Electromagnetic Radiation (EMR) Level Measurement and Analysis at UniSZA Gong Badak Residential College for Health Concern

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Abstract: *The advancement of communication technology has brought forward an era of interconnected world using smartphone, computer, and electronic gadgets in the presence of wireless network. The utilization of this kind of technology become a necessity nowadays during and post COVID19 pandemic. These electronics equipment as well as the wireless network itself are the sources of non-ionizing radiation (NIR) which may cause adverse health effect in long term exposure. Thus, this study is conducted to measure and analyze the NIR exposure level at UniSZA Gong Badak Residential College. The measurement was conducted using a spectrum analyser connected to a low-noise amplifier (LNA) and an omni-directional antenna. Blok C shows the highest electric field strength with 31.70 V/m at frequency 2520 MHz, while Blok M recorded 33.46 V/m at 1780 MHz. The exposure recorded do not ecxeed the standard guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) which is approximately about 61.00 V/m for frequency range of 2560 MHz until 4000 MHz. This study shows that the exposure levels are within the standard limit and most of the sources contributing to the NIR exposure in UniSZA Gong Badak residential college comes from the cellular mobile services which coincide with the increasing usage of telecommunication technology in the society.*

Keywords: Radiofrequency; Electromagnetic Radiation; Non-Ionizing Radiation; Exposure Level; Public Health

1. INTRODUCTION

The advancement in technology is so rapid that it brings a huge impact to mankind as well as environment, especially in terms of radiation. Radiation refers to the emission or transmission of energy through space [1]. Radiation can be divided into two primary categories namely the non-ionizing and ionizing radiation. Non-ionizing radiation is a contradiction of that ionizing radiation. It has a lower energy than the ionization energy and as a result, it is not capable of splitting apart the molecules and ionizing matter. Non-ionizing radiation (NIR) does not have sufficient energy to dislodge electrons [2]. Electromagnetic radiation (EMR) under non-ionizing radiation is refer to as electromagnetic field waves that includes radiofrequency (RF) wave which propagates or radiate through space and carry electromagnetic energy [3]. Some of the examples of the damage that has been reported are thermal effect [4], reduce sperm count [5], and electromagnetic hypersensitivity (EHS) [6]. With regards to this concern, the World Health Organization has put RF EMR exposure as a priority in their research agenda [7].

Every day, modern society is exposed to a high-tech lifestyle. For example, in current day of globalisation, cell phone usage is an important element of daily life as well as a communication tool for people of all ages [8]. Humans have been relying on mobile phones and internet connection as part of modern telecommunications. The number of smartphone users globally surpasses three billion and is expected to grow by several hundred million in the next few years [9]. Students especially, are surrounded with mobile phones, laptops, and constant connection to Wi-Fi in residential college as they are relying on those technologies as part of the needs in their studies. This online learning practice is increasing during COVID19 pandemic era and persisting during post-pandemic era. The downside of these is that residential college could probably have a high reading of RF EMR. Studies have shown that RF EMR exposure in residential area is alarming which suggests that the exposure in residential college should be more or less similar [10]. Interpolation techniques including IDW, Natural Neighbor, and Kriging were employed to determine the optimal method for estimating frequency levels (in MHz) using Geographical Information System (GIS) Mapping. Correlation between signal strength levels (amplitude) and Land Use Land Cover (LULC) data using several statistical methods such as the Linear Regression Model and Rank Spearman Correlation Coefficient [11]. Using Geographic Information System (GIS), the distribution of drug addiction cases across different districts was visualized, and a combination of multivariate analysis techniques were employed. Specifically, cluster analysis was applied to the database to confirm the correlation between data points within the same cluster [12].

EMR exposure has increased drastically in recent years due to technological advancement. Its influence on health especially, even the exposure below the standard guidelines have drawn the attention of researchers to study the impact that it could produce. This issue is worrying as residential college is one of the places expected to be polluted with RF EMR, in addition to the

fifth-generation mobile network or 5G that are expected to be roll out soon in the future [13]. 5G will play a big role in education sector as it will enable realistic use of rich digital content and feasibly offer a fully digital education [14]. Hence, it is important to measure and assess the levels of RF EMR at a place where it has a high number of people as well as high usage of technology and communication system which in this case, the study will be done at Universiti Sultan Zainal Abidin (UniSZA) residential area. The aim of the study is to make use of the measurement and assessment as a reference points to take measures for future precautions..

2. METHODOLOGY

This study was conducted from July 2020 until June 2021 at University Sultan Zainal Abidin Gong Badak Campus. The data collection took about six months from September 2020 until March 2021. All the data was collected during daytime from eight o'clock in the morning until two o'clock in the evening [15].

2.1 Study Location, Site Identification, and Site Selection

This study took place at several spot in Blok C and Blok M of UniSZA Gong Badak residential college as shown in Figure 1. The floor plan was sketched using Microsoft Publisher 2019 to get a better representation location of the measurement points. The measurement of EMR exposure were conducted at two points in UniSZA Gong Badak female residential college which is Blok C, and one point in a male residential college which is Blok M. The location for measurement is decided based on the number of routers available at the area and the population of the block. This is due to WiFi from the router is one of the common sources that exposes people to radio frequencies [16].

Fig. 1. On the left side is the floor plan of second floor at Blok C and on the right side is the floor plan of fourth floor at Blok M. The point of measurement is marked using a red pin on the plan. The blue colored symbol on the plan represents a router.

2.2 Data Collection

In this study, the measurement was carried out using Keysight spectrum analyser (model N9915A). This equipment external gain, reference attenuation, and frequency span parameter were set to 100 dB, 10 dB, and 0 GHz to 4 GHz respectively. The instrument setup, consists of a spectrum analyser (SA), connected to a low noise amplifier and an omni-directional circular patch antenna [17] using a female-to-male connector as shown in Figure 2. The low noise amplifier was used to amplify a very low-power signal without significantly degrading its signal-to-noise ratio [18]. The setup was tested in an open area to ensure the equipment operated normally before a measurement was made on the first point.

The instrument was placed at a height of 150-centimeter above the ground using a table and were left to take the measurement for ten minutes for every point. The temporal average value of exposure for any 6-minute period must be used for comparison with the established reference levels, according to the ICNIRP principle [19]. The same setup was used for each single point. The raw data of radiation is recorded internally in the form of decibels relative to one millivolt (dBmV) against frequencies (f) thrice for every second.

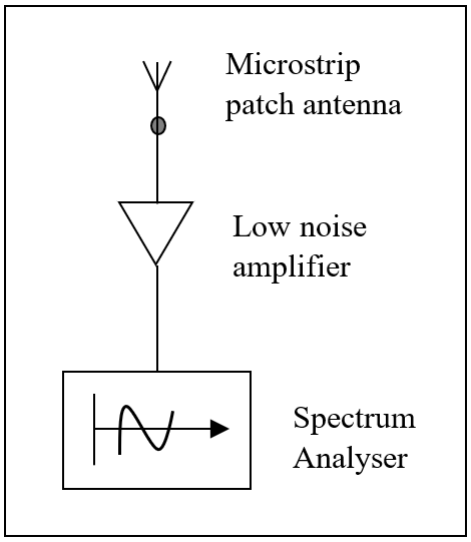

Fig. 2. Equipment Setup that consists of Spectrum Analyzer, Low Noise Amplifier (LNA) and Isotropic Antenna

2.3 Data Analysis

After the data collection completed, the raw data which are saved in individual files for each data cycle was extracted from the SA to a laptop using a local area network or LAN cable. Then, the large datasets were

managed using Anaconda programming software to merge and compile the files into one single file for every point. The managed file was then analysed by first converting the signal strength data in dBmV into electric field strength which is in V/m using the following equation [20]:

$$V/m = (dBmV/20) \times 0.021f \times 1000$$

where f in the equation is the frequency in MHz, and 0.021 is a multiplication factor on leakage measurement with included the antenna factor of a resonant half-wave dipole [18]. A graph of frequency against signal strength in dBmV was plotted to identify the peak. Then, a graph of frequency against electric field strength (V/m) was plotted along with the ICNIRP limit to compare the data acquired with the standard exposure limit set by ICNIRP for public exposure as stated in guidelines [19]. This is crucial to know the extent of the exposure compared to the prescribed limit.

3. RESULTS AND DISCUSSION

3.1 Determination of the Frequency of the Highest Value of Exposure

Based on the data collected, Blok C EMR exposure is as shown in Figure 3, the prominent signal strength peaks were identified at frequencies of 960 MHz, 1770 MHz, 1860 MHz, 2150 MHz, and 2560 MHz. Each peak mentioned is the highest five in terms of the Voltage Amplitude recorded with a value of 61.05 dBmV, 56.67 dBmV, 63.01 dBmV, 64.56 dBmV, and 65.96 dBmV respectively. Based on all the value above, the highest recorded reading is 56.67 dBmV at 1770 MHz.

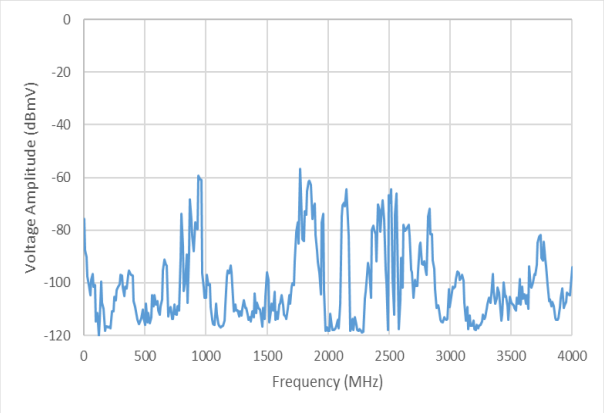

Fig. 3. The variety of peak and the highest value of Voltage Amplitude at Blok C.

Meanwhile, Figure 4 below is a graph plotted for M block and it can be seen that five prominent peaks were identified at frequencies of 870 MHz, 970 MHz, 1300 MHz, 1750 MHz, and 3950 MHz T with values of Voltage Amplitude is about 56.67 dBmV, 61.40 dBmV, 64.55 dBmV, 65.96 dBmV and 59.31 dBmV respectively. The highest peak is recorded at 870 MHz with 56.67 dBmV.

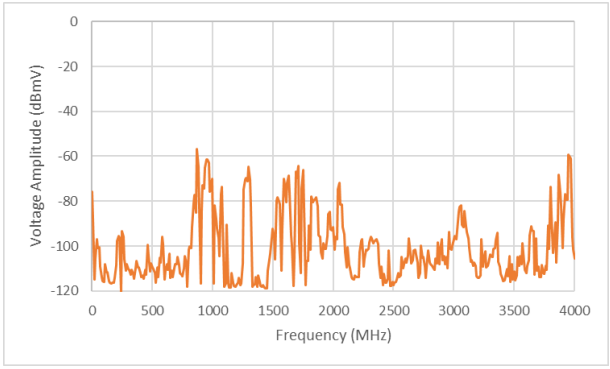

Fig. 4. The variety of peak and the highest value of Voltage Amplitude at Blok M

Table 1 shows the common sources of spectrum allocation plan prepared by the Malaysia Communications and Multimedia Commission in 2019, guided by the International Telecommunication Union (ITU). The general idea of why the allocation spectrum plan is made is to provide a framework to make full use of the spectrum to achieve harmony and balance of the global use on the spectrum. The same goes to the spectrum management in Malaysia guided by ITU, where the plan sets out the allocation of frequency bands to various types of services in order to achieve that optimum and efficient use of the spectrum as a whole.

Table 1. A Few Common Sources of Spectrum Allocation [21]

Services		Frequency Band (MHz)
Aeronautical Broadcasting	Aeronautical	108-137
	FM Radio	87.5-108
	VHF TV	171-230
	UHF Mobile	470-510
	UHF TV	510-798
Cellular Mobile Services	GSM 900	925-960
	GSM 1800	1805-1880
	3G	2110-2170
	4G	850, 900, 1800, 2100, 2300, 2600
		450-6000, 24250-52600
WiMAX Wi-Fi	WiMAX	2300-2390
	Wi-Fi	2390-2500
		5180-5875

Referring to the Table 1, the sources that contributed to that highest peak in Blok C could be coming from either Wi-Fi or cellular mobile services and the sources that contributed to that highest peak in Blok M could be coming from the cellular mobile services. Although the frequency is not exactly within that range of frequency stated in Table 1, it is highly likely that the sources contributed to those peaks are from the sources mentioned earlier because Table 1 acts as a guidance from ITU, thus showing a rough value to guide the Malaysia authority.

Table 2 and Table 3 shows a detailed information on the spectrum allocation for cellular mobile services for Malaysia. Based on these table, it is confirmed that the sources contributed to the highest peak in Blok C and Blok M are from the cellular mobile services, particularly from the GSM 2600 MHz band and GSM 1800 MHz band respectively.

Table 2. Spectrum Assignments for 1800 MHz Band [22]

Spectrum Assignment Holder	Frequency Band (MHz)
Celcom Mobile Sdn Bhd	17.45 - 1765 / 1840 - 1860
Digi Telecommunications Sdn Bhd	1765 - 1785 / 1860 - 1880
Maxis Broadband Sdn Bhd	1710 - 1730 / 1805 - 1825
U Mobile Sdn Bhd	1730 - 1745 / 1825 - 1840

Table 3. Current Operators in 2600 MHz Band [21]

Operators	Frequency Range (MHz)
Redtone	2500 - 2510 / 2620 - 2630
Maxis	2510 - 2520 / 2630 - 2640
U Mobile	2520 - 2530 / 2640 - 2650
Celcom	2530 - 2540 / 2650 - 2660
Altel	2540 - 2560 / 2660 - 2680
Digi	2560 - 2570 / 2680 - 2690
TM/Webe	2575 - 2595
YTLC	2595 - 2615

Since there are many frequencies band that is allocated for cellular mobile services, it is not unusual to see many of the peaks emerge from it in Blok C and Blok M, especially the 1800 MHz band which are more utilized in densely populated areas [23], which in this regard a residential college is considered as a densely populated area. Hence, the sources that contributed to the most RF EMR levels in UniSZA Gong Badak residential college is from cellular mobile services

3.2 Comparison with the Standard Guideline by ICNIRP

Based on the signal strength value plotted in Figure 3 and Figure 4, the EF strength (V/m) have been calculated. The graphs of frequency (MHz) against EF strength (V/m) for Blok C and Blok M were plotted as illustrated in Figure 5 and Figure 6 respectively

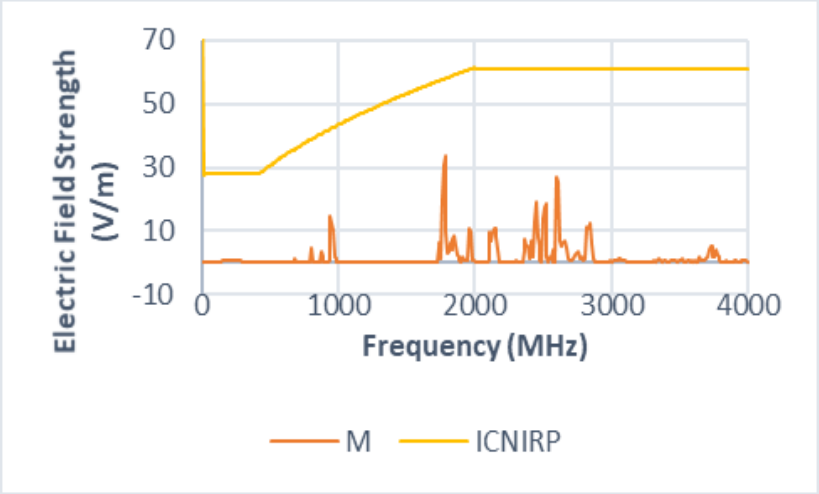

Fig. 5. The Value of EF Strength at Blok C in Comparison to the ICNIRP Limit

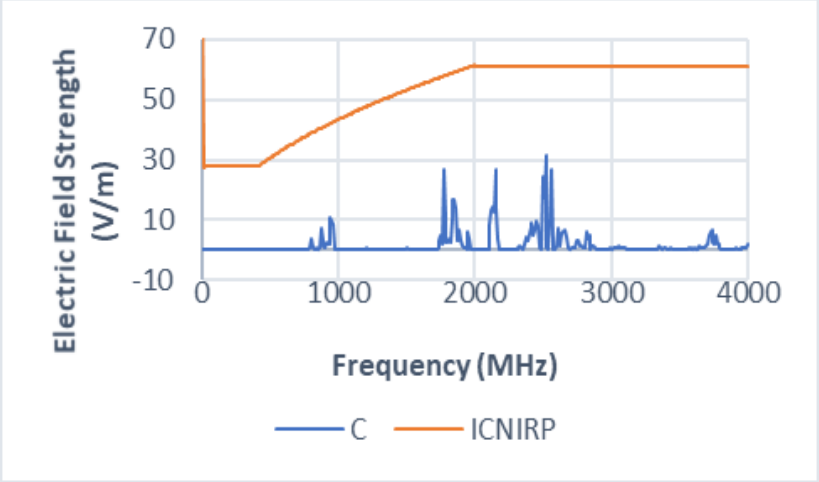

Fig. 6. The Value of EF Strength at Blok M in Comparison to the ICNIRP Limit

As in the previous subsection, we have concluded five frequencies which hold the highest signal strengths for both Blok C and Blok M. In line with the graph in Figure 5 and Figure 6, the EF strength values for these frequencies are as tabulated below (Table 4):

Table 4. Five prominent frequencies with highest value of Electric Field (EF) Strength at Blok C and Blok M.

Blok C		Blok M	
EF Strength (V/m)	Frequency (MHz)	EF Strength (V/m)	Frequency (MHz)
27.02	1770	31.09	1770
26.72	2150	18.89	2450
24.20	2500	27.05	2600
24.05	2560	25.35	2610
31.70	2520	33.46	1780

It can clearly be seen that all of the recorded values are still within the reference level limit for general public exposure set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Then highest exposure at Blok C which is approximately about 31.70 V/m is below the ICNIRP limit of 61.00 V/m at 2520 MHz. The ICNIRP limit is obtained from the calculation based on the formula listed in Table 5 below. However, the exposure value is quite high with approximately 52% of the limit.

Table 5. Reference Levels for General Public Exposure to Time-varying Electric and Magnetic Fields [19]

Frequency Range	Electric Field Strength (V/m)
Up to 1 Hz	-
1-8 Hz	10 000
8-25 Hz	10 000
0.025-0.8 kHz	250/f
0.8-3 kHz	250/f
3-150 kHz	87
0.15-1 MHz	87
1-10 MHz	87/f
10-400 MHz	28
400-2000 MHz	1.375f
2-3000MHz	61

Meanwhile, the highest exposure for Blok M, 33.46 V/m is also below the reference level of value 57.85 V/m at 1780 MHz with approximately 59% off the limit. Blok M shows higher percentage of exposure. This is alarming due to the fact that the long and repetitive exposure to RF EMR can cause suppression of nervous system, as reported in the study of white rat that led to weakening quality of locomotion done by Sultangaliyeva et al. [24]. Moreover, study by K Dhami et al., also show the decline in the diversity of the bird species that may lead to certain population of bird species become extinct and destroy the ecosystem.

4. CONCLUSION

In summary, the non-ionizing radiation exposure issue is concerning due to the harmful effects that it may bring, that is why it is important to have a current reading to ensure that the current reading does not exceed the standard limit which in turn contributing indirectly to the health monitoring action for public NIR exposure. This study shows that the exposure levels are within the standard limit and most of the sources contributing to the RF EMR in UniSZA Gong Badak residential college comes from the cellular mobile services. In future, it is better to have a RF EMR exposure map generated using GIS software because it will assist in representing the overall data in a much simpler but precise way. In a simpler word, it is better to have a spatial model for a better representation of data. An automated system for monitoring exposure should be developed in the future, building upon the methods previously implemented by Sabri and Nasir [25][26]. Mapping of exposure in the surrounding environment should be considered for the future, as demonstrated by Cauba et al[27].

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