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WIRELESS INDUSTRY EMISSION: ELECTROMAGNETIC FIELD MONITORING AND ANALYSIS

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ABSTRACT

This study is prepared by the Wireless Communication Centre (WCC) Universiti Teknologi Malaysia (UTM) as collaboration with the Malaysian Communication and Multimedia Commission (MCMC) from Northern, Central and Southern regions to study the non-ionizing radiation (NIR) emission to public. This study aims to investigate the EMF pattern and its bio-effect to human kind. The installations of mobile base stations among residential areas have raised widespread concerns about the possibility on radio frequency (RF) exposure to human being. The rapid growth of mobile telecommunication technologies which subscription estimated about 9.3 billion by 2019 will affect each person in the world. The proposed study aims to evaluate the communication science, radio frequency technologies and recommend some solutions to fill any gaps in knowledge of electromagnetic field (EMF). In addition, five EMF area monitoring systems will be placed nearby mobile base stations to record the radiating sources in real time for a year period. The methodology frame work covers the investigation of emission from FM radio, analogue TV broadcasting, WiMAX, 2G, 3G and 4G mobile base stations 24 hours every day. This study has given the opportunity to identify the most sensitive systems of human body. Biological reaction of human body are obligatory taken into account, when assessing the risk of EMF effects to body tissues to develop standards of the electromagnetic safety.

Keywords: GSM, 5G, EMF, base station, electric field, non-ionizing radiation, radiation protection.

INTRODUCTION

The main purpose of the "Wireless Industry Emission: Electromagnetic Field Monitoring and Analysis" is to provide the general public with independent and factual information about the subject of non-ionizing radiation (NIR) such as electromagnetic field (EMF) emission from mobile base station especially the coming 5G technologies where sub-base stations are very close to each other for better backhaul and transfer rate. At the time that the project was started, non-ionizing radiation, particularly the high-frequency emissions from mobile phone base stations, was one of the environmental topics most often discussed by the public in Malaysia. The study is divided into the following three sections:

Instruments installation and lab setup

The selective AMS-8060 Area Monitor represents the state-of-art for technical characteristics and operating possibilities. Equipped with solar panel back-up and connected to the control centre by GSM, it can be easily installed wherever required to monitor up to 20 different EMF sources; the latter's frequency bands can be programmed and modified directly from the control centre. Narda Area Monitors are supplied with a powerful PC utility, useful for managing the monitoring network easily and immediately:

- Create and manage the settings of each unit
- Connect to units manually or automatically
- Download data to the PC
- Check operating status of field units
- Display graphs of the levels vs time
- Export data to other applications
- Handover measurement data to a database for representation in Internet

Standard Narda PC software brings the Narda Area Monitors into service immediately. For those large system applications, users have remote controls available to integrate measurements and controls of the Narda Area Monitors into their own platforms.

Measurement

WIE in Malaysia covers temporary measurement of the electromagnetic radiation from mobile phone and broadcasting transmitters, regular transfer of the measured values into a database, and graphical representation of the results on the Internet.

Measurements are made at a total of 5 locations spread across the three states of Peninsular Malaysia. Measurements are made at each location during a period of about 12 months.

The measurements are focused on determining the level of high frequency electromagnetic radiation (mobile telephony, broadcasting), and investigating the interference effects of these radiating sources. Low frequency fields from high-tension lines or transformer stations are not recorded by these measurements.

Information

The Malaysian Communication and Multimedia Commission (MCMC) (rfemissions.skmm.gov.my/) and Malaysian Nuclear Agency (nuclearmalaysia.gov.my/) website, provide the general public of Malaysia with general information about NIR emissions, non-ionizing radiation laboratory testing and calibration, telecommunication/broadcasting site radiation surveys, wireless networks and their biological effects as well as about the legal regulations regarding their limitation. The latest radio frequency radiation safety assessment report and updated publications can also be accessed from this website.

Apart from that, this project will develop a EMF monitoring webpage to store and present all the valuable data to public and user for education information and research purposes. The webpage also capable to generate assessment report of the monitored sites.

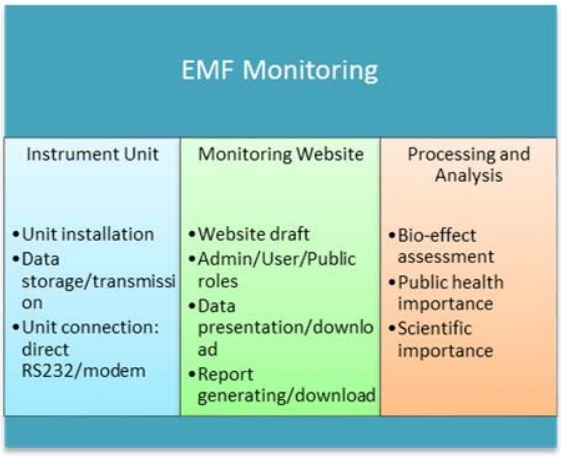

Figure- 1. EMF monitoring stages.

RESEARCH REVIEW

Mobile phone base stations are known as base transceiver stations or telecommunications structures. The base stations are multi-channel two way radios with low power. Antenna as transmitter and receiver is mounted on transmission tower, on ground or roof top structure. These antennas produce RF radiation for communication and therefore exposed residents and people nearby with RF radiation.

Electromagnetic spectrum

Electromagnetic spectrum in Figure-2 shows the behavior of ionizing and non-ionizing sources. Radiation emitted from mobile phones and base stations are lower than ultraviolet (UV) radiation from sun (Polfer, 2013 and Tong *et al.* 2013).

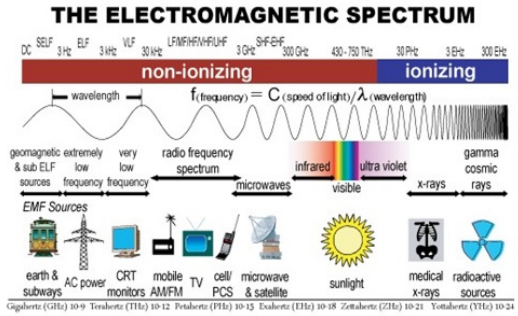

Figure-2. Ionizing and non-ionizing radiation spectrum.

Mobile base station and broadcasting tower

Figure-3 shows the power and coverage of mobile base station and broadcasting tower. According to the values recorded, the power emitted from broadcasting towers is higher than mobile base station. In other words, the EMF field from broadcasting towers are stronger than mobile base station.


	Mobile Base Station	Broadcasting Tower (TV & Radio)
Power Level (W)	40 - 60	1000 - 30000
Height of Antenna (m)	40 - 100	~ 400
Installation Location	Rooftop / Neighborhood	High altitude
Coverage Radius (km)	1 - 30	> 70

Figure-3. Difference between mobile base station and broadcasting tower.

EMF categories

The exposure to EMF sources can lead to significant absorption of energy and increment of temperature. For the absorption of energy by human body, EMF wave can be divided into four categories (Repacholi, 2001, Rowley & Joyner, 2012 and Felix *et al.* 2014):

- ≥ 100 kHz to ≤ 20 MHz
- where absorption in the trunk decreases rapidly with decreasing frequency, and significant absorption may occur in the neck and legs.
- ≥ 20 MHz to ≤ 300 MHz
- which relatively high absorption can occur in the whole body and to even higher values if partial body (e.g. head) resonances are considered
- ≥ 300 MHz to ≤ 10 GHz
- which significant local, non-uniform absorption occurs
- ≥ 10 GHz

- which energy absorption occurs primarily at the body surface

EMF health effect

Long term EMF exposure is possibly affecting human body such as nervous, endocrine, immune, cardiovascular and reproductive systems. By cumulating long term effects from EMF sources within many years, the resultant late effects are possible including degeneration processes in the central nervous system, leukemia, brain tumors, cardiovascular and hormonal diseases. Apart from that, EMF can be easily dangerous in children, pregnant women, patient with diseases of central nervous, hormonal and cardiovascular systems, allergy and person of weaken immunity. These data were proved by the contemporary Russian electromagnetic safety standards for the 55 years of comprehensive hygienic, clinical, physiological and experimental studies (Grigoriev *et al.* 2003).

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Figure-4. Narda area monitor (left) and portable RadManXT monitor.

The instruments equipped with a wide choice of sensors that can meet any EMF monitoring demand. Figure-5 shows the most common applications divided by frequency band and type of field measurement (Narda-STS, 2006 and Wuschek *et al.* 2006).

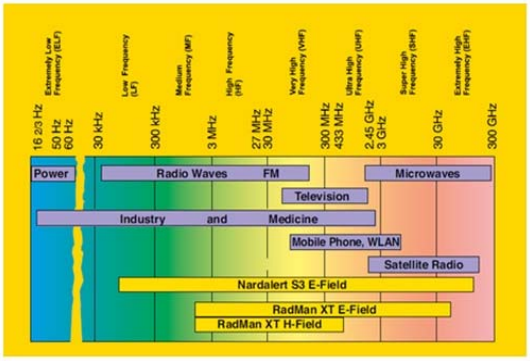

Figure-5. Frequency band and type of field measurement.

Measurement principles

The measurements are basically performed in the far field of the electromagnetic radiation sources. The field components E and H are not considered to propagate as plane waves but can be able related by using the intrinsic impedance of the medium 377 ohms. The measuring point or measuring distance is defined by meeting two conditions:

$$R \geq 4\,\lambda \quad (1)$$

$$R \geq 2\,\frac{D^2}{\lambda} \quad (2)$$

R = Distance between the radiation source and the measuring point
D = Largest mechanical dimension of the radiating antenna
λ = Wavelength

The boundary curve of the far field is given by:

$$R(\alpha) \geq \frac{2D^2\cos^2\alpha}{\lambda} \quad (3)$$

α = Angle between the horizontal axis and the propagation direction

The boundaries of the regions only depend on antenna dimensions and wavelength, they do not depend on any case on the emitted power (Rappaport *et al.* 2002).

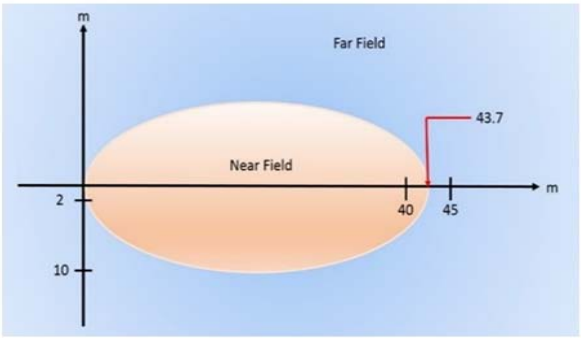

Figure- 6. Near field and far field boundary.

Measurement principles

In 1998, ICNIRP has published the recommended limits on human exposure limits and the recommendation was reviewed again in 2009. The development of the ICNIRP guidelines was according to the database of studies which has grown over the years.

Table-1 shows the radiation levels approved limits set by International Commission on Non-Ionizing Radiation (ICNIRP). Table-2 shows the example results of electric field measurements on the ground in Malaysia which are well below ICNIRP exposure limits.

Table-1. Radiation safety limit for public by ICNIRP (Ahlbom *et al.* 1998 and ICNIRP, 2009).

Frequency	900 MHz	1800 MHz	2100 MHz	2600 MHz
Power Density (W/m^2)	4.5	9	10	10
E-Field Value (V/m)	41.25	58.3	61	61

Table-2. Radiation level in Malaysia (Ismail *et al.* 2009).

Frequency	900 MHz	1800 MHz	2100 MHz
Power Density (W/m^2)	139×10^{-6}	3×10^{-6}	7×10^{-6}
E-Field Value (V/m)	0.23	0.03	0.05

Existing research

Research was done by Wuschek *et al.* (Wuschek *et al.* 2006) to monitor and record the NIR exposure of high frequency electromagnetic field to the Citizens of Central Switzerland. A typical measurement site is shown in Figure-7 (location "Freienbach canton school"). Since the nearest mobile phone transmitter here is located several hundred meters from the measurement location, the measured values are comparatively low. Nevertheless, the variations in emissions at certain times of the day that are typical of mobile phone transmissions are clearly seen.

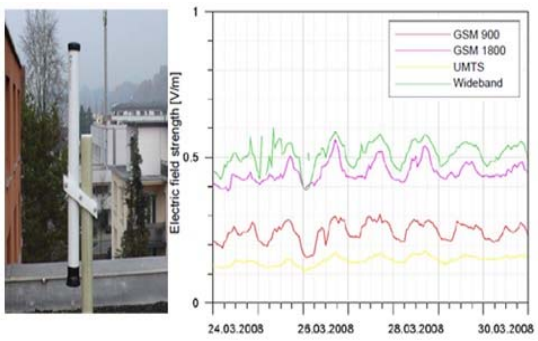

Figure-7. Measurement field in Switzerland by Wuschek *et al.* (Wuschek *et al.* 2006).

Apart from that, Greece (Gotsis *et al.* 2008), India (Kumar, 2014 and Jain *et al.* 2014), Americana and Lithuania (Morozionkov & Virbalis, 2008) had conducted such research up to 3G.

RESEARCH METHODOLOGY

Like every other physical quantity referred to the environment, control of EMF requires specific sensors installed in the places where it is advisable to monitor, permanently or periodically the EMF level. Examples are public places like schools, hospitals, streets and squares, private residences; areas near electric power lines and installations; work places.

The Narda EMF Area Monitors measure the EMF levels present in the installation site then store the data permanently and safely in their internal memory. This memory can be downloaded from a distance at any time through the GSM mobile phone network. SMS warnings can also be sent to preset numbers whenever field values exceed preset limits. By using Narda EMF Area Monitors, efficient EMF monitoring systems meeting all requirements can be set up, from a local community to nationwide coverage.

The purpose of the monitoring networks is also to publish data; this is done by the Authority in charge, either on Internet or through the creation of data-bases for successive investigation. Whatever the choice, the data provided by Narda EMF Area Monitors is accurate and reliable.

It is often necessary to evaluate the EMF generated by installations situated in "work places", not accessible to the public, to evaluate the impact on surroundings, with particular respect to the residential structures that may coexist with them: examples are power lines and public and private telecommunication installations, to show existing radiation before and after installation of new services.

The EMF Area Monitors are focused to combine all characteristics needed for: autonomy, outdoor operation, portability, robustness and low operating costs. There are different approaches for distribution of EMF Area Monitors:

- Geometric, in arrays forming a grid over the place of interest, with an Area Monitor located at each cross intersection;
- Based on measurement campaigns on "hot spots" to monitor a defined period of time;
- Referred to concern: an EMF Area Monitor is installed wherever people feel unsafe.

Figure-8 shows the overview of the study. Narda STS area monitoring system was installed at five potential sites in Peninsular Malaysia (Penang, Butterworth, UTM KL, MBJB and Perling JB). The proposed sites cover residential area, urban area, university campus and surau. The instrument will be mounted and installed at a strategic location where people reside, gather or passing through to

reflect the real situation. Electric field strength and power density are the main focused elements in the study. Data recorded from EMF sensor are transmitted into local control centre for storage. These data can be download from distance through internet. Data with difference frequency bands will be analyzed and their effects toward human biological structure will be interpreted.

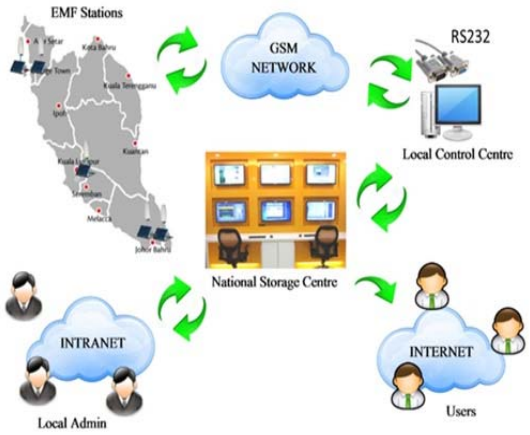

Figure-8. Study methodology of EMF monitoring.

Frequency setting

The frequency band of the proposed study is covered 6 bands, they are FM radio, analog TV, digital TV, GSM 900, GSM 1800, IMT 2000, WiMAX and LTE from 88 MHz to 2690 MHz.

Table-3. The frequency band setting of area monitors.

Band	Frequency
Band 1: Blank Start	75-88
Band 2: FM Radio	88-108
Band 3: Analog TV	174-230
Band 4: Digital TV	470-798
Band 5: Digi	931-933
Band 6: Celcom	933-950
Band 7: Maxis	950-960
Band 8: Maxis	1805-1830
Band 9: Celcom	1830-1855
Band 10: Digi	1855-1880
Band 11: U Mobile	2110-2125
Band 12: Maxis	2125-2140
Band 13: Celcom	2140-2155
Band 14: Digi	2155-2170
Band 15: YTL	2330-2360
Band 16: PacketONE	2360-2390
Band 17: Maxis	2630-2640
Band 18: Celcom	2650-2660
Band 19: Digi	2680-2690
Band 20: Blank End	2690-3000

Proposed sites

The Multiband Area Monitor AMS-8060 from Narda STS is used for recording the NIR measurements. The instrument measures the NIR exposure separately for each of the four frequency bands listed in Table-3.

The probes operate fully automatically and transmit the measurement results via mobile phone daily to a central station where the results are stored in a database. The probes save the measured values once every six minutes internally. To keep a clear overview of the results, the measurement data is compressed into 6-minute, hourly, and daily average values for the display on the Internet of the four separately investigated frequency bands. These values are plotted as a collective graph against time for each measurement location. Each probe has been installed at a different one of the 5 designated locations for a period of about 12 months.

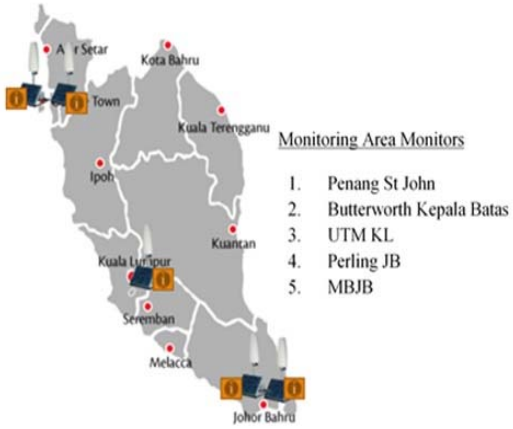

Figure-9. Monitoring sites of the study (northern, central and southern Malaysia).

ICNIRP safety limit

Table-4. Safety radiation limit for public by ICNIRP.

Frequency Band	Safety Limit (V/m)
Radio/TV Broadcasting	28
GSM 900	41
GSM 1800	58
IMT 2000	61
WiMAX	61
LTE	61

RESEARCH RESULT

Results of the study show that the total emission of radiation from base station are far below the ICNIRP safety limit, even the total peak emission are 6.32 % of the standard safety level.

The monitors are located at the five respective sites since 2-4 months (up to: 15 April 2015), monitoring up to six different frequency band types including radio and broadcasting, GSM, IMT, WiMAX and LTE.

Table-5. Total average emission, total peak emission and percentages of ICNIRP level of five monitor stations.

Location	Installed Date	Total Average Emission[1] (V/m)	Total Peak Emission[2] (V/m)	ICNIRP Safety Limit[3] (V/m)	Percentage of ICNIRP[4] (%)
UTM KL	Oct 2014	0.63	1.32	41	3.22
Perling, Johor	Dec 2014	0.38	1.21	41	2.95
MBJB, Johor	Feb 2015	1.64	2.59	41	6.32
Penang St John	Dec 2014	0.97	2.03	41	4.95
Kepala Batas, Butterworth	Dec 2014	1.02	1.29	41	3.15

[1] Note: Total emission includes all 6 frequency bands.
[2] Note: Total peak emission includes all 6 frequency bands.
[3] Note: GSM 900 safety limit is selected due to the focus on radiation from mobile base station.
[4] Note: Percentages are calculated based on the ratio of total peak emission to ICNIRP safety limit (41 V/m).

Figure-10. Installation at St John Penang approximately 15 meter from the building.

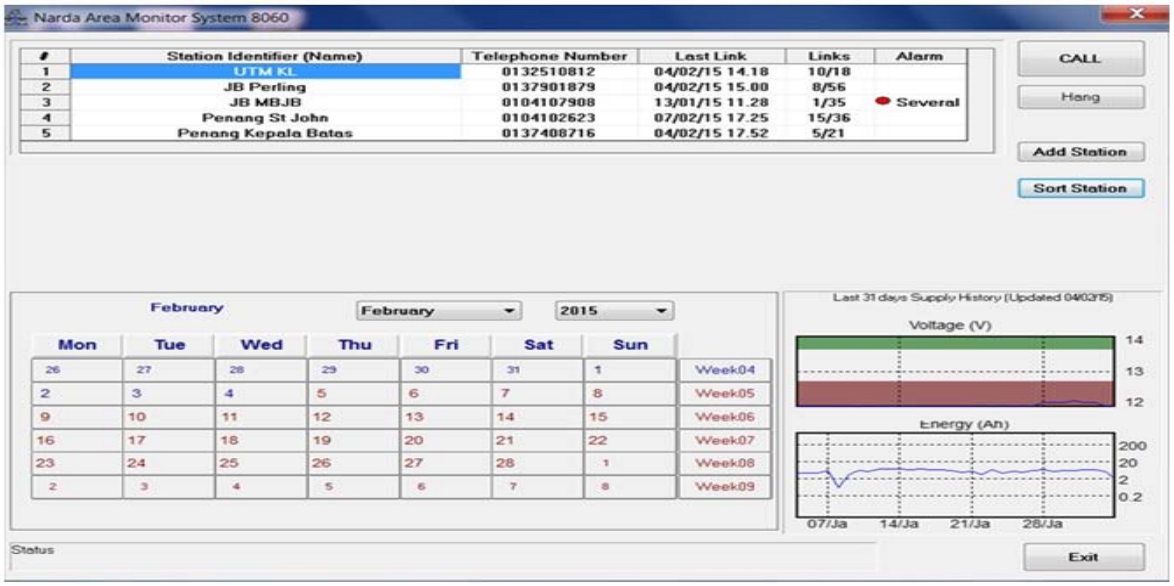

Figure-11. Narda area monitoring system software.

Figure-12. Data uploading, presentation and report generating webpage.

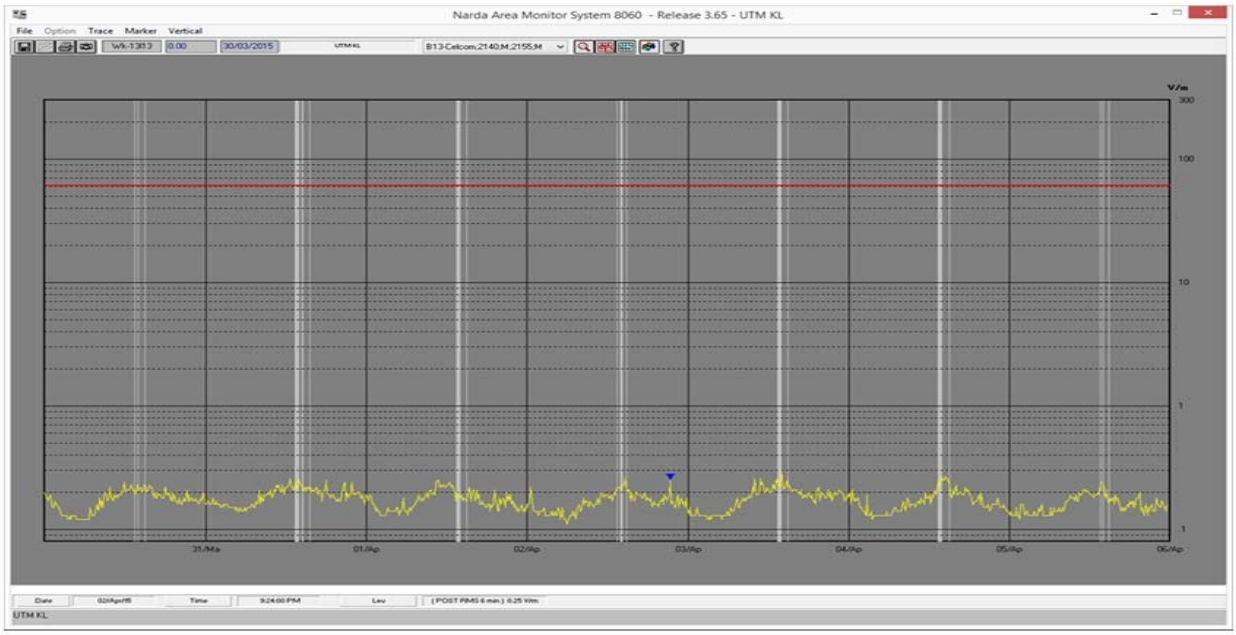

Figure-13. Radiation from IMT 2000 base station in UTM KL with ICNIRP reference (red line).

RESEARCH CONCLUSIONS

The results obtained within the framework of the project described here provided answers to some interesting questions regarding the NIR emission situation in Peninsular Malaysia, and it may be assumed that the knowledge gained here can be applied to regions of a similar nature.

Figure-14. Important result of the study.

ACKNOWLEDGEMENTS

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