10. Research and Analysis on Floor Exposure due to Electromagnetic Radiation from Mobile Towers in Residential Areas of Kolhapur

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ABSTRACT

The public concern about the possible adverse health effects of the human exposure to the electromagnetic radiation of cellular base station antennas has incremented in recent years. The investigation aimed to provide information for the variation of electromagnetic field exposure (power density and Electric field) radiated from antenna in the residential area in Kolhapur city. The paper summarizes the electromagnetic field (EMF) levels on different floors of a building due to electromagnetic radiation from cellular mobile base stations (CMBS). Electromagnetic field exposure was measured in culled buildings in Kolhapur area. EMF exposure was measured at different floors such as ground floor, first floor, terrace etc. of a building with the help of RF exposure meter KM 195. The measured floor exposure is then analyzed. The maximum value of power density recorded was 37511 µw/ m^2 and minimum 3.4 µw/ m^2. The measured values of EMF exposure were well below the ICNIRP reference levels.

Keywords— *cellular mobile base stations, electromagnetic field exposure, human exposure, power density, floor exposure, reference level, urban environment.*

INTRODUCTION

Cellular mobile towers are installed in an urban environment, consisting of a number of antennas on it. Even though there is a limit on a number of antennas on a single mobile tower, it is not followed by network operators. The antenna is an electromagnetic device which works on electromagnetic (EM) waves. It transmits and receives EM waves. An antenna has various important parameters such as directive gain, beam width, radiation pattern, operating frequency, and polarization. Antennas are classified as directional, sector and omnidirectional. The gain of the antenna magnifies the incoming EM signal and then radiates the power in the desired direction. Directional antennas only direct the signal in the desired direction. Whereas Omnidirectional antennas radiate power equally in all direction. Antenna gain depends on antenna radiation angles. The sector of an antenna is the angle in a horizontal plane where the power flux density is at least -3 dB with respect to the maximum power flux density [1][2][3][4]. The sector antennas having angle 1200 are widely used in GSM base stations. Such three antennas make a total angle of 3600 and cover the entire surrounding area. Sector antennas gain varies from 12 to 18dBi. Its length is from 1.5 to 2.5 meters. Omnidirectional antennas are used in highly populated areas. GSM uses vertical polarization hence all antennas adopt the vertical polarization [5][6].

Down tilting of the antenna is necessary for GSM [18][20]. Some antennas were down tilted with some angle. Such antennas were mounted with 900 with respect to horizontal plane. Such antennas are mechanically down tilted at the required angle so that all radiated energy goes to a coverage area of the required radius. Sector antennas with Horizontal 60, 90, 120, 180 and vertical 3…to 100 respectively are widely used [11].

The electromagnetic field generated by the base stations of the cellular mobile communication system is highly dependent on mechanical and electrical down tilting angles of antennas [6]. Actual values of the EM radiation should match with design values in the radiation pattern [22-25]. Exposure to RF field from a cell phone is short term but exposure to RF field emitted from cellular base stations is of long duration. Nowadays these base stations were mounted in densely populated areas in the urban environment. Actually according to norms antenna tower must be away from the residential area, more correctly it should be away from the residential area by 300

meters, but mobile tower operators, different network operators do not obey this. Thus people living in the building/apartments are exposed to EMF radiation. Hence people are asking questions about EMF exposure. Kolhapur is one of the well-developed city in recent years. So tall buildings, apartments and commercial business towers were built-up in the city. Thus quantification of power density and electric field in such tall building and apartments will be useful in determining the electromagnetic field (EMF) exposure levels of the general public in each floor of the building/apartments and this, in turn, determines whether the exposure levels are within the maximum permissible limits or not[12][13].

MATERIALS AND METHODS

A. MEASUREMENT PROCEDURE

Here the main aim is to measure electronic radiation in building/apartment, the distance between the building and mobile tower, the number of antennas on each tower etc. and then data is analyzed. Initially, electromagnetic field exposure is measured in terms of power density and electric field. Their units are μw/m2 and mv/m respectively. The device used to measure the EM radiation on different floors of the building is KM 195 three axes RF field strength meter. The KM 195 is capable of measuring the RF field exposure from base stations. The meter is calibrated precisely over the frequency range of 50MHz ~ 3.5GHz. There are different sources of electromagnetic field such as TV transmitters, Radio broadcast transmitters, and cellular mobile towers etc. Due to these transmitters, electromagnetic field exposure increases in surrounding areas and people get exposed to it. It measures electric as well as the magnetic field. KM 195 three axis exposure meter measures this EM radiation. The meter having units mV/m, V/m, mA/m, mA/m, mW/m2, mW/m2, mW/cm2 etc.

B. SITE SELECTION

Before measurement of EM exposure, we culled the measurement sites i.e. identified buildings at different locations in Kolhapur city [15]. Average floors on the identified buildings are around five. Exposure is quantified indoor and outdoor on each floor of a building.

Mobile tower is mounted on some of the buildings/apartments. The height of the antenna is around 5 to 10 meters when is mounted on the rooftop of buildings. Most of the buildings/apartments are selected in such a way that in front of that site there will be a mobile tower. Exposure was measured on each floor, inside the room and also on building a terrace. It is measured in μw/m2 and V/m. Total 5 buildings/apartments are selected for the floor exposure measurement. Different building sites selected for the floor exposure measurement and their average exposure are listed in Table 10-1.

Table 10-1 LIST OF BUILDING SITES AND AVERAGE EMF EXPOSURE

Building Location	**Table Column Head**	
	Average Power density μw/ m2	***Average Electric field v/m***
Hanuman Nagar	1902	666.09
I.T.I Kolhapur	3330	697.80
Devkar Panand	91.76	117.14
Hockey stadium	67.30	250.03
Ambai Tank	8192.86	2430.08

C. SITES SELECTED

First building site selected is near Hanuman Nagar consisting of six floors. Measured EMF exposure shows variation in exposure at each floor due to number of reasons such as location of mobile base station tower from building, at which side of the building antenna tower is located, what is the antenna tilt angle etc. in case of site 1 building highest exposure is at floor six, medium is on the first floor and low at remaining floors. This is shown in figure 1.0. Average power density and electric field at floor six is 1823 mv/m and 8830 µw/m2.

The second building site is close to I.T.I. Kolhapur. It also consists of six floors. Here floor 3 is more exposed and the exposure level is 5686 µw/m2 .lowest exposure is on the last floor which is 1075 µw/m2. On an average mobile tower, antenna covers almost all floors except floor six.

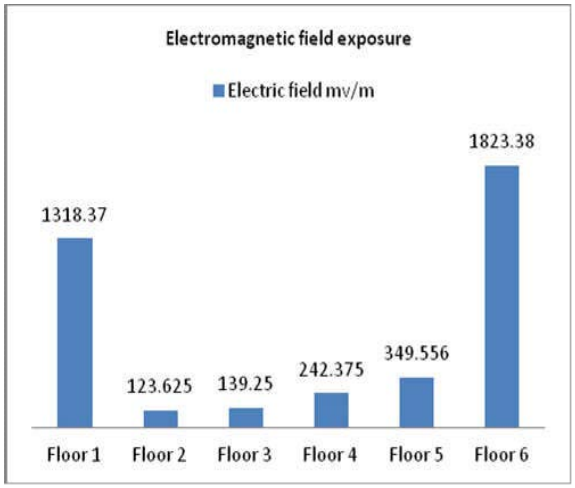

Figure 10-1 ELECTRIC FIELD INSIDE A 6-STOREY BUILDING AT THE MIDDLE OF THE ROOM.

The third building site is at the west side of Kolhapur i. e. Devkar Panand. 5 kilometers from a central place. Since the location of the mobile tower site is far from the building site exposure is less on the floors. Maximum exposure measured is 308.35 mv/m and the minimum is 26.71mv/m. The fourth site is at hockey stadium it is a 6 story building on which mobile tower antenna is mounted as shown in figure 2.0. More than 20 antennas are installed on the tower. More are used for voice and data communication and few for traffic transmission from one base station to another. Since the antenna is mounted on building itself, therefore, the exposure level found is less.

Figure 10-2 SIX STORY BUILDING SITE AT HOCKEY STADIUM.

The fifth site is Ambai tank near Rankala. The building consists of five floors. Highest power density is observed on floor 2 which is 88560 μw/m2 and the highest electric field is on the first floor which is measured as 12401 mv/m. The radiation standards accepted in some countries such as India is based on ICNIRP guidelines of 1998 for the safe power density of f/200, where frequency (f) is in MHz. Thus, for GSM-900 transmitting band (935-960 MHz), power density is 4.7W/ m2 and for GSM-1800 transmitting band (1810-1880 MHz), it is 9.2W/m2. Then 2010 DoT has reduced this level by 1/10th and revised the ICNIRP norms which are as shown in the following table.

Table 10-2 RADIATION NORMS.

Frequency	ICNIRP radiation norms	Revised DoT norms
900 MHz	4.5 w/m^2	0.45 w/m^2
1800 MHz	9.0 w/m^2	0.90 w/m^2
2100 MHz	10.5 w/m^2	1.05 w/m^2

Considering the ICNIRP guidelines, for instantaneous exposure to numerous frequency fields, the summation of all the radiation in particular surroundings must be taken into consideration. Thus, the addition of all the radiation from a mobile tower base station antennas serving two or more service providers' signal transmission must also be considered.

RESULTS AND DISCUSSION

The measurement results show that power density is more at the floor, where floor height and antenna height is the same and they are in the same line. Also, power density and electric flux were more in case of direct line of sight (LOS) buildings. According to the measurements, floor exposure was varying from ground floor to the top floor. Nature of graphics is changing it is not the same for all sites because the height and distance of transmitting base station are changing from the building/apartment under measurement. Measurement results showed that the antenna covers an area up to 20 meters height approximately floors from the ground to six are in coverage area and floors above six get less coverage. In short middle floors of a building get more EM exposure than others also it depends upon location and distance of the mobile tower from the building.

A. SITE 1 RESULTS

Site 1 is having six floors; this site is in Hanuman Nagar west side of Kolhapur district. The total number of antennas mounted is 19. Its height is around 100 feet. The distance between site 1 and mobile base station tower is 80 feet. Site 1 measured data is as shown in Table 10-3.

Table 10-3 AVERAGE EMF EXPOSURE AT SITE 1

No. of floors	Electromagnetic field exposure	
	Average Power density μw/ m2	Average Electric field v/m
Floor 1	**2224.5**	**1318.37**
Floor 2	**33.031**	**123.625**
Floor 3	**24.741**	**139.25**
Floor 4	**53.287**	**242.375**
Floor 5	**246.451**	**349.556**
Floor 6	**8830.38**	**1823.38**

From figure 10-1, it is seen that exposure was more at first and last floor. And goes on increasing from floor 2 to floor 6. This means that the antenna tilt is not adjusted properly. As exposure in maximum at floors 1 and 6 they are exposed more to the EMF. Average power density at floor 1 is 2224.5 µw/ m^2 and on floor 6 it is 8830.38 µw/ m^2. Power density at floor 6 is three times more than power density at floor 1.

B. SITE 2 RESULTS

Site two is also having six floors; this site is near to I.T.I. Kolhapur west side of Kolhapur district. Total number of antennas mounted is 22. Its height is around 80 feet. Distance between site 1 and mobile base station tower is 75 feet. Site 2 measured data is as shown in table 10-4.

Table 10-4 AVERAGE EMF EXPOSURE AT SITE 2.

No. of floors	Electromagnetic field exposure	
	Average Power density µw/ m2	***Average Electric field v/m***
Floor 1	4461.28	364.57
Floor 2	2867.42	34.92
Floor 3	5686.222	2459
Floor 4	3375.526	188.37
Floor 5	2515.33	871.1
Floor 6	1075.38	268.889

As compare to first site here distance between site and building / apartment is less, also antennas mounted on tower having direction towards the building site 2, antenna tilt angle is adjusted properly hence EMF exposure is more.

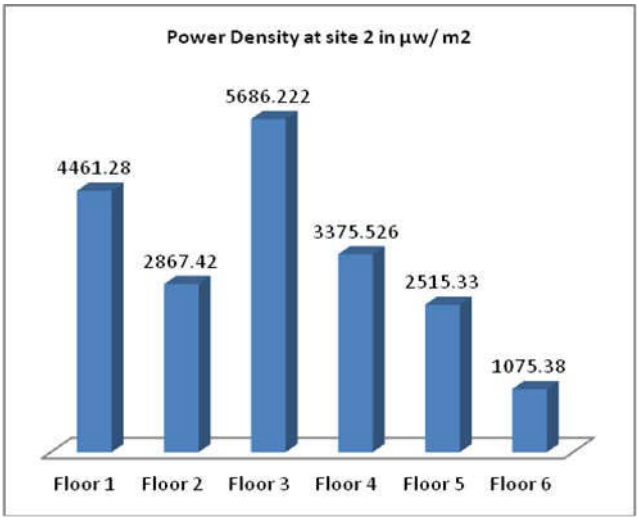

Figure 10-3 AVERAGE POWER DENSITY INSIDE A 6-STOREY BUILDING.

Figure 10-3 shows that floor 6 is having less EM exposure. Remaining floors get the power density level satisfactory. Power density is highest at floor 3. From figure, it can be concluded that floor 3 is in line with the transmitting antenna. In other words, the height of transmitting antenna and height of floor three is approximately same. Average EMF exposure for site 2 is 3330.19 µw/ m^2 and electric field is 697.80 mv/m.

Figure 10-4, shows that floors 2, 4 and 6 are having less electric field. Middle at floor 1 and 5. And high at floor 3. Here one can conclude that only floors 3 and 5 get the sufficient electric field exposure for remaining floors there is less EMF exposure. As electric field exposure is high at floor 3 therefore people living on this floor may face the problems of health effects due to excessive electric field.

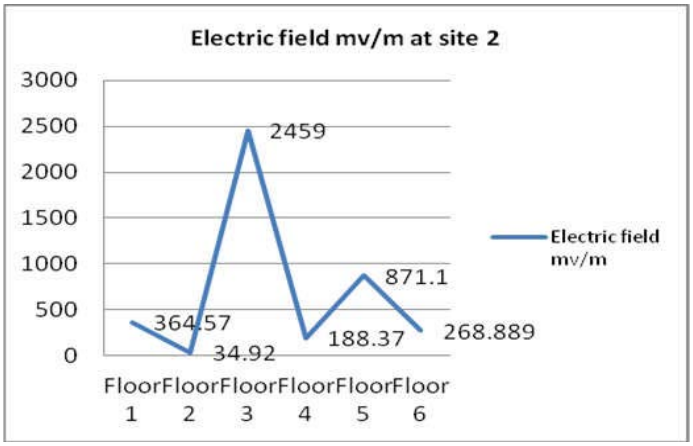

Figure 10-4 AVERAGE ELECTRIC FIELD AT A 6-STOREY BUILDING.

C. SITE 3 RESULTS

From figure 10-5 and 10-6, it is clear that the power density and electric field is high at floor six so they get more EMF exposure than other floors. Since site 3 is far away from building / apartment hence exposure, magnitude is less for both power density and electric field. As antenna tilt angle matches with floor six, therefore EMF exposure is more on this floor.

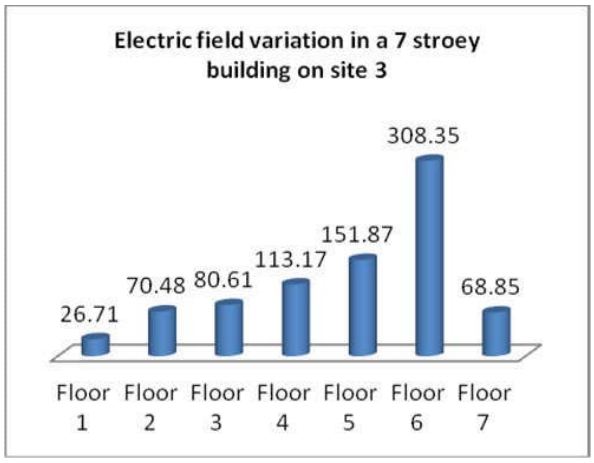

Figure 10-5 ELECTRIC FIELD INSIDE A 7-STOREY BUILDING AT DEVKAR PANAND

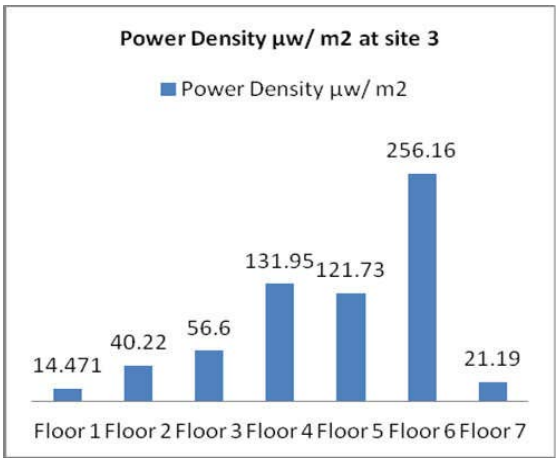

Figure 10-6 POWER DENSITIES INSIDE A 7-STOREY BUILDING AT THE MIDDLE OF THE ROOM.

Figure 10-7 shows electric field variation in a 7-storey building near hockey stadium. Here Electric field is maximum at terrace. In case of this site antenna tower is mounted on rooftop of a building.

After measurement of EMF exposure at all sites that is in all building / apartments it is found that people are complaining about the mobile tower, particularly in case of towers mounted on rooftop of the buildings. People are asking questions about the electromagnetic radiation from the antenna towers. Whether it is harmful or not? How to measure it? What should be its standard value? In addition, what to do if radiation is excessive? Etc.

D. OBSERVATIONS

- Electromagnetic field exposure from base station antenna towers is not same for all the floors in a building / apartment.
- Magnitude of electromagnetic field exposure is highly dependent on distance between mobile tower and building / apartment site, number of antennas on base station towers.
- Antenna tilt angle and its direction play an important role in electromagnetic field exposure on a particular floor.

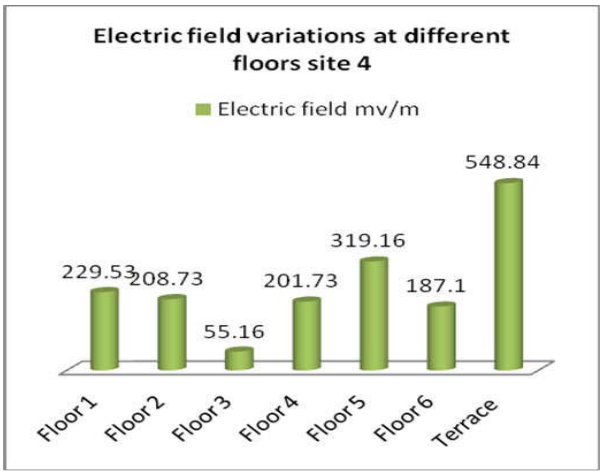

Figure 10-7 . ELECTRIC FIELD VARIATION IN A 7-STOREY BUILDING AT HOCKEY STADIUM

E. CONSOLIDATED FIGURES AND TABLES

Table 10-5 shows consolidated data of EMF exposure from all building / apartments sites.

Building / Apartment	**Consolidated Electromagnetic field exposure**				
	Average P.D. µw / m2	***Average E. field mv/m***	***No. of Antennas***	***Distance (feet)***	***Height (feet)***
Hanuman Nagar	1902	666.09	19	80	100
I.T.I. Kolhapur	3330	697.80	22	75	80
Devkar Panand	91.76	117.14	15	150	80
Hockey Stedium	67.30	250.03	17	0	125
Ambai Tank	8192.86	2430.08	24	50	100

As seen from the figure 6.0 in Ambai tank area EMF exposure measured were highest, medium at I.T.I Kolhapur and lower at Hanuman Nagar.

From figure 10-9 it is clear that percentage contribution of EMF exposure is more in case of Ambai tank and it is 60%. Followed by I.T.I site and Hanuman Nagar their contribution is 25 % and 14% respectively. Devkar Panand and hockey stadium sites are having lowest contribution in EMF exposure.

Measurements of the mobile base station antenna signals conducted from 10.00 AM to 5:00 PM local time in Kolhapur. The power radiated by base stations is extremely dependent on the number of subscribers making calls simultaneously. Therefore, the measured radiated power depends on local time, place, antenna direction, distance of measurement.

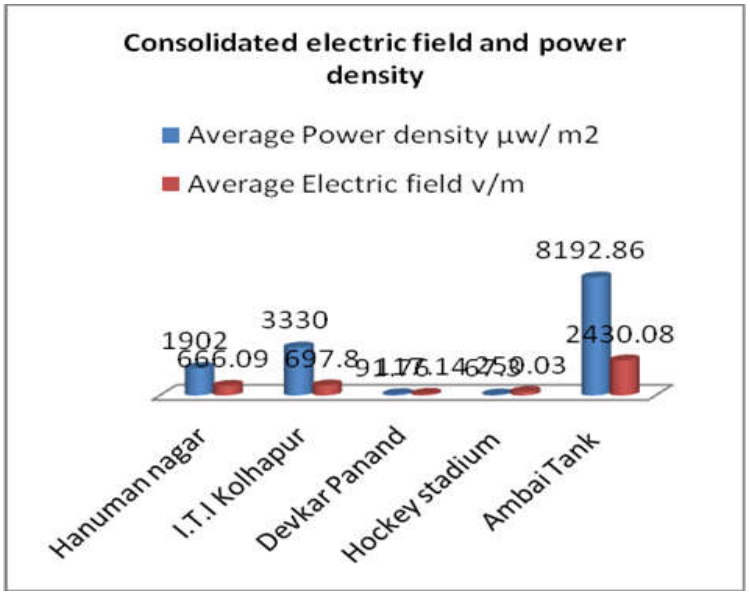

Figure 10-8 CONSOLIDATED ELECTRIC FIELD AND POWER DENSITY AT ALL SITES.

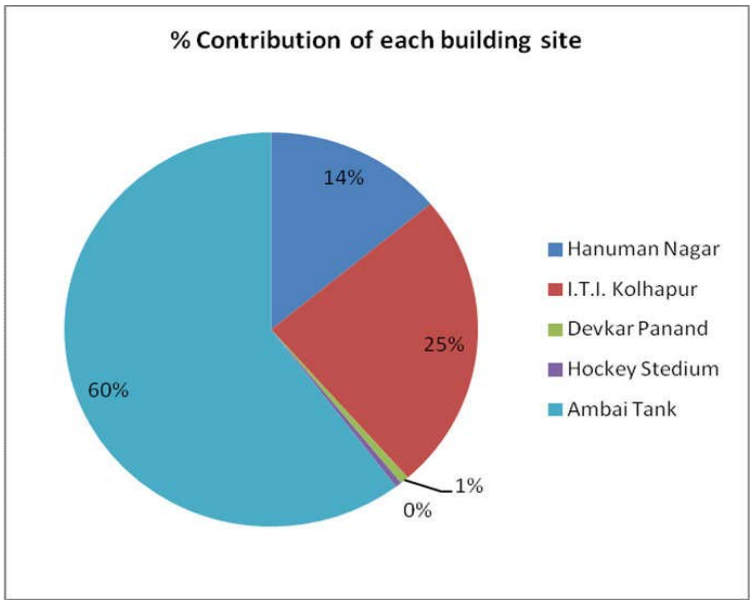

Figure 10-9 % Contribution of each building / apartment site

CONCLUSION

In this research work, measurements have been carried out at various places at distances about 100 feet away from the cell towers inside buildings / Apartments in Kolhapur. Total of 450 measurements has been taken at different buildings / Apartments sites in an urban environment. The results of this study show that average power density and electric field were 2582.23 µw/m2 and 804.02 mv/m respectively. This amount of power density is less than the standard reference level set by ICNIRP.

After analysis of measured EMF exposure at different buildings/apartments, it was concluded that EMF exposure at a particular floor depends upon the distance between mobile tower antenna and a building as well as the height of the mobile tower antenna.

If the height of a particular floor matches with mobile tower antenna height in that case EMF exposure was maximum at that particular floor. The maximum value of power density recorded was 37511 µw/ m2 which are higher than the standard reference level adopted by DoT that is 0.45 w/m2 and the minimum is 3.4 µw/ m2. The average power density and electric fields were 2582.23 µw/ m2 and 804.02 mv/m respectively, this value also exceeds the DoT reference level. All measured values of EMF exposure were well below the reference level set by ICNIRP and exceeds the national standard (DoT). The EMF exposure measured at each building site near base stations is useful for the local base station operators to install antenna properly and readjust EMF exposure in surrounding areas.

Therefore, many comprehensive studies are necessary for this country, to protect people from the risk of the exposure to this high power density of the radiation from mobile tower base stations installed especially in residential areas.

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REFERENCES

[1] R. Buckus and P. Baltrènas, "Research and analysis of electromagnetic radiation from mobile telephone base station antennas in residential environment," *2012 19th International Conference on Microwaves, Radar & Wireless Communications*, Warsaw, 2012, pp. 171-175.

[2] P. Baltrénas and R.Buckus, "Research and assessment safety distance of TV electromagnetic fields", *International Journal of Occupational Safety and Ergonomics*, vol. 17, pp. 33-39, 2011.

[3] P. Baltrenas and R. Buckus, "The exploration and assessment of electromagnetic fields in duplicators", *Enviromental Engineering and Landscape Management*, vol. 17, pp. 89-96, 2009.

[4] P. Bemardi, M. Cavagnaro, S. Pisa and E. Piuzzi, "Human exposure to radio base-station antennas in urban environment", *IEEE Transactions on Microwave Theory and Techniques*, vol. 48, pp. 1996-2002, 2000.

[5] R. Cicchetti and A. Faraone, "Estimation of the peak power density in the vicinity of cellular and radio base station antennas", *IEEE Transaction on Electromagnetic Compatibility*, vol. 46, pp. 275-290, 2004.

[6] R. Cicchetti, A. Faraone and Q. Balzano, "A uniform asymptotic evaluation of the field radiated from collinear array antennas", *IEEE Transaction on Antennas and Propagation*, vol. 51, pp. 89-102, 2003.

[7] C. Damian and C. Fosalâu, "Sources of indoor noise and options to minimize averse human health effects", *Environmental Engineering and Management Journal*, vol. 10, pp. 393-400, 2011.

[8] A.Faraone, R. Yew-Siow Tay, K.H. Joyner and Q. Balzano, "Estimation of the average power density in the vicinity of cellular base-station", *IEEE Transactions on Vehicular Technology*, vol. 49, pp. 984-996, 2000.

[9] S.I. Henderson and M.J. Bangay, "Survey of exposure levels from mobile telephone base stations in Australia", *Biolelectromagnetics*, vol. 27, pp. 73-76, 2006.

[10] V. Hrvoje, "Wire antenna theory applied to the assessment of the radiation hazard in the vicinity of the GSM base station", *Serbian Journal of Electrical Engineering*, vol. 1, pp. 15-26, 2003.

[11] Raimondas, "Electromagnetic field in the workplace and living environment. Parameters values and measurements requirements of 10 kHz - 300 GHz frequency band", *Valst. Žinios [State's News]*, no. 29-1374, pp. 6, 2011.

[12] S.P. Loughran, A.W. Wood, J.M. Barton, R.J. Croft, B. Thompson and C. Stough, "The effect of electromagnetic fields emitted by mobile phones on human sleep", *Neuroreport*, vol. 16, pp. 1973-1976, 2005.

[13] M.A. Mangoud, R.A. Abd-Alhameed and P.S. Excell, "Simulation of human interaction with mobile telephones using hybrid techniques over coupled domains", *IEEE Transactions on Microwave Theory and Techniques*, vol. 48, pp. 2014-2021, 2000.

[14] S. Miclaus and P. Bechet, "Estimated and measured values of the radiofrequency radiation power density around cellular base stations", *Romanian. Joumal Of. Physks*, vol. 52, pp. 399-409, 2007.

[15] C. Olivier and L. Martens, "Optimal settings for narrow-band signal measurements used for exposure assessment around GSM base stations", *IEEE Trans. on Instrumentation and Measurement*, vol. 54, pp. 311-317, 2005.

[16] D. Poljak and N. Kovac, "A simplified electromagnetic-thermal analysis of human exposure to radiation from base station antennas", *Automatika*, vol. 45, pp. 11-17, 2004.

[17] R. Pocius, "The influence of downtilt of antennae directional diagrams on the formation of mobile network cells and estimation of electromagnetic field intensity", Elektronika Ir Elektrotechnika, vol. 64, pp. 31-36, 2005

[18] D. Wojcik, T. Topa and K. Szczepanski, "Absorption of EM energy by human body in the vicinity of GSM base station antenna", Journal of Telecommunications and Information Technology, vol. 32, pp. 3438, 2005.

[19] Amar. Renke and Mahesh. Chavan, "An investigation on residential exposure to electromagnetic field from cellular mobile base station antennas," Computing, Communication and Security (ICCCS), 2015 International Conference on, Pamplemousses, 2015, pp. 1-4.

[20] Amar Renke and Mahesh Chavan. Article: A Review on RF Field Exposure from Cellular Base Stations. International Journal of Computer Applications 104(12):9-16, October 2014.

[21] Amar Renke and Mahesh Chavan. Article: An Estimation of Electromagnetic Field Exposure from Cellular Mobile Base Station Towers in Densely Populated Residential Areas. Communications on Applied Electronics 4(3):5-9, January 2016. Published by Foundation of Computer Science (FCS), NY, USA.