

ANALYSIS OF THE ENVIRONMENTAL CONSEQUENCES OF E.M.F. ON INDIVIDUAL'S AND ELECTRONIC EQUIPMENTS

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ABSTRACT

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The consequential effect measurement of the absorption of electromagnetic energy on both individuals and electronic equipments is essential. Through out of this research, the electromagnetic emission on the human and electronic devices was examined with scientific experiments. According to this research experiment, model of human brain simulated with the effect of Electro Magnetic Field (EMF) was observed. The experiment was conducted in the Electronics Laboratory, Department of Electronics and Telecommunication Engineering, University of Development Alternative (UODA) in collaboration with the Department of Computer Science and Engineering, Faculty of Engineering, UODA, Bangladesh during the period of 2008 and 2009. The outcomes of the paper are evaluated with the results of the literature studies; an excellent conformity is identified where it was observed that the EMF has effects on human body which varies with the different parts of the body.

Keywords: *Environmental consequences, human brain simulation, electromagnetic field*

INTRODUCTION

Electrical and electronic devices, wireless cellular telephones and other mobile personal communication services is the fastest growing field in the world. There is uncertainty about the health effects of Radio Frequency (RF) a certain amount of energy from radiation is absorbed by the body and converted to heat. This is called thermal effect. It results in public concern about possible health effects of human exposure to electromagnetic energy (Bernardi, *et al* 2000; Nikita, *et al* 2000). Concerns about other possible, so-called a thermal effects arising from exposure to RF frequencies include suggestions of subtle effects on cells that could have an effect on cancer development or influences on electrically excitable tissue. It could influence the function of the brain and nervous tissue. There has also been concern about whether there could be effects on brain function, with particular emphasis on headaches and memory loss. Few studies have yet investigated these possibilities (Stevens and Martens, 2000). The basic limit of exposure is expressed by the quantity called "specific absorption rate" (SAR). SAR is the time rate at which EM energy is absorbed by (dissipated in) an element of biological body mass, and is expressed in units of watts per kilogram (W/kg) (Stevens and Martens, 2000). The maximum local SAR, which is the most critical quantity in the context of potential health effects of RF energy radiated, depends on a large number of factors, such as: Design of the device, its operational frequency and antenna input power and orientation with respect to the human. The most investigated effect of EM energy on biological tissues is the transformation of energy entering the tissues into increased kinetic energy of the absorbing molecules, thereby producing a general heating in the medium. The power absorbed by the tissues will produce a temperature rise that is dependent on the cooling mechanism of the tissue.

The SAR can applicable to mobile phones and it is a way of measuring the RF that is absorbed by the tissue. Determination of SAR can be made either by using sophisticated computer modeling techniques or by performing tests on a model called a "phantom". Years of research have gone into understanding and developing ways to calculate the complexities involved in determining SAR values for products that produce radio frequency emissions. The results of that research are the current and recently revised FCC RF emissions guidelines based on the ANSI/IEEE and NCRP standards. (Çelik, 2001; Demirbilek, 2001; Anonymous, 1998; Anonymous, 2000). SAR testing on wireless phones is done at the maximum power output level for the phone. Wireless phones though, typically operate at power levels below peak power and often at just 25% their allowable power. Phones operate at constantly varying power levels due to many factors such as distance from the nearest base station and also to conserve battery power. SAR is defined as;

$$SAR = \sigma \frac{E_i^2}{\rho}$$

$$\text{Or } SAR = C_i \frac{dT}{dt}$$

$$\text{Or } SAR = \frac{J^2}{\rho\sigma}$$

σ = conductivity of body tissue s/m, ρ = density of body tissue in kg/m³, E_i = rms value electric field in the tissue V/m, C_i = heat capacity of body tissue in J/kgK, T = temperature, J = magnitude of the induced current, density in the body tissue A/m^2 .

Safety and Standards

The guidelines published by the NRPB were based on the potential of RF radiation to cause illness or injury through heating of body tissues. While some research had suggested that adverse health effects might occur from exposures lower than those needed to produce significant heating, the evidence for this was not considered sufficient to form a basis for the derivation of exposure guidelines which incorporate basic restrictions on the SAR. The SAR is averaged over an exposure time and a specified mass tissue, depending on the tissue region. Average times are specified because of the time taken for the temperature of tissues to equilibrate when they are exposed to the radiation. The fields are assumed to be in the far-field region. The second guidelines on exposure to RF radiation were also published by the Anonymous, 1998. These were designed to prevent illness and injury through heating effects. Their starting point is the behavioral changes found when experimental animals were exposed to RF radiation at levels that produced a rise in whole body temperature in excess of 1 °C. An SAR of 1-4 W/kg or higher is needed to cause these changes. The ICNIRP guidelines (Anonymous, 1998) feature a two-tier system with lower limits (five times lower) for exposure to the general public than for occupational exposure.

Table 1. ICNIRP basic restrictions on occupational exposure and general public exposure (in brackets) in the frequency range 10 MHz to 10 GHz (Anonymous, 1998)

Tissue Region	SAR limit (W/kg)	Mass (G)	Time (Minutes)
Whole Body	0.4(0.08)	-	6
Head, Trunk	10(2)	10	6
Limbs	20(4)	10	6

The ICNIRP guidelines for the public have been adopted in a European Council Recommendation (1999), which has been agreed to in principle by all countries in the European Union.

Table 2. ICNIRP reference levels for public exposure to mobile telecommunications frequencies (ICNIRP, 1998)

Frequency (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m ²)
400- 2000	$1.375 \sqrt{f}$	$0.0037 \sqrt{f}$	$f / 200$
2000- 3000	61	0.16	10

RESULTS

Maximum electric field values were measured from the front side very close to the mobile phones for different phones and the results are given by Figure1. This measurement was repeated for other sides.

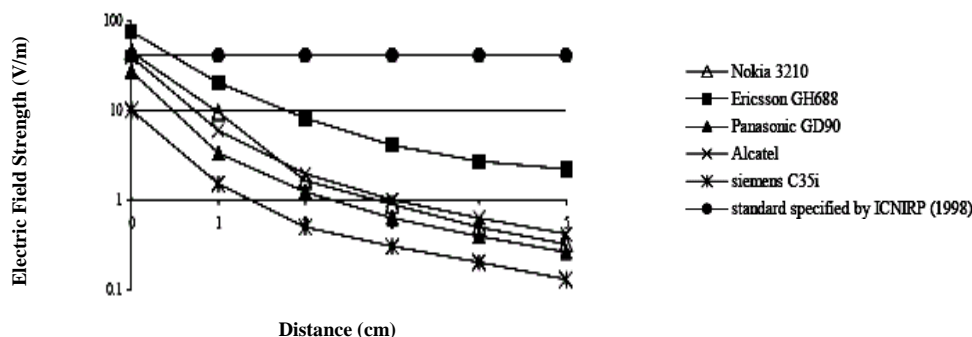


Figure 1. Electric field values measured at distance from the front side of the mobile telephones in logarithmic scale

Among the mobile phones, subjected to our measurements, Siemens C35i is the phone that radiated the lowest electric field; up to 10,2V/m in the outgoing call phase. Ericsson GH688 is the phone that radiated the highest electric field; up to 76V/m. Maximum values were recorded during dialing due to contact with the base station. The higher electric fields occurred at the front side of Alcatel, Panasonic GD90 and Ericsson GH688 than the backside. Nokia 3210 that have patch antennas radiated lower electric fields at the front side than backside. It more reliably protects the head of the user from the electromagnetic field. The electric field measurements with distance show that the decreasing rate of electric field with distance is different for each mobile telephone. Some uncertainties arise from changes in the dielectric parameters of the biological tissue caused by aging. Another uncertainty arises from the body size of human. The variation of ± 10 % due to different sizes of human was found. In this study, the simulation of human head was performed using HP Agilent High Frequency Structure Simulator. Agilent HFSS is a software package for electromagnetic modeling of passive, three dimensional structures. The solution is performed at a single frequency or over a range of frequencies. The post processor of the software makes possible to view and analyze the simulation data that include E and H fields, far field, and

antenna parameters. The human head was modeled with a dipole antenna at a frequency of 900 MHz. The electric field distribution in the head and the SAR values were given in Figure 2.

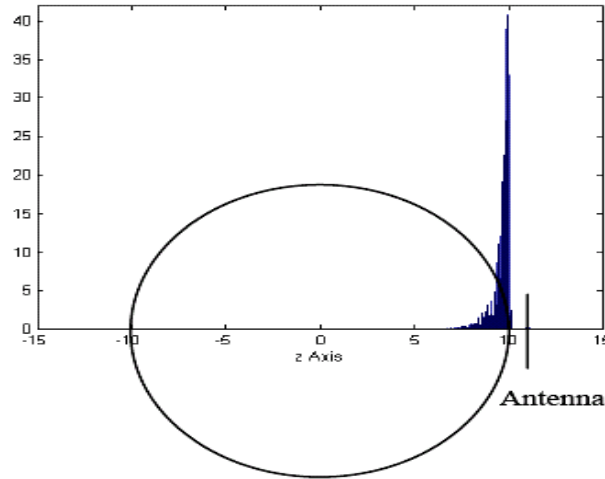


Figure 2. The distribution of electric-field and local SAR values in the yz-plane

In the study of Konstantina S. (Nikita, *et al* 2000) a dipole antenna was used and the antenna input power was 1W. The parameters used in simulations in our study were taken from this study in order to be able to compare the results. The local peak SAR values in Nikita's study and in our study were given in Table 3.

Table 3. Comparison of the Peak SAR Values

Study Items	Homogeneous Sphere	Three-Layer Sphere
Peak Values of Local SAR (W/kg) of Nikita's study [2]	39.4	29.3
Peak Value of local SAR of our study	40.73	32.8245
Difference (%)	3.26	10.73

It can be seen from Table 3 that there is a good agreement between the local SAR values of our study and the literature. The results of our study also have been compared with the other literature (Anonymous, 2000).

EM Interference

The undesirable fields in the environment may be of natural origin, but most often they are man made. It has not been until the last decades that concern has been expressed over man made EMFs from power, communication, and electrical process systems. At HF, the general EMF background consists predominantly of the AM radio band (0.535- 1.604 MHz) and the FM and TV band (54-806 MHz). EMF emanating from electrical power system (60 Hz in USA, and 50 Hz in Europe) constitute most of the artificial low frequency EMF background. The average background 60 Hz electric field (EF) is about 1 V/m, and the average background magnetic field (ME) is about 800 micro Gauss. EMFs much greater than the background are found in the vicinity of specific sources. The power density from a typical 50 kW AM radio station does not decrease below 1 micro W / cm² within a radius of about 3280 ft. FM radio stations vary in strength and antenna design, but some stations have levels exceeding 1000 microW/cm2 within 200 ft of the antenna. In large urban areas, the elevation necessary for transmission of radio and TV signals is sometimes obtained by mounting the antenna atop of a tall building. This produces high EMF levels in nearby buildings. When antennas are grouped, they produce relatively intense EMF levels over broad areas. Because of stray radiation from radar, exposure levels near airports and military bases can be in range of 10-100 microW/cm2 at distances up to 0.5 miles.

Microwave relay antennas are used for long distance telephone service and for private communications. At a 10 ft diameter antenna positioned 100 ft above the ground produces ground level EMF of approximately 0.03-7.5 microW/cm2 within 376 ft of the tower. Mobile communication equipment and hand-held walkie-talkies are relatively low power sources, but they account for significant exposure levels because the radiating antenna is ordinarily close to the user. A walkie-talkie operating at 165 MHz, with an output of 1.8 W results in 144-12000 microW/cm2 in the vicinity of the head of the user (Battocletti, 1976; Becker and Marino, 1982; Tell, 1972; Gavan and Joffe, 1992) [8-11]. Power lines transport energy and they are usually built overhead rather than underground. The energy carried by a power line actually moves through the space that surrounds the wires, and consists of EM and MF. Various design considerations such as line geometry, phase spacing, and operating voltage affect field strength at various lateral distances. An EF of 2900 V/m is approximately the measured value from an electric blanket which operate at 60 Hz. Video display terminals produce environmental EF of 10

Hz to 200 MHz. An EF of 300 V/m is an approximate value that could be measured from 20 cm from such a device. The 5 mW/cm² power density at a frequency of 2.45 GHz, is measured in experiments 5 cm from a microwave oven's surface. This is the upper limit which must not be exceeded over the useful lifetime of any oven. Inside the oven the radiation source delivers a peak power of 1.5 kW and an average power of 500 W. Diathermy devices utilize EMF to heat patients' sore muscles and other tissues. These devices have output power up to 100 W and deliver many watts of absorbed microwave power to the patient. Microwave diathermy operates at 2.45 GHz and shortwave diathermy operates at 27.12 MHz. Dielectric heaters are in widespread use in various industries to seal, dry or mold materials. These devices generate hundreds or thousands of watts of RF power at 20 to 70 MHz, and their exposure fields exceed 1000-2700 V/m or 1-5 A/m (equivalent power density of 10 mW/cm²) (Battocletti, 1976).

At present time, the chief known effect of radio or microwave energy on living cells is to produce heat. If you are exposed to high intensity microwaves, you may feel warm. At some frequencies this warmth may be felt too late to give you adequate warning of the danger. The eyes are particularly susceptible or vulnerable because of their poor ability to dissipate heat, and this can cause cataracts and other eye problems. At one test site 20% of the microwave workers have been found to possess the first indication of microwave eye damage. And it should be noted that the power level does not have to be high in order to cause damage; if you are close to the source, low power levels can create the same problem. Nonthermal effects that cannot be attributed to temperature elevations under investigation include thyroid enlargement, headaches, loss of memory, change of pulse rate, genetic effects and behavioral effects. Most of the dangerous cases of EMF exposure is seen in the vicinity of occupationally produced EMF due to the high levels of power density. Several investigators reported similar results. People occupationally exposed to EMF exhibited respiratory distress, bradycardia, and changes in CNS function. The latter included hypertension, decreased reaction time to a visual stimulus, and a decrease in memory and attentiveness (Becker and Marino, 1982; Tell, 1972; Gavan and Joffe, 1992). Protection of personnel from high levels of RF radiation can be achieved by a number of methods:

- 1) By de-energizing antennas and high power sources for the purposes of maintenance,
- 2) By lowering the power during periods of maintenance such that the levels to which personnel are exposed are below the current accepted exposure standards,
- 3) By incorporating equipment shielding and other engineering measures to reduce exposure to RF workers,
- 4) By providing RF protective clothing.

The first method is the most desirable from the point of view of ensuring personnel exposure is as low as possible but may be impracticable in a few sensitive situations. The second method is may also be impracticable in a number of situations, particularly for frequencies up to 1 GHz, because a lower transmit power may give an unacceptable system performance, in which case the system might just as well be de-energized. However, this method may prove practicable in broadcast installations below 1 GHz. The third method may be prohibitively expensive if not included in the original equipment design, or may be impossible due to the nature of RF processing involved. The fourth method, providing RF protective clothing [4], may have merit in those few sensitive situations where maintenance is required and the system cannot be de-energized, provided: clothing has been shown to be effective at shielding RF radiation, and clothing does not in itself present a hazard.

Today electromagnetic interference (EMI) and the frequency with which it occurs are growing with the rapid spread of electrical and electronic devices. The primary vehicle used to understand the effects of interference is a mathematical model. A mathematical model quantifies our understanding the phenomenon and also may bring out important properties that are not so readily apparent. An additional, important advantage of a mathematical model is its ability to aid in the design process. The criterion that determines whether the model adequately represents the phenomenon is whether it can be used to predict experimentally observed results. If the predictions of the model do not correlate with experimentally observed behavior of the phenomenon, it is useless. However, our ability to solve the equations resulting from the model and extract insight from them quite often dictates the approximations used to construct the model. For example, we often model nonlinear phenomena with linear approximate models. EMI interference can be demonstrated by tuning a radio receiver to a quiet of the AM band where there is no radio station and placing a calculator with a LED display near the receiver. Turn on the receiver and then turn on the calculator. You should hear a buzzing sound from the receiver when you turn on the calculator. The noise you will hear is caused by the circuit which strobes the LED display and each impulse sound is made by a small current pulse to a display segment. Today, we recognize that almost any device which operates on the principle of moving an electron from one point to another can be either a source or a receiver of electrical noise.

EMI is a problem with two sides. On one hand is the concern that some sensitive electronic instrument or control system will suffer a loss of performance when an outside signal invades its circuitry. It is said that the device is a victim, and that it is susceptible to outside interference. The device in effect becomes a receiver of

EM noise. On the other hand, if the device is noisy it is said that it is a culprit, and the main concern is due to its emission. Besides concern for the safety and the security of communications, there are concerns for the integrity of control, computing and measurement systems. In addition to possibly disrupting communication to essential services, such as fire and police departments, the possibility also exists of interfering with such diverse electronics as computers, robotics control systems, missile firing systems, aircraft controls, and microwave ovens. No one wants the computer in a banking institution to miscalculate a bank transaction due to radar from a passing airplane or a night guard's walkie-talkie; or for a weighing system to overcharge a truck transport company for road usage when a nearby driver asks for a weather report using his CB radio. And certainly no one would want the lives of patients in a hospital emergency room threatened by a malfunction in the electronic life support systems due to unintentional outside interference. These are just a few examples of how an EMI cause important problems. In attempting to resolve the possible conflicts between sensitive electronics and a noisy environment, engineers seek to make circuits, which are potential receivers, more immune and those which are potential emitters less noisy. The causes of EMI may be either within the equipment with which one is concerned, in which case it is known as intra-system interference, or it may come from outside the equipment, in which case it is known as inter-system interference. The source of interference is called the emitter and the device upset by interference is called the suscepter. In all cases EMI arises from a combination of three factors: source, transmission path, and a device sensitive to the type of energy being generated, one of which is unplanned.

CONCLUSIONS

The near electric field radiated from mobile phones has been evaluated. It was observed that electric fields radiated from mobile phones were two times higher during speaking than listening. However, the results obtained during contact with the base station much higher than the 42V/m that is the limit specified by the ICNIRP. It must be noted that, a maximum SAR value of 10.8 W/kg gives rise to a temperature increase in the brain of about 0.931°C, which is suitable for the CENELEC limit of 2W/kg when averaged over 10g the increase in brain heat is about 0.2°C. In this study, spherical human head and dipole antenna were modeled to investigate the effects of the electromagnetic field of an antenna on human head because of the impossibility of the in vivo experiments on human. Local SAR values were calculated for two different human head models; single and three-layered spherical models. The application presented here seems to be reliable when comparing the results with the literature. The pattern of energy absorption inside an irradiated body is non-uniform, and biological responses are dependent on distribution of energy and the body part that is affected. The rate of absorption and the distribution of EMR energy in an organism depend on many factors: the dielectric composition (i.e., ability to conduct electricity) of the irradiated tissue, e.g., bones, with a lower water content, absorb less of the energy than muscles; the size of the object relative to the wavelength of the EMR (thus, the frequency); shape, geometry, and orientation of the object; and configuration of the radiation.

REFERENCES

- Anonymous, 2000. WHO, World Health Organizations Fact Sheet No.193. *Electromagnetic Fields and Public Health, Mobile Telephones and Their Base Stations*. <http://www.who.int/intfs/en/fact193.html/>
- Anonymous, 1998. ICNRP GUIDELINES. *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)*. ICNRP GUIDELINES, Vol.74, No.4, pp.494-522.
- Battocletti, J.H. 1976. *Electromagnetism, Man and the Environment*. Westwiew, London.
- Becker, R.O. and Marino A.A. 1982. *Electromagnetism and Life*. State University of New York Press.
- Bernardi, P., S. Pisa, E. Puizzi, 2000. "Specific Absorption Rate and Temperature Increases in the Head of a Cellular-Phone User," IEEE Transactions on Microwave Theory and Techniques, Vol. 48, no. 7, pp. 1118-1126.
- Çelik, C.G. 2001. *EM Effects of Mobile Phone on Human being*. MS. Thesis, Boğaziçi University, Istanbul, Turkey.
- Demirbilek, B. 2001. *Specific Absorption Rate Assessment in a Human Head Model Exposed to Radiation from Cellular Phone*. MS. Thesis, Boğaziçi University, Istanbul, Turkey.
- Nikita, K.S., G.S. Stamatakos, N.K. Uzunoğlu, and A. Karafotias. 2000. *Analysis of the Interaction Between a Layered Spherical Human Head Model and a Finite-Length Dipole*. IEEE Transactions on Microwave Theory and Techniques, Vol. 48, no.11, pp. 2003-2012.
- Stevens, N., and L. Martens. 2000. *Comparison of Averaging Procedure for SAR Distribution at 900 and 1800 MHz*. IEEE Transactions on Microwave Theory and Techniques, Vol. 48, no.11, pp. 2180-2184.
- Tell R.A. 1972. *Broadcast Radiation How Safe is Safe*. IEEE Spectrum.
- Gavan J., Joffe E.B. 1992. *An Investigation of the Desensitizing Effects by HF Broadcast Transmitters on HF Airborne Receivers*. IEEE Transaction on EMC Vol. 31, No: 2.