember when looking at these graphs that microwave signals from mobile phone masts are often above 0.6 V/m at up to 400 metres distance (figure 6). Non-thermal effects of Radio frequency radiation accumulate over time and the risks are more pronounced after several years of exposure. The effects are not observed in the initial years of exposure as the body has certain defence mechanisms and the pressure is on the stress proteins of the body, namely the heat shock proteins (HSPs).

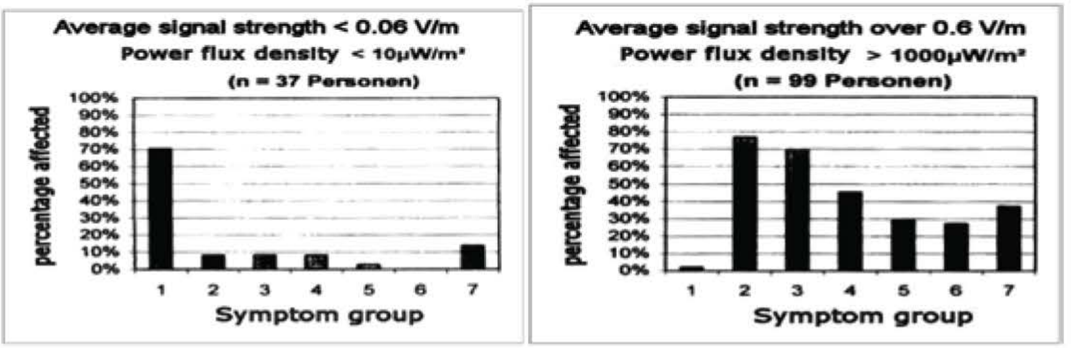

Figure 6: Signal strength over o.o6V/m of affects versus public domain

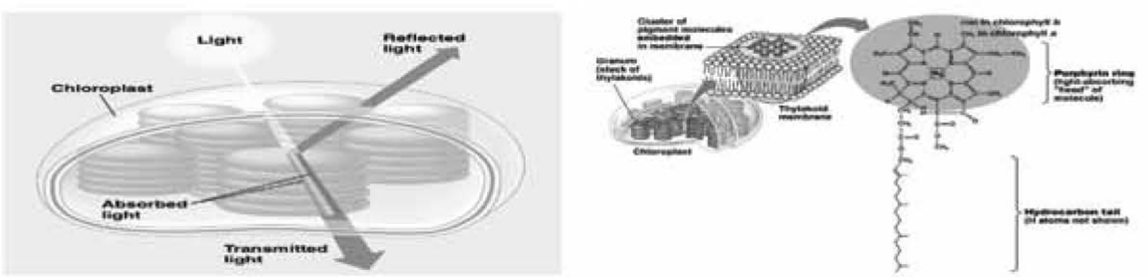

Figure 7: Molecules resonates in fluctuating EMR

If the stress goes on for too long, there is a reduced response, and the cells are less protected against the damage. This is why prolonged or chronic exposures may be quite harmful, even at very low intensities. Approximately 70 percent of the Earth's land surface is covered with vegetation. Furthermore, vegetation is one of the most important components of ecosystems. Knowledge about variations in vegetation species and community distribution patterns, alterations in vegetation phonological (growth) cycles, and modifications in the plant physiology and morphology provide valuable insight into the climatic, edaphic, geologic and physiographic characteristics and area. Scientists have devoted a significant amount of effort to develop sensors and visual and digital image processing algorithms to extract important vegetation biophysical information from remotely sensed data. The impact of different types of vegetation, from grassy to forested types, is one of the main problems to be discussed when conducting remote sensing of the land surface. There are two types of interest arising in this area of remote sensing. The first one consists in revealing the screening effect of vegetative cover on the remote sensing of a land surface itself and developing technologies by taking this effect into consideration when assessing the land surface condition. The second one consists of developing technologies of remote sensing application for assessing the properties of vegetative cover. In both cases the attenuation of EM waves and its relation to biometrical features of vegetation is of great importance. Prevalence of mobile radio systems requires studies of spectral characteristics of electromagnetic wave attenuation by vegetative media in wide frequency range (Figure 7). It is necessary to assess the influence of vegetation on the quality of radio communication, especially for radio communication in forested terrains. Studies show definitive clues that cell phone/tower radiation can choke seeds, inhibit germination and root growth, thereby affecting the overall growth of agricultural crops and plants. Trees located inside the main lobe (beam), have much lower fruit yield, have dried tops, show slow growth and high susceptibility to illnesses and plagues. Also, electromagnetic radiation generates heat, which may kill micro-organisms present in the soil near it. This in turn harms those organisms which feed on them and disturbs the ecological cycle. Vegetation NDVI typically ranges from 0.1 up to 0.6, with higher values associated with greater density and greenness of the plant canopy. NDVI values for soil and rock values are close to zero while the differential for water bodies such as rivers and dams have the opposite trend to vegetation and the index is negative. The information regarding the vegetation density can be of great help to identify and declare each morphology terrain type. In order to get these in formations, NDVI approach has been used, which is highly correlated with vegetation parameter such as green leaf, biomass, leaf area and is indicator of photosynthetic activity and hence is of considerable value for vegetation discrimination and monitoring. NDVI values ranges between -1 to +1 and except vegetation, other features show either negative or zero NDVI values.. In fact, military applications utilize this capability in trees for low-flying weapon systems. In an observational study, it was found that the output of most fruit-bearing trees reduced drastically from 100% to, 5% after 2.5 years of cell tower installation in a farm facing four cell towers in Karkala taluk (Figure 8). The most general phenomenological interpretation of high frequency biological effects assumes that RF or MW photon absorption is triggering a cascade of complex synergic cellular processes that can result in molecular damages leading either to DNA fragmentation or to free radical production. Or, free radicals as very reactive chemical species may interfere with various molecular processes involved in the growth of photosynthetic plants; this could be also the case regarding the changes evidenced in the frame of our experiment. 10 % of total towers in Udupi district (345) towers was classified in to high, medium and low radiation (more than two providers, two providers and single provider) and 3500 households (100 from each tower area) was selected based on population and households having livestock as per census 2011 in urban , semi urban and rural areas of Udupi District and impacts observed. Using information derived from NDVI, the study area is broadly classified into five categories among which the higher values show agricultural region while the most of the forest area fall under moderate value and lowest value reflect no vegetation, and most of them are fallow or waste land. Tops of trees tend to dry up when they directly face the cell tower antennas and also have a gloomy and unhealthy appearance, possible growth delays, and a higher tendency to contract plagues and illnesses. It is observed that trees, algae, and other vegetation may also be affected by RF-EMF. Some studies have found both growth stimulation and dieback. The browning of tree tops is often observed near cell towers, especially when water is near their root base. NDVI map of Udupi district derived from satellite imagery for vegetation studies as shown in figure 9.

Figure 8: Telecom towers are installed nearby forest observed loss of greenness

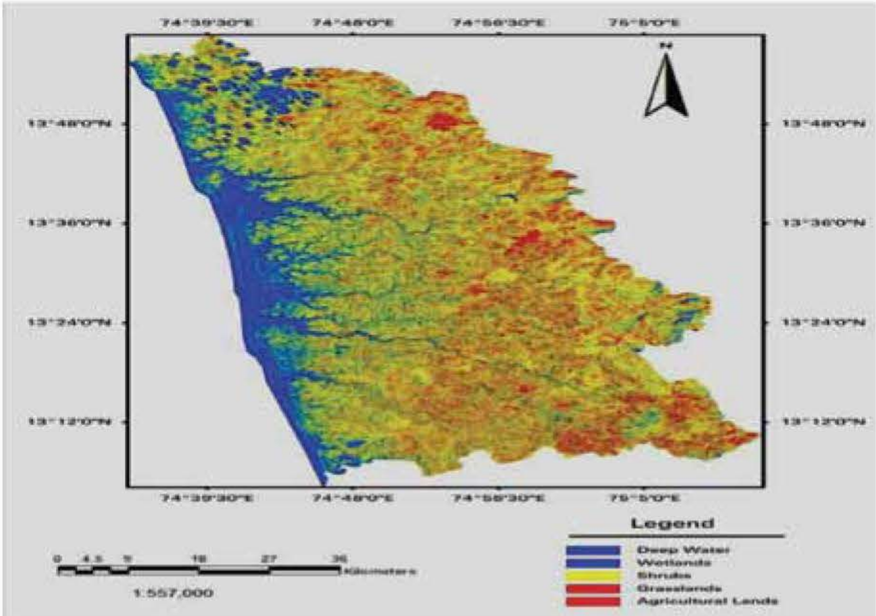

Figure 9: NDVI map of Udupi for the vegetation impact studies

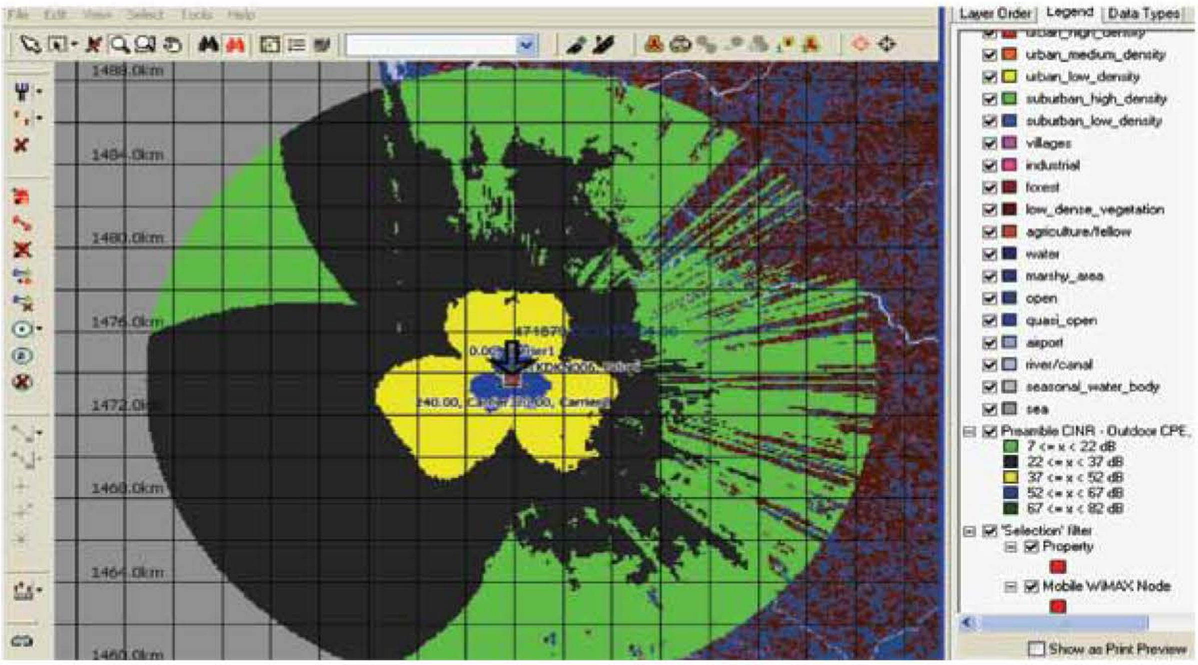

Figure 10: Integration of signal strength and LU/LC status thereby measuring power density of the EMR Tower on the terrain

This research work attempts to model the localized environmental features and then use them to tune the propagation model for optimal predictions for measuring signal strengths. Propagation models have traditionally focused on predicting the received signal strength at a given distance from the transmitter, as well as the variability of the signal strength in a close spatial proximity to a particular location (Naveenchandra et al., 2011). Radio transmission in a mobile communication system often takes place over irregular terrain. The terrain profile of a particular area needs to be taken into account for estimating the path loss. The terrain profile may vary from a simple curved earth profile to a highly curved mountainous profile. The GIS mapping of the Base Trans receiver station was prepared using satellite data and GIS software so that accurate signal strength and coverage estimation calculated which helps in measuring power density over the study area without the help of survey externally as shown in figure 10.

5. Conclusions

India is one of the fastest growing mobile telephony industries in the world. It is estimated that by 2013, 1 billion plus people will be having cell phone connection in India. With the growth of cell phone subscriber, it has also lead to growth of infrastructure in the form of mobile phone towers. Today, in absence of any policy on infrastructure development and location of cell phone towers, large number of mobile phone towers are being installed in a haphazard manner across urban and sub urban habitats in India. Well-designed long-term impact assessment studies would be required to monitor the impact of ever-increasing intensities of EMRs on our biological environment. The locations of Cell phone towers and other EMF radiating towers along with their Frequencies should be made available on public domain. This can be at city/ district/ village level. Location wise GIS mapping of all cell phone towers are to be done by Department of Telecom. Awareness drive with high level of visibility in all forms of media and regional languages should be undertaken by the Government to make people aware about various norms in regard to cell phone towers and dangers from EMR.

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