Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **3(8),** 11-17, August **(2014)** *Res. J. Engineering Sci.*

Electromagnetic Radiation Compatibility Survey and Safety Analysis around Mobile Base Transceiver Stations: Case Studies around Kathmandu Valley

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Available online at: www.isca.in, www.isca.me
Received 1st August 2014, revised 10th August 2014, accepted 25th August 2014

Abstract

The rapid growth of global mobile communication networking raises the concerns of electromagnetic radiation (EMR) hazards to the general public. In Nepal's scenario, this issue is more serious due to haphazard and unplanned installation of different kinds of antennas and base transceiver station (BTS) mostly on the rooftops of buildings, and lack of any extensive studies. This study hence surveys and analysis the electromagnetic compatibility to identify whether the level of radiation from those BTS are hazardous to human health through numerical analysis and some typical case studies around some sample area of Kathmandu Valley of Nepal. The study first identifies the problems related to the health hazards due the EMR. Limiting exposures to harmful EMR are then studied in both theoretical and observational approaches. For the theoretical approach, three numerical models viz., far-field, cylindrical and non-vanishing models are used to find exclusion zones around the BTS of a global system of mobile communication (GSM) network and the exclusion zones are evaluated with the some international standards, namely the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and American National Standard Institute (ANSI, 1982) standard. Simulations with the typical GSM parameters reveals a limiting distance for the exclusion zones around the the radiating near fields closer to the BTS where the observations around three sampled base stations viz., Pulchowk, Dhapakhel and Chabahil areas resemble the trend of the simulated values revealing the exclusion zones nearby the BTS where the public exposure level is above the prescribed threshold value of the ICNRIP that predicts the possible health hazard if entered. The mean value of power density around those sampled domains however is found to be about 10% below of ICNIRP safety limits. In another analysis, spectrums of the radiation due to other RF sources like local TV, FM and mobile transmitters are studied and found that the mean radiation levels are quite below the ANSI, 1982 standard. These case studies can be considered as the representative cases of current scenario. Extension of research like ours more extensively in a national dimension may help one to formulate national EMR standard, policy and guidelines, which should be the urgent needs for the country's environmental and public safeties.

Keywords: Electromagnetic radiation (EMR), base transceiver station (BTS), power density, EMR fields, EMR exposures and safety standards.

Introduction

During the last decade we all have witnessed the boosted evolution of modern communication systems of mobile broadcasting and wireless networking at radio frequency (RF) and microwaves bands. Increased use of cellular mobile communication led to the installation of Base Transceiver Station (BTS) antennas even as much close to public houses and schools, somewhere even on their rooftop, and in the vicinity of a densely populated area. The Electromagnetic Radiation (EMR) from such BTS raises question of possible adverse health effects to the public exposures[1,2]. It is therefore necessary to surveys and analysis the electromagnetic compatibility to identify whether the level of radiation from those BTS are hazardous to human health from the point of view non-ionizing thermal radiation. The EMR levels and the public exposures to those RF fields should comply with local or international RF safety standards and regulations[1-7].

In Nepal's scenario this issue is more serious due to haphazard and unplanned installation of different kinds of antennas and BTS scattered mostly on the rooftops of the public buildings. The rapid growth and thick concentration of BTS and their unplanned installations have not only raised concerns and questions regarding health issues but also the fact of degrading Grade of Service (GoS) since the service providers concurrently install the BTS (as depicted in Figure-1 for two major telecommunication service providers i.e., Nepal Telecom Corporation (NTC) and Ncell, for example) wherever they feel comfortable rather than complying with the cellular design.

Due to the bioelectrical nature of human beings, EMR interacts with biological processes in the human body casing health hazards. Studies so far claim that the EMR has link with various health problems such as effects 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 and so on[3-7]. Therefore there exist several national and international standards, regulations and recommendations for RF energy exposure, separate for the general public and the occupational exposures[1-7]. In the case of Nepal, such studies so far remain yet a matter of researches with extensive case studies. In this research we have conducted the a survey on EMR compatibility to identify whether the EMR levels of some of the mobile communication BTS represents hazards for human health through some case studies. The research is focused mainly on the measuring of EMR around some sample base stations of Kathmandu valley, and to compare them with the international standards so that such studies help formulate/review national EMR standard, policy and guidelines. The research methodology is described and the applied EMR field models[8-11] for simulation are reviewed in Chapter 2 while Chapter 3 briefly introduces the instrumentations for field observation. Chapters 4 and 5 present the results and discussions, and conclusion.

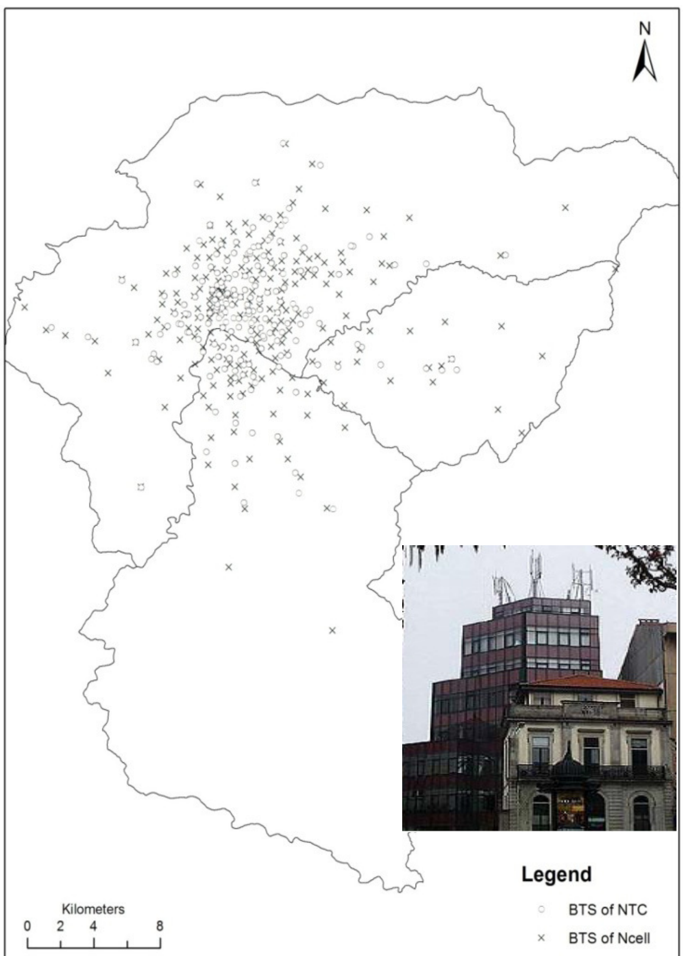

Figure-1
BTS locations of Nepal Telecom Corporation (NTC) and Ncell Nepal in Kathmandu Valley. Shown in the inset a photograph of concurrently installed BTS antennas of different service providers

Methodology

The main focus of the research is to identify the limiting exposures to harmful EMR levels through both theoretical and observational approaches. For the theoretical approach, three numerical models viz., far-field, cylindrical and non-vanishing models are used to find exclusion zones around the BTS of Global System of Mobiles (GSM), and the exclusion zones[7-11] are evaluated with the international standards, namely that of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) using threshold power densities and the Equivalent Isotropic Radiated Power (EIRP) calculations[1].

The far field model calculates the power density S at a distance R from the BTS as

$$S = \frac{PG}{4\pi R^2} \quad (1)$$

where P is the power and G is the antenna gain. The term $4\pi R^2$ represents the area of a sphere illuminated by the radiation from an antenna at a distance of R where the antenna is assumed to be a point source. This model is valid only for the far field region defined by a distance greater than $2D^2/\lambda$, where D is the maximum dimension of the antenna and λ is the operating wavelength of the BTS. For a typical GSM BTS with the antenna dimension of 0.5 m and the operating frequency of 900 MHz, the far field distance is around 20 m and therefore this model is valid only beyond this distance. Minimum threshold value of the power density defines the limiting distance, which constitutes the exclusion zone where the power density is higher than the threshold value and there may exist risk of health hazard.

At the distance less than $2D^2/\lambda$ from the antenna point, which is very close to the BTS, the BTS cannot be assumed to be a point source and the illuminated area cannot be considered to be spherical. For a vertical collinear dipole antenna commonly used in cellular communication, this model considers a cylindrical area close to the antenna for estimating the power density. With this model, spatially averaged power density parallel to the antenna can be estimated by dividing the net antenna input power by the surface area of an imaginary cylinder surrounding the length of the radiating antenna[6]. Then, the average value of the power density near the antenna array can be calculated as

$$\mathrm{S} = \frac{\mathrm{P}}{2\pi \mathrm{LR}} \quad (2)$$

where L is the length of the antenna length. For the GSM sector type antenna, the power density is given by

$$S = \frac{180.P}{\theta_{BW}\,\pi LR} \quad (3)$$

where θ_{BW} is the azimuthal 3-dB beam width in degrees. As the distance from the antenna increases, this model over predicts the exposure level due to the fact that the percentage of the total power radiated through the lateral surface of the cylinder decreases.

For the far field model, as R becomes smaller the spherical area of illumination becomes smaller and tends to be zero as R approaches zero, but in reality this behavior is not true since the physical dimension of the antenna is finite and non-vanishing. Such error can be eliminated by the following formulation.

$$S = \frac{PG}{4\pi(R^2 + \frac{G}{4\pi}wh)} \quad (4)$$

where h and w are the height and width of the antenna respectively. And, the model is called Non-Vanishing model.
The study is then focused on the measuring of EMR around some typical BTSs over Kathmandu valley viz. Pulchowk, Dhapakhel and Chabahil. The Pulchowk area is chosen because there are a numbers of RF sources and large public exposures, while the Dhapakhel area represents a rural site where the cell sizes are quite larger with larger power transmission. The Chabahil area is a typical one with congested residential buildings with large number of BTS placed just in front.

Instrumentations: RF field strength probe along with a Global Position System (GPS) receiver are used to record the EMR levels along with the geo-location. The field strength meter has an isotropic antenna and works in the frequency range of 50 MHz - 3.5GHz. A GPS receiver, GARMIN eTrex module is used to determine the geographical position. This receiver has higher accuracy as it receives signal from both GPS and Global Navigational Satellite System (GLONASS). Also, a broadband (1 KHz – 26.5 GHz) spectrum analyzer of Hewlett Packard, Model No. HP 8562A, is used to inter-calibrate the measurements of the field strength meter, as compared in figure-2. As depicted in the figure, where each point represents an averaging of 0.1 hour averaged data, the measurements of both equipments agree quite well. Additionally, the spectrum analyzer is used to analyze the EMR spectrums of all available local Frequency Modulated (FM) radio, Television (TV), GSM and Code Division Multiple Access (CDMA) transmitters.

Results and Discussion

Installation guidelines of BTS antenna and evaluation procedures of the EMR exposure levels are generally common for every telecommunication practices[12], which should comply with ITU-T Recommendations K.52 (2004) - Guidance on complying with limits for human exposure to electromagnetic fields, and K.61 (2003) - Guidance to measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations. Accordingly, this study also considers similar procedure to evaluation the EMR levels of the mobile BTS as defined in the previous chapter, where the RF fields (namely, reactive field, radiating near field and radiating far field) and the power density are predicted first theoretically and the field measurements are then evaluated.

Figure 3 compares the simulation results obtained from all three models explained in the previous section. It is obvious that different types of antennas are used in cellular communication system depending upon the types of cells. Our concerned BTS are mainly the rooftop antennas and antennas on the building walls in the urban environment where people and workers can have easy access to the direct beam of the antenna. The simulation results shown in figure-3 consider such BTS antenna that operates at GSM 900 MHz band. An operating power of 6 W, maximum antenna dimension of 0.5 m with 1.71 m height, antenna gain of 16.5 dBi and a beam width of 6 degrees are considered for the simulations. It should be noted that the power assigned to given base station is determined from its coverage, cell size and capacity requirements. Every operator desires to use the licensed spectrum as efficiently as possible with minimum power. Simulations with different power class of different cell sizes[6] are also considered but not shown here.

The results from the simulation shows that at a distance far away from the BTS the cylindrical model overestimates the power density whereas at a closer distance to the BTS both the far field and non vanishing models over predicts the exposure level. At a distance very close to the antenna, only the non vanishing model gives a finite power density value as expected. For the antenna height of 1.71 m and frequency of 900 MHz, the far field distance is around 20 m. The horizontal solid line in the figure represents the maximum safety threshold value of the power density, i.e., of 0.45 mW/cm^2 given by ICNIRP[1]. Figure 3 also compares those three models with the measurements around Pulchowk domain, as shown by figure-4 as a power density map where the size of the circle increases with the increase in power density varying from 0.01 to 1 mW/cm. The observations generally follow the simulated data resembling the real scenario that is the power density decreases with the increasing distance from the BTS site.

For practical purposes, existence of three zones is commonly described viz. reactive field ($R < \lambda/2\pi$, radiating near field ($\lambda/2\pi < R < 2D^2/\lambda$) and radiating far field, illustrated as in figure-3. As revealed in Figure-3, there exists the limiting distance for the exclusion zones. For the far field model, for example, the limiting zones are below 1.5 m and 12 m (falling in the lower portions of the radiating near fields) for the BTS operating with the power of 6 W and 100 W, respectively. All observations of this study well agree with these values. These limiting distances from the BTS represent the exclusion zones where the public exposure level is above the prescribed threshold value of the ICNRIP that predicts the possible health hazard if entered.

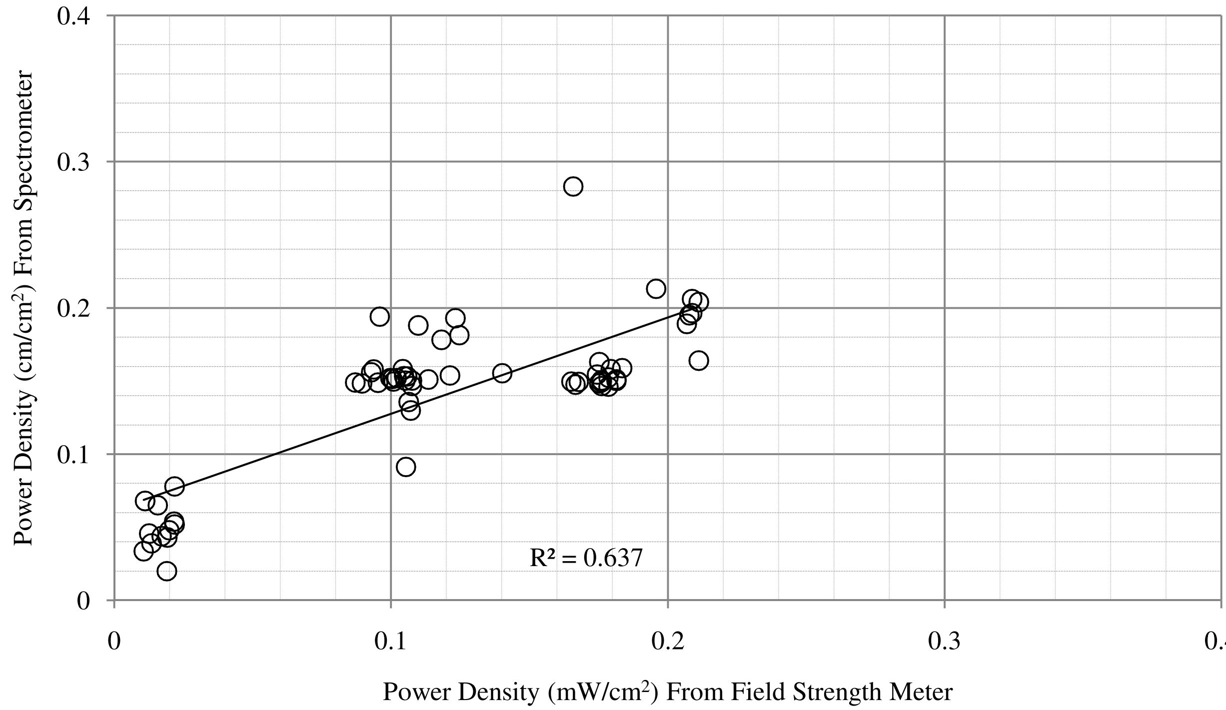

Figure-2
Scatter plot of the measured power density by the field strength meter against the spectrometer

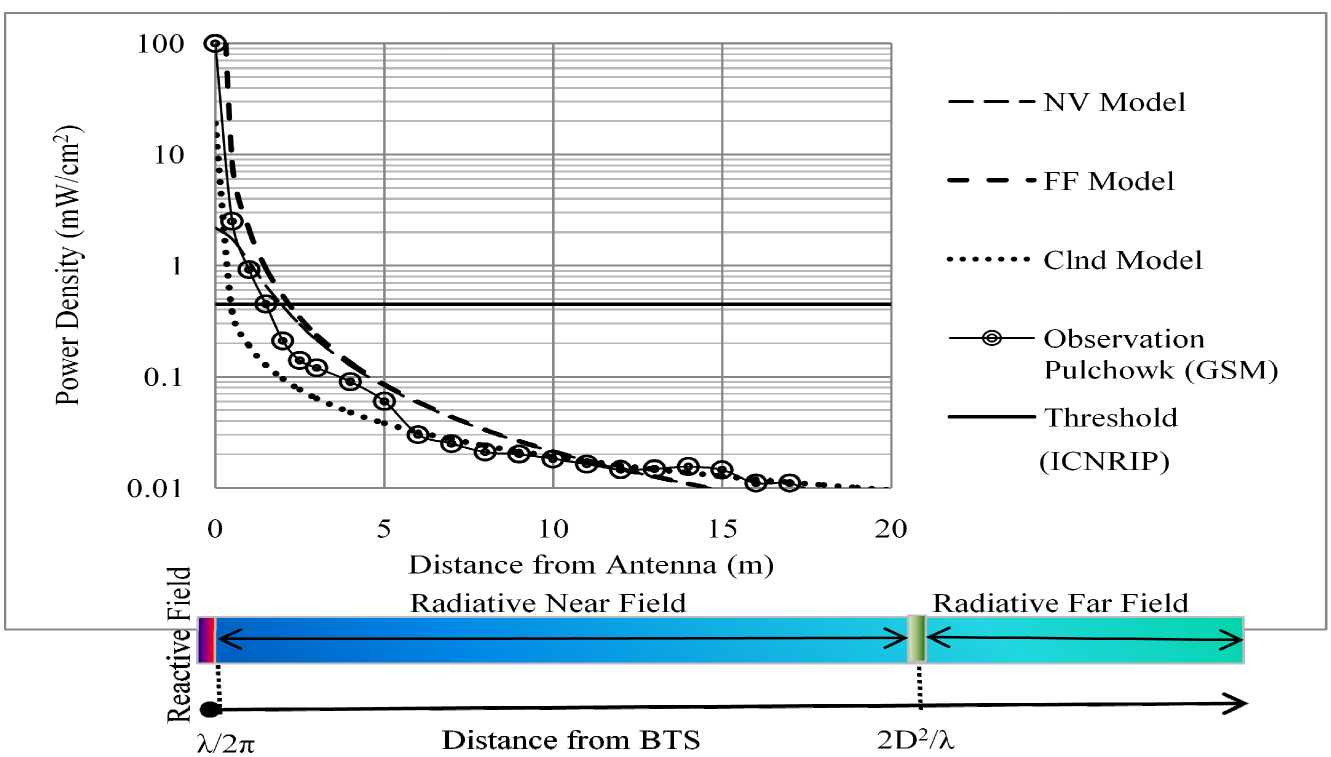

Figure-3
Comparison of the observed EMR field intensity with that from simulations using three different models and ICNRIP standard

Despite analyzing the EMR exposure levels of the GSM BTS, the study also considers a survey of EMR exposure levels other RF transmitters. A spectrum analyzer is used to analyze the EMR spectrums of available RF sources from local Frequency Modulated (FM) radios, UHF Television (TV) channels, and Code Division Multiple Access (CDMA) transmitters at an arbitrarily selected place (namely, at RF and Microwave Research Lab (27°40'56.40"N and 85°19'6.35"E) of Institute of Engineering, Pulchowk Campus, Tribhuvan University, Nepal. Figure 4 displays the averaged observation data collected for about 270 minutes (from 10:50 to 15:20 LT). Along with those RF sources the figure includes those EMR readings of Dhapakhel, Pulchowk and Chabahil BTSs in terms of averaged power density. For the comparison, the figure includes a safety threshold line established by IEEE - C.1992 standard. As revealed in the figure, the average radiation levels around our study area due to mobile BTS as well as other RF broadcastings are well below the internationally accepted standard. It means that the exposure levels are beyond the limiting distances meaning to far from the exclusion zones.'

Figure-4

Observed power density map around Pulchowk domain. Size of the circle increases with the increase in power density varying from 0.01 to 1 mW/cm^2

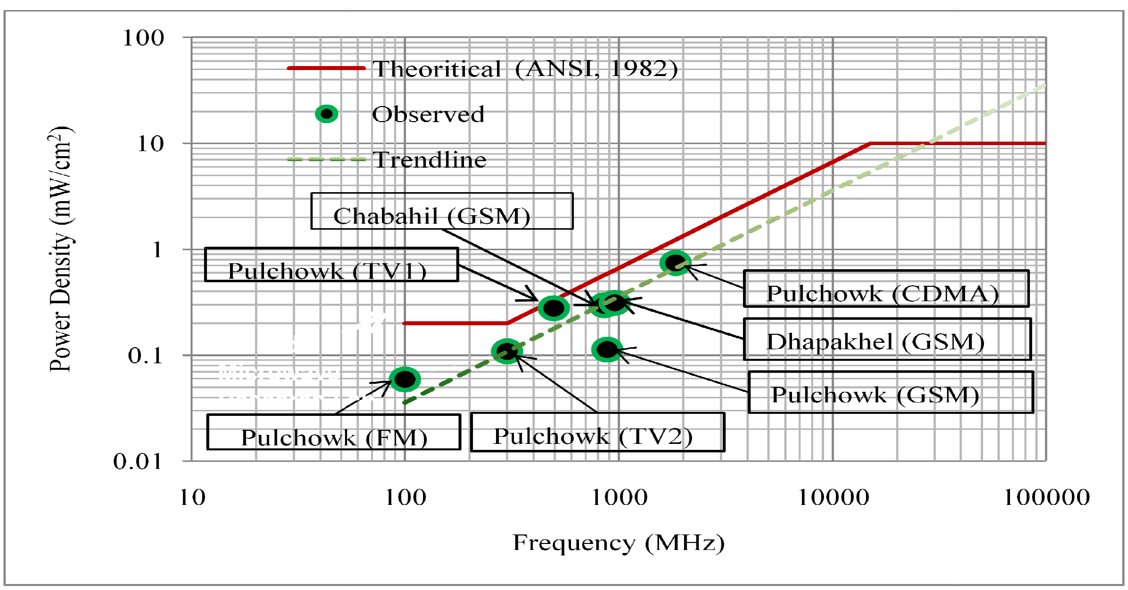

Figure-5

Measured average power density levels of different RF sources at RF and Microwave Research Lab, Department of Electronics and Computer Engineering, Institute of Engineering, Pulchowk Campus (27°40'56.40"N and 85°19'6.35"E), and their comparison with ANSI,1982 standard

Conclusion

The rapid growth of global mobile communication networking raises the concerns of EMR hazards to the general public. In Nepal's scenario, this issue is more serious due to haphazard and unplanned installation of different kinds of antennas and BTS mostly on the rooftops of buildings, and lack of strict guidelines to which the service providers should comply with. These issues still remain beyond the knowledge of most of the general public. These issues still remain the matter of extensive studies. This study hence surveys and analysis the electromagnetic compatibility to identify whether the level of radiation from those BTS are hazardous to human health through numerical analysis and some typical case studies around some sample area of Kathmandu Valley of Nepal. The study first identifies the problems related to the health hazards due the EMR. Limiting exposures to harmful EMR are then studied in both theoretical and observational approaches. For the theoretical approach, three numerical models viz., far-field, cylindrical and non-vanishing models are used to find exclusion zones around the BTS of a GSM network and the exclusion zones are evaluated with the standards of the ICNIRP standard[1]. The simulation parameters considered in this study are the BTS antenna operating at 900 MHz band with the power of 6 W and 100 W, maximum antenna size of 0.5 m with 1.71 m height, antenna gain of 16.5 dBi and a beam width of 6 degrees, which are typical for GSM communication. From the result, it is found that for the far field model, for example, the limiting distance for the exclusion zones exist below about 1.5 m and 12 m (falling in the lower portions of the radiating near fields) for the BTS operating with the power of 6 W and 100 W, respectively.

The research focus is then given on the measuring of EMR around three sampled base stations of Kathmandu valley viz., Pulchowk, Dhapakhel and Chabahil areas. The Pulchowk area is chosen because there are a numbers of RF sources and a large flow of people, while the Dhapakhel area represents a rural site where the cell sizes are quite larger with larger power transmission. The Chabahil area is a typical one with congested residential buildings with large number of BTS placed just in front. RF field strength probe along with a GPS receiver were used to find the geo-location and the record the EMR levels. All observations of this study well resemble the trend of the simulated values revealing the exclusion zones nearby the BTS where the public exposure level is above the prescribed threshold value of the ICNRIP that predicts the possible health hazard if entered. The mean value of power density around those sampled domains however is found to be about 10% below of ICNIRP safety limits. The average reading of the power density is found to be the highest at the Dhapakhel (~ 0.31 mW/cm^2) which is followed by the Chabahil area (~ 0.23 mW/cm^2 and then the Pulchowk domain (~ 0.15 mW/m^2). To identify whether the signals here have either destructive or instructive interferences a spectrum analysis of the radiation due to the base stations together with the other sources like local TV, FM and CDMA transmitters are performed and quantify the EMR levels of each local radio transmitters over a frequency band of 50 MHz to 3 GHz; and it is found that the mean radiation levels so far are quite below the ANSI, 1982 standard[2].

Note that to date since we do not have any guidelines for test procedure we have followed most relevant international standard for this study. Also, the study is limited only to three sample base stations. So one cannot make conclusion of the exposure levels of all the BTS based on these results. A thorough research for each site is necessary. Extension of research like ours more extensively in a national dimension may help one to formulate national EMR standard, policy and guidelines, which should be the urgent needs for the country's environmental and public safeties.

Acknowledgements

The research is supported by University Grant Commission, Nepal in a part.

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