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NON-IONIZING RADIATION EXPOSURE: ELECTRIC FIELD STRENGTH MEASUREMENT AROUND SELECTED BASE STATIONS IN KUALA NERUS

S. N. Hazmin[1,2,*], A. R. S. N. Dianah[1], R. Umar[3], A. N. Dagang[4], M. K. A. Kamarudin[3] and H. Jaafar[5]

[1]School of Fundamental Science, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

[2]Pusat Islam Sultan Mahmud, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

[3]East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia

[4]School of Ocean Engineering, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

[5]Faculty of Electrical Engineering, Universiti Teknologi MARA, 23000 Dungun, Terengganu, Malaysia

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ABSTRACT

The human technology advancement grows rapidly especially in telecommunication sector, led to the construction of more base stations tower (BST). The non-ionizing radiation (NIR) produced is believed to have adverse impact on living things and caused public concern. This study is conducted to measure electric field (EF) strength around several selected BST around Kuala Nerus. The measurement is carried out using circular patch antenna designed and fabricated for frequency up to 3GHz, connected to spectrum analyzer.

Author Correspondence, e-mail: norhazmin@umt.edu.my

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In this research, the measured values are compared with the international standard recommended by ICNIRP then were also compared with previous study from several locations around Malaysia. The result shows an increase in the values of electromagnetic field radiation. The result of this study could be used for health risk monitoring and also benefit telecommunication service provider.

Keywords: non-ionizing radiation; radiation protection; base station; electric field strength.

1. INTRODUCTION

Electromagnetic (EM) energy represents all kinds of energies that released by stars into space. While, electromagnetic radiation (EMR) existed in electromagnetic field (EMF) which generated from electric and magnetic field that propagate perpendicularly through free space or any material at the universal speed of light. The EMF is produced by any wiring or equipment carrying electric current [1]. By referring to the EM spectrum, EMR level is described in terms of its wavelength, frequency and energy which are related to each other mathematically such as field strength or power density.

Since EMR is an energy transferred in the wave form, thus it can be reflected, refracted, transmitted or absorbed through any medium by depending on the conductivity of the exposed medium and the frequency of the field. This radiation is believed harmful for human health as long as to living things. It is because this radiation energy can be converted to other forms of energy and the most is heat energy. Hence, when this energy is exposed to the human, it can penetrate deep into the surface of the body and cause the thermal damage to the cell.

Studies had been conducted on the effect of electric field strength on environment by considering several factor such as base stations [2]. From the result, they found the levels of exposure measured were complied both local and international safety limit guideline. The basic restrictions for human exposure to time-varying electric and magnetic fields limit are recommended by International Commission on Non-Ionizing Radiation Protection (ICNIRP).

As the public demand on human technology are increasing, the use of mobile phone, electronic gadgets, smart tool and home appliances grow very rapid. The demand on telecommunication technology advancement has led to an increase of the BST installation, which are normally build close to the public and residential area. Moreover, the BST are usually mounted closer to each other with high transmitting power so that the signals are able to propagate up to several kilometers [3].

Non-Ionizing Radiation (NIR) is referring to energy forms with lower frequencies. Usually, the strength of NIR of man-made sources such as base stations, vehicles, power lines etc. are many thousands of times greater than natural sources (geomagnetic field and atmospheric electric field). While WHO claims that there is no adverse health effects are expected from this form of radiation, many people are concerned about how long-term exposure to excessive NIR may impact human health and nature [4]. According to some of previous studies, a repetitive exposure to NIR not only can cause common health effects such as headaches, insomnia and dermatitis but also on cancer and reproductive system [5-6]. Therefore, it is necessary to conduct surveys on the level of EMR sourced from BST to find out whether the level of radiation are hazardous to human health from the point of view of non-ionizing thermal radiation.

The main objective of this study is to determine the public radiation exposure of several selected BST around Kuala Nerus by measuring the ambient electric field strength. The measured values obtained are then compared with the international standard recommended by ICNIRP. By conducting this study, health risk monitoring could be done. Besides, it will benefit telecommunication service provider and spectrum monitoring could be managed by MCMC.

2. METHODOLOGY

In this study, measurements of EF strength were performed for 10 minutes at each selected point of distance from BST. The distances were set up at 15 m, 50 m, 100 m, 150 m, 200 m, 250 m, 300 m, 350 m, 400 m and 450 m from the BST (Fig. 1). Three BSTs were selected around Kuala Nerus base on population density named as BST 1, BST 2 and BST 3 as detailed in Table 1.

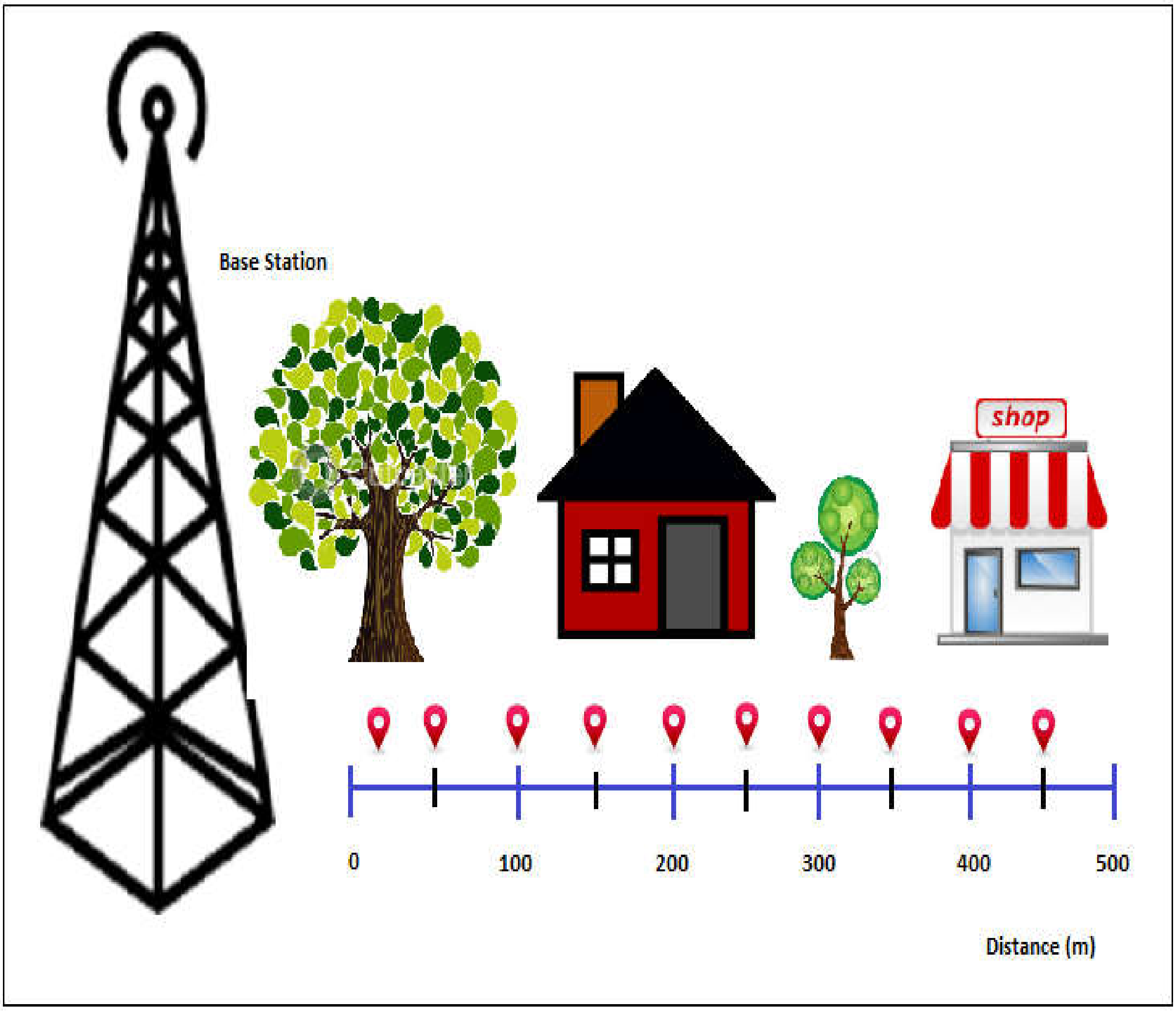

Fig.1. Point of measurement taken

Table 1. Description of selected sites

Sites	Location	Latitude (N)	Longitude (E)	Category of Area	Number of Antenna
BST 1	Gong Badak	5˚23”55.5”	103˚5’10.8”	suburban	18
BST 2	ILP, Gong Badak	5˚23’57.8”	103˚4’18.5”	suburban	23
BST 3	Batu Rakit	5˚26’49.0”	103˚3’3.1”	rural	5

The main equipment for EF measurement is spectrum analyzer (Keysight N9915A, USA). The spectrum analyzer is able to detect the level of measurable strength at a very wide range of frequency up to 9000 MHz and appropriate instruments for high mobility and robustness. Passive antenna used to detect signals radiated in ambient was an omnidirectional circular patch antenna (Fig. 2) that had been fabricated specifically for this study.

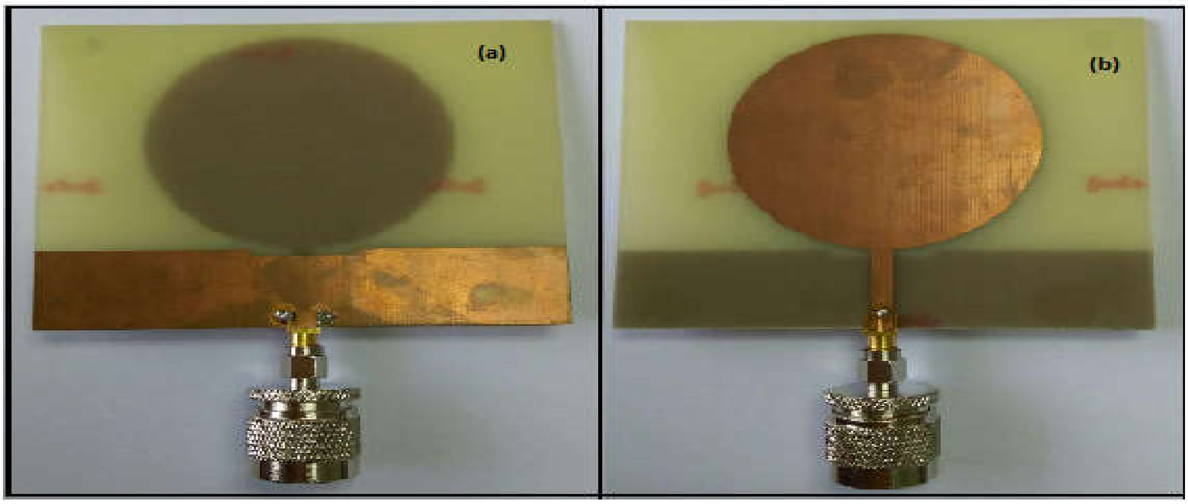

Fig.2. Circular patch antenna (a) rear view (b) front view

The antenna is mounted to the low noise amplifier and connected to spectrum analyzer as shown in Fig. 3.

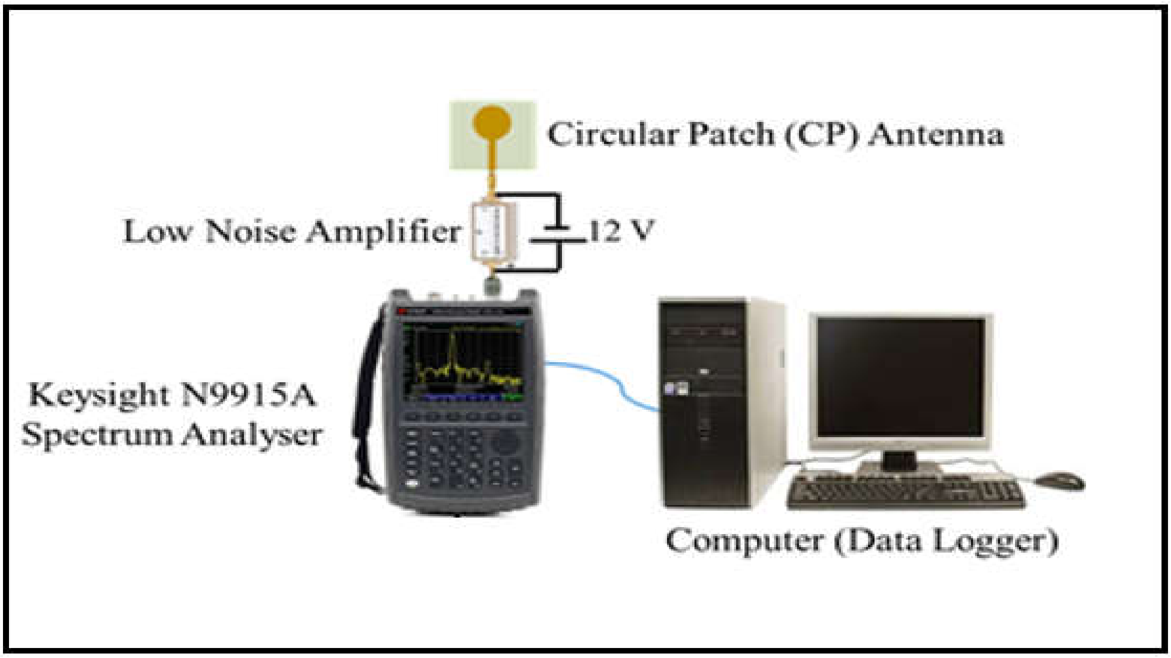

Fig.3. Measurement set up

Before the observation was carried out, the coordinates of measurement sites for each point distance were recorded using Global Position System (GPS) to ensure the distance at the point from BST was accurate. The spectrum of power level (dBmV) versus frequencies (*f*) data were recorded. The data were then converted into EF strength and then compared with the international standard public exposure limit recommended by ICNIRP. The data were also compared with previous study conducted from several locations around Malaysia.

3. RESULTS AND DISCUSSION

3.1. Exposure Level

Measurements of exposure levels have been carried out at three selected BST around Kuala Nerus based on different category of area with different number of antenna installed on top of the single tower. The signal travel paths of all BSTs are observed to have an unobstructed Line of Sight (LOS) path due to the presence of buildings, conducting structures and trees.

Fig. 4 shows the trend of the highest electric field (EF) strength measured with respect to distances for all of the BSTs. Theoretically, EMR follows the inverse-square law where the EF level might be decreased when farther from the EM source. Otherwise, the inverse-square law is neglected if the EMR does not propagate in LOS path [7].

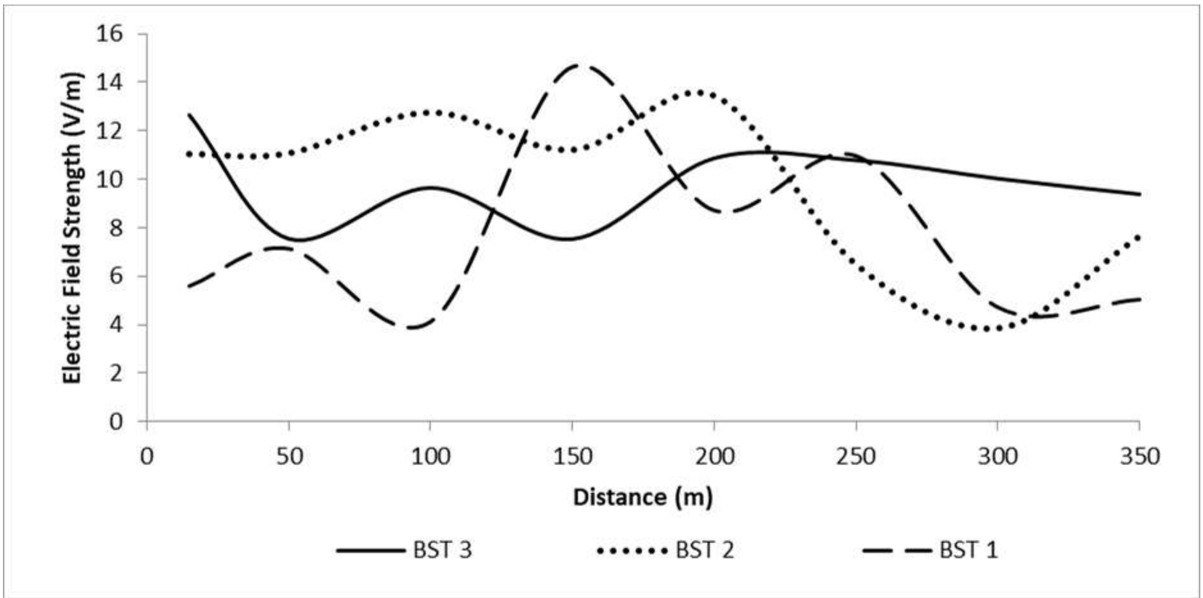

Fig.4. Trend of electric field strength measured at distances from BSTs

The results have shown a great variation of exposure level measured in terms of EF strength. It is obvious that the EF strength varied not only as a function of distance (inverse-square law), but also varied due to other factors.

In [8] explained that the fluctuations probably occurred due to the signal traffic changing depending to the number of calls. The result shown in Fig. 4 also seems that the exposure level directly below the BST was not in zero values. The reason may be due to the side lobes of the antenna radiation beam pointed directly beneath the BST. The main lobe beam of the transmitting antenna also influences the radiation exposure level. The power radiated from the side beam of antenna radiation would be expected lower when far away from the main beam. Such at distance 100 m to 150 m from BST 1, the EF strength tend to rise up about 10.5 V/m (71%) as the main beam of transmitting antenna at the BST 1 facing at this point. Moreover, there were several other antennas nearby installed on top of the UniSZA mosque which were believed causing the signals stronger. This is due to the overlapping of the antenna radius patterns. When two waves with same frequency propagating in the same direction through each other, the constructive interference will occur. Therefore, the larger voltage amplitude will be formed.

BST 2 shows the relatively stable trend and sudden quickly drop at distances 200 m to 350 m. This was because at this point the transmission path of the radio signal was not propagated in LOS path due to several factors such as reflection, diffraction and diffusion by physical objects such as buildings, trees or other obstruction which also depends on their electrical properties [9].

Since BST 3 is located in rural area, thus, there are only a few buildings around the study area. Therefore resulted in a relatively stable with slightly fluctuate trend of EF strength due to the LOS path travelled. But, it is still slightly fluctuate probably due to the other EMR sources from surrounding such as power lines. Besides, the trend of EF strength of BST 3 probably due to the lowest number of antenna on top of the BST 3 compared to other two as shown in Table 1. It is because the number of antenna will enhance the exposure level from single BST [10]. According to [11], this probably due to the effective radiation power of the antennas or the less number of users at the area.

3.2. Comparison of Exposure Level with ICNIRP Standard

The measured EF strength obtained were then compared with the international standard recommended by ICNIRP (Fig. 5) and reveals that the maximum levels of exposure from the selected BSTs are well below the limits [12-13].

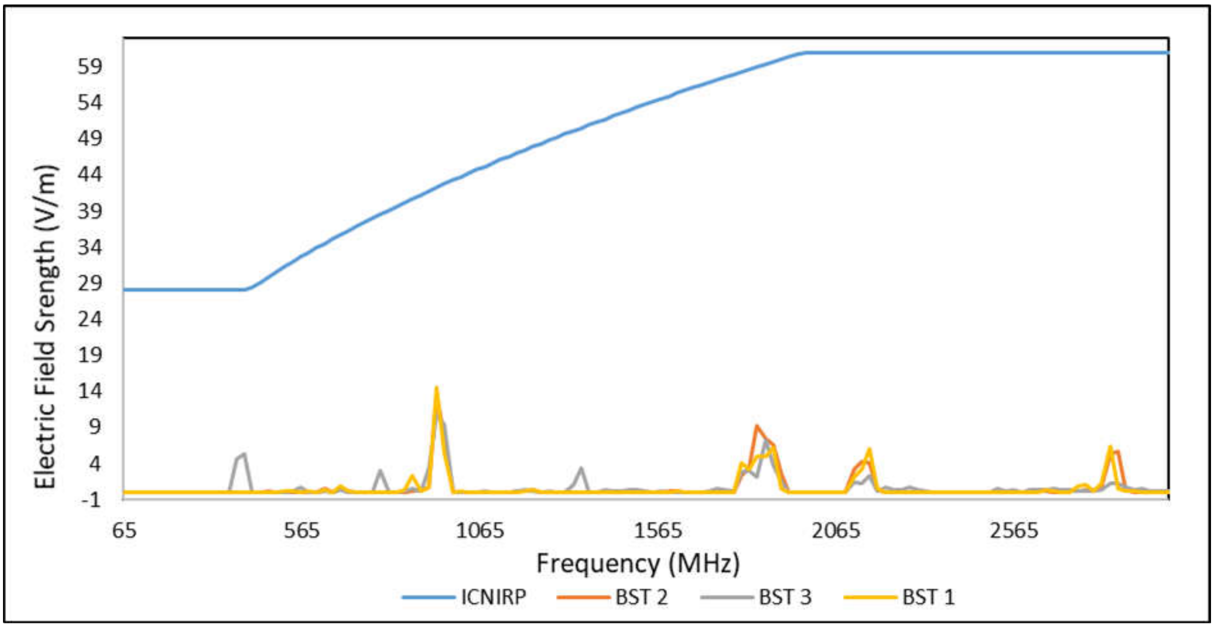

Fig.5. The comparison of EF strength with ICNIRP standard

It seems the maximum EF strength of all of the BSTs were found at frequency 945 MHz followed by GSM1800 and UMTS2100 bands. Based on [14], it found that the highest value of EF has contribution from multiple GSM transmitters from 900, 1800 and 2100 MHz. In [15] also found that 20%, 40% and 40% of the total EF is contributed by BST antennas in the 900, 1800 and 2100 MHz bands respectively. While, in [5] established that the highest reading of EF and power density for GSM1800 system which 34.38% of the limit. According to [16], GSM900, GSM1800 and 3G BST were found as the main contributors to EM exposure levels [16]. Other researcher had mentioned that the 900 MHz band is often used more in rural areas, while the 1800 and 2100 MHz bands are used more in densely populated areas [11].

The maximum value and percentage exposure of all of the study sites in comparison to the ICNIRP exposure limit are shown in Table 2, which is the highest percentage exposure is the nearest to the recommended limit.

Table 2. The maximum EF with the percentages for each site within the ICNIRP standard

Sites	Maximum EF, Distance	Percentage of ICNIRP Limit (%)	Number of Antennas on the Top of BST
BST 1	14.629 V/m, 150 m	34.61	18
BST 2	13.461 V/m, 200 m	31.85	More than 20
BST 3	10.859 V/m, 15 m	25.69	5

The highest maximum measured value of EF strength was at BST 1 which is varied from 0% to 34.61%, then followed by BST 2 and BST 3 which are varied from 0% to 31.85% and 25.69% of the ICNIRP general public permissible respectively. The maximum peak values were detected at different point distance for all sites.

The number of antennas on single tower is said to enhance the total exposure level. However, there were other factors must be considered. As shown in Table 2, even though BST 2 has the highest number of antennas on top of the tower, the highest of maximum EF values of BST 1 among other sites is to be expected due to the existence of other antennas installed nearby.

3.3. Comparison of Exposure Level with Previous Study in Malaysia

The EF values obtained were also compared with other previous study from several locations around Malaysia. Fig. 6 shows the different results between this study and the previous one. This might be due to some differences in measurement techniques, equipment used, location criteria and several surrounding factors that probably affect the EF values.

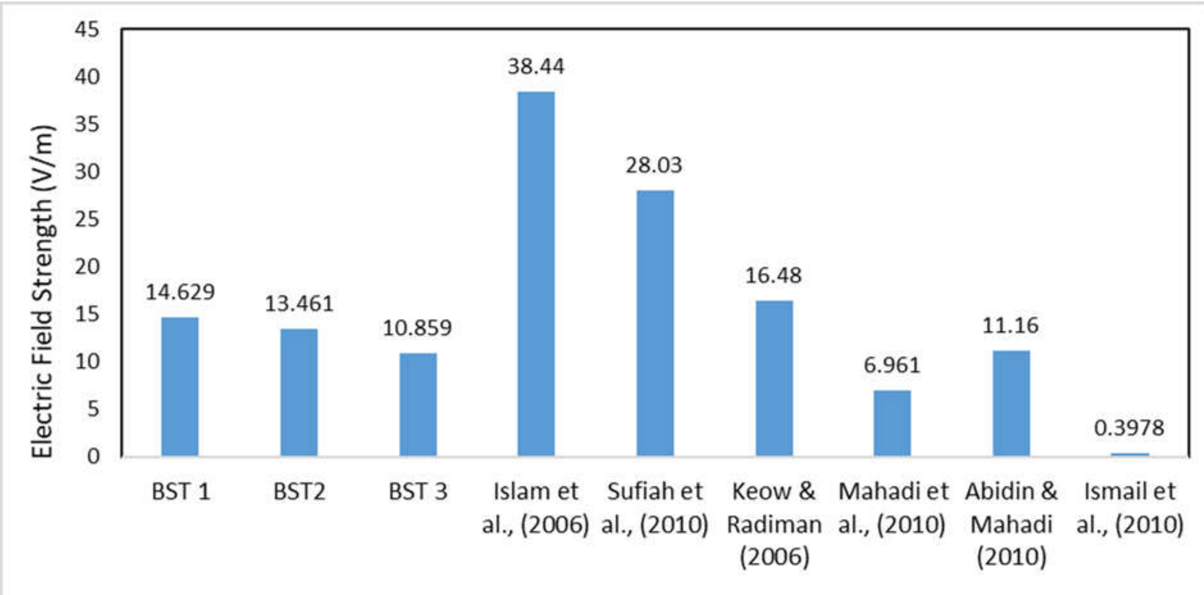

Fig.6. Comparison the maximum EF strength with previous study

However, the EF values are still well below the limits recommended by ICNIRP and other safety guidelines. Table 3 shows the description of the previous study. Based on [5], the maximum EF strength was found at frequency 2.4 GHz which is refers to Wi-Fi frequency bands. It is because Wi-Fi is always available at the institution area and cause the higher user for the frequency.

Besides that, this study is a kind of an outdoor observation and the exposure level may probably due to the survey point being located at nearby the busy road traffic. Thus, interfering of incoming signals sourced from neighbouring moving vehicles and surrounding objects is said would influence the measured EF values.

Moreover, the height and the down tilt angle of antenna also may contribute to the maximum level of exposure [5-6]. This both factors may influence the main beam of transmitting antenna radiation pattern to reach the ground surface. According to the previous study, the maximum level of exposure is reached at 300 m on ground level for high positions of antenna whereas, reached about 50 m for low positions of antenna.

Table 3. Description of previous study

References	Location Survey	Maximum EF Strength	Distances	Equipment Used
[5]	IIUM Campus	38.44 V/m	<100 m	1. Tri-axis probe 2. Portable spectrum analyser FSH3
[17]	MOZAC, Ayer Keroh, Melaka	28.03 V/m	500 m	1. Omnidirectional antenna 2. Spectrum analyzer
[8]	Bidor	16.48 V/m	70 m	1. Digital Radio Frequency Analyzer HF35C
[18]	-	3.16 /m	3 m	1. Tablet PC 2. NEMO Outdoor Software
[19]	Segamat (suburban)	6.96 V/m	10 m	1. Receiving antenna(50Ω) 2. Wiltek9102 hand held spectrum analyzer
[7]	Kuala Lumpur	0.368 V/m	10 m	1. Broadband omnidirectional antenna 2. Portable spectrum analyzer

Furthermore, since receiving antenna is an important component in EM study which is used to capture the radio signal transmitted from BST, thus, its sensitivity and performance must be considered. To measure the level exposure, high efficiency of antenna used is needed to have higher sensitivity. Thus, strong signal from sources can be captured. In this study, the appropriate antenna was fabricated to detect the signal strength nearly as much as transmitted from BST (sources). Therefore, it can be concluded that the exposure level from antennas BST not only influenced by distances from sources but also by other sources.

4. CONCLUSION

The main objective of this study is to measure the EF strength around 3 selected BST around Kuala Nerus using omnidirectional circular patch antenna [20]. The results is then compared with ICNIRP recommendations for safety guidelines. This study also done by comparing the EF strength measured with other previous study from several locations around Malaysia.

The results of the study are clearly show that the exposure level are far below the ICNIRP standard limit. However, the long term effect is of concern due to the long term exposure and can produce the same effect as higher level in short term exposure. Several studies had proved the biological effects would be occurred even at very low power densities (Specific Absorption Rate) which lower than exposure limit.

However, there are no investigation on the long term exposure from BST in Malaysia has ever been conducted. The result of this study could be used to determine the public radiation exposure around Kuala Nerus. Furthermore, this study will help in monitoring the health risk besides propose to Malaysian government for health concern.

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