Empirical Perspective on the Effects of GSM Mobile Phones and Base Stations on Human Biological Systems

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Abstract– **The invention of mobile phones has brought revolution to human activities but, there has been concerns raised about the possible health effects of the use of mobile phones and the erection of the masts in residential areas. This has led to various researches by different bodies to ascertain the veracity of the claim that mobile phones affect human beings adversely. Mobile phones operate on radio waves which are produced in the frequency range of 3MHz to 30,000MHz. Some SAR values are presented based on standard recommendation and available ratings as guide to assess possibility of damages to human tissue. The claim that mobile phones also cause cancer, brain tumor and cell damage is also discussed in this work and hopefully should allay the fear of imminent or possible health risks associated with the use of mobile phones and erection of communication transmission mast as inconsequential.**

Keywords– **GSM, Radio Waves, Interaction of Radio Waves, Cell Damage, SAR and Risks**

I. INTRODUCTION

Over the past three decades, mobile telecommunication system has been developed and utilized all over the world. The use of mobile phones has gained great public acceptance and new designs with exquisite features are daily being introduced. This has led to the expansion being experienced in mobile phone usage. When mobile phones were first released, they were only really used by the wealthy business men more as a status defining symbol. They were so large that is was nearly impossible to carry them around. However the situation has changed with improved designs and modern production techniques. This has brought down the cost considerably thus allowing even peasants to be able to afford cell phones.

Presently there are more than 5 billion users of mobile phones with daily emergence of new users. This justifies the concerns raised about the consequences of radiation on human health. As of June, 2009 there were more than 4.3 billion users worldwide.As a result of the increase in the number of people using mobile phones, mobile communication companies have also been increasing the number of base stations deployed to enhance the integrity of their services. Most often than not these base stations are erected in densely populated residential areas often constituting public disturbance. The noise and carbon fumes generated by these base stations also contribute greatly to the environmental pollution being experienced.

The safety of cell phone towers or base stations especially in residential areas is another subject of extensive scientific debate. The towers receive and emit radio frequency wave, a form of electromagnetic radiation for up to a distance of two and a half miles.

However serious concern has been raised about the possibly related detrimental health effects associated with the use of mobile phones and the siting of the base stations (Hyland G.J, 2000).Several research works have been carried out to ascertain the possible health effects linked to the use of mobile phones. The report of these research works have even thrown up more arguments. Health care professionals have been agitating for rules and policy guidelines that will streamline the activities of mobile phone companies and protect people from the harmful effects of mobile phones. On the other hand, Scientist and mobile phone companies have been reassuring the populace of the safety of using mobile phones. So who is wrong and who is right?

Effects such as headaches, memory loss and sleep disorders have been alleged to be caused by cell phone radiations. If these alleged effects are true then children would be at the greatest risk due to their thinner skulls and rapid growth rate. Also at greater risks would be the elderly and pregnant women.

Mobile phones use electromagnetic radiation in the radio frequency range with operational frequencies in the range 850MHz to 1900MHz. Widespread concerns have been raised about the possibility that exposure to the radiofrequency field from mobile phones or their base stations could affect people's health. A large body of research exists both epidemiological and experimental, with claims of harmful health effects. Therefore the goal of this treatise is to look at the possibility of any direct link between electromagnetic radio wave propagation and the reported observed harmful effects. We will look at the technical attribute of radio wave frequency field from mobile phones and its interaction with

matter especially human tissue and see if this interaction can solely be responsible for any harmful health effect.

A pertinent question that arises is if the maximum wavelength of radio waves which is the basis of GSM communication produces enough energy that will ionize a typical atom in the tissue of human body.

Obviously electromagnetic waves originate from interaction of electric and magnetic fields which are present in our natural environment. Static electric and magnetic fields arise from natural and man- made sources, whereas electric and magnetic fields in the extremely low frequency (ELF) range are mostly associated with man-made sources. These are numerous and include electric power systems, electric and electronic appliances and industrial devices of which GSM mobile phones is one. Environmental levels of extremely low frequency fields (ELF) are very low. Exposure levels for the general population are typically 5-50mV/m for electric fields and 0.01-0.2μT for magnetic fields. It should be noted that the earth's magnetic field (25-65μT, from equator to poles) is a static field to which everyone is exposed.

Measurements of electric and magnetic fields are used to characterize sources and levels of exposure to humans. The capabilities of instruments to measure such fields have advanced in recent years, particularly for magnetic fields. In addition to simple, easy-to-use hand-held survey meters, there are now portable personal exposure meters capable of recording and describing the statistical, threshold frequency and wave form characteristics of magnetic field exposure. The limiting factor in exposure assessment is not instrumentation but the lack of a consensus as to what exposure characteristics should be measured that are biologically relevant.

In order to understand the effects of electric and magnetic fields on animals and humans, their electrical properties have to be considered. Static magnetic fields which are not attenuated by the organism, can exert forces on moving charges, orient magnetic structures, and affect the energy levels of some molecules. However static and ELF electric fields are greatly attenuated inside the body.

Exposure to electric and magnetic fields result in induction of electric fields and associated current in tissues. The magnitudes and spatial patterns of these fields depend on whether the external field is electric or magnetic or both, its characteristics (e.g., frequency, magnitude, orientation and waveform) and the size, shape and electrical properties of the exposed body. The induced electric field increases with the frequency of the external field and size of the object. A well-established effect of induced fields above a threshold level is the stimulation of excitable cells. Typical residential exposure results in very small induced electric field while some occupational exposure may result in electric fields of the order of 1mV/m in some tissues.

II. EMPIRICAL ANALYSIS

Electromagnetic waves cover an extremely broad spectrum of wavelength and frequency. Radio and television transmission, visible light, infrared and ultraviolet radiation, X-rays and gamma rays all form part of the electromagnetic spectrum. Despite vast differences in their uses and means of production, they all have the general characteristics including the common propagation speed (in vacuum) c=299,792,458m/s. All are the same in principle but differ in frequency and wavelength but the relation $c = f\lambda$ holds for each. The wavelength range of radio frequencies is 10^6-10^{11}nm while the corresponding frequency range is 3MHz to 30,00MHz. However GSM mobile phones make use of frequency ranges designated by International Telephone Union (ITU) for the operation of the GSM for mobile phones. There are four main GSM bands of 850, 900, 1800 and 1900MHz. In Africa, Europe, Middle East and Asia, most of the providers use 900MHz and 1800MHz bands. These have a corresponding wavelength of 0.333m and 0.1667m.

It is a familiar fact that energy is associated with electromagnetic waves. In deriving the energy associated with electromagnetic waves, such as radio waves we need to note that EM waves consists of both electric and magnetic fields and we refer to such energy associated with these fields as energy densities.

The total energy density U in a region of space where E and B fields are present is given by (Hugh D. Young, 1992):

$$U = \frac{1}{2}\varepsilon_o E^2 + \frac{1}{2\mu_0} B^2 \quad (1)$$

E and B fields are related by:

$$B = \frac{E}{C} = \sqrt{\varepsilon_0 \mu_0}\, E \quad (2)$$

Therefore,

$$U = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2\mu_0}\left(\sqrt{\varepsilon_0 \mu_0}\, E\right)^2 \quad (3)$$

$$U = \varepsilon_0 E^2 \quad (4)$$

This shows that the energy density associated with the electric field is equal to the energy density of the magnetic field.

Electric and magnetic fields advance with time into regions where originally no fields were present, so it is clear that the radio wave transports energy from one region to another. We can describe this energy transfer in terms of energy transferred per unit time per unit cross-section area or power per unit area for an area perpendicular to the direction of wave travel. The energy flow per unit time per unit area is:

$$S = \varepsilon_0\, c\, E^2 \text{ or } S = \frac{EB}{\mu_0} \quad (5)$$

For sinusoidal waves and more complex waves, the electric and magnetic fields at any point vary with time. So the average value of the magnitude of the energy flow per unit time per unit area is called the intensity of the radiation at that point with the SI unit of watt per square meter (W/m^2). However the intensity of a sinusoidal wave will be:

$$S = \frac{EB}{\mu_0} = \frac{E_{\max} B_{\max}}{\mu_0} \sin^2(wt - kx) \quad (6)$$

$$S = \frac{E_{\max} B_{\max}}{2\mu_0}\left[1-\cos 2\left(wt-kx\right)\right] \quad (7)$$

The time average value of cos 2(wt-kx) is zero because at any point it is positive during half a cycle and negative the other half cycle. So the average value Sav of the pointing vector magnitude over a full cycle is

$$S_{av} = \frac{E_{\max} B_{\max}}{2\mu_0} \quad (8)$$

This means that the average value of S for a sinusoidal wave (i.e., intensity) is one half of the maximum value of Emax and Bmax.

By using $E_{\max} = cB_{\max}$ and $\varepsilon_0\mu_0 = \frac{1}{c^2}$ then

$$I = S_{av} = \frac{E_{\max} B_{\max}}{2\mu_0} = \frac{E^2{}_{\max}}{2\mu_0 c} = \frac{1}{2}\sqrt{\frac{\varepsilon_0}{mo}}E^2{}_{\max} = \frac{1}{2}\varepsilon_0 c\, E^2{}_{\max} \quad (9)$$

III. ELECTROMAGNETIC WAVES IN MATTER

Electromagnetic waves comprising radio waves can be analyzed in vacuum and dielectrics. The wave speed is not the same as in vacuum and we represent this speed in dielectric as Y instead of C so that we can alter our guiding relations as;

$$B = \varepsilon\mu v E \quad (10)$$

and the relationship between speed in vacuum and speed in a material e.g., a dielectric becomes:

$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{1}{\sqrt{KK_m}}\frac{1}{\sqrt{\mu_0\varepsilon_0}} = \frac{c}{\sqrt{KK_m}} \quad (11)$$

For most dielectrics, the relative permeability K_m is very nearly equal to unity so that $v = \frac{c}{\sqrt{k}}$

Because k is always greater than unity, the speed v of electromagnetic waves in a dielectric is always less than the speed c in vacuum by a factor of $\frac{1}{\sqrt{k}}$. With the presence of a dielectric the energy density becomes:

$$U = \frac{1}{2}\varepsilon E^2 + \frac{1}{2\mu}B^2 = \varepsilon E^2 \quad (12)$$

The energy densities in the electric and magnetic fields are still equal. The pointing vector becomes:

$$S = \frac{1}{\mu}\ \text{E x B} \quad (13)$$

With magnitude

$$S = \frac{EB}{\mu} = \sqrt{\frac{\varepsilon}{\mu}}E^2 \quad (14)$$

The intensity I of a sinusoidal wave is obtained by replacing ε_0 with ε and μo with μ to have.

$$I = \frac{E_{\max} B_{\max}}{2\mu} = \frac{E^2{}_{\max}}{2\mu v} = \frac{1}{2}\sqrt{\frac{\varepsilon}{\mu}}E^2{}_{\max} = \frac{1}{2}\varepsilon v E^2{}_{\max} \quad (15)$$

This means that GSM radio waves cannot propagate any appreciable distance in a dielectric material such as human tissue because the electric and magnetic fields lead to currents that provide a mechanism for dissipating and reflecting the energy of the wave.

Also we look at the energy equivalent in electron volt of the wave length used by GSM radio frequency band.

From $E = hF = \frac{hc}{\lambda}$ (16)

(where h = Planck's constant). For GSM wavelength of 0.333m, then

$$E = \frac{6.63x10^{-34}\,J.SX\,3X10^8\,m/s}{0.333m}$$

$$E = 5.973\,X10^{-25}\ Joules$$

Since 1eV= 1.6 x 10^{-19} Jthen E = 3.733 x 10^{-6}eV.

For the GSM wavelength value of 0.1667m, E = 7.457 x 10^{-6}eV, if we relate this energy to the energy possessed by a particle at room temperature (300K) using the equipartition principle then:

$$E = \frac{3}{2}KT \quad (17)$$

where K is the Boltzmann's constant and T is the Kelvin temperature.

$$E = \frac{3}{2}x\left(8.167x10^{-5}eV/k\right).\left(300k\right) = 0.0388eV \quad (18)$$

This means that the energy possessed by a particle at room temperature is about 5203 times or 10,393 times greater than that of the corresponding energy possessed by the GSM radio frequency bands used in Africa, Middle East, Europe and Asia.

Conversely if we relate the energy derived from the radio frequency bands of GSM mobile phones to the equivalent heat that will be generated, we have:

$$E_1 = \frac{3}{2}KT_1 \quad (19)$$

3.733 x 10^{-6}eV= $\frac{3x8.167x10^{-5}(eV/k)xT_1}{2}$

$T_1 = \frac{2x3.733x10^{-6}eV}{3x8.167x10^{-5}eV/k} = \frac{7.466x10^{-6}eV}{2.450x10^{-4}eV/k}$

T_1 = 0.0305 K and T_2 = 0.0609 K

These temperatures seem not likely to pose any health threat to people using GSM mobile phones. Part of the radio

wave emitted by a mobile telephone handset can have a peak power of 2 Watts, and a US analogue phone had a maximum transmit power of 3.6 Watts. Other digital mobile technology such as CDMA 2000 and D-AMPS use lesser output power, typically below 1Watt. The maximum power output from a mobile phone is regulated by the mobile phone standard and by the regulatory agencies in each country.

The rate at which radiation is absorbed by the human body is known as the 'specific absorption rate' (SAR) and its maximum has been set by regulatory authorities in different countries. The Federal Communication Commission (FCC) in the USA recommended 1.6W/Kg averaging over1gram of tissue. The recommended maximum limit in Europe is 2W/Kg averaging over a volume of 10 grams of tissue. SAR data for specific mobile phones, classification with other useful information can be found directly on the manufactures websites, as well as on the third party websites (1988).

Moreover from the foregoing it is evidently clear that the energy possessed by the GSM radio frequency band is almost inconsequential compared to the energy possessed by a particle moving at room temperature. Obviously, these energies are not high enough to ionize hydrogen atoms. It is well known that ionization of water molecules in human tissues lead to uncontrolled breaking and forming of tumour cells and cancerous growth. Pertinently, if the energy of the waves radiated from GSM phones and GSM base stations is not enough to ionize a tissue molecule, then this cannot be said to pose any serious health effect as to cause tumour or cancerous growth.

Another point to consider is the fact that most of the reported cases or experiments done to infer correlation between GSM mobile phones usage and these harmful health effects have not succeeded in directly linking these health effects to GSM mobile radio frequency bands while completely extricating other extraneous causative factors in a controlled laboratory experiment.Most of the reports have based their assertions on perceived effects felt by people who use GSM phones for long hours or by people living near GSM base stations. Clearly this cannot be said to be objective enough to confirm or concretize the direct relationship between GSM usage and reported harmful health effects.

Table 1: Specific Absorption Rates (SAR) limits averaged over body volume (Celtech)

Averaging time (6minutes)	Whole body SAR	Partial body SAR	Head SAR	Local SAR	
Body region	Whole body	Exposed body part	Head	Trunk	Extremities
Operating Mode	(W/Kg)	(W/Kg)	(W/Kg)	(W/Kg)	(W/Kg)
Normal	2	2-10 (b)	3.2	10	20
1st Level Controlled	4	4-10 (b)	3.2	10	20
2nd Level Controlled	>4	>(4-10)	>3.2	>10	>20

Notes:

(a) local SAR is determined over a mass of 10g.

(b) the limit scales dynamically with the ratio ''exposed patient mass/patient mass.

Normal Operating Mode: Patient body SAR=10W/Kg-(8W/Kg*exposed patient mass). In cases where the orbit is in the field of a small scale local RF transmit coil, care should be taken to ensure that the temperature rise is lowered to 1^0C. For whole body exposure, there is a limit of 0.08W/Kg averaged over the whole body.

FIRST LEVEL CONTROLLED OPERATING MODE: Partial body SAR = 10 W/kg – (6 W/kg * exposed patient mass / patient mass).

Table 2: Mobile– Phones SAR List

Brand	Model	Operating System	SAR (W/Kg)
LG	Optimus 2X	Android	0.546
Samsung	Nexus S		0.58
HTC	Nexus One		0.37
BlackBerry	Torch	BlackBerry	0.91
BlackBerry	Curve 9300	BlackBerry	1.07
Motorola	Elipside	Android	0.5
Huawei	Ideos X5		0.34
Motorola	Devour	Android	0.45
Nokia	E5	Symbian	0.88
Sony Erricsson	Spiro		1.03
Motorola	Droid X		1.43

IV. FURTHER DISCUSSION: EFFECTS OF ELECTROMAGNETIC RADIATION ON HUMANS

Many scientific studies have investigated possible symptoms of mobile phone radiation, which are occasionally reviewed by some scientific committees to assess overall risks. A recent assessment published in 2003 by the European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIGH), conclude that three lines of evidence viz: animal, in vitros, and epidemiological studies indicate that 'exposure to RF fields is unlikely to cause an increase in cancer in humans'.

SAR values are essentially crucial in assessing safety standards of mobile cell phones and can guide the general public to judiciously use and take requisite caution to avert possible hazards that could be associated with the radiation field of mobile phones. A list of recommended safety limits averaged over body mass for major parts of the body has been presented in table 1.0 above and also table 2.0 shows ''Mobile – Phones SAR'' list that can guide subscribers in choosing their choice of mobile phones.

No consistent relationship has been found in studies of childhood brain tumours or cancers at residential low frequency electric and magnetic fields. Some of these studies have generally been smaller and of lower quality. The association between childhood Leukemia and high levels of magnetic fields is unlikely to be due to chance but it may be affected by bias. In particular selection bias may account for

part of the association. The WHO has classified mobile phone radiation on the IARC scale to Group 2B possibly carcinogenic. That means there ''could be some risk'' to carcinogenicity, so additional research into the long-term use of mobile phones need to be conducted (IARC, 2011).

Numerous studies of the relationship between electrical appliance use and various childhood cancers have been published. In general, these studies provide no discernible pattern of increased risks associated with increased duration and frequency of use of appliances. Since many of the studies collected information from interviews that took place many years after the time period of etiological interest, recall bias is likely to be a major problem.

While a number of studies are available, reliable data on adult cancer and residential exposure to electric and magnetic fields, including the use of appliances like GSM mobile phones, are sparse and methodologically limited. None of the studies reported so far has included long term or personal measurement. Although there have been a considerable number of reports, a consistent association between residential exposure and adult Leukemia and brain cancer has not been established and for breast cancer and other cancers, the existing data are not adequate to test for an association with exposure to electric or magnetic fields.

SAR values or ratings for various cell and mobile phone products are available from the vendors, testing laboratories, websites and third parties. Compliance within the safety recommended maximum limit by various standard regulatory agencies such as the American and European safety maximum limit will tremendously avert and virtually eliminate any possible hazards to the human health.

V. CONCLUSION

It seems to be psychological impression of the mind that people anticipates GSM cell phones are associated with inherent health risks which are not clarified.

To ascertain the possibility of damages to biological cells, it is pertinent to consider the frequency range and the available energy at a particular frequency or wavelength in addition to the SAR values.

This study which is an empirical perspective should allay the possible fear of risks or damages associated with the radiation field from GSM cell phones as there has not been obvious report of fatal emergency associated with the use of mobile phones. Thus it becomes highly imperative to disseminate vital and crucial information such as SAR recommended values and ratingsto serve as guide to both manufactures and users of GSM mobile cell phones. This study will obviously avail the public and stake holders the access to basic relevant and crucial information engendered to ensure precautionary use of mobile phones for optimal benefits having addressed key issues.

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