Environmental radio frequency radiation (RFR) safety assessment at the vicinity of telecommunication structures in Malaysia

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Abstract. Radio Frequency Radiation (RFR) from the existing and newly erected telecommunication structures has turned out to be a major public health concern in many countries of the world including Malaysia. The public in general are not only apprehensive about the growing weight of scientific evidence associating health effects to mobile phone use, nevertheless they are also increasingly concerned about the chronic, low-level RFR exposure from the stated structures. The paper highlights the study on the RFR emanated from the antennas installed on the telecommunication structures in Malaysia. The objectives of the study are to determine the level of RFR present and to assess the potential exposure received by the general public at the vicinity of the telecommunication structures. The study encompassed on the assessment of the RFR emitted by the antennas which displayed the results in the power density unit measured in microwatts per square centimeter (\(\mu\text{W/cm}^2\)) at each identified locations. The results obtained from the study showed that the RFR level present in the area assessed were well below and less than 1\% of the reference level for exposure stated in the Malaysian Communications and Multimedia Commission (MCMC) Mandatory Standard and International Commission on Non-Ionizing Radiation Protection (ICNIRP).

1. Introduction
Mobile phones play an essential part of modern telecommunications, whereby in many countries, over half the population use mobile phones. The usage of mobile phones has been increasing exponentially over the past decades in line with the needs of high-speed communication. As of first quarter 2020 (Q1 2020), the number of mobile subscriptions in Malaysia was at 41.74 million [1]. In conjunction, for the year 2020, the number of smart phone users in Malaysia is estimated to reach 30.41 million. In line with this, the telecommunications companies are establishing more telecommunication structures at every strategic location as the demand for mobile users are tremendously high at the stated areas and to ensure the quality of services to their customers. The number of telecommunication structures built by the Network Service Providers (NSP) and Network Facility Providers (NFP) in residential areas has raised concerns from the public about possible radio waves effects caused by these structures to them. Therefore, this study aims to determine and assess the Radio Frequency Radiation (RFR) present at the concerned areas and at the same time, analyse the RFR level based on the Malaysian Communications and Multimedia Commission (MCMC) Mandatory Standard and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines.
2. Description of assessment locations
The RFR safety assessment was conducted at 25 locations at 5 selected states namely Wilayah Persekutuan Kuala Lumpur, Selangor, Penang, Malacca and Sarawak. 5 locations were selected from each states for the safety assessment. It should be noted that the RF radiation levels at the time of the measurement were from the background radiation and sources from several rectangular and point-to-point parabolic antennas installed on the telecommunication structures. The sites were named as Location 1-5, followed by the name of the state to represent the 25 locations. The locations of measurement selected was based on the worst-case situation, as an example those which were potential to present the higher radiation exposure to people living or working in that area and the areas with the direct antenna beam path. The main objective of the measurement were to determine and assess radio frequency radiation (RFR) present in all accessible places at the concerned area and to analyse the RF radiation level based on the Malaysian Communications And Multimedia Commission (MCMC) Mandatory Standard 2010 [2] and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [3] recommendation for the reference level of exposure at identified locations around the site.

3. Safety guidelines and exposure limits
The reference level or exposure limits are referred to RFR frequency involved and set differently for workers and members of the public. Public being more critical to radiation because of longer exposure time involved, unknown exposure situation and are more diverse in term of health status and age groups represented, has had the limits established at much lower levels (by 2 to 5 times lower) than the workers [2-10]. Based on the recommended guidelines for public, the Exposure limit of RF radiation is very much dependent on frequency of the transmitted radiation. The frequencies transmitted by the rectangular antennas are within the range of 2.0 GHz and above. The frequency range is based on the spectrum allocation of each service providers in Malaysia. Therefore, for this study, the lowest frequency radiation expected to be transmitted by the antennas is taken as the reference frequency point to derive the reference level or the exposure limit for public at each site. The reference level for each frequency range is summarised in Table 1. For this study, the unit of power density was stated in microwatts per square centimeter (µW/cm²).

Table 1. Mandatory Standard Reference Levels of EMF exposure.

| Type of Exposure | Frequency range (f) | Equivalent plane wave power density (W/m²) |
|------------------|---------------------|------------------------------------------|
| Occupational     | 10MHz-400 MHz       | 10                                       |
|                  | 400MHz-2000 MHz     | f/40*                                    |
|                  | 2GHz-300 GHz        | 50                                       |
|                  | 10MHz-400 MHz       | 2                                        |
| General Public   | 400MHz-2000 MHz     | f/200*                                   |
|                  | 2GHz-300 GHz        | 10                                       |

*Note: f is the frequency of operation in MHz

4. Methodology
The RFR safety assessment was performed using standard measurement protocol and procedures developed by Malaysian Nuclear Agency based on the standards recommended by more established organizations and government agencies, such as International Telecommunication Union (ITU), International Commission on Non-Ionizing Radiation Protection (ICNIRP), Institute of Electrical and Electronics Engineers (IEEE) and Canadian Safety Code 6 guidelines [5-10]. All measurements were performed at 1.5 meters above the ground. At each point, measurements were taken for 6 minutes within which 360 data are recorded, which means that for each second, one data will be logged into the instrument.
The data will be analysed by using the software embedded in the equipment itself and transferred to the laptop for further analysis and computation. The measurement encompassed only on the assessment of the RFR generated by the antennas installed on the telecommunication structures. The measurement was arranged to include both the electric field strength and power density at identified locations around the building [2-10]. Results of radio-frequency measurement were recorded in unit of power density measured in microwatts per square centimeter (µW/cm²). The measured radiations were assessed and evaluated against the exposure limits and the recommendations of standard guidelines issued by the MCMC Mandatory Standard and the ICNIRP. The broad band frequency was measured by using Narda NBM-550 attached with isotropic probe Model EF0691 (100kHz - 6GHz). For detailed spectrum analysis of radiations involved, measurements were made using a Narda-Safety Test Solution instrument Model SRM-3006 attached with Three-Axis Antenna, which measure radio-frequency and microwave electric field strength from 27MHz up to 3 GHz.

5. Results and discussion
The RFR power density measured at all the 25 locations were ranging from 0.02 µW/cm² to 4.15 µW/cm². The highest value of RFR power density was recorded at Location 4 in the state of Selangor. This level corresponds to 0.42 % power density of the reference level or the exposure limit as stated in MCMC Mandatory Standard. The results of the 25 locations of the 5 states in Malaysia are as summarised in Table 2. The plot of the radiation level compared to the reference level or the permissible exposure limit is shown in Figure 1. Detailed investigation of the RFR present utilizing the spectrum analyser around the telecommunication structure was performed on all the selected sites. The RFR observed consists of radio, TV, mobile phones and signals from other telecommunication structures. On average for all the RFR analysed, it was recorded that around 60% of the radiation strength is from the signals from the transmitting antennas of the stated telecommunication structures, 22% of the strength is from mobile phone signals, 10% from TV signals and 8% from radio signals.

![Figure 1. Plot of RFR levels in microwatts per unit area (µW/cm²) against location of the measurement and their comparison with MCMC & ICNIRP Reference Level for public.](image-url)
6. Conclusion

The RFR measured in all the sites were well below the reference level and comply with the MCMC Mandatory Standard and ICNIRP Guidelines for members of the public. Detailed analysis at each telecommunication structures shows the presence of other RF signals such as Radio, TV and Mobile Phone Signals. Based on the findings from this assessment, the presence of the RFR emitted by the antennas from the telecommunication structures would not lead to any significant radiation exposure received by the public in the area. It should be noted that RFR safety assessment must be done during the commissioning of new transmitting antenna or any modification on the existing antenna.

Table 2. Summary of the RFR results of the 25 locations consisting of 5 states in Malaysia

| Location            | Maximum RFR Level in terms of Power density (µW/cm$^2$) | Reference Level (µW/cm$^2$) | Comparison with Reference Level (%) |
|---------------------|-------------------------------------------------------|-----------------------------|-----------------------------------|
| Location 1_K. Lumpur| 1.32                                                  | 1,000                       | 0.13                              |
| Location 2_K. Lumpur| 2.61                                                  | 1,000                       | 0.26                              |
| Location 3_K. Lumpur| 1.50                                                  | 1,000                       | 0.15                              |
| Location 4_K. Lumpur| 3.05                                                  | 1,000                       | 0.31                              |
| Location 5_K. Lumpur| 1.05                                                  | 1,000                       | 0.11                              |
| Location 1_Selangor | 1.80                                                  | 1,000                       | 0.18                              |
| Location 2_Selangor | 1.25                                                  | 1,000                       | 0.13                              |
| Location 3_Selangor | 0.66                                                  | 1,000                       | 0.07                              |
| Location 4_Selangor | 4.15                                                  | 1,000                       | 0.42                              |
| Location 5_Selangor | 1.25                                                  | 1,000                       | 0.13                              |
| Location 1_Penang  | 2.52                                                  | 1,000                       | 0.25                              |
| Location 2_Penang  | 1.85                                                  | 1,000                       | 0.19                              |
| Location 3_Penang  | 2.05                                                  | 1,000                       | 0.21                              |
| Location 4_Penang  | 2.89                                                  | 1,000                       | 0.29                              |
| Location 5_Penang  | 1.58                                                  | 1,000                       | 0.16                              |
| Location 1_Malacca | 0.85                                                  | 1,000                       | 0.09                              |
| Location 2_Malacca | 1.70                                                  | 1,000                       | 0.17                              |
| Location 3_Malacca | 0.95                                                  | 1,000                       | 0.10                              |
| Location 4_Malacca | 0.67                                                  | 1,000                       | 0.07                              |
| Location 5_Malacca | 0.91                                                  | 1,000                       | 0.09                              |
| Location 1_Sarawak | 1.18                                                  | 1,000                       | 0.12                              |
| Location 2_Sarawak | 0.50                                                  | 1,000                       | 0.05                              |
| Location 3_Sarawak | 1.18                                                  | 1,000                       | 0.12                              |
| Location 4_Sarawak | 0.98                                                  | 1,000                       | 0.10                              |
| Location 5_Sarawak | 0.59                                                  | 1,000                       | 0.06                              |
7. References

[1] MCMC 2020 Communication and Multimedia Facts and Figures 1Q 2020.

[2] MCMC 2010 Commission determination on the mandatory standard for electromagnetic field emission from radio communications infrastructure Determination No. 1 of 2010.

[3] International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020; Guidelines for limiting exposure to electromagnetic fields (100kHz to 300 GHz) ICNIRP Guideline 118(5) 483-524.

[4] International Commission on Non-Ionizing Radiation Protection (ICNIRP) 1998 Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz) Health Phys. 74 494-522.

[5] ITU 2019 Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service ITU-T K 100.

[6] ITU 2018 Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations ITU-T K 61.

[7] ITU 2019 Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields ITU-T K. 91.

[8] ITU 2018 Guidance on complying with limits for human exposure to electromagnetic fields ITU-T K 52.

[9] Institute of Electrical and Electronics Engineers (IEEE) 2019 IEEE standard for safety levels with respect to human exposure to electric, magnetic, and electromagnetic fields, 0 Hz to 300 GHz.

[10] Health Canada 2015 Technical guide for interpretation and compliance assessment of health canada's radiofrequency exposure guidelines Canadian Safety Code 6.