SAFETY MEASUREMENT OF ELECTROMAGNETIC FIELD RADIATION FROM MOBILE STATIONS AT A NAJRAN CITY IN KSA

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ABSTRACT
The recent years shows increasing mobile users every day. In order to supply the demand suppliers of different companies' install many base stations almost everywhere. This paper focuses on reporting measurement of the power density around mobile base stations to locate the Maximum Peak Point (MPP). The safety measurement was performed at different distances and directions from 20 selective base stations located in Najran city Saudi Arabia using Radio Frequency (RF) Electromagnetic Field Strength Meter Model 480846. The measured power density ranged between 195.5 µW/m2 and 12540 µW/m2 at 5 to 100 m from the base station. The result of the paper shows that the maximum power density of 12540 µW/m2 is by far less than the ICNIRP values of 4.5 W/m2 and 9.0 W/m2. The results show that power density levels at all surveyed sites are far below the National Guidelines for public exposure to RF and that the MPPs are found within the distance range suggested in the Commutation and Information Technology Commission (CITC) in Saudi Arabia.

INTRODUCTION
There are two types of radiation ionizing or non-ionizing depending on the energy of the radiated particles. Non-ionizing radiation does not carry enough energy to break molecular bonds and ionize atoms. An example of non-ionizing is radio frequency radiation. Ionizing radiation is the type of radiation that carries enough energy to break bonds between molecules and ionize atoms. An example of Ionizing radiation is the gamma rays emitted by radioactive materials, cosmic rays, and X-rays. Non-ionizing radiation comes from extremely low frequency, very low frequency, radio waves, microwaves, infrared radiation and visible light. Advancements in innovation and industry have improved human life. Be that as it may, presentation to electromagnetic fields (EMFs) by utilizing electrical machines, apparatuses, modern instruments, electrical cables and specialized gadgets has happened as a consequence of these mechanical advancements and is bringing about a risk to typical lives [1]. The fast and so close technologies in our daily life is a mobile phone. Ionizing radiation is a well-known type of radiation that will give harm to the human body as it can ionize cell body in a second. Non-ionizing radiation can penetrate but have no enough energy to ionize an atom molecule of the human body, but long time exposure to the human body can lead to harm it, as its exposure is one of the important factors for an EMF to react with human body [2]. In order to protect human from the base station electromagnetic radiation, several studies have been piloted to identify the effect of base stations to the ambient EMR exposure. Arithmetic mean value for mobile phone base station exposure at Basel, Brussels and Amsterdam were far below the international reference level proposed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [3]. The table shows the exposure limits for Radiofrequency (RF) fields in term of power density for different Countries and Organization.

The mobile phone systems technologies use electromagnetic radio frequency ranges and the human body is particularly sensitive to electromagnetic radio frequency fields. At these high frequencies, the human body absorb a significant amount of the radiated energy from these technologies [4], [5]. Radio frequency radiation causes an increase to the concern diseases of possible health effects that may be associated with these exposures of radio frequency radiation [6], [7]. The rapid growth in the number of mobile subscribers has increased the number of base stations around the world. Communications commission in Saudi Arabia reported in 2016 the number of mobile subscribers rose to 49.5 million subscribers [8]. This increase in subscribers requires the expansion of the mobile phone network, and therefore more base stations are deployed. The National Communications and Information Technology Commission in Saudi Arabia has established national guidelines for regulating radio frequency levels throughout the country with the help of base station used for mobiles. The ICNIRP made the guidelines which are used by the country. The International Electrotechnical Commission and IEEE standards used the national guidelines required for determining compliance used by the RF measurement method. Cell phone stations may be stand-alone towers or installed on existing structures, such as trees, water tanks or high buildings. Antennas should be high enough to cover the area adequately. The base stations are usually 15 to 60 meters [9].
The work in this field done during past has considered the level of radiations form the base station situated in different areas of the world as given in the references [10]–[15] . In [12], A measure was made in student hostels

and office premises near base stations at the International Islamic University of Malaysia, the Gombak campus. The measured values are compared with the Malaysian Communications and Multimedia Commission, IEEE and ANSI recommendations for safety guidelines. Also in [16] focused on measurement and assessment of voltage amplitude and carried out the measurements at various places near the base stations inside residential areas in Terengganu Malaysia. Moreover, in [10], they measured the strength of EMFs around base stations in the western region of Saudi Arabia and presented results that EMF levels at all surveyed sites are far below the National Guidelines.

This paper presents measurement results of 20 base station sites located in Najran city. These sites are operated by Saudi Telecom Company (STC), Mobily and Zain companies. The comparison of results of power density measurements with national and international limitations are provided form different organization. This paper gives statistical measurement data of electrical fields for 20 base stations, which are located in different areas in Najran.

This paper are organized as follows. Section 2 discusses the measurement methodology. Section 3 summarizes and analyzes the results. The overall paper conclusion is finally discussed in Section 4.

MATERIALS AND METHODS

There are some national and international radiation exposure standards (Bratislava and Helsinki; Seltzer et al. 2011) to provide information on radiation exposure limits as shown in Table 1. The results of measurements in this paper is compared with limitations in Table 1. Figure 1 shows different sector antenna structures for base stations which were found in Najran city. The left sideshow of Figure 1 illustrates green location and right side illustrates the rooftop location of base station. The selected antenna must have enough space along its transmission direction to allow free movement for determining the Maximum Peak Point (MPP) location easily.

Table 1. General National and International levels and power density

Exposure limits for RF fields in term of power density		**Country/ Organization**
900MHz	**1800MHz**	
0.00045 W/m²	0.0009 W/m²	BUND recommendation 1997
0.001 W/m²	0.001 W/m²	Precautionary limit in Austria
0.02 W/m²	0.02 W/m²	Exposure limit in Russia
0.045 W/m²	0.09 W/m²	ECOLOG-recommendation 1998 (Germany)
0.1 W/m²	0.1 W/m²	Exposure limit in Poland
0.16 W/m²	0.16 W/m²	Exposure limit in Italy
0.24 W/m²	0.24 W/m²	Exposure limit in CSSR
2 W/m²	2 W/m²	Exposure limit in New Zealand
2 W/m²	2 W/m²	Communication and Information Technology Commission (CITC) in Saudi Arabia
3 W/m²	3 W/m²	Exposure limit in Canada (Safety Code 6, 1997)
4.5 W/m²	9 W/m²	Exposure limit in Germany and ICNIRP recommendation 1998

Figure 1. Different structures of base stations observed in Najran city.

The measurement methodology adopted in this paper to assess each site has been taken from the Commutation and Information Technology Commission (CITC) guide- lines [17]. RF field emission from each mobile base station should not exceed the national and international levels of power density as shown in Table 1 is the purposes of the initial site survey to ensure that the people has access outside the site boundary. Also to find the place of the Maximum Peak Point (MPP) around the location in areas which are accessible by the people.

All the base stations surveyed had at least three antennas on them with each antenna covering a sector of 120°. Thus, it was possible for measurement to be taken in any convenient direction within a particular sector. RF EMF Strength Meter Model 480846 as shown in Figure 2 detector have been used for electromagnetic radiation measurement. This meter is a broadband device for monitoring high-frequency radiation in the range of 10 MHz to 8 GHz. The non-directional electric field and high sensitivity. The unit of measurement and the measurement types are expressed in units of electrical and magnetic field strength and power density. The power density equations was driven in [18] is used in this paper measurements with unit of W/m^2. The power density (intensity of the EM radiation) on the surface *S* can be written as:

$$P_D = \frac{P}{S} \qquad (1)$$

Where *P* is resultant transmitted power of the EM wave.

At high frequencies, the power density is of particular significance. The area that was selected for this study demonstrates the use of different types of Supplier Company and measurement at difference distance up to 5 m to 100 m far from the base station. In order to obtain more accurate values, many measurements are normally performed at every location to get the MPP of power density.

Figure 2. RF EMF Strength Meter Model 480846 device

RESULTS AND DISCUSSION

To determine the MPP areas easily allow free movement of its transmission direction for the selected base station of mobile. Based on the location of base station there are two key tower arrangements: green location and rooftop location. The green location tower is fixed on the ground and the antennas required are mounted at the upper level of the tower. In contrast, the rooftop location tower is set on the roof of a building and sometimes the antennas are not fixed on a single tower: instead, they are split apart. It is not easy to measure the different dimensions in rooftop location as in base station number 4 as shown in Table 2. Tables 2 present the results for 20 base station measured in Najran. All measurements in Table 2 has taken around peak hours. The first two columns in Table 2 provide base station. The others columns provide the measurement results that show the power density at the MPP with different distance from base station and finally the percentage of the maximum power density from the general public limit as suggested in the CITC guidelines.

The current investigation were covered for 20 base station in Najran city. The measurement of power density max level were found to be in the range of 77.9 - 10410 $\mu W/m^2$ as shown in Table 2 with 100 m distance from base station. The results obtained shows that the power density max measured at Najran city is extremely low. Upon comparing the max value of power density in this survey with international data, The obtained values are far below the allowable limit set by ICNIRP 4.5 W/m^2, Germany(4.5 W/m^2), New Zealand(0.5 W/m^2), Canada (3 W/m^2) and Italy (0.1 W/m^2) , Poland (0.1 W/m^2), Russia (0.1 W/m^2), China (0.4 W/m^2) and the CITC for human exposure to RF(2-10 W/m^2). However, the level of power density observed in this study is significantly higher than standard limits proposed by Austria (0.001 W/m^2),Bio initiative report (outdoor) 0.001 W/m^2 and Germany (BUND 2007-Precautioary Recommendation) 0.0001 W/m^2.

According to the Table 2 the MMP of power density in base station 1 increase up to a distance of 100 m, while in base station 7, decline at a distance up to a distance of 100 m. Whereas, for base station 15, the reading be enhanced at the beginning of distance 5 m up to 50 m but began to decline until the distance of 100 m. The dissimilarity of measuring of reading MPP of power density be attributed to the antenna height, the 3-dB beam-width and tilt angle of the antenna and the angle of the antenna.

Table 2. Measurement of power density of mobile base station by µW/m²

Base Station No.	Operator Company	Data 2018	Power density (µW/m²)with different distance (m) from base station					Inside house µW/m²	MPP µW/m²	Percentage of CITC limit %	Percentage of Russia limit %
			5	30	50	70	100				
1	STC	3/12	2440	211	12540	311.3	393.5	--	12540	0.63	63
2	STC	3/12	1145	791.8	805.8	916.1	10410	--	10410	0.52	52
3	Zain	3/12	487	1415	678.6	963.8	2108	--	2108	0.11	11
4	STC	18/11	2606	--	--	828.5	--	132.8	2606	0.13	13
5	Mobily	29/11	290.9	410.5	490.3	1400	981.1	--	1400	0.07	7
6	Mobily	29/11	2000	124	195.5	303.6	437.6	--	2000	0.10	10
7	STC	18/11	9585	897.8	696.5	471.4	77.9	--	9585	0.48	48
8	STC	24/11	1787	2652	1228	1042	1847	--	2652	0.13	13
9	STC	24/11	1510	1233	1137	1630	1762	--	1762	0.09	9
10	STC	24/11	2100	601.2	373.8	1018	487.4	--	2100	0.11	11
11	Mobily	18/11	2000	5002	2700	411.3	393.5	--	5002	0.25	25
12	Zain	19/11	902	850	702	12000	9500	--	12000	0.60	60
13	Mobily	13/11	654	1325	825	3542	2151	--	3542	0.18	18
14	Mobily	12/11	805	12001	654	859	847	--	12001	0.60	60
15	Zain	11/11	325	548.5	8520.2	821	658.6	--	8520.2	0.43	43
16	Zain	10/11	3000	4500	1196	524	509.3	--	4500	0.23	23
17	STC	4/11	9587	10025	7852	5684	2001	--	10025	0.50	50
18	STC	3/11	1584	2752	2515	1500	1700	--	2752	0.14	14
19	STC	2/11	3500	2200	2015	1820	1760	--	3500	0.18	18
20	STC	1/11	2100	2601	1205	1058	701.4	--	2601	0.13	13

Figure 3 shows MPP power density for around 20 mobile base stations. The MMP may be accrued at any distance within 50m to 300 m based on the location of the cell, the antenna height, the 3-dB beam-width and tilt angle of the antenna and the angle of the antennas [19]. The maximum value of MPP at base station one is 12540 µW/m^2 while the minimum value of MPP at base station one is 2506 µW/m^2 for green location of the base station type. The MPP in all 20 base stations within the safe limits established by almost of general national and international power density levels.

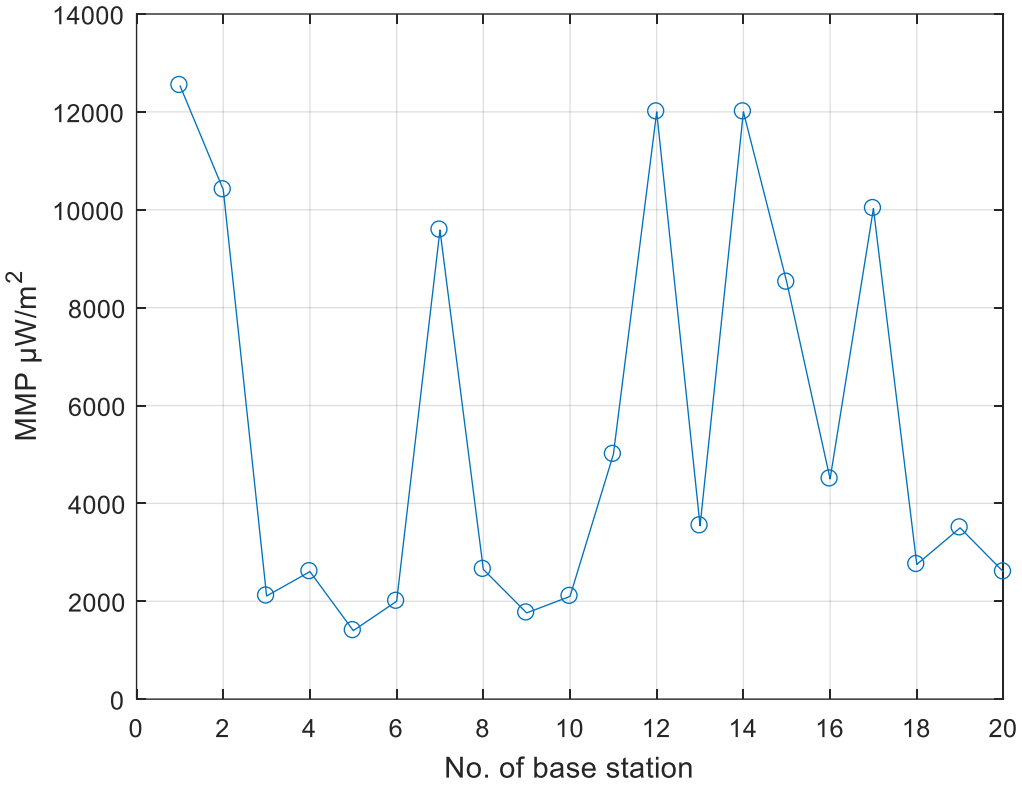

Figure 3. MPP for 20 base stations in Najran city in Saudi Arabia.

CONCLUSION

The main objective of the paper is to measure and evaluate the RF EMF exposure in MPP of power density measuring from selected base stations in Najran Saudi Arabia. The measurements have been conducted on 20 selected communication base stations and the results obtained are analyzed and compared. Based on the current investigation, the results yielded from this investigation show that the RF radiation levels from all base station antennas were far below the maximum permissible exposure limit set by the CITC guidelines, thus, fall within the safe limits established by the international standard organizations except Austria, Bio initiative report and Germany. Hence, no further "narrowband" investigation is needed. In order to lower radiation exposure level to the people who are living nearby the antennas, the minimum distance from base station to the nearest buildings must be more than 15m for safety measure. It is preferable to increase the number of communications towers in populated areas in order to reduce the radiation exposure.

REFERENCES

1. C. W. Pennington, “Exposing America: comparative assessments of ionizing radiation doses to US populations from nuclear and non-nuclear industries,” *Prog. Nucl. Energy*, vol. 49, no. 6, pp. 473–485, 2007.
2. E. Hidisoglu *et al.*, “2100-MHz electromagnetic fields have different effects on visual evoked potentials and oxidant/antioxidant status depending on exposure duration,” *Brain Res.*, vol. 1635, pp. 1–11, 2016.
3. D. Urbinello, W. Joseph, L. Verloock, L. Martens, and M. Röösli, “Temporal trends of radio-frequency electromagnetic field (RF-EMF) exposure in everyday environments across European cities,” *Environ. Res.*, vol. 134, pp. 134–142, 2014.
4. R. W. Y. Habash, “Electromagnetic Fields and Radiation,” *CRC Press. Marcel Dekker, New York ISBN 10 0824706773*, p. 416, 2001.
5. F. O. R. Limiting and E. To, “ICNIRP GUIDELINES FOR LIMITING EXPOSURE TO TIME - VARYING ELECTRIC , MAGNETIC AND ELECTROMAGNETIC,” 1999.
6. C. Silverman, “Epidemiologic studies of microwave effects,” *Proc. IEEE*, vol. 68, no. 1, pp. 78–84, 1980.
7. L. Hardell, A. Näsman, A. Påhlson, A. Hallquist, and K. Hansson Mild, “Use of cellular telephones and the risk for brain tumours: A case-control study.,” *Int. J. Oncol.*, vol. 15, no. 1, pp. 113–119, 1999.

8. Communications commission in Sadia Arabia, “Communications commission report,” 2016. [Online]. Available: https://www.argaam.com/ar/article/articledetail/id/457869. [Accessed: 01-Dec-2016].
9. American Cancer Society, “Cellular Phone Towers,” 2016. [Online]. Available: https://www.cancer.org/cancer/cancer-causes/radiation-exposure/cellular-phone-towers.html#written_by. [Accessed: 18-Oct-2017].
10. M. Nahas, “Safety Measurements of Electromagnetic Fields Radiated from Mobile Base Stations in the Western Region of Saudi Arabia,” *Wirel. Eng. Technol.*, vol. 2, no. October, pp. 221–229, 2011.
11. E. Hanada, “The electromagnetic environment of hospitals: How it is affected by the strength of electromagnetic fields generated both inside and outside the hospital,” *Ann. Ist. Super. Sanita*, vol. 43, no. 3, pp. 208–217, 2007.
12. R. Islam, O. O. Khalifa, L. Ali, A. Azli, and M. Zulkarnain, “Radiation Measurement from Mobile Base Stations at a University Campus in Malaysia Department of Electrical and Electronic Engineering , Faculty of Engineering , Universiti Putra Malaysia,” *Am. J. Appl. Sci.*, vol. 3, no. 4, pp. 1781–1784, 2006.
13. N. N. Udora, “Investigation of Electromagnetic Radiations by GSM Base Stations in Nigeria for Compliance Testing,” vol. 47, pp. 10–18, 2015.
14. M. I. Ahmed, M. Osman, S. Ahmed, H. F. A. L. Rahman, and I. S. M. Mousa, “Investigation of electromagnetic radiation emitted from mobile base stations in Khartoum state,” vol. 6, no. 4, pp. 98–107, 2016.
15. R. Mohammed Ahmed, A. Mohamed Taha Elamin, and W. B. Hassan, “Knowledge and Performance of Radiographers towards Radiation Protection, Taif, Saudi Arabia,” *IOSR J. Dent. Med. Sci. Ver. II*, vol. 14, no. 3, pp. 2279–861, 2015.
16. M. Atefifard *et al.*, “Exposure level from selected base station tower around Kuala Nerus: a preliminary analysis,” *J. Fundam. Appl. Sci.*, vol. 9, no. 5S, pp. 367–380, 2016.
17. V. Anderson, M. Repacholi, B. Moule, and F. Meyer, “National Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields,” *CITC Regul. Doc.*, pp. 23–97, 2009.
18. M. Muhibbullah, A. M. A. Haleem, and Y. Ikuma, “Frequency dependent power and energy flux density equations of the electromagnetic wave,” *Results Phys.*, vol. 7, pp. 435–439, 2017.
19. CITC and King Saud University, “Measurement Proce-dures for Electromagnetic Radiations from Wireless Base Stations,” 2008.