© April 2019 | IJIRT | Volume 5 Issue 11 | ISSN: 2349-6002

A Review on Brainwave Asymmetry Influenced by Radio Frequency Waves Emitted by Mobile Phones

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***Abstract*- During operation, mobile phones can emit energy in the form of electromagnetic fields, which can be absorbed by a user's head. However, it is presently unclear whether this electromagnetic energy can cause biological consequences or adverse health effects. Mobile phone usage around the world is enormous and is still on the rise. Currently, it is estimated that there is over 1.7 billion mobile phone users globally. Consequently, if there were to be adverse health implications due to exposures from mobile phones, the effects could be widespread amongst vast populations. It is thus vital that all present and valid possibilities of biological effects due to mobile phone radiated fields be examined and resolved. Various studies so far examining biological effects of mobile phone exposures have included the investigation of potential connections to cancer, cell division, blood pressure alteration, induction of epilepsy, depression in melatonin levels, DNA strand breaks, effects on the eyes, and human cognitive alteration, to name a few. The overall correlation between left and right brainwaves signal for all bands shows decrement for during and after phone calls, thus reducing brainwaves balancing. Therefore, there is evidence that the usage of mobile phones affect the brainwaves.**

Index Terms- EEG, brainwave, asymmetry, radiation, classification, Mobile Phones, Frequency.

I. INTRODUCTION

Mobile phone has become one of the most important items in human daily lives in line with the increase in functionality and applications. However, the effect of mobile phone usage on human health is now become the subject of recent interest and study. Mobile phone operates in microwave range using Radiofrequency (RF) electromagnetic radiation. Data communication network and other digital wireless systems also emit the same radiation. Electromagnetic components have been shown to be directly and independently causing biological changes[1, 2]. Microwave radiation from mobile phones could modify certain brain electrical activity under both awake and sleep conditions and inducing abnormal slow waves in Electroencephalograph (EEG) of awake persons [3-5].

Technology is considered to be the mount to climb up and attain the desired degree of development in a society. Man has been trying to facilitate his life through inventions and innovation. He invaded telecommunication system which leads to invention of mobile phones. In recent years usage of mobile phone increased drastically. Since the mobile phone comes close to the head, concern about adverse effects of mobile phone radiation on the nervous system increased and this badly affects the human brain. According to the studies done so far, it has been shown that the exposure to the electromagnetic wave radiation will leads to various health problems such as headache, cancer, memory loss, genetic damage, increased blood pressure, migraines and weakening of the immune system. The electromagnetic radiations from mobile phone will interact with human body which results in displacement of ions and electrolytes in human body since it is made up of approximately 65-70% water, electrolytes and ions [1]. The radiations interfere with the electrical impulses that two neurons connect each other with. This can lead to deafness and migraines. The cellular phone is a low-power, single-channel, two-way radio. EMFs emitted by cell phones are harmful for the human brain and it is more pronounced in children than adults, indicating that the children may be more vulnerable to the adverse health effects of mobile phones than adults, probably because absorption of microwaves is greatest in an object about the size of a child's head [13]. Radio frequency used to communicate by mobile phone has the ability to penetrate through semi-solid substances like meat, and living tissue to a distance proportional to its power density [10]. It also can cause dielectric heating effect or thermal effect [11] [12]. Mobile phones emit electromagnetic radiations and Electromagnetic radiation can be classified into ionizing and non-ionizing radiation. Electromagnetic radiation can be classified into ionizing and non-ionizing radiation. Ionizing radiation is the radiation with high energy which will remove tightly bound between electrons and atoms resulted tissue damage while non-ionizing radiation is the radiation that has enough energy to vibrate the atoms and molecule but do not remove the electrons in the molecule [1]. In this era of globalization it's really difficult to stop using mobile phones even it have various bad effects on human health. So there is a need to find out the ways to reduce the effect of electromagnetic radiations on human health.

1.1 MOBILE PHONE TECHNOLOGIES

1.1.1GLOBAL SYSTEM FOR MOBILE COMMUNICATION (GSM)

GSM (Global System for Mobile Communications), is a standard set developed by the European Telecommunications Standard Institute (ETSI) to describe technologies for second generation (or "2G") digital cellular networks.

1.1.1.1 COMPONENTS AND PROCESSES OF GSM

- Basic Components of GSM - MS/SIM/ME/BTS/BSC - MSC/VLR/HLR/IN/AuC/EIN
- Basic Process of GSM - Handover - Paging - Location updating - Incoming/outgoing Call
- MS Mobile Station
- SIM Subscriber Identity Module
- BTS Base Transceiver Station
- BSC Base Station Controller
- HLR Home Location Register
- VLR Visitor Location Register
- AuC Authentication Centre
- IN Interrogating Node

1) MOBILE STATION (MS): MS is the physical equipment used by a GSM subscriber (their 'mobile handset'). It consists of two parts:

- Subscriber Identity Module (SIM) and Mobile equipment (ME)

2) SUBSCRIBER IDENTITY MODULE (SIM): SIM is a smart card which carries all the subscriber specific information used by a MS. Its specific functions are:

a) Permanent storage of a subscriber's International Mobile Subscriber Identity (IMSI) and Authentication key.

b) Semi permanent storage of user data, 'telephone directory', short messages

c) Participation in mobility procedures e.g. user authentication.

d) Protected by PIN

3) MOBILE EQUIPMENT (ME): ME provides the radio and processing needed to access the GSM network, plus a man machine interface MMI to enable the user to access services. Its specific functions are:

a. Radio transceiving and Signal processing

b. Call handling c. Interfaces to external equipment e.g. laptops/ palmtops.

4) BASE TRANSCEIVER STATION (BTS): (BTS) provides GSM radio coverage within a cell. It comprises radio transmitting and receiving equipment (including antennas) and associated signal processing. Its Specific functions are

a. Antennas

b. Radio transceiving and signal processing

c. Sending TDMA timing advance instructions to MS & slow frequency hopping (SFH), ciphering and power control

5) BASE STATION CONTROLLER (BSC): BSC is a small switch with enhanced processing capability. It provides local switching to effect handover between a numbers of BTSs. It manages the radio channel and undertakes control of a variety of radio related procedures ensuring that reliable radio links are maintained. Its Specified functions are:

a. Co-ordination and control of a number of BTSs

b. Traffic concentration

c. Low level switching operation

d. Network management interface to all radio elements

6) MOBILE SWITCHING CENTRE (MSC): MSC is an ISDN switch with significantly enhanced processing capability. An MSC will parent a number of BSCs. Responsible for call handling of the mobile subscribers within its domain; this includes

generating call charging records (for billing). Its Specific functions are:
a. Call control
b. Generation of call records
c. Inter BSC and Inter MSC handover

7) HOME LOCATION REGISTER (HLR): HLR is an intelligent database and service control function responsible for management of each subscriber's records and control of certain services (primarily) those associated with incoming calls). It carries subscription details for a subscriber and location information enabling the routing of incoming calls towards the subscriber, i.e. the MSC/VLR currently serving the MS. Its specific functions are:
a. Management of service profiles
b. Mapping of subscriber identities (MISDN,IMSI)
c. Passing subscription records to VLR

8) VISITOR LOCATION REGISTER (VLR): VLR is an intelligent database and service control function. It stores (on a temporary basis) the information needed to handle calls set up or received by MSs registered with it and controls certain services (primarily those associated with outgoing calls). This includes their International Mobile Subscriber Identities (IMDI), current Location Area Identities (LAIs) and supplementary service entitlements. Its specific functions are: a. initiating authentication and ciphering
b. Initiating paging
c. Mapping of various identities (MSISDN, IMSI, TMSI)
d. Passing location information to HLR

9) INTERROGATING NODE (IN): IN is the target for calls bound for GSM users. It is responsible for determining the location of a called subscriber and routing calls accordingly. The IN is commonly combined with an MSC forming what is known as a Gateway MSC (GMSC).

1.1.1.2 The GSM System

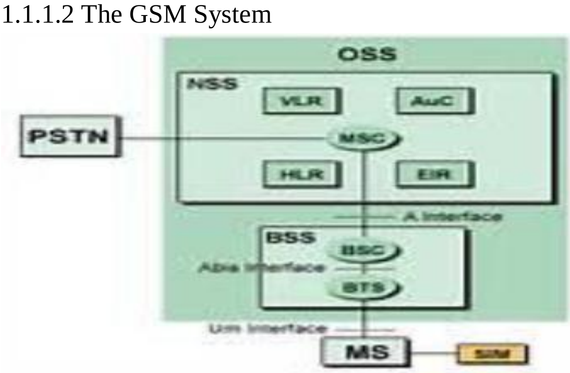

Fig. 1 Structure of GSM Network

1.1.1.3 GSM Processes

- Handover - Brief introduction
- Paging - Location Area - Location Update - Location Area Message Sequence as example
- Incoming Call
- Outgoing Call

1) Handover: Handover is the means of maintaining a call when a user moves outside the coverage area of the serving BTS.
2) The call must be switched to an alternative BTS to provide service, automatically and without loss of service.
3) Handover is complex process requiring synchronization of events between the mobile station and the network.
4) Incoming Call: An incoming call is presented to the Gateway MSC- one containing the Interrogating Node. The IN determines the HLR from the Mobile Subscriber ISDN number and requests routing information from the HLR towards the MSC/VLR where the mobile was last located. The MSC/VLR pages the mobile and if this is in range it responds to the page and requests a radio channel. The MSC/VLR authenticates the MS and sets and ciphering. The bearer is now established and the alerting signal can be activated on the mobile.
5) Outgoing call: An outgoing call begins when the user dials a number and presses send. The MS then requests a radio channel. The Local MSC/VLR authenticates the MS and establishes a radio channel with ciphering. The call is routed in accordance with the dialed number and the MSC/VLR maintains the charging records.

1.2 MOBILE TELEPHONY GENERATIONS

There are different generations of mobile telephony such as 1G, 2G, 3G, and 4G. 1G (First Generation):- 1G (or 1-G) refers to the first-generation of wireless telephone technology, mobile telecommunications. These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications. The main difference between two succeeding mobile telephone systems, 1G and 2G, is that the radio signals that 1G networks use are analog, while 2G networks are digital. Although both systems use digital signaling to connect the radio towers (which listen to the handsets) to the rest of the telephone system, the voice itself during a call is encoded to digital signals in 2G whereas 1G is only modulated to higher frequency, typically 50 MHz and up. The inherent advantages of digital technology over that of analog meant that 2G networks, eventually replaced them almost everywhere. 1G speed varies from that of a 28k modem (28kbit/s) to a 56k modem (56kbit/s).

2G (Second Generation):- 2G (or 2-G) is short for second-generation wireless telephone technology. Second generation 2G cellular telecom networks were commercially launched on the GSM standard in Finland by Radio Iinja in 1991. Three primary benefits of 2G systems over their predecessors were that phone conversations were digitally encrypted; 2G systems were significantly more efficient on the spectrum allowing for far greater mobile phone penetration levels; and 2G introduced data service for mobile, starting with SMS text messages. 2G technologies enabled the various mobile phone networks to provide the services such as text message, picture message and MMS (multimedia messages). All text messages sent over 2G are digitally encrypted, allowing for the transfer of data in such a way that only the intended receiver can receive and read it.
2G services are frequently referred as Personal Communications Service, or PCS, in the United States.

2.5G (GPRS)
2.5G ("second and a half generation") is used to describe 2G-systems that have implemented a packet-switched domain in addition to the circuit-switched domain. It does not necessarily provider faster services because bundling of timeslots is used for circuit-switched data services as well. The first major step in the evolution of GSM networks to 3G occurred with the introduction of General Packet Radio Service (GPRS).

2.75G (EDGE)
GPRS1 networks evolved to EDGE networks with the introduction of 8PSK encoding. Enhanced data rates for GSM Evolution (EDGE), Enhanced GPRS (EPRS), or IMT Single Carrier (IMC-SC) is a backward-compatible digital mobile phone technology that allows improved date transmission rates, as an extension on top of standard GSM. EDGE was deployed on GSM networks beginning in 2003—initially by AT&T in the United States. EDGE is standardized by 3GPP as part of the GSM family and it is an upgrade that provides a potential three-fold increase in capacity of GSM/GPRS networks.

3G (THIRD GENERATION)
3G, short for third Generation, is the third generation of mobile telecommunications technology. This is based on a set of standards used for mobile devices and mobile telecommunications use services and networks that comply with the International Mobile Telecommunications-2000 (IMT-2000(specifications by the International Telecommunication Union. 3G finds applications in wireless voice-telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV.

4G (FOURTH GENERATION)
4G is the fourth generation of mobile telecommunications technology, succeeding 3G and preceding 5G. A 4G system, in addition to the usual voice and other services of 3G, provides mobile ultra-broadband Internet access, for example to laptops with USB wireless modems, to smart phones, and to other mobile devices. Even though 4G is a successor technology of 3G, there can be signification issues on 3G network to upgrade to 4G as many of them were not built on forward compatibility. Conceivable applications include amended mobile web accesses, IP telephony, gaming services, high definition mobile TV, video conferencing, 3D television, and cloud computing. Two 4G candidate systems are commercially deployed: the Mobile WiMAX standard (first used in South Korea in 2006), and the first release Long Term Evolution (LTE) standard (in Oslo, Norway and Stockholm, Sweden since 2009).

5G (FIFTH GENERATION)
5G denotes the next major phase of mobile telecommunications standards beyond the current 4G/IMT-Advance standards. 5G is also referred to as beyond 2020 mobile communications technologies. 5G does not describe any particular specification in

any official document published by any telecommunication standardization body.

1.3 EEG Characteristics

In this section we introduce the main characteristics of EEG signals. The EEG is a measure of voltage as a function of time. The voltage of the EEG determines its amplitude (measured from peak to peak). EEG amplitudes in the cortex range from 500-1500 μV, however, the amplitudes of the scalp EEG range between 10 and 100 μV [16]. The attenuation is due to the poor electrical conductivity of brain tissues, skull and scalp. In general, EEG signals represent the combination of waveforms, and are generally classified according to their:

a) Frequency (speed);

b) Amplitude (power);

c) Wave morphology (shape);

d) Spatial distribution (topography);

e) Reactivity (behavioral state);

EEG characteristics are highly dependent on the degree of activity of the cerebral cortex [23, pp. 2–5], which represents a very complex neural wiring, and therefore are unique for each person [24, p. 18]. The following illustration 1.1 shows EEG measurements of 5 seconds. The horizontal axis shows the timeline in seconds and the vertical axis corresponds to fluctuations in μV measured from different positions of the scalp, according to the International 10-20 system.

The digital EEG signal is stored electronically and can be filtered for display. Typical settings for the high-pass filter and a low-pass filter are 0.5-1 Hz and 35-70 Hz, respectively. The high-pass filter typically filters out slow artifact, such as electro galvanic signals and movement artifact, whereas the low-pass filter filters out high frequency artifacts, such aselectromyographic signals. A typical adult human EEG signal is about 10uV to 100uV in amplitude when measured from the scalp and is about 10-20 mV when measured from subdural electrodes. Since an EEG voltage signal represents a difference between the voltages at two electrodes, the display of the EEG for the reading encephalograph may be set up in one of several ways. The representation of the EEG channels is referred to as a montage [25].

II LITERATURE REVIEW

Dayang Azra, Awang Mat et al. (2009) had done the research work on “The effect of Bluetooth Headset and Earphone on Reducing Electromagnetic Radiation from Mobile phone towards Human Head”. In this research work thermal imaging technique is used to detect the effect of electromagnetic radiations from mobile phone serving GSM 900 and GSM 1800 on human brain. This technique is used to measure and capture the temperature distribution during the experimental analysis for every 5 minutes interval. Bluetooth headset and earphone are used to study whether these devices are able to reduce effect of radiations on human brain. There are two types of mobile phone, one with internal antenna and other with external antenna. The result shows that at 900 MHz frequency, mobile phone serves highest thermal radiation with almost 38.3ºC. When using Bluetooth headset or earphone, it can be seen that the thermal radiation is reduced. Thermal radiation pattern operating at frequency 1800 MHz is shown. It is almost similar as of mobile phone operating at 900 MHz except the highest temperature is only 37.5 MHz. In this case too, when Bluetooth headset and earphone are used the effects of electromagnetic radiations are reduced. This shows that the radiation for mobile phone operating at 1800MHz is lower compare to mobile phone operating at 900 MHz.

Heow Pueh Lee*, Siak Piang Lim et al.(2014) conducted study on Comparative studies of perceived vibration strength for commercial mobile phones shows Among the five mobile phones for the survey, most of the student volunteers or participants felt that product E and product C had better vibration perception than the remaining phone models, be it holding in palms or putting in their pockets. Product A had the weakest vibration perception level when putting inside the pocket. Product E had the highest peak acceleration as well as inertial force among the five phone samples. This was probably the reason why it was consistently ranked as the phone which gave the strongest vibration alert. The student volunteers in general felt that mobile phone placed inside pocket would result in lesser vibration perception as compared to mobile phones held in palms. Both product A and product B had the lowest peak acceleration as well as inertia force values among the five mobile phone models. This was the reason why both of these mobile phones had the lowest vibration perception among all five mobile phones.

Christoph Augner, Timo Gnambs, Robert Winker, Alfred Barth et al (2012) study acute effects of electromagnetic fields emitted by GSM mobile phones on subjective wellbeing and physiological reactions: A meta-analysis gives provides evidence that short term exposure of RF-EMF emitted by mobile phones do not affect well-being and related parameters. We found no impact on headaches, nausea, fatigue, dizziness, skin irritation, blood pressure, heart rate, heart rate variability and skin resistance, or respiration. Additionally, there was no evidence that subjects were able to detect RF-EMFs under blind experimental conditions. The results of our meta-analysis are supported by previous reviews.

Rubin et al. (2010) and Roosli (2008) identified 7 and 6 studies, respectively dealing with 'mobile phone handset experiments. All but one of these studies was included in our meta-analysis.

Although only one study (Hillert et al., 2008) found a significant effect for headaches it is intriguing that despite the small number of studies and the short exposure duration the overall meta-analytical effect for headaches was 0.08 with a standard error of 0.05.

V.I. Thajudin Ahamed, N.G. Karthick, Paul K. Joseph(2007) study Effect of mobile phone radiation on heart rate variability on Neurological effect of the electromagnetic field emitted from MP, using HRV measures is examined. The indices, namely sample entropy and scaling exponent, indicate an increase when MP is placed near the chest and a decrease when MP is placed near the head. It can be concluded that the variation is not significant as the 'p' value is high, compared to 'without MP condition'. This might be because MPs emit very low power to cause any detectable heart rate variation, when the user is not communicating. In order to get more insight into the neurological effect of radiation from MP, more studies may be conducted with more number of subjects.

III CONCLUSIONS

Power Asymmetry Ratio (PAR) has been shown to be able to determine which brain will be dominant during a certain task. From the observation, brain hemisphere dominant changed after being exposed to the mobile phone RF for 5 minutes and the changes depend on the side of exposure. Research will be continued with further analysis to investigate the effects of RF emission to human brainwave signals specifically on beta, theta and delta sub-bands. Other than that, the EEG data will also be analyzed on the statistical part as future work to obtain more significant different of the EEG signals influenced by the mobile phone RF emission.

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