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EFFECT OF SHORT-TERM LTE (850, 1800, 2600MHz) BASED ON COGNITIVE PERFORMANCE

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Technical Report

TECHNICAL REPORT

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Tel: (04) 977 5159, Fax: (04) 977 5135
Website: http://penerbit.unimap.edu.my
E-mail: penerbitan@unimap.edu.my

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1. ACKNOWLEDGEMENT

Firstly, we want to extend our thanks to Malaysian Communications and Multimedia Commission (MCMC) for giving us such a precious opportunity in funding this project. We also want to extend our gratitude to Universiti Malaysia Perlis (UniMAP) and the Faculty of Electronic Engineering Technology for giving us such an opportunity that allows us to use the facilities and resources in completing this research project.

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PREFACE

Enormous use of mobile phone has led to apprehension on the potential human health effects of exposure to electromagnetic fields (EMF) radiation from the mobile phone base stations. Children are exposed to these base stations from the very first day of their life until the end of life. That means the children of the modern age faces higher lifetime exposure than the adults. In addition, children may also be more vulnerable to potential effects of EMF due to their on-going developing organ and tissue systems. Children also have a greater Specific Absorption Rate (SAR) of EMF than in adults because of differences in the size, shape, water content, and tissue distribution of the head, brain and other tissues. Undoubtedly, these two factors have led the children to the highest level of risk.

Thus, the aim of this study is to clarify whether short-term exposure at 1 V/m to the latest mobile communication technology, Long Term Evolution (LTE) at 850, 1800 and 2600 MHz affects EMF perception, cognitive performance, well-being Encephalogram (EEG) response and physiological parameters (body temperature, blood pressure and heart rate) of the Malaysian children. This study implements counterbalanced randomizing single blind tests to verify if sensitive children experience more negative health effects when they are exposed to base station signals than the normal children. The sample size is 63 subjects with 49% Idiopathic Environmental Intolerance attributed to electromagnetic fields (IEI-EMF) known as sensitive and 51% (non-IEI-EMF). The findings reveal that in both sensitive and normal groups, there is no significant difference between the exposure to LTE signals and Sham exposure towards cognitive (P's > 0.05).

1. INTRODUCTION

Worldwide, the introductions of the Global System for Mobile Communication (GSM) in the 1990's, Universal Mobile Telecommunication system (UMTS) in 2000 and Long Term Evolution (LTE) in 2010 have dramatically increased the use of cellular telephones. There is widespread public concern about the potential adverse health effect of mobile phones in general and their associated base station in particular. In virtually all cases the reports relate to experiments that either studies on animals or short-term studies on human subject. The investigated items are the incidence of brain tumors, influence on Electroencephalogram, excretion of pituitary hormones, cognitive functions, thermal changes in the brain, DNA damage, lymphocyte and mitogen stimulation, visual functions and others.

Negeri Sembilan Cement Industries Sdn. Bhd. (NSCI), Perlis is one of the Portland cement producers in Malaysia, which involves processes such as selecting, grinding, heating, cooling and packaging. Each one of these processes discharges certain amount of particulate matter (PM) and harmful gases. However, when considering budget, only selected processes with higher particulate matter and harmful gases emission will be equipped with Air Pollution Control System (APC). The processes that take place in coal mill, kiln and grinder are the most likely to release high emission of particles, thus suitable air pollution control equipment is needed.

The existence of radio frequency electromagnetic field (RF-EMF) exposure effect from base station and mobile phone and their implication has not been sufficiently established to allow for them in the standard. Most of the previous review studies are concentrated on the possible effects caused by base station and mobile phone operating at various frequencies including the Global System for Mobile Communication (GSM) 900 MHz and 1800 MHz exposures. For the Third-Generation (3G) technology or also known as Universal Mobile Telecommunication System (UMTS), most of the studies focused on the effect to human cognitive functions. Experimental studies applying short-term exposure to base station signals gave various results (Zwamborn, Vossen, Van Leersum, Oumens & Makel, 2003; Eltiti, et. al., 2007; Regel, et. al., 2006; Eliti, et. al. 2009; Riddervold, et. al., 2008; Furubayashi, et., al., 2009), but there is weak evidence that UMTS and to lesser degree GSM signals reduce wellbeing in persons that report to be sensitive to such exposure. To the best of our knowledge, there are no studies yet on the possible effects to children caused by base station operating at the Long Term Evaluation (LTE) frequency, 850, 1800, and 2006 MHz. Mixed results have been reported in many studies conducted at GSM and UMTS frequencies. In Malaysia, the public are continuously expressing their concern on the risk of the base station radiation. Complains about physiological effect such as headache and dizziness when living in the vicinity of base station have been reported. No similar study has been done in Malaysia to investigate the issue among local public. Many studies conducted locally only focused on base stations exposure measurement. Therefore, there is an urgent need for a study performed on Malaysia public to shed light on the issue as well as to regain the confidence of local public on the mobile technology especially with regard to mobile base stations and the public safety when living near to base stations.

The goal of this research is to determine whether a relation exists between RF-EMF and the children subjective complaints together with cognitive performance associated with an electromagnetic stimulus. Only effects present during and shortly after exposure to electromagnetic field will be studied. This research also uses a single blind design in order to investigate the real influence of fields on the complaints reported. Children with idiopathic environmental illness with attribution to electromagnetic fields (IEI-EMF) believe they suffer negative health effect when exposed to electromagnetic field from everyday objects such as mobile phone base stations. Comparing the complaints as reported by the children subjects with and without the presence of GSM and UMTS fields, and without their knowledge of that exposure condition, eliminates subjectivity.

In this study, the following hypotheses will be verified:

Null-hypothesis: There is no statistically significant difference with respect to any of the children subjective complains and tests on cognitive function performance during Sham exposure, relative to standardized 850, 1800, and 2600 MHz LTE field exposure.

Alternative *hypothesis:* The data analysis shows that there is a statistically significant difference between one or more children subjective complaints and tests on cognitive function performance as recorded during sham exposure, relative to standardize 850, 1800, and 2600 MHz LTE field exposure.

1.1 Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields

Electromagnetic Hypersensitivity (EHS) is characterized by variety of nonspecific symptoms, which afflicted individuals attribute to exposure to EMF. The symptoms most commonly experienced include dermatological symptoms (redness, tingling, and burning sensations) as well as neurasthenic and vegetative symptoms (fatigue, tiredness, concentration difficulties, dizziness, nausea, heart palpitation, and digestive disturbances). The collection of symptoms is not part of any recognized syndrome. EHS is currently also known as Idiopathic Environmental Intolerance attributed to electromagnetic fields (IEI-EMF).

1.2 Safety Levels of Radiofrequency Exposure and Compliance Boundary

International organizations such as: IEEE and ICNIRP have fixed the international RF safety standards. The RF safety standards defined by IEEE and ICNIRP are well-known as EEE C95.1 (IEEE SCC, 1992) and the ICNIRP 1998 (Guideline, ICNIRP 1998). Both the RF safety standards are based heavily on a perceptive of the effect of high temperature on safety. This is the only recognized biophysical mechanism by which RF can affect biological tissue through heating (ICNIRP, 2009; Vecchia et al., 2009). On the other hand, as the amount of RF emission reported in different studies are only able to enhance temperature of human brain by an adequate amount (say approximately 0.1^0 C, around temporal cortex). The thermal mechanisms which do not spontaneously appear are able to explain the above electroencephalogram (EEG) effects. Therefore, although these EEG effects do not directly correspond to health effects, the researchers discovered a limitation in current bioelectromagnetics knowledge that is important to RF health standards and needs to be resolved.

To ensure the safety for the employers within RF exposure, International Commission on ICNIRP has fixed "Compliance boundary in the context of base station antennas. The RF exposure levels beyond the compliance boundary" are considered low enough to be in line with appropriate safety levels. The dimensions of a given compliance boundary differs with different parameters such as: type of antenna. Frequency and output power of the antenna. For instance, let us consider a typical base-station antenna having operating power of 25 W. The compliance boundary of the base -station antenna is cylindrical in shape with a radius of 1.5 m, and height is near about 50 cm higher than the antenna height. According to the safety margin set by the

ICNIPR, exterior of this virtual boundary RF levels can be considered near to the ground enough to be safe for the mankind (Mild et al., 2006). However, in the closer surrounding area of base antennas RF levels can be considerably higher (Wilen et al., 2004).

ICNIRP has published a human exposure limit recommendations in 1998. The ICNIRP guidelines are recommended by the WHO and have been adopted by more than 35 countries. A review of the ICNIRP recommendations has been published in 2009. The database of studies that led to the development of the ICNIRP guidelines has grown, with about 500 studies at mobile phone frequencies including many modulated signals. The WHO has more than 1500 original, peer-reviewed papers useful for public health risk assessment of RF exposure. The database provides even stronger evidence today that RF exposures within ICNIRP limits associated with mobile telephony pose no known health risks and warrant no special precautions for any segments of the population. The research study types include epidemiology, human studies, animal studies and cellular studies The publication of the recently revised IEEE C95.1-2005 RF safety standard includes a comprehensive review of more than 1300 primary peer reviewed papers on RF biological effects. Much of the older research investigated the effects of 2.45 GHz radiation on rodents and other mammals, while some of the more recent studies have concentrated on elucidating possible mechanisms at the cellular level. Table 2.3 provides a summary of the ICNIRP exposure guidelines for power density and electric (E)-field value.

Table 1.1: ICNIRP exposure guidelines for power density and E-field value (ICNIRP, 1998)

Frequency	**850 MHz**	**1800 MHz**	**2600 MHz**
Power Density (W/m^2)	4.25	9	10
E-Field value (V/m)	40.09	58.34	70.11

2. PROJECT DEVELOPMENT PLAN

The study focuses on the LTE field conditions to ensure consistent results, in addition to the field strength of 1 V/m with 10 mW/m^2 power flux density. This study used counterbalanced randomized double-blind tests to determine if sensitive children subjects experience more negative health effects when exposed to base station signals compared with sham (control) children.

Children subjects were recruited through local advertising, action groups, and word of mouth. Children subjects (accompanied by adults/parents) reported to the research committee for an interview, briefing and to practice the cognitive tests prior to the experiment. A total of 15-17 male and 15 female children subjects each for two groups (i.e., IEI-EMF and non-IEI-EMF categories) participated in the study. A sample size of 63 should give a significant statistical power to evaluate the results. The children subjects for this study were classified into two groups. All children subjects were divided into four (4) groups (2 groups for each gender). Group A denoted the group of subjects that have previously reported to experience complaints and have attributed these complaints to LTE exposure (i.e., sensitive category); Group B denoted the reference group, namely a group of subjects without any complaints (i.e., non-sensitive category).

Exclusion criteria comprised pacemakers, hearing aids, artificial cochleas, polymorbidity with respect to chronic diseases, a medical history of head injuries and or neurologic/psychiatric diseases, sleep disturbances, and an average consumption of caffeinated beverages amounting to > 450 mg caffeine/day (e.g., approximately three cups of coffee). On their first appointment, all children subjects filled in a questionnaire to verify the exclusion and matching criteria (age in decades, sex, and residential area. Children subjects were between 9 and 15 years of age. The children subjects were required to have a written consent, signed by their parents/guardians. If the complaints were an effect of the LTE fields, the subjects should more frequently report complaints during a period of exposure than during a period without exposure.

The subjects were recruited from the general public by visiting to villages and schools around Kedah and Perlis states. Two research officers (ROs) were appointed to carry out this demographic survey and subjects recruitment. The ROs visited and surveyed four primary schools and one orphanage, around Kedah and Perlis states in order to obtain the subjects for this project. The targeted subjects were from age 9 to 15 years old, covering the major races in Malaysia. The races consisted of Malay, Chinese, Indian, and Siamese. The primary schools and orphanage involved in this survey were as the following:

1. Sekolah Rendah Jenis Kebangsaan Cina (C) Khay Beng, Kuala Perlis, Perlis
2. Sekolah Kebangsaan Seberang Ramai, Kuala Perlis, Perlis
3. Sekolah Jenis Kebangsaan Cina (C) Yit Min, Changlun, Kedah
4. Sekolah Kebangsaan Panggas, Bukit Keteri, Mata Ayer, Perlis
5. Teratak Rahmat, Rumah Anak-anak Yatim, Mata Ayer, Perlis

In addition, the subjects were also obtained from the villages around Kuala Perlis and Kangar areas. The locations of villages were given as:

1. Kampung Tandiap, Kuala Perlis, Perlis
2. Taman Semarak, Kuala Perlis, Perlis
3. Kampung Wai, Kuala Perlis, Perlis
4. Kampung Penggau, Kangar, Perlis

The schools and villages locations were shown in Figure 3.1 and Figure 3.2, respectively. Prior to the commencement of the experiment, the ROs prepared several official letters in which to be disseminated to headmasters and information letter for the nearby villagers.

The demographic survey and subjects recruitment were conducted from January to August 2015. Prior to the recruitment of the subjects, the ROs organized several meetings with the school headmasters and the parents of the children involved in this measurement. The ROs spoke to the headmasters and the parents in order to explain about electromagnetic field (EMF). Besides that, the ROs also gave talks on EMF to the parents and teachers about the benefits in participating in this MCMC project. Through this demographic survey, it is also aimed to increase awareness about EMF exposure to the parents and the teachers. The parents and teachers appreciated the effort undertaken by Universiti Malaysia Perlis (UniMAP) and MCMC, thus, permitted their children and their students to participate in this measurement project.

(a) (b)

(c)

Figure 2.1: Locations of demographic survey in primary schools and orphanage around Perlis (a) Kuala Perlis (b) Mata Ayer and Kedah (c) Changlun.

3. DETAIL DESIGN WORK

3.1 Design Procedure

The condition (LTE 850, 1800, and 2600 MHz at 1 V/m of field strength with power flux density 10 mW/m^2 including Sham (no exposure)) was applied in a randomized single-blind design. Exposure for the frequency session lasted for 40 minutes. Immediately before, during and after the end of exposure the children have to fill in the well-being questionnaire. The experiment also included cognitive performance test and EMF perception test. Physiological changes of children were monitored before and after the exposure session. In order to avoid possible carryover effects of the EMF, the four field conditions will be applied on different days (at least 1 week apart). Only three children will be selected each day and testing will always be at the same time of day (±3 hours) to rule out possible circadian effects. The experiment was scheduled for once a week for 4 weeks (at least a gap of 1 week after each session) to avoid EMF carryover effects.

3.1.1 Exposure Setup

All exposure, measurement and testing procedures were conducted in a shielding room at School of Electrical System Engineering, Universiti Malaysia Perlis. Exposure was under counterbalanced randomized single-blind conditions, which was in a randomized crossover design. During the single-blind tests neither the children subjects were not notified of which exposure was being generated. Before exposure, children subjects were given a briefing and training in an office room and were escorted to the exposure room.

Children subjects were exposed to LTE fields in a shielding room at School of Electrical System Engineering, Universiti Malaysia Perlis. This shielding room provided a conditioned environment in which exposure to RF-fields is limited to the in-room generated RF-fields. Before the experiments, the exposure of 850, 1800, and 2600 MHz LTE fields were defined and verified. The field strengths at the location of the subjects were determined not to exceed 1 V/m and power flux density 10 mW/m^2 (based on actual approximated exposure measurement readings in Malaysia).

The measuring equipments used for the experiments are composed of the followings:

i) RF Shielded room :
   - Microwave absorber sheet layers.

ii) Signal generator:
- R&S® SMBV100A Vector Signal Generator (100 kHz to 3 GHz)

iii) Antenna configuration:
- Kathrein800 10046 (LTE).
- Frequency range: 850, 1800, and 2600 MHz

iv) Spectrum analyzer and monitor probes:
- R&S® FSH4 Handheld Spectrum Analyzer (9 kHz to 3.6 GHz)
- R&S® HE300 directional antenna (20 MHz to 7.5 GHz)

The exposure setups are presented schematically in Figure 4.1.

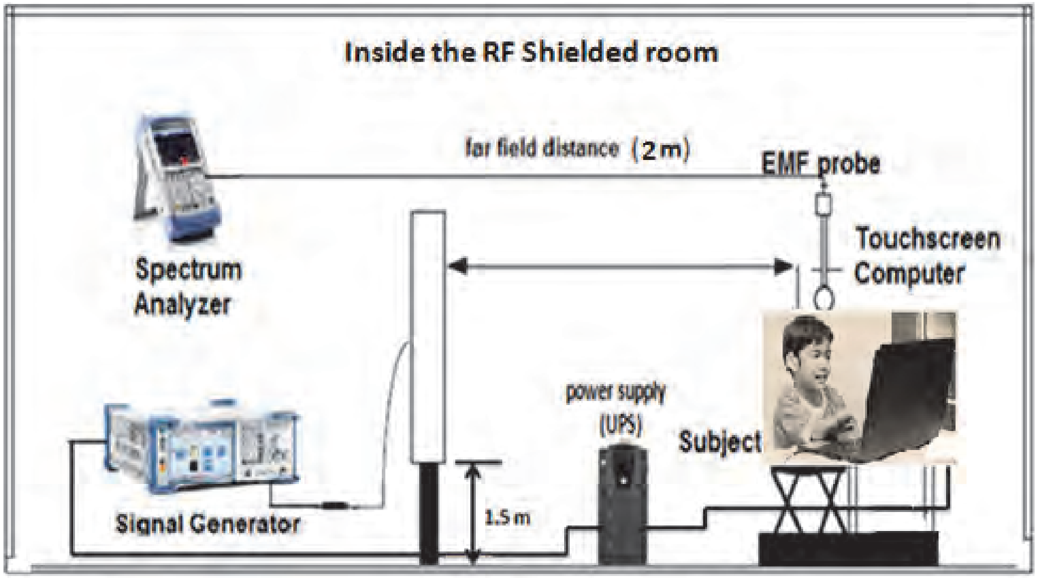


Figure 3.1: Schematic of the exposure setup in a RF shielded room.

The experiment was carried out in a RF-shielded room, shielded with microwave absorbing sheets in the High Voltage Laboratory, Faculty of Electrical Engineering Technology, Universiti Malaysia Perlis, as shown in Figure 2.3.

Figure 3.2: The RF-shielded room in High Voltage laboratory.

The width, length and height of the RF-shielded room were 2.4 m, 3.7 m and 2.47 m respectively. Hence, the total surface area for RF-shielded room was 41.96m^2. The base station antenna was placed at 1.5 m from the ground floor, to avoid the ground reflection and 2 m distance from the child subject. The LTE base station antenna was connected to signal generator via the coaxial cable of 1 m. Four exposure signals were tested which include LTE850, LTE1800, LTE2600, and Sham. The instruments used in this measurement were the Rohde & Schwarz (R&S) Signal Generator (SG) model SMBV100A, the R&S Handheld Spectrum Analyzer (SA) model FHS4 (9 kHz – 3.6 GHz), base-station antenna and far-field EMF probe antenna model R&S HE300 Antenna module 4067.6458.00, as shown in Figure 4.3. The far-field EMF probe antenna measures the RF electric field strength from 500 MHz up to 7.5 GHz.

Table 3.1: Type of probes and instrument use in the measurement

Probe Type and Instrument	Frequency Range
Far-field EMF probe antenna model R&S HE300 Antenna module 4067.6458.00	500 MHz – 7.5 GHz
R&S Handheld Spectrum Analyzer (SA) model FHS4	9 kHz – 3.6 GHz

3.1.2 Far-Field Distance Measurement

The far field distance required to generate a base station-like signal is calculated by:

$$d = 2D^2/\lambda$$

Where, D = largest dimension of the source of the radiation.

Table 4.2 lists out the far-field distance of each measured frequency. The far-field measurement has been performed in the RF-shielded room, as shown in Figure 4.2.

Table 3.2: Far-field distance for LTE 850MHz, 1800MHz and 2600MHz

Frequency, f (MHz)	Wavelength, λ(m)	Far-Field Distance, d (m)
850	0.3529	0.2869
1800	0.1667	0.6075
2600	0.1154	0.8775

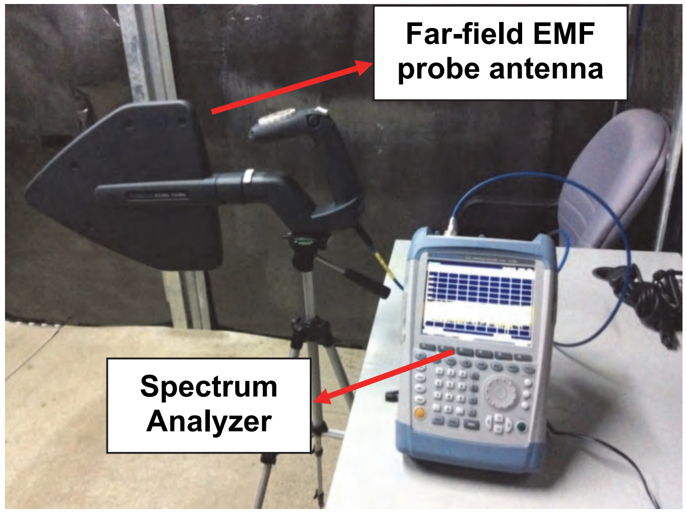
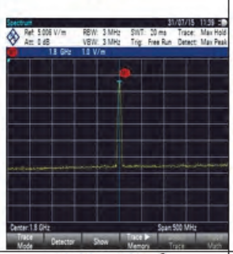
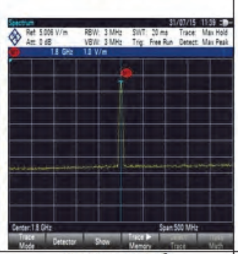
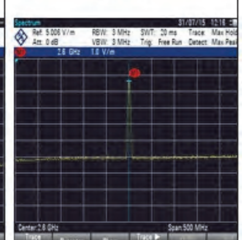
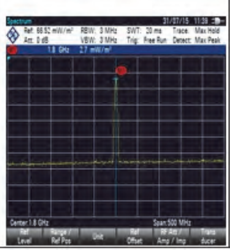
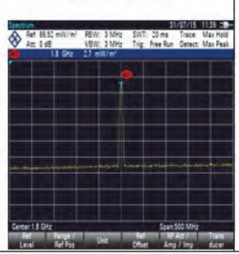
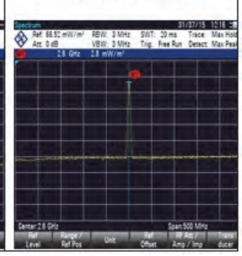


Figure 3.3: Far field distance measurement setup EMF probe and spectrum analyzer.

An E-field distribution that emulates the far field of a base station was measured to ensure that power received by each subject is set to 1 V/m, for all field exposure. SG was connected with the far-field EMF probe antenna. Table 4.4 summarizes the E-field and power density receive outcomes from 850, 1800, and 2600 MHz exposure obtained from the spectrum analyzer. To obtain electric field strength at 1 V/m from LTE850, LTE1800 and LTE2600, the transmitted RF power for LTE1800 and LTE2600 is set at 20 dBm, 20 dBm and 15 dBm, respectively in the SG.

Table 3.3: Electric field strength of base station signal in far field distance from LTE850, LTE1800, and LTE2600 field exposure

FREQUENCY	LTE850 MHz	LTE1800 MHz	LTE2600 MHz
E-FIELD RECEIVE (V/m)	1 V/m 	1 V/m 	1 V/m 
POWER DENSITY RECEIVE (W/m^2)	0.0027 W/m^2 	0.0027 W/m^2 	0.0028 W/m^2 

The results show that the E-field intensity is set at 1V/m for LTE850 signal exposure in the shielded room contributes to the radiation level of only 0.0027 W/m^2, corresponding to about 0.06% lower than the ICNIRP exposure limit for general public, as shown in Table 4.3. Meanwhile, the E-field intensity is set at 1 V/m for both LTE1800 and LTE2600 signal exposure leads to the radiation level of 0.0027 W/m^2 and 0.0028 W/m^2, respectively. This level corresponds to about 0.03% lower than the ICNIRP exposure limit for general public in both LTE1800 and LTE2600 exposures, as listed in Table 4.4.

Table 3.4: Comparison of the measured electric field with the exposure limit recommended by ICNIRP for LTE850, LTE1800, and LTE2600 exposures (Masrakin et al., 2018).

	Electric Field (V/m)			**Power density (W/m^2)**		
	LTE 850	**LTE1 800**	**LTE2 600**	**LTE8 50**	**LTE1 800**	**LTE2 600**
Receive value	1	1	1	2.7 x 10^{-3}	2.7 x 10^{-3}	2.8 x 10^{-3}
Exposure limit for general public	40.0 9	58.34	70.11	4.25	9	10
Comparison with exposure limit (%)	0.00 2	1.71	1.43	0.06	0.03	0.03

3.1.3 Long Term Evolution (LTE) Signal

One of the key elements of Long Term Evolution (LTE) is the use of OFDM (Orthogonal Frequency Division Multiplex) as the signal bearer and the associated access schemes, OFDMA (Orthogonal Frequency Division Multiplex) and SC-FDMA (Single Frequency Division Multiple Access). OFDM is used in a number of other of systems from WLAN, WiMAX to broadcast technologies including DVB and DAB. OFDM has many advantages including its robustness to multipath fading and interference. In addition to this, even though, it may appear to be a particularly complicated form of modulation, it lends itself to digital signal processing techniques. In view of its advantages, the use of ODFM and the associated access technologies, OFDMA and SC-FDMA are natural choices for the new LTE cellular standard.

One of the key parameters associated with the use of OFDM within LTE is the choice of bandwidth. The available bandwidth influences a variety of decisions including the number of carriers that can be accommodated in the OFDM signal and in turn this influences elements including the symbol length and so forth. LTE defines a number of channel bandwidths. Obviously, the greater the bandwidth is, the greater the channel capacity will be. The channel bandwidths that have been chosen for LTE are: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz. In addition to this the subcarriers are spaced 15 kHz apart from each other. To maintain orthogonality, this gives a symbol rate of 1 / 15 kHz = of 66.7 µs. Each subcarrier is able to carry data at a maximum rate of 15 ksps (kilosymbols per second). This gives a 20 MHz bandwidth system a raw symbol rate of 18 Msps. In turn this is able to provide a raw data rate of 108 Mbps as each symbol using 64QAM is able to represent six bits. It may appear that these rates do not align with the headline figures given in the LTE specifications. The reason for this is that actual peak data rates are derived by first subtracting the coding and control overheads. Then there are gains arising from elements such as the spatial multiplexing, etc.

Figure 4.4 shows an example screenshot of an LTE FDD signal as captured on the Signal Generator and Spectrum Analyzer and Figure 4.5 shows an example screenshot of an LTE FDD transmit measurement on a protocol analyzer.

Figure 3.4: An example screenshot of an LTE FDD signal as captured on the Signal Generator and Spectrum Analyzer

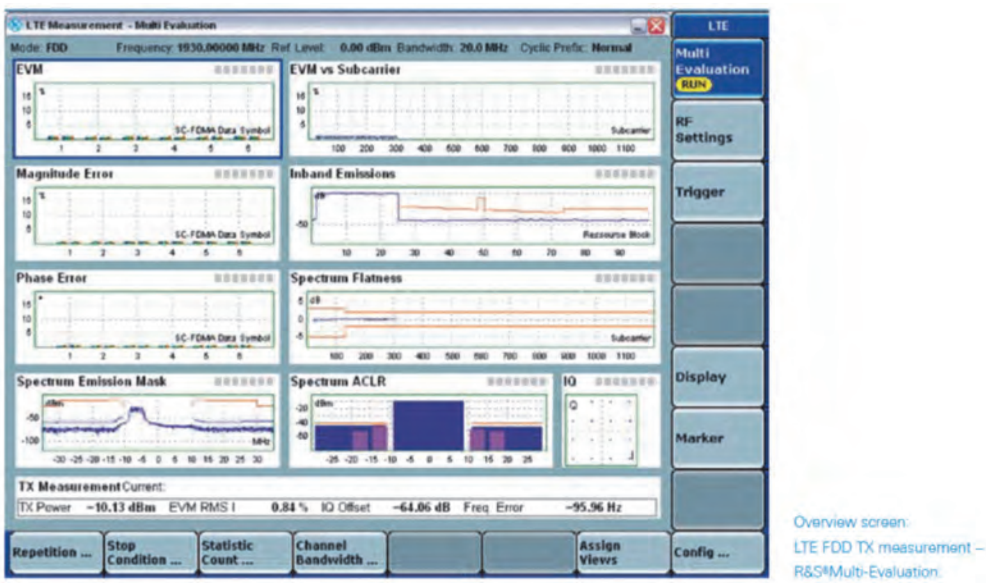


Figure 3.5: An example screenshot of an LTE FDD Transmit measurement on a Protocol Analyze

3.2 Experimental Session Design

Children subjects were randomly allocated according to a counterbalanced block randomization. Group A denotes the group of children subjects that previously reported to experience complaints and have attributed these complaints to LTE exposure (i.e., sensitive category); Group B denotes the reference group, namely a group of children subjects without any complaints (i.e., non-sensitive category). Each day was allocated with three experiment sessions. Three children subjects were exposed each day (i.e., one children per session). The subjects covered all Malaysian children for each category such as race, gender, and were between the age of 7 and 12 inclusive.

All children subjects are classified as follows:

i) Gender:
   - Male (M)
   - Female (F)

ii) Category:
   - Sensitive or IEI-EMF (S)
   - Non-sensitive/Normal or Non-IEI-EMF (N)

Example: MN1 – male children subject, normal, subject no. 1

FS3 – female children subject, sensitive, subject no. 3

For group MN, each children subject required 1 experiment blocks (equivalent to two days) to complete two types of exposure. Three children subjects were allocated to each exposure day. Each exposure day were divided into three exposure sessions. Exposure was performed on 33 male children subjects (16 MN + 17 MS subjects). Similarly, 30 female children subjects followed the same session plan. The exposure session plan schedule is shown in Appendix A.

Each exposure session was divided into three test sections:

Pre-Exposure Section

i) Registration and Interview
ii) Informed consent
iii) Demographic information
iv) Cognitive test training

Exposure Section (60 minute)

i) Cognitive performance (CP) test

Each experiment session was divided into parts (refer section 5.1), which include tests and questionnaires. Only three sessions were available each day and each session was occupied by one subject.

3.2.1 Pre-Exposure Section

The exposure was turned ‘off’ in this section. The pre-exposure section included the following:

Registration and Interview

A registration session and short interview was conducted to all interested children subject candidates for children subject selection.

Informed Consent

A letter of consent was mandatory to be signed by the children subject as a form of agreement on risk and consequences for participation.

Subject Information

Personal and demographic information of all children subjects were collected for children subject identification, actual exposure scheduling and research implementation. Electromagnetic hypersensitivity questionnaire also were given in this section to identify the children subject group. The Subject Information Form is available in Appendix E.

Cognitive Test Training

The training for cognitive test activity (32 minutes) was done prior to the first exposure session in each experiment session. During the training activity, the children subjects were explained on the cognitive function test for training reasons only. It is stressed that during this activity none of the children subjects have been exposed to electromagnetic fields. The children subjects were informed on the absence of LTE fields. The children subject will be given a briefing on the procedures and tests involved within the 40 minutes exposure period.

3.2.2 Exposure Section

Cognitive Performance (CP) Test

To evaluate cognitive functions the following tests will be performed:

a) Reaction Time (RTI) - 5 minutes

This task is designed to measure the children subject's speed of response to a visual target where the stimulus is either predictable (simple reaction time) or unpredictable (choice reaction time). The task for the clinical mode of RTI is divided into five stages, each successive stage having increasingly complex response requirements.

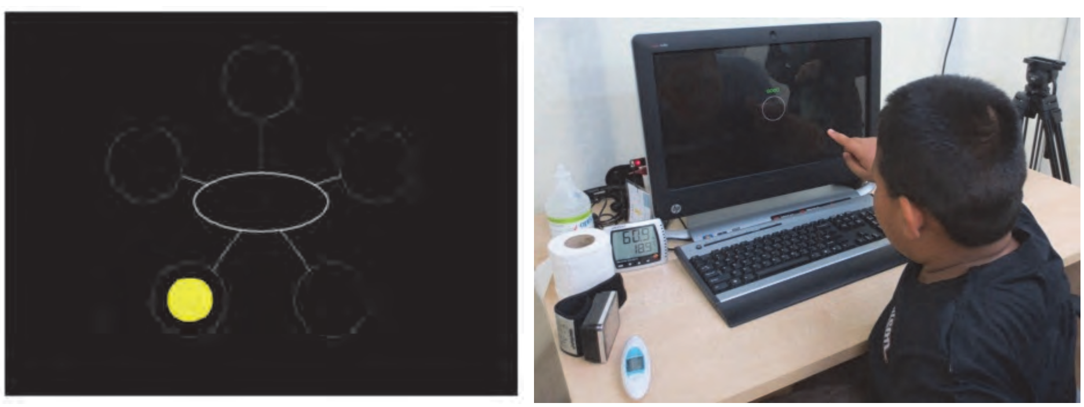


Figure 3.6: The RTI task screen for the second stage of the RTI test

a) Rapid Visual Information Processing (RVP) - 10 minutes

This test is sensitive to dysfunction in the parietal and frontal lobe areas of the brain and is also a sensitive measure of general performance. For scoring purposes, CANTABeclipse calculates the number of responses recorded as having occurred within 1800 milliseconds of the final digit presentation for each of the target sequences. CANTABeclipse also records the number of false alarms, defined as occasions upon which the subject incorrectly identified a target sequence, as well as misses.

Figure 3.7: The RVP test

b) Paired Associated Learning (PAL) - 10 minutes

The 14 outcome measures for the PAL test may be divided into the following groups:

i) Errors
ii) Trials
iii) Memory scores
iv) Stages completed

c) Spatial Span (SSP) - 5 minutes

The six outcome measures for the SSP test may be divided into the following groups:

i) Span length
ii) Errors
iii) Number of attempts
iv) Latency

All cognitive tests will be administered on subject using CANTABeclipse v4.0 cognitive software by Cambridge Cognition Ltd, United Kingdom.

Figure 3.8: Cognitive tests: PAL and SSP

3.3 Statistical Design and Analysis

This is a single blind, randomized, counterbalanced and cross-over design to determine the difference with respect to any of the subjective complaints and the cognitive function parameters as recorded during sham exposure, relative to standardized 850, 1800 or 2600 MHz LTE field exposure. A power analysis was conducted to determine the number of participants needed in this study using G*Power version 3.1.3 (Faul et al., 2007). The α for the ANOVA was set at .05 to achieve power of 0.95 with a small effect size ($f^2 = .15$).

A complete schedule has been generated manually to ensure the orders are balanced for all participants. To make sure the data are randomly allocated, a set of random number (1 to 64) has been generated. Once a participant meets the inclusion and exclusion criteria, a research officer picked a random number according to the list. Participant was not informed about the order of the exposure that has been scheduled for them.

Demographic and baseline characteristics including age, gender, educational attainment, sensitivity towards the base station signal radiation using activity were summarized and tabulated. Continuous variables were summarized by descriptive statistics, which includes mean, median, standard deviation, minimum and maximum. On the other hand, discrete variables were summarized by frequency and percentage. ANOVA with repeated measures were used to detect differences in performance across exposure. All analysis was conducted using SPSS (Statistical Package for Social Science version 11.0).

4. SAFETY, HEALTH AND ENVIRONMENTAL CONSIDERATION

4.1 Hazard Identification, Risk Assessment and Risk Control

Bag failures occur at varying times depending on the operation of the collector. Hence, it is important to schedule monitoring and maintenance activities of the bag houses. The bag house that is maintained properly will ensure the smooth run for filtration process as the possibilities for damaged can be avoided. The hazard identification, risk assessment and risk control is identified as in the following Table 5.1.

4.2 Hazard and Operability (HAZOP) Worksheet

Hazard and Operability (HAZOP) report is a comprehensive approach to recognize hidden dangers in the working system. In this method, the procedure is broken down into stages, and any change in the function parameters is evaluated from each step to see what might go wrong. The report extensively examines the growing aspect of the system. The purpose is to detect possible scenarios that might allow the item to present a danger or to restrict the activity of the system as a whole. The HAZOP report is carried out during the planning stage of the new project. The success of the analysis ensures that all possible sources of failure will be known. The HAZOP report would include an overview of the possible deviations, consequences, causes, safeguard and recommendation. From this stage on, improvements to the program will be made to eliminate issues from happening. In the ongoing facilities, HAZOP has been operating to enhance the procedure without any defined end date. The HAZOP worksheet for this research was developed using Process Hazard Analysis (PHAWorks) software and tabulates in Table 5.2.

5. ECONOMIC EVALUATION

Total capital investment includes the baghouse structure costs, bags' initial complement costs, auxiliary equipment costs, usual direct costs and indirect costs correlated with installing or erecting new structures. These costs are introduced below.

5.1 The Equipment Cost

5.1.1 Bare Baghouse Costs

Relationship between cost and fabric area for 3 types of baghouses are presented. These three types which are preassembled are listed in Table 6.1. Figures 6.1 and 6.2 show common-housing and modular pulse-jet baghouses, respectively. Common housing units have all bags within one housing; modular units are constructed of separate modules that may be arranged for off-line cleaning. Note that in the single-unit (common-housing) pulse jet, for the range shown, the height and width of the unit are constant and the length increases; thus, for a different reason than that for the modular units discussed above, the cost increases linearly with size. Because the common housing is relatively inexpensive, the stainless-steel add-on is proportionately higher than for modular units. Added material costs and setup and labor charges associated with the less workable stainless-steel account for most of the added expense. Figure 6.3 shows costs for cartridge baghouses cleaned by pulse.

Table 5.1: List of cost curves for three baghouse types

	Baghouse Type	Figure No.
	Preassembled Units	
Continuous	Pulse-jet (common housing)	6.1
Continuous	Pulse-jet (modular)	6.2
Continuous	Pulse-jet (cartridge)	6.3

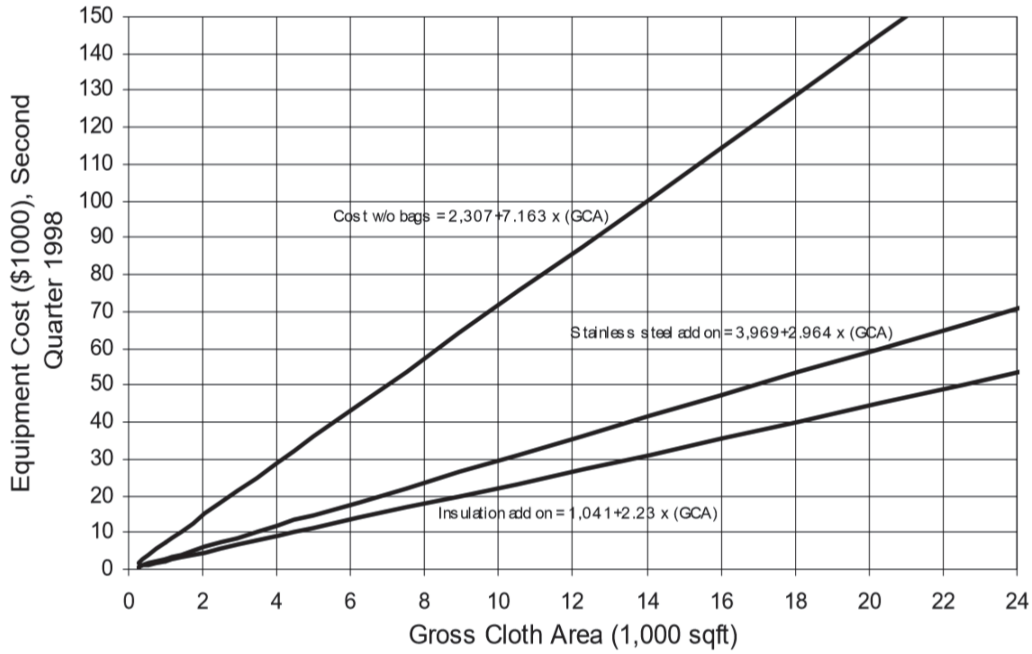


Figure 5.1: Equipment Costs for Pulse-Jet Filters (Common-housing)

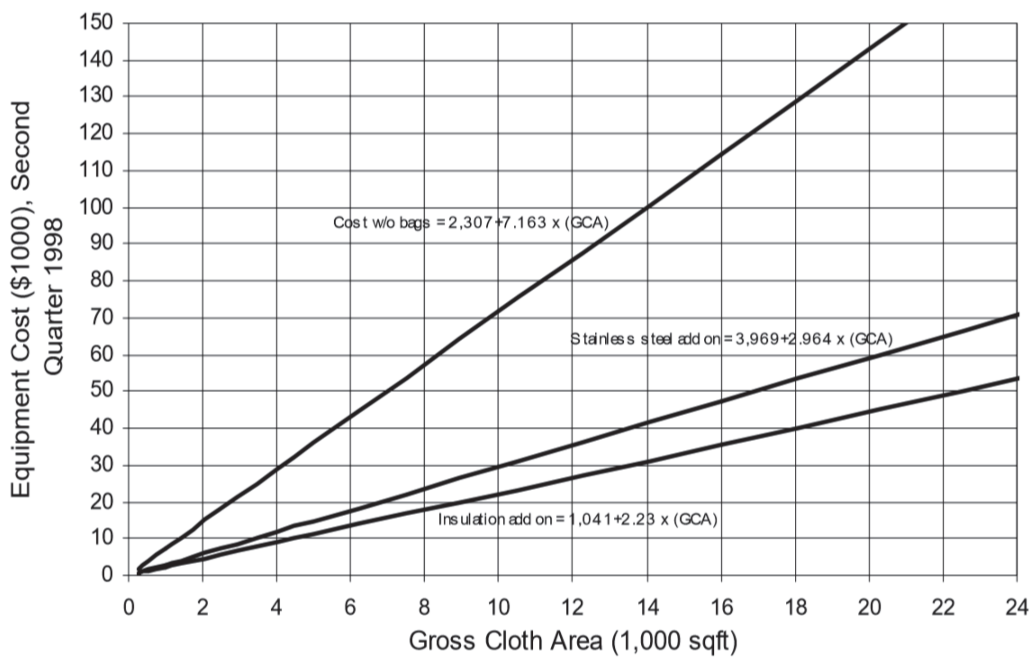


Figure 5.2: Equipment Costs for Pulse-Jet Filters (Modular)

The capital cost factors are calculated as the following:

Cost Item	Factor (MYR)
Direct costs	
Purchased equipment costs	
Fabric filter (EC)	60,000
Bags	28,000
Auxiliary equipment	12,000
Total, A	**100,000**
Instrumentation, 0.10A	10,000
Sales taxes, 0.03A	3,000
Freight, 0.05A	5,000
Purchased Equipment Cost, PEC, B = 1.18 A	**118,000**
Direct installation costs	
Foundations & supports, 0.04 B	4,720
Handling & erection, 0.50 B	59,000
Electrical 0.08 B	9,440
Piping, 0.01 B	1,180
Insulation for ductwork, 0.07 B	8,260
Painting, 0.04 B	2,360
Direct installation costs, 0.74 B	84,960
Total Direct Cost, DC, B+ 0.74B = 1.74 B	**202,960**
Indirect Costs (installation)	
Engineering, 0.10 B	11,800
Construction and field expense, 0.20 B	26,600
Contractor fees, 0.10 B	11,800
B Start-up, 0.01 B	1,180
Performance test, 0.01 B	1,180
Contingencies, 0.03 B	3,540
Total Indirect Cost, IC, 0.45 B	**53,100**

Total Capital Investment = 1.74 B + 0.45 B = 2.19 B 256,060

The construction estimation cost of the baghouse filter including equipment costs, installation cost and total capital investments estimated around RM 256,060. The equipment cost including fabric filter with insulation, bag, cages and auxiliary equipment which is RM 118,000 while for total indirect cost is RM 202,960.

5.2 Total Annual Costs Estimation

5.2.1 Direct Annual Costs

Direct annual costs include operating and supervisory labor, operating materials, replacement bags, maintenance, utilities, and dust disposal. Majority costs are talked separately below. They differ with place and time and should be gained to fit the particular baghouse system being costed.

5.2.1.1 Operating and Supervisory Cost

Typical operating labor requirements are 3 hours per 8-hours shift for a wide range of filter sizes. When fabric filters are operated to meet Maximum Achievable Control Technology (MACT) regulations, it is likely that the upper end of the range is suitable. Small or well-performing units may need less time, while very large or troublesome units may need more. Supervisory labor is taken as 15% of operating labor.

Operator cost (OL): requirement of 3 h per 8 h shift = RM56.21/h
Annual cost of OL = (3 h/shift / 8 h/shift) X 6,000 hours/year X RM56.21/h = RM12,472.50
Supervisory cost (SL): 15 % of OL = 0.15 x RM 12,472.50 = RM 1,870.88

5.2.1.2 Operating Materials

Operating materials are usually not essential for baghouses. An exception is the precoat materials used injected on the inlet side of the baghouse to give a layer with protective dust on the bags when adhesive or destructive particles may hurt them. Adsorbents might be injected in the same way while the baghouse is used for simultaneous particle and removal of gas. Materials costs shall be cover on a dollars-per-mass.

6. CONCLUSION

In order to clear out the misconception spred among local public on the mobile telecommunication technologies, particularly towards the mobile base stations and the public safety when living near to base stations, the researchers have come forward to ascertain whether the sensitive children experience more negative health effects when exposed to LTE base station signals than the normal children (control). This research was conducted among 63 subjects, which were selected according to the Malaysia demographics profile. The outcome of the EMF perception test shows that 33out of 63 subjects (19 Normal and 14 Sensitive) answered “No” to questions ‘Can you feel the radiation/aura/energy?” for all signals exposures including Sham. 7out of 63 subjects (1 Normal and 6 Sensitive) answered “Yes” to the same question at each signal. Only 3subjects (2 Normal and 1 Sensitive) answered “Yes” correctly to the same questions for all 3 signals; LTE850 MHz, 1800 MHz and 2600 MHz.

The cognitive performance test includes Paired Associated Learning (PAL), Spatial Span (SSP), Reaction Time (RTI), and Rapid Visual Processing (RVP). From the outcome of cognitive tests, it has been revealed that the cognitive performance of the Malaysian children is not affected by all four Signal exposures such as: Sham, LTE850, LTE1800, and LTE2600 (P>0.05) both for Normal and Sensitive groups. The outcome of the well-being test performed before, during and after the sessions such as: Sham, LTE850, LTE1800, and LTE2600 both for Normal and Sensitive groups obtained no significant negative effect on Malaysian children.

Summary

Enormous use of mobile phone has led to apprehension on the potential human health effects of exposure to electromagnetic fields (EMF) radiation from the mobile phone base stations. Children are exposed to these base stations from the very first day of their life until the end of life. That means the children of the modern age faces higher lifetime exposure than the adults. In addition, children may also be more vulnerable to potential effects of EMF due to their on-going developing organ and tissue systems. Children also have a greater Specific Absorption Rate (SAR) of EMF than in adults because of differences in the size, shape, water content, and tissue distribution of the head, brain and other tissues. Undoubtedly, these two factors have led the children to the highest level of risk.

Thus, the aim of this study is to clarify whether short-term exposure at 1 V/m to the latest mobile communication technology, Long Term Evolution (LTE) at 850, 1800 and 2600 MHz affects EMF perception, cognitive performance, well-being Encephalogram (EEG) response and physiological parameters (body temperature, blood pressure and heart rate) of the Malaysian children. This study implements counterbalanced randomizing single blind tests to verify if sensitive children experience more negative health effects when they are exposed to base station signals than the normal children. The sample size is 63 subjects with 49% Idiopathic Environmental Intolerance attributed to electromagnetic fields (IEI-EMF) known as sensitive and 51% (non-IEI-EMF). The findings reveal that in both sensitive and normal groups, there is no significant difference between the exposure to LTE signals and Sham exposure towards cognitive (P’s > 0.05).

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8. APPENDIX

Inside the RF shielded room: