ELECTROMAGNETIC HYPERSENSITIVITY (EHS)

A study of possible effects on Malaysians

Mohd Fareq bin Abd Malek, Ph.D
Universiti Malaysia Perlis (UniMAP)

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Electromagnetic Hypersensitivity

Study finds no link between electromagnetic hypersensitivity and cell-tower radiation

People the world over have increasingly become concerned about the effects on their health and well-being due to exposure to electromagnetic radiation from an increasing number of cellular base station antennas and the ubiquity of mobile phones.

The proliferation of the Internet has fuelled these concerns. While the Internet has been a boon for people by letting them access knowledge and information instantly, it has also allowed unfounded fears, rumours, disinformation and misconceptions to spread faster than a wildfire.

However so far, most results of peer-reviewed studies show no correlation between long-term exposure to electromagnet radiation and human health and well-being, especially where the radiation levels are well within approved limits set by bodies such as the International Commission on Non-Ionising Radiation Protection (ICNIRP). For example, results of electric field measurements on the ground in Malaysia are well below ICNIRP exposure limits. (Tables 1 and 2).

Nevertheless, since this area concerns public safety, studies are always being carried out. Recently, researchers in Malaysia contributed to this body of knowledge by conducting a study on the effects of Electromagnetic Hypersensitivity (EHS) on Malaysians. The findings of that study are presented in this booklet.

State of research

ICNIRP published its recommended limits on human exposure in 1998, with a review carried out in 2009. The database of studies that led to the development of the ICNIRP guidelines has grown over the years. Today, there are around 500 studies of mobile phone frequencies including many modulated signals [1].

Table 1: ICNIRP (1998): Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz).

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

Source: Health Phys. Vol. 74 (4): 494-522 (1998) [1]

Table 2: Electric field measurements in Malaysia

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

Source: Electromagnetic Assessment for Mobile Phone Base Stations at Major Cities in Malaysia, Universiti Tenaga Nasional, [2].

Note: the measured power densities in Malaysia were 139, 3 and 7 micro watts per square metre.

The World Health Organisation (WHO) recommends these ICNIRP guidelines which have been adopted by over 35 countries. It has reviewed over 1,500 peer-reviewed papers on public health risk assessment of radiofrequency (RF) exposure. Its 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 1,300 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 [3].

After many years of studies conducted worldwide on the possible effects of low-level electro-magnetic radiation, only a few subtle effects have been seen, but there is still no convincing biological evidence to suggest that exposure to the fields commonly encountered in the environment would cause any significant adverse health effect in humans.

Some major studies

The first epidemiological study on EMF and chronic disease risk conducted by Wertheimer and Leeper in 1979 was based on a characterisation of the homes of children with respect to potential magnetic field power lines. The concern for microwave and RF radiation was that long-term exposure to even low levels could have detrimental consequences on human health especially on the young.

Many experiments have been performed with microwave and RF radiation over the last 30 years or so, although interest largely declined in the 1980s as attention shifted to the effects of power frequency fields. It has however made a full circle back to microwave radiation again, but now focused on 3G/UMTS technology which power today's mobile networks.

Virtually all reports relate to studies of its effects on animals or short-term studies on human subjects. The investigations focused on the incidence of brain tumours, influence on electroencephalogram, excretion of pituitary hormones, cognitive functions, thermal changes in the brain, DNA damage, lymphocyte and mitogen stimulation, visual functions and other consequences.

Still, there remains widespread public concern about the potential adverse health effects of mobile phones in general and their associated base stations specifically. In particular, science has been perplexed by a complaint known as electromagnetic hypersensitivity (EHS).

EHS

EHS is not one specific illness or complaint. Rather, it is a collection of various symptoms that afflicted people say are being caused to them by exposure to electro-magnetic fields (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 recognised syndrome. EHS is currently also known in medical terms as 'idiopathic environmental intolerance attributed to electromagnetic fields' (IEI-EMF). Naturally, researchers have investigated this area and tried to determine if there is any basis to the claims by individuals that the symptoms they are experiencing are caused by exposure to electromagnetic fields. Cognitive studies have

been carried out on healthy adult volunteers who report experiencing a variety of symptoms such as headaches in the vicinity of RF sources. Mixed results have been reported in many studies conducted at GSM and UMTS frequencies.

For example, in 1999 Preece investigated the performance of 36 volunteers on a wide range of tasks, including short and long-term memory, simple and choice reaction time, and sustained attention, which, together, yielded a total of 15 dependent variables. The objective was to study whether a simulated mobile phone transmission at 915 MHz has an effect on cognitive function in humans [4].

Simple reaction times were unaffected and there were no changes in word, number or picture recall, or in spatial memory. There was no significant effect of exposure to the pulsed GSM signal.

In another study led by Koivisto in 2000, volunteers were exposed or sham exposed (no exposure) to a 902 MHz GSM signal. That study found that exposure to the signals actually speeded up response times and the volunteers were able to complete mental arithmetic tasks slightly faster [5].

Another researcher investigated people who claim to be affected by electromagnetic radiation. Zwamborn conducted a study in 2003 with exposure levels similar to that from cellular base stations. The research investigated subjective feeling and cognitive functions in a group of 36 subjects who claimed to experience symptoms related to living near a GSM base station and a second group of 36 healthy subjects [6].

The groups differed in terms of age and gender distribution and therefore no comparisons could be made between the groups, only within groups for periods with and without exposure.

The subjects were exposed to a 1 V/m (volt per metre) strength field at 900 and 1800 MHz (GSM signal), and 2100 MHz (UMTS signal). Each subject participated in three sessions, one of which was unexposed, using a double-blind design.

Each session took 45 minutes including exposure (during which cognitive functions were tested), questionnaire, and break. Cognitive function tests included reaction time, memory comparison, dual-tasking, selective visual attention and filtering irrelevant information.

A corrected analysis of the data was presented in a report of the Health Council of the Netherlands (2004). Only one statistically significant result was found with the cognitive function tests. In the control group without symptoms, UMTS exposure resulted in an increased completion of the memory comparison test. It is believed this could be a chance effect.

In a follow-up study, Regel investigated the effect only of the 2140 MHz UMTS base station-like RF signal, identical to that used by Zwamborn's team, on well-being and cognitive performance in 33 RF-sensitive subjects and in 84 non-sensitive subjects. Regel's team found that no effect of either exposure level was observed on cognitive performance [7].

It is worth noting that a wide range of subjective symptoms have been attributed to exposure to various sources of RF both at home and at work. Some people report they suffer a variety of subjective complaints, including headaches and migraines, fatigue, skin itches, and sensations of warmth. Less commonly reported symptoms include dizziness, blurred vision, memory loss, confusion and vagueness, toothaches, and nausea. An increasing number of those people consider themselves as electro-sensitive.

Besides reports on the effects of exposure to GSM and UMTS signals on cognitive functions, Zwamborn also had the subjects report on their well-being. He found a small but significant decrease in well-being after UMTS exposure was seen in both study groups - i.e. subjects who had previously reported symptoms attributed to GSM radiation and a control group without such symptoms. No effects were seen using GSM signals either at 900 or 1800 MHz.

Even though RF-sensitive subjects generally reported more health problems, Regel found no difference between the two groups with respect to the applied field conditions. Subjects also could not discriminate between exposure levels, but they reported more health complaints when they suspected exposure, suggesting that psychological factors may be involved in this condition.

Malaysian Study

This Malaysian study was done in 2012 by a team from Universiti Malaysia Perlis (UniMAP) and Polytechnic Tuanku Syed Sirajuddin, Perlis. The findings were published in a report entitled, **'Effects of short-term GSM and UMTS base station signal exposure on cognitive performance, well-being and physiological parameters of the Malaysian people.'**

The study was initiated because the team noted that the public have been continuously expressing their concerns over radiation risk from mobile phone base stations. According to reports, they usually complain about physiological effects such as headache and dizziness when living in the vicinity of a base station.

Since previous studies conducted in Malaysia only focused on base station exposure measurement, they decided to study possible effects of these signals on Malaysians. The aim was to shed light on the issue, as well as to regain peoples' confidence in mobile technology, especially with regards to mobile base stations and public safety when living in their vicinity.

The researchers' objective was to determine whether there is a relation between electromagnetic fields (EMFs) and the subjective complaints, together with physiological changes and cognitive performance associated with an electromagnetic stimulus. The aim was to investigate the influence of GSM900, GSM1800 and UMTS fields exposures on cognitive functions performance of subjects.

When planning the study, they drew upon the aforementioned peer-reviewed papers in the WHO's database and the methodologies employed. Only effects present during and shortly after exposure to electromagnetic fields were studied. The research also used a single blind design in order to investigate the real influence of fields on the complaints reported.

Cognitive functions, well-being and physiological changes were evaluated. Areas measured included brains waves, body temperature, blood pressure and heart rate of subjects.

Methodology

The research focused on the effects of exposure to GSM and UMTS signals of 1 V/m field strength and 10 m W/m2, which is higher than actual measured exposure levels in Malaysia.

It used counterbalanced randomised double-blind tests to determine if sensitive individuals experience more negative health effects when exposed to base station signals compared with those who say they cannot feel radiation signals. The term 'blind' here means that the participant was not informed about the presence or absence of actual radiation.

The volunteers were recruited through local advertising, action groups, and word of mouth. They were then interviewed by the research committee and had to fill in a questionnaire to verify the exclusion and matching criteria such as age, sex, and residential area. Participants were between 18 and 45 years of age and they had to provide written consent.

The researchers excluded those with health problems, indulged in unhealthy habits such as smoking and alcohol consumption, and also excluded those who had done shift work within one month of the experiment. Those deemed fit were briefed and practiced the cognitive tests prior to the experiment.

The volunteers

Altogether, 200 volunteers were selected, 100 of whom had reported being IEI-EMF (Group A) and another 100 who were not IEI-EMF (Group B). Group A denotes the group of subjects that have previously reported to experience complaints or sensitive and Group B denotes the reference group, namely a group of subjects without any complaints. There were in total four groups because each of the above groups were further divided by gender as in Male Normal (MN), Male Sensitive (MS), Female Normal (FN), Female Sensitive (FS).

Tests

All exposure measurements were conducted on the 200 volunteers in a radio-frequency (RF) shielding room at the Department of Electrical Engineering, Polyteknik Tuanku Syed Sirajuddin, Perlis.

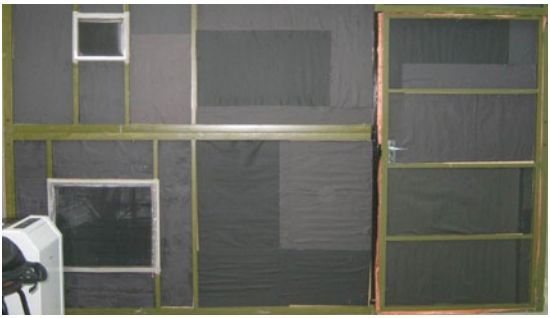


Figure 1: RF Shielded Room

The tests comprised three parts; namely the Pre-Exposure, Exposure (40 minutes) and Post-Exposure sections. The test subjects had to fill in the well-being questionnaire before, during and after the end of exposure.

An Electroencephalogram (EEG) was used only during the exposure section, for five minutes without exposure and five minutes with exposure. An EEG test is used by doctors and scientists to measure and record electrical activity in the brain. Electrodes were connected to a subject's scalp and the EEG recorded electrical activity in their brains, including spontaneous activity and bioelectrical events produced by single neurons.

During actual exposure, subjects were exposed to GSM900, GSM1800 and UMTS radiation (945MHz, 1840MHz and 2140MHz respectively) of 1V/m field strength and 10 m W/m2 power flux density for 40

Figure 2: Electroencephalogram Test

minutes. Some of them were sham sessions where there was no exposure.

To avoid possible carryover effects of the EMF, the four field conditions were applied on different days (at least one week apart). Only three subjects were selected each day and testing was always at the same time of day (±3 hours) to rule out possible circadian effects. The circadian rhythm is more commonly known as the body clock. After the exposure section, the subjects had a 'cooling-down' period of 10 minutes before continuing with the post-exposure section.

Subjects had to undertake various tests and fill in questionnaires for researchers to identify physiological changes of subjects.

The Big Five Personality Test, Well-Being Test, Physiological Test and EMF Perception Test were conducted pre-exposure. Commonly used by psychologists for personality research, the Big-Five Personality Test helps them to identify personality traits such as extraversion, agreeableness (kindness, sympathy, affection, and so on), conscientiousness (organised, thorough, forward-looking and so on), neuroticism (tense, moody, anxious, etc) and

openness to experience (imaginative, intelligent, insightful, wide interests, etc).

Figure 3: Big Five Personality Test

The Well-Being Test is a questionnaire comprising 23 questions about any symptoms such as headache, dizziness, pains, weakness, lethargy, anger level and other symptoms. Each subject filled in an identical well-being questionnaire before, during and after exposure.

The EMF Perception Test is a simple questionnaire which subjects fill in before, during and after exposure. It asks two questions - i.e. "Can you feel the radiation/aura/energy?" and "Did the field/ radiation change?"

The cognitive and performance (CP) test was performed in 'Exposure' sessions. All cognitive tests were administered on subjects using CANTAB eclipse v4.0 cognitive software by Cambridge Cognition Ltd, United Kingdom. Cognitive Test training was performed during pre-exposure and subjects took the Cognitive Performance test during the exposure. Using internationally accepted software designed in UK, subjects were tested for reaction time (RTI), rapid visual information processing (RVP), paired association learning (PAL) and Spatial Span (SSP).

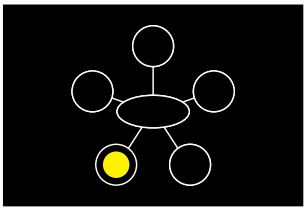


Figure 4: RTI Test

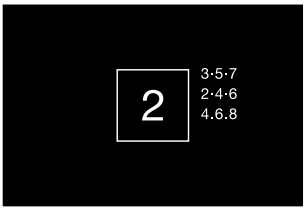


Figure 5: RVP Test

Figure 6: PAL Test

Figure 7: SSP Test

The Final Analysis

At the conclusion of the study, the researchers reported that they found no significant effects of short-term GSM and UMTS base station signal exposure on cognitive performance, well-being and physiological parameters of the Malaysian people.

To recap, the study's objective was to determine whether there is a relation between the presence of electromagnetic fields (EMFs) and the subjective complaints together with well-being, physiological changes and cognitive performance associated with them.

Table 3 shows the exploratory analysis on the question "Can you feel the radiation/aura/energy?" on exposure session only based on EMF perception test. There were 16 possible combination answers of conditions in which subjects can feel the radiation at each signal. After exposure session in each signal, 111 out of 200 subjects answered 'no' to the question;

"Can you feel the radiation/aura/energy?" and 26 out of 200 subjects answered 'yes' to the same question at each signal. Meanwhile, only 8 subjects answered correctly based on their judgements that they felt the radiation/aura/energy in all sham and three signals out of the 200, which is an insignificant number to associate the ability of subjects being able to perceive EMF presence. During the sessions, neither the Normal subjects nor Sensitive subjects were aware whether they were exposed or not, and accordingly they did not know which field-type was applied. Sensitive subjects claimed that they can feel the radiation. However, the result of this analysis did not show that sensitive subjects were able to judge whether the base station was turned 'on' or 'off'.

Table 3: Frequency distribution of possible combination subject answered 'yes' by case

Signals				Case		Total
Sham	GSM900	GSM1800	UMTS	Normal	Sensitive	
No	No	No	No	64	47	111
No	No	No	Yes	1	2	3
No	No	Yes	No	2	1	3
No	No	Yes	Yes	0	6	6
No	Yes	No	No	0	3	3
No	Yes	No	Yes	0	0	0
No	Yes	Yes	No	2	3	5
No	Yes	Yes	Yes	4	4	8
Yes	No	No	No	6	3	9
Yes	No	No	Yes	0	2	2
Yes	No	Yes	No	1	5	6
Yes	No	Yes	Yes	3	3	6
Yes	Yes	No	No	2	2	4
Yes	Yes	No	Yes	1	2	3
Yes	Yes	Yes	No	3	2	5
Yes	Yes	Yes	Yes	11	15	26
					TOTAL:	**200**

Table 4: Number of participants with Symptoms of 'Dizziness' 'Fatigue' and 'Headache' during the Exposure (including Sham)

No	Symptoms	Case	Rating			
			1	2	3	4
Sham	Dizziness, or sick feeling	Normal	65	32	3	0
		Sensitive	56	37	7	0
	Fatigue or lack of energy	Normal	79	19	2	0
		Sensitive	67	27	4	2
	Headache	Normal	69	26	5	0
		Sensitive	71	24	3	2
GSM900	Dizziness, or sick feeling	Normal	64	31	5	0
		Sensitive	55	39	4	2
	Fatigue or lack of energy	Normal	75	19	2	0
		Sensitive	59	34	5	2
	Headache	Normal	74	22	4	0
		Sensitive	65	29	5	1
GSM1800	Dizziness, or sick feeling	Normal	74	24	2	0
		Sensitive	48	43	7	2
	Fatigue or lack of energy	Normal	81	19	0	0
		Sensitive	69	22	5	4
	Headche	Normal	76	22	2	0
		Sensitive	58	34	6	2
UMTS	Dizziness, or sick feeling	Normal	67	31	2	0
		Sensitive	64	30	6	0
	Fatigue or lack of energy	Normal	75	25	0	0
		Sensitive	73	23	3	1
	Headache	Normal	74	24	2	0
		Sensitive	64	32	3	1

Notes: Ratings 1 = Not Annoying; 2 = Slightly Annoying; 3 = Annoying; 4 = Very Annoying

Well-Being

During each session the subjects were asked to complete a Well-being questionnaire assessing self reported symptoms or perception. They were asked to rate the strength of the symptom and perception rating from 'not annoying' to 'very annoying' on the Well-being questionnaire. There were 23 items investigated in the study. On the average, people reported they did 'not feel annoying' on all 23

symptoms. Fewer subjects commonly reported feeling 'annoying' to 'very annoying'. In addition, most Normal subjects felt 'not annoying' compared to Sensitive subjects with (Exposure) and without (Sham) the presence of GSM and UMTS fields (Appendix 1).

Table 4 summarises the descriptive findings focused on 'dizziness', 'fatigue' and 'headache' that are commonly reported by sensitive subjects. Most of the reading falls within the rating of 'Not Annoying' and 'Slightly annoying'. The overall outcome, however, did not demonstrate any significant pattern shift between sham and the presence of signals.

Cognitive Test

The computer-administered Cambridge Neuro-psychological Test Automated Battery (CANTAB eclipse™) was used to examine specific components of cognition. Three tests were chosen to evaluate attention and memory: Reaction Time (RTI), Rapid Visual Processing (RVP) and Paired Associates Learning (PAL). One test was chosen to evaluate executive function; Spatial Span (SSP). The results of the Cognitive Test for both cases can be seen in Appendix II. No effects of either exposure levels were observed in cognitive performance using Reaction Time (RTI), Rapid Visual Processing (RVP), Paired Associates Learning (PAL) and Spatial Span (SSP).

There is no statistically significant difference mean with respect to any of the subjective complaints and tests on well-being conditions as recorded during sham exposure. This result was identical to that found by an overseas study [6] on well-being and cognitive performance in 33 RF-sensitive subjects and in 84 non-sensitive subjects.

Physiological Measures

Across all 200 subjects, the mean of heart rate was between 74 - 82 beats per minute where the heart rate of subjects was classified being in normal resting heart rate (60-100 beats per minutes) Table 5.

Table 5: Descriptive Statistics for Physiological Measures for Sensitive and Normal Subjects by Exposure (including Sham)

Test	Sham		GSM900	
	Normal	Sensitive	Normal	Sensitive
	Mean (S.E)	Mean (S.E)	Mean (S.E)	Mean (S.E)
1. PreBT	36.04(0.11)	36.04(0.06)	35.93(0.12)	35.86(0.12)
2. PostBT	36.08(0.06)	36.02(0.11)	36.58(0.50)	36.72(0.70)
3. PreHR	80.23(1.35)	82.90(1.29)	79.85(1.35)	81.29(1.38)
4. PostHR	80.03(1.66)	80.51(1.70)	75.71(1.28)	79.17(1.93)
5. PreBPS	127.59(1.98)	129.18(2.15)	127.17(2.36)	127.07(2.02)
6. PostBPS	126.81(2.00)	126.81(2.00)	125.53(2.19)	126.36(2.22)
7. PreBPD	80.32(1.33)	79.36(1.61)	78.74(1.50)	78.15(1.69)
8. PostBPD	87.29(6.36)	79.10(1.39)	86.09(6.75)	79.29(1.57)
9. PreMAP	94.94(1.47)	96.11(1.64)	94.83(1.65)	94.51(1.64)

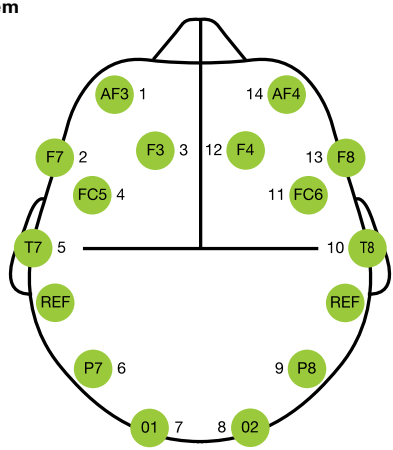
Test	GSM1800		UMTS	
	Normal	Sensitive	Normal	Sensitive
	Mean (S.E)	Mean (S.E)	Mean (S.E)	Mean (S.E)
1. PreBT	36.09(0.05)	36.14(0.23)	35.84(0.12)	35.92(0.16)
2. PostBT	35.86(0.13)	36.01(0.06)	35.88(0.11)	36.08(0.06)
3. PreHR	77.81(1.26)	80.11(1.30)	81.92(1.65)	81.18(1.40)
4. PostHR	74.20(1.14)	78.06(14.26)	77.36(1.43)	76.80(1.11)
5. PreBPS	126.92(2.26)	129.22(2.21)	124.99(1.99)	126.25(2.03)
6. PostBPS	125.04(1.94)	140.01(1.76)	124.75(2.05)	125.05(2.35)
7. PreBPD	80.29(1.55)	77.92(1.61)	79.85(1.32)	79.08(1.35)
8. PostBPD	76.60(1.23)	85.87(6.44)	80.30(1.27)	79.60(1.45)
9. PreMAP	95.83(1.63)	95.01(1.55)	94.78(1.45)	94.92(1.49)

Notes: Pre:Pre-Exposure, Post:Post-Exposure, BT:Body Temperature, HR:Heart Rate, S.E: Standard Error.
Systolic Blood Pressure (Heart Beats) equal or above 140 mm Hg and / or a Diastolic Blood Pressure (Heart Relaxes) equal to or above 90 mm Hg blood pressure is considered to be raised or high. [10]

In both the EHS (sensitive) and non-EHS (Normal) groups, there were no significant differences mean in body temperature, blood pressure and heart rate between sham and real exposures to an electromagnetic stimulus before and after exposure, indicated that in average the physiological parameter of Normal and Sensitive subjects remained unchanged/ constant after exposure to all signals. These results parallel with previous studies using a similar experimental design to investigate effects of radiation on the physiological factor which found that radiation did not affect the heart rate of the subjects [8-9].

EEG results showed that the EEG spectral power varied between pre-exposure, exposure and post-exposure sessions. However, these differences were marginally small and showed a decrease in EEG spectral power when subject was exposed to the related signal (Sham, GSM900, GSM1800, UMTS). Also, during the exposure session, each electrode (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4) had no significance difference between baseline (Sham) and other signals.

Figure 8: Emotiv EPOC electrode placement according to the 10-20 system



Conclusion

In summary, similar to the many studies carried out over the years across the globe, the research team from UniMAP found no strong evidence that people who say that they are sensitive to electromagnetic radiation and have related health issues actually are affected by such waves.

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APPENDIX I

Number of participants with all 23 Symptoms during the Exposure (including Sham)

No	Symptoms	Case	Rating			
			1	2	3	4
1	Dizziness, or sick feeling	Normal Sensitive	65 56	32 37	3 7	0 0
2	Fatigue or lack of energy	Normal Sensitive	79 67	19 27	2 4	0 2
3	Nervousness	Normal Sensitive	87 73	12 24	1 2	0 1
4	Feeling of pressure or tightness in head or body	Normal Sensitive	85 83	13 14	2 2	0 1
5	Fast or hard heart beat without any reason (or banging stumps)	Normal Sensitive	90 82	9 16	1 1	0 1
6	Headache	Normal Sensitive	69 71	26 24	5 3	0 2
7	Restlessness or nervousness	Normal Sensitive	82 75	18 22	0 1	0 2
8	Chest pain or breathing difficulty	Normal Sensitive	88 85	11 14	1 1	0 0
9	Feel guilty	Normal Sensitive	94 87	6 11	0 2	0 0
10	Feel annoyed	Normal Sensitive	82 74	18 22	0 2	0 0
11	Muscle pains	Normal Sensitive	91 84	9 16	0 0	0 0
12	Anger	Normal Sensitive	96 93	4 3	0 3	0 1
13	Difficulties with clear thinking	Normal Sensitive	80 68	19 27	1 1	0 4
14	Feel tense or excited	Normal Sensitive	83 74	16 23	1 1	0 2
15	Wandering minds	Normal Sensitive	70 59	26 32	4 6	0 3
16	Parts of the body feeling numb or tingling	Normal Sensitive	90 87	9 11	1 2	0 0
17	Unwanted thoughts	Normal Sensitive	79 66	21 28	0 3	0 3
18	Parts of the body feeling weak	Normal Sensitive	90 85	8 13	2 2	0 0
19	Cannot concentrate	Normal Sensitive	70 55	28 37	2 5	0 3
20	Impatient	Normal Sensitive	89 82	10 11	1 4	0 3
21	Easily distracted	Normal Sensitive	76 63	22 26	2 8	0 3
22	Hostile/aggressive feeling	Normal Sensitive	93 92	6 5	1 2	0 1
23	Lack of attention	Normal Sensitive	68 54	29 36	3 7	0 3

Notes: Rating 1 = Not annoying, Rating 2 = Slightly Annoying, Rating 3 = Annoying, Rating 4 = Very Annoying

APPENDIX II

Cognitive Performance Measured by Paired Associates Learning (PAL) Test, Reaction Time Test, Rapid Visual Processing (RVP) Test and Spatial Span (SSP) Test during the Exposure (including Sham)

Cognitive Test	Sham		GSM900	
	Normal Mean (S.E)	Sensitive Mean (S.E)	Normal Mean (S.E)	Sensitive Mean (S.E)
PAL Total errors (adjusted)	7.94 (0.89)	7.50 (0.74)	5.14 (0.56)	6.06 (0.78)
PAL Mean errors to success	1.58 (0.18)	1.49 (0.15)	1.03 (0.11)	1.21 (0.15)
RTI Five-choice movement time	575.40 (17.99)	570.22 (15.87)	575.47 (20.32)	587.60 (16.75)
RTI Five-choice reaction time	346.07 (7.07)	345.74 (7.28)	351.15 (7.04)	360.15 (7.57)
RVP A'	0.90 (0.01)	0.92 (0.01)	0.92 (0.01)	0.92 (0.01)
SSP Span length	7.44 (0.15)	7.34 (0.16)	7.67 (0.14)	7.54 (0.17)

Cognitive Test	GSM1800		UTMS	
	Normal Mean (S.E)	Sensitive Mean (S.E)	Normal Mean (S.E)	Sensitive Mean (S.E)
PAL Total errors (adjusted)	5.09 (0.58)	4.68 (0.51)	5.34 (0.55)	6.20 (1.55)
PAL Mean errors to success	1.02 (0.12)	0.94 (0.1)	1.07 (0.11)	1.08 (0.18)
RTI Five-choice movement time	568.57 (17.10)	563.19 (17.80)	559.06 (17.86)	546.41 (12.98)
RTI Five-choice reaction time	348.41 (6.97)	360.32 (7.90)	343.94 (6.34)	363.41 (7.51)
RVP A'	0.93 (0.01)	0.93 (<0.01)	0.92 (0.01)	0.93 (0.01)
SSP Span length	7.84 (0.15)	7.65 (0.15)	7.58 (0.16)	7.53 (0.19)

Notes: PAL: Paired Associates Learning, RTI: Reaction Time, RVP: Rapid Visual Processing, SSP: Spatial Span, S.E: Standard Error

APPENDIX III

Estimated Marginal Mean of EEG spectral power by signal

F8 Electrodes	Session	Sham		GSM900	
		Mean	Std. Error	Mean	Std. Error
AF3	1	-0.45	0.08	-0.17	0.08
	2	-3.34	0.08	-2.56	0.08
	3	-2.19	0.07	-3.00	0.07
F7	1	-0.51	0.09	-0.55	0.09
	2	-2.93	0.08	-2.07	0.08
	3	-3.38	0.09	-3.24	0.09
F3	1	-0.47	0.08	-0.44	0.08
	2	-3.46	0.08	-2.56	0.08
	3	-1.48	0.07	-3.03	0.07
FC5	1	-0.50	0.10	-0.64	0.10
	2	-3.40	0.08	-2.40	0.08
	3	-3.01	0.09	-2.51	0.09
T7	1	-0.24	0.07	-1.46	0.07
	2	-3.63	0.07	-2.68	0.07
	3	-2.41	0.08	-3.10	0.08
P7	1	-1.02	0.09	-0.67	0.09
	2	-3.97	0.07	-2.36	0.07
	3	-3.23	0.10	-2.18	0.10
O1	1	-1.30	0.10	-0.47	0.10
	2	-2.65	0.07	-2.09	0.07
	3	-1.74	0.07	-3.46	0.07
O2	1	0.99	0.08	-0.08	0.08
	2	-2.70	0.08	-3.12	0.08
	3	-2.97	0.08	-2.22	0.08
P8	1	1.13	0.08	0.50	0.08
	2	-2.06	0.08	-1.85	0.08
	3	-1.33	0.09	-0.84	0.09
T8	1	0.50	0.08	0.67	0.08
	2	-2.28	0.09	-1.91	0.09
	3	-2.60	0.09	-1.53	0.09
FC6	1	1.01	0.09	-0.35	0.09
	2	-2.46	0.09	-3.66	0.09
	3	-1.79	0.08	-1.72	0.08
F4	1	0.56	0.08	0.04	0.08
	2	-3.09	0.08	-2.78	0.08
	3	-2.89	0.07	-1.88	0.07
F8	1	0.51	0.09	0.68	0.09
	2	-2.56	0.07	-3.13	0.07
	3	-2.08	0.08	-0.83	0.08
AF4	1	0.28	0.08	0.22	0.08
	2	-2.79	0.07	-2.83	0.07
	3	-2.40	0.08	-2.11	0.08

Notes: Session 1:Pre-Exposure, Session 2:Exposure, Session 3:Post-Exposure, S.E: Standard Error

APPENDIX III, continued

Estimated Marginal Mean of EEG spectral power by signal

F8 Electrodes	Session	GSM1800		UMTS	
		Mean	Std. Error	Mean	Std. Error
AF3	1	-0.79	0.08	0.07	0.08
	2	-3.88	0.08	-2.79	0.08
	3	-2.57	0.07	-1.10	0.07
F7	1	-0.62	0.09	-0.29	0.09
	2	-2.55	0.08	-2.37	0.08
	3	-1.61	0.09	-0.63	0.09
F3	1	-0.39	0.08	-0.95	0.08
	2	-3.84	0.08	-2.33	0.08
	3	-1.02	0.07	-1.16	0.07
FC5	1	-1.04	0.10	0.76	0.10
	2	-2.84	0.08	-3.49	0.08
	3	-1.76	0.09	-0.83	0.09
T7	1	0.38	0.07	-0.64	0.07
	2	-4.15	0.07	-3.55	0.07
	3	-2.66	0.08	-1.85	0.08
P7	1	-0.37	0.09	-1.53	0.09
	2	-3.56	0.07	-3.39	0.07
	3	-3.46	0.10	-3.38	0.10
O1	1	-0.41	0.10	-1.50	0.10
	2	-3.98	0.07	-3.24	0.07
	3	-0.14	0.07	-2.94	0.07
O2	1	1.13	0.08	-0.67	0.08
	2	-0.78	0.08	-2.27	0.08
	3	-0.65	0.08	-1.63	0.08
P8	1	1.06	0.08	0.76	0.08
	2	-0.93	0.08	-2.09	0.08
	3	-0.77	0.09	-0.79	0.09
T8	1	1.28	0.08	0.10	0.08
	2	-1.89	0.09	-2.36	0.09
	3	-1.34	0.09	-1.39	0.09
FC6	1	0.56	0.09	-0.83	0.09
	2	-1.82	0.09	-2.44	0.09
	3	-2.09	0.08	-1.12	0.08
F4	1	1.03	0.08	-0.47	0.08
	2	-2.07	0.08	-2.47	0.08
	3	-2.13	0.07	-1.88	0.07
F8	1	1.13	0.09	-1.12	0.09
	2	0.09	0.07	-1.87	0.07
	3	-0.46	0.08	-1.68	0.08
AF4	1	0.65	0.08	-0.05	0.08
	2	-1.33	0.07	-2.32	0.07
	3	-0.97	0.08	-1.58	0.08

Notes: Session 1:Pre-Exposure, Session 2:Exposure, Session 3:Post-Exposure, S.E: Standard Error

Acknowledgements

(Project leader)
Mohd Fareq bin Abd Malek, Ph.D
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Tharek bin Abd Rahman, Ph.D
Wireless Communication Centre,
Universiti Teknologi Malaysia

Ng Kwan Hoong, Ph.D
Department of Biomedical Imaging,
Faculty of Medicine, Universiti Malaya

Md Noor bin Baharom
Politeknik Tuanku Syed Sirajuddin, Perlis

Rogayah bte Chat @ Arshad
Department of Electrical Engineering
Politeknik Tuanku Syed Sirajuddin, Perlis

Khairudi bin Mohd Juni
Department of Electrical Engineering
Politeknik Tuanku Syed Sirajuddin, Perlis

Khatijahhusna binti Abd Rani
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mohd Hafizi bin Omar
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mohd Fikri bin Mohamad
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Muhammad Nadeem Iqbal, Ph.D
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Ummi Habibah binti Abd Rani
Politeknik Tuanku Syed Sirajuddin, Perlis

Farahany Sofiah binti Zakaria
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Liyana binti Zahid
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Syafawati binti Kamaruddin
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Siti Nurhafizah binti Zainal
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Raja Abdullah bin Raja Ahmad
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Iskandar Zulkarnain bin Shamsudin
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Nur Aishah binti Abdul Aziz
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Hasliza binti A. Rahim@Samsuddin
School of Computer and Communication Engineering
Universiti Malaysia Perlis (UniMAP)

Lee Yeng Seng
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Ye Htut @ Mohammad Iqbal bin Omar
School of Mechatronic Engineering
Universiti Malaysia Perlis (UniMAP)

Muhammad Solihin bin Zulkefli
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mohd Hafizuddin bin Mat
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Cheng Ee Meng, Ph.D
School of Mechatronic Engineering
Universiti Malaysia Perlis (UniMAP)

Nur Adyani binti Mohd Affendi
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Norshafinash binti Saudin
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Latifah binti Mohamed
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mardianaliza binti Othman
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Farrah Salwani binti Abdullah
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Hana binti Abdull Halim
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Ahmad Zaidi bin Abdullah
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Nur Sabrina binti Md Noorpi
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mohd Asri bin Jusoh
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Fairul Afzal bin Ahmad Fuad
School of Computer and
Communication Engineering
Universiti Malaysia Perlis (UniMAP)

Syafruddin bin Hassan, Ph.D
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mohd Saufi bin Ahmad
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Y. M. Tunku Muhammad Nizar bin Tunku Mansur
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Azuwa binti Ali
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Nur Fairuz binti Mohamed Yusof
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Noor Anida binti Abu Talib
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Nuriziani binti Hussin, Ph.D
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mohd Hariz Faizal bin Mohd Fakri
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Abdul Halim bin Mohamad
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Som Thop A/L Emai
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Muhammed Sabri Salim, Ph.D
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Zarinatul Jamaliyah binti Jaafar
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Khairul Nizam bin Zainon
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Gomesh Nair A/L Shashidaran
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Muhammad Irwanto, Ph.D
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mohd Irwan bin Yusoff
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Melaty binti Amirruddin
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Mohd Annuar bin Mohd Isa
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Haji Pungut bin Ibrahim
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Khor Shing Fan, Ph.D
School of Electrical System Engineering
Universiti Malaysia Perlis (UniMAP)

Haji Hasnain bin Abdullah @ Idris
Faculty of Electrical Engineering,
Universiti Teknologi MARA Pulau Pinang

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