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BIOLOGICAL EFFECTS AND HEALTH RISKS OF MOBILE COMMUNICATION

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ABSTRACT

The effect of mobile communication can be understood as a biological effect (normal situation) and when this effect exceeds a certain limit so that the temperature of the body increases the health hazard takes place. Also the effect of extremely low frequency radiation (elfEM) and the effect of radio frequency (RF) is described .The non-thermal and thermal effects of RF radiation is explained, the guidelines and recommendations are presented. It was concluded that the rise of 1°C in the body temperature will cause a change in the body behavior. The minimum safety distance for different mobile models and the mobile station were both also calculated for safety purposes.

يمكن اعتبار تأثير الاتصالات النقالة حيويا بالأساس وعندما يزداد هذا التأثير عن حد معين يحدث التأثير الصحي بسبب زيادة حرارة الجسم الذي بدوره يغير سلوك أجهزة الجسم البشري المختلفة. وتم التطرق في هذا البحث إلى تأثيرات الترددات القليلة جدا وتأثيرات الترددات الراديوية إضافة إلى التوصيات المطلوبة لمنع حدوث أي ضرر صحي إضافة إلى الاستنتاجات المذكورة في متن البحث،وتم إيجاد اقل مسافة عن الرأس للأنواع المختلفة من الهواتف النقالة بحيث يكون التأثير اقل ما يمكن وكذلك تم حساب اقل مسافة ممكنة عن محطات الإرسال لأغراض الحماية من الأضرار الصحية المترتبة على تعرض الإنسان للإشعاع الكهرومغناطيسي المنبعث من الهواتف النقالة وكذلك محطات الإرسال.

Key words: RF radiation, Biological effect, safety exposure distance.

1. INTRODUCTION

Microwaves are specific category of radio waves that can be defined as radio frequency radiation where frequencies range upward from several hundreds of megahertz (MHz) to several gigahertz (GHz). One of the most familiar and widespread uses of microwave energy is found in household microwave ovens, which operate at a frequency of 2450 MHz (2.5 GHz).

Concern continues about exposure to radio frequency (RF) fields from the different sources such as mobile telecommunications, radars, radio and television broadcast, some medical and industrial apparatus. Much of this concern arises because new technologies are introduced. In the mean time mobile phone use has increased dramatically with falling costs. Industrial sources suggest that there will be over one billion users by 2007, far exceeding telephone use via fixed-lines. The question that can be asked is the fact that, if any adverse health effect is established from mobile phone use, it will be a global concern because developing countries are establishing this technology in preference to the more fixed systems. Thus, even a small impact on health could have major public health consequence.

The power output from the antennas of digital mobile phones is much lower than the earlier technology analogue models. However, RF emissions from the base stations that communicate between the mobile phones and the workers are of order of magnitude smaller than the hand sets. We will describe the effect of extremely elfEMF and the RF EMF.

1.1. ELF EM

The range of extremely low frequency fields (ELF) is (30-300) Hz. The sources are power distribution networks, public transportation systems, electrical appliances, motors, electrical beds, blankets ... etc. The reported effects are increased incidence of childhood leukemia, increased incidence of nervous system, brain, skin, eye and throat cancers, changes in ca++ movement through membrane, enhanced fracture repair, changes in circadian rhythm of melatonin, changes in behavioral response ... etc. The fields in power stations are (105) kvm^{-1} for electric field and 0.02-20 μ tesla (μT) for magnetic fields.

There is increasing public interest in possible health effects associated with exposure to extremely low frequency (elf) electromagnetic fields (EM). Concern has escalated, in part, as the result of media coverage of epidemiological studies which suggest a probable, but controversial, line between exposure to EM fields and increased incidence of some cancers in both children and adults. Public awareness has lead to the inclusion of exposure to elfEM fields as part of a growing series of environmental exposures related to "quality of life" in the industrial world.

Electromagnetic fields are produced when electric current flows through an electrical conductor such as power line. Most human exposures are elfEM fields (normally defined as less than 200-300 Hz) which are present in both residential and work place environments. Although EM fields are also associated with high-voltage power lines and power stations, they are also produced by any electric–powered device, and exposure occurs, for example, from the routine use of common household and work place appliances such as video display terminals, TV, hair dryer, and cellular phones. At ELF frequencies the magnetic field leads to induction of circulating currents in the body. The existing safety limits restrict the intensity of exposure that manifests itself through body temperature rise. On the other hand, the human body could compensate and handle the extra energy load through the efficient thermoregulatory mechanisms and maintain homeostasis through certain amount of stress still developed.

Besides the intensity components induced effects (thermal effects) which are known to occur in living and non living organisms, the uniqueness of the living organisms is their ability to respond to aspects of technologically produced radiation other than its intensity, like coherence, at intensities well below the limits of safety guidelines.

There is no specificity with respect to cancer type or site associated with EM field exposure ,but positive risk factors have been associated with leukemia ,lymphoma ,melanoma, lung cancer ,and other malignancies .The most persuasive evidence is from studies of male electrical workers who are more likely to have certain forms of cancer, including an unusual incidence of breast cancer, which occur about six times that of normal incidence in men.

There are hundreds of basic scientific studies that have tested the effects of elfEM fields on cells and whole animals. Some studies have observed no effect, but growing number of reports show that exposure to elfEM field can produce an amazing array of effects.

A few examples of diversity of response to EM fields include:

- Altered rate of cell growth, suppression of T-lymphocyte cytotoxicity.
- Increase in the growth related enzyme ornithine decarboxylase.
- Altered quantities of RNA transcripts and proteins.
- Effect on development and nerve generation.

It has been proposed that EM fields do not initiate cancer, but rather, may promote cancer that has been initiated by other causes: that is, the rule of EM fields would one involved in co-carcinogenesis or augmentation of preexisting transformation features. Changes normally associated with tumor initiation, such as chromosomal anomalies, DNA crosslinks, or changes in DNA repair, are not observed in cells exposed to EM fields. Other effects observed following EM field exposures support the hypothesis that co-carcinogenesis is induced. These include modification in growth rates of tumor cells and an increase in the level of the enzyme ornithine decarboxylase (ODC).

1.2. RF EM Radiation

At RF (radio frequencies) such as those used for heating could be due to the electric field of microwave. In the modern world, with the use of sophisticated microwave emitting devices for communication in the air surveillance system, industry, diagnostic and therapeutic purposes in medicine-the importance of electromagnetic pollution need not be over emphasized. Microwave communication equipments are in use in defense and commercial networking systems. The primary character of duties of any organization is to safeguard its personnel like radar workers and the personnel concerned with the manufacturing of high power equipment, working in the near field of microwave generating sources.

Starting from the radar worker in the defense setting to the housewife using the microwave oven –all are exposed to potential hazards.

The sources of microwave and RF radiation are:

- Air Traffic control systems.
- Police and military radar.
- Earth to satellite broad cast.
- Television systems.
- Long distance telephone equipment.
- Medical diathermy devices.
- Cancer diagnostic & therapeutic (Hyperthermia) equipment.
- Microwave ovens.
- Industrial applications and microwave generators.

There are many reports pouring on in the literature(1,2,3,4) indicating adverse health effects of cell phones which emit electromagnetic radiation with maximum value of 50% of their energy being deposited when held close to the head . Hence there is no need to explore the biological effects of electromagnetic radiation in different frequency ranges.

2. FIELDS FROM MOBILE PHONE SYSTEMS

2.1. Output From Mobile Phone

The RF power from a phone is mainly transmitted by the antenna together with circuit elements inside the handset. The antenna is usually a metal helix or a metal rod a few centimeters long extending from the top of the phone .Neither type is strongly directional,

although more power is radiated in some directions than others. It was found that at points 2.2 cm from an antenna (the distance at which calculations were made), the maximum values of the electric field are calculated to be about 400v/m for 2w, 900 MHz phone and about 200v/m for 1w, 1800MHz phone and the maximum magnetic field is calculated to be about 1μT for both phones. When the antenna is near to the body, the radiation penetrate it but the fields inside are significantly less, for the same antenna, than the values outside.

However the received power at any point from the mobile phone can be calculated from the equation:

$$P_d = P_t / (4\pi d^2) \quad (1)$$

Where

P_t The total radiated power from the mobile phone.

Pd The power density at any distance (d) from the mobile phone

Figure (1) shows the power density (mw/cm^2) and minimum safety exposure distance from the mobile phone for different groups of mobile models. The head of the user is in the near field of the radiation pattern of mobile antenna and for short antennas, the outer boundary exists at a distance (D) from the antenna surface where [9]

$$D = \lambda / 2\pi \quad (2)$$

And the mobile phones operate at frequencies from 900 MHz to 1800MHz which means that the values of D will be in the range (2.6-5.3 cm). The minimum safety exposure power density is 0.4mw/cm^2.

The minimum safety exposure distance for each mobile model is calculated (using Eqn (1)) and presented in Table (1).

2.2. Output from Base Stations

The base station antennas transmit appreciably greater power than phones. The limit to the power is formally set by the need to avoid RF interference and defined by a license issued by the Radio communications Agency. This does not directly limit the total power emitted but does so by fixing the maximum intensity that an antenna can transmit into the main beam. This is done by defining the maximum "equivalent isotropically radiated power "(EIRP) that can be transmitted. The EIRP is the power that would have to be emitted equally in all directions to produce a particular intensity. In fact, the antennas used are very far from Isotropic, with most of the power being emitted into the main beam, and the ratio of the EIRP to the total power output is called the gain of the antenna. For a 120 sector antenna the gain is usually between about 40 and 60.

The maximum size of the electric fields resulting from base stations to which the general public is exposed is around 5v/m, although the largest field measured to date is 2V/m .

However the minimum distance from the base station antenna (in terms of the base station transmitted power) can be calculated as follows:

Let there are N transmitter with M watt each, therefore the maximum power is

$$P_{max} = 10 \log (M*N) \text{ dB} \quad (3)$$

The total losses in combiners between transmitters, connectors and cables is about 9dB. Therefore the maximum input power to the antenna is:

$$Y = P_{max} - 9\text{dB} \quad (4)$$

If the antenna gain is Z dB, then the effective Isotropic power (EIRP) in the direction of the main lobe is:

$$\text{EIRP} = Y+Z \text{ dB or } \text{EIRP}=10(Y+Z)/10 \text{ watt} \quad (5)$$

Notice that in other directions (not in the main lobe directions) the EIRP is less 10 dB than the main lobe (i.e EIRP = EIRP_{main} - 10dB), the minimum safety distance from the base station (taking into account the minimum safety power density 0.4mw/cm^2) is:

$$D_{min} = (\text{EIRP(w)}/4\pi*4*10^{-3})^{1/2} \quad (6)$$

As a practical example, if there are four transmitters with 60 w each, then the maximum power is

$$P_{max} = 10 \log(4*60) = 23.8 \text{ dB}$$

And the maximum input power to the antenna is

$$Y = 23-9 = 14.8 \text{ dB}$$

If the antenna gain is about 16 in the main lobe direction, therefore

$$\text{EIRP} = 14.8+16 = 30.8 \text{ dB} = 1202.26 \text{ w}$$

Taking into account the minimum safety power density as 0.4mw/cm^2.Therefore

$$D_{min} = (1202.26/4\pi**4*10^{-3})^{1/2} = 4.89 \text{ m}$$

This means that the person must be at a distance not less than 4.89 m from the base station, otherwise the effect may occur.

This distance will increase with increasing the number of transmitters and power. Figure (2) shows the relation between the transmitted power (EIRP) and the required minimum safety distance from the base station.

3. MECHANISMS OF INTERACTION

RF fields induce torques on molecules that can result in displacement of ions from unperturbed positions, vibrations in bound charges (both electrons and ions), and rotation and reorientation of dipolar molecules such as water. These mechanisms, which can be described by classical electrodynamics theory, are not capable of producing observable effects from exposure to low level RF fields, because they are overwhelmed by random thermal agitation. Moreover, the response time of the system must be

fast enough to allow it to act within the time period of interaction. Both considerations imply that there should be a threshold (below which no observable response occurs) and a cut-off frequency (above which no response is observed).These thresholds would be expected to be present in more refined models if they correctly take into account thermal noise and kinetics of the system.

Exposure to EMF at frequencies above about 100 kHz can lead to energy and temperature increases. In general, exposure to uniform (plane wave) EMF results in a highly non-uniform deposition and distribution of energy within the body, which must be assessed by dosimetric measurement and calculations.

For absorption of energy by the human body, EMF can be divided into four ranges:

- About 100kHz to less than about 20MHz,where absorption in the trunk decreases rapidly with decreasing frequency ,and significant absorption may occur in the neck and legs.
- From about 20Mhz to 300MHz, at which relatively high absorption can occur in the whole body and even higher values if partial body (e.g head) resonances are considered.
- From about 300 MHz to several GHz, at which significant local, on-uniform absorption occurs.
- Above about 10 GHz, at which energy absorption occurs primarily at the body surface.

In tissue, the specific absorption rate (SAR) of RF energy absorbed per unit mass is proportional to the square of the internal electric field strength. The average SAR and SAR distribution can be computed or estimated from laboratory measurements. The localized SAR is calculated as follows:

$$SAR = БE2/\rho \qquad (7)$$

Where:

Б(S/m) is the electrical conductivity of the tissue

E(V/m) is the measured internal electric field strength

ρ (Kg/m3) is the mass density of the tissue

The recommended value of SAR is 0.4 w/kg. Values of SAR depend on the following factors:

1- The incident field parameters, i.e the frequency, intensity, polarization, and source-object configuration (near field or far field).

2- The characteristics of the exposed body, i.e its size, internal and external geometry, and the dielectric properties of the various tissues

3- Reflection, absorption and scattering effects associated with the ground or other objects in the field near the exposed body.

4. BIOLOGICAL EFFECTS OF EXPOSURE TO RF FIELDS.

Mobile telephony is based on radio communication between a portable handset and the nearest base station. Every base station serve as a "cell" varying in radius from hundreds of meters in densely populated areas to kilometers in rural areas, and is connected both to the conventional landline telephone network. As the mobile phone user moves from cell to cell, the call is transferred from one base station to the next without interruption. The radio communication depends on microwaves at 900 or 1800 MHz to carry voice information via small modulations of the wave's frequency. A base station antenna typically radiates 60w and a handset between 1 and 2w (peak).The antenna of a hand set radiates equally in all directions, but base-station produces a beam that is more directional.

4.1. Non Thermal Effects

Microwaves do have a range of non-thermal effects as shown below:

a- In Vitro studies

Reports from in vitro research indicate that low level RF fields may alter membrane structural and functional properties that trigger cellular responses .It has been hypothesized that the cell membrane may be susceptible to low-level RF fields, especially when these fields are amplitude modulated at low frequencies. At high frequencies, however, low-level RF fields do not induce appreciable membrane potentials. They can penetrate the cell membrane and possibly influence cytoplasm structure and function. These RF field induced alterations, if they occur, could be anticipated to cause a wide variety of physiological changes in living cells that are only poorly understood at the present time.

Lack of effects of RF exposure on mutation frequency has been reported in a number of test samples including yeast and mouse lymphoid cells. No effect of RF field exposure on chromosome aberration frequency in human cell has been confirmed.

b- In vivo studies[6,7]

Several studies indicate that RF fields may affect DNA directly. also it has the following effects ,Exposure to mobile phone radiation also decrease the preparatory slow potentials in certain regions of the brain and affect memory tasks, resting blood pressure was found to increase during exposure to radiofrequencies.

4.2. Thermal Effects

Exposure to RF fields can cause the following effects:

1- Nervous system

There is particular concern about the possible effects on the brain and behavior of repeated acute exposure to RF fields, largely because mobile phones are conventionally held close to the head. Recent [9] reports in the media, for instance, have implied that the use of mobile phones can cause memory loss, changes in attention, variation of blood pressure.

2- Effects on cell membranes

There is evidence that RF fields can affect membrane proteins and can change the movement of ions across membranes. Some of these effects seem to occur in cells only at temperatures well below normal body temperature or with RF intensities that cause significant heating. However, some evidence suggests that RF radiation at levels produced by mobile phones might influence ion channels and other membrane proteins of neurons in the brain under normal conditions. This might cause subtle changes in cell function, but the significance of such effects for human health is uncertain .Moreover, these effects have not been independently confirmed, which is important given the frequent lack of reproducibility of RF biological effects.

3- Calcium efflux

Although the weight of evidence suggests that RF exposure at average levels, too low to cause significant heating, does increase the release of calcium from brain tissue, there are contradictory results. The suggestion that these effects occur specifically with fields that are amplitude modulated at extremely low frequencies is intriguing but difficult to interpret. Further, this finding is of no obvious relevance to mobile phones technology, where the amplitude modulation within the critical frequency band is very small .If such effects occur as a result of exposure to mobile phones, their implications for cell function are unclear and no obvious health risk has been suggested .Nevertheless, as a precautionary measure, amplitude modulation around 16 Hz should be avoided, if possible, in future development in signal coding.

4- Neuronal excitability

Any tendency for calcium to move out of neurons and to accumulate on the surface of membranes would be expected to stablise them electrically and hence decrease the general excitability of neurons. It was concluded that there is good evidence that exposure to high intensity RF fields, sufficient to cause significant rise in tissue temperature, reduce the excitability of neurons. Exposure that does not cause an increase in temperature produces no obvious effects.

5- Neurotransmitter systems:

Changes in the amount of neurotransmitter substance released by nerve terminals could alter brain function. Since release is dependent on intracellular calcium levels, there has been concern that it could be affected by RF radiation.

6- Studies of melatonin

Melatonin is a hormone secreted by the pineal gland, which controls our diurnal rhythm (day-night cycle). Peak levels are produced in people during the night (in the dark period). Melatonin affects the mammalian reproductive system, as well as other physiological and biochemical functions. The function of the pineal gland is strongly influenced by visible radiation, because signals from the optic nerve affect the suprachiasmatic nucleus in the hypothalamus, which in turn regulates the secretion of melatonin from the pineal gland ,and there is an evidence that melatonin has a protective effect against cancer. Thus, changes in melatonin secretion could conceivably alter tumor initiation and promotion.

There were an effect on melatonin production in animals resulting from a direct interaction of fields within the brain; it would be much less likely to occur in people.

7- Effect on the eye

The lens of the eye is potentially sensitive to RF exposure because it lacks a blood supply and therefore has reduced ability to dissipate heat. Further, the fibers that make up the bulk of the lens have only a limited capacity for repair and hence the effects of minor insults tend to accumulate, resulting in clouding of the lens (cataract).

8- Influences on the cardiovascular system

Radiofrequency radiation might affect the heart and circulation through a number of routes. There could be direct effects on heart and the blood vessels. There might be influences on the cardiovascular centers in the medulla of the brainstem, which regulate the heart and circulation via the outflow in the sympathetic and parasympathetic systems .Exposure to RF fields might conceivably affect the receptors in the carotid body, which normally detect blood pressure and blood gases and which initiate reflex influences on the heart and blood vessels .Finally , the cardiovascular system is known to be affected by a variety of circulating substances ,especially catecholamine hormones , whose might possibly be changed by exposure to RF fields.

9- Ornithine decarboxylase

Protein kinases, such as decarboxylase (odc) ,are key enzymes that are normally activated as a result of the action of hormones, growth factors and lymphocytes on receptors in cell membranes. ODC is the rate-limiting enzyme in the synthesis of substances called polyamines, which can trigger DNA synthesis, cell growth and cell differentiation . Inhabitation of ODC activity retards the growth of both normal cells and

tumor cells. ODC activity is modulated by membrane-mediated signaling events, and its activation is associated with the activity of mitogens (substance that cause mutation) and tumour-promoting agents of various types ,such as the phorbol ester TPA, during carcinogenesis. Activation to ODC has been related to the late," promotional" phase of cancer production, which is usually (but not always) correlated with proliferation (an increase in the rate of cell division)in the affected tissue.

10- Genotoxicity

Many studies of potential genotoxicity have been carried out, involving the exposure of molecules, cells,isolated explants of tissue and whole animals to RF radiation in and around the frequency band used for mobile communications. The thermal effects of higher intensity stimulation complicate interpretation, since heating alone can be genotoxic and can enhance the action of known genotoxic agents.

However some individual experimental studies[8] have suggested that RF radiation can initiate tumour formation, enhance the effects of known carcinogens or promote the growth of transplanted tumours. However, in some of these the intensity was high enough to produce thermal effects. The balance of evidence, from both in vitro and in vivo experiments, indicates that neither acute

Nor chronic exposure to RF fields increases mutation or chromosomal aberration frequencies when temperatures are maintained within physiological limits. This suggests that RF exposure is unlikely to act as a tumour initiator. Furthe, a variety of cancer studies using animals have sought evidence of an effect to RF exposure on spontaneous or natural cancer rates, the enhancement of the effects of known carcinogens or effects on growth of implanted tumours. However, they have provided equivocal evidence for an effect on tumor incidence

5. GUIDELINES AND RECOMMENDATIONS

5.1. Sources of Exposure

For base station emissions, exposures of general population will be to the whole body but normally at level of intensity many times less than those from handsets. Base stations communicate with mobile phones with a defined area or "cell'. This can be of three types: macrocells, microcells and picocells depending upon their size and the power output of the antenna.

1- ***Macrocells*** provide the main structure for the base station network. The base stations for macrocells have power outputs of tens of watts and communicate with phones up to about 35 kilometers distance. There are concerns, nevertheless, about whether the emissions from all base stations are uniformly low, about whether the emissions could cause unknown health effects, and whether, with the increased use of mobile telecommunications, their output will have to rise.

2- ***Mirocells*** are used to infill and improve the main network, especially where the volume of calls is high .They are sited in places such as airports, railway stations and shopping malls. Their number is rapidly increasing in line with the growth in demand for mobile phones .The microcell base stations emit less power than those for macrocells and their range is a few hundred meters. We understand that exposures above guidelines do not occur, provided the case surrounding the antenna is kept in place.

3- ***Picocell*** base stations have a lower power output than those of microcells (a few watts) and are generally sited inside buildings .It is likely that the number of picocells within buildings will substantially increase. We are satisfied that their emissions should not exceed the guidelines.

5.2. Current Guidelines on Acceptable Levels of Exposure to Radiofrequency Radiation

In 1998 the international Commission on Non-Ionizing Radiation Protection (ICNIRP) published its own guidelines covering exposure to RF radiation .These were based on essentially the same evidence as that used by NRPB,and for workers the limits on exposure are similar(100mwlcm2) .However, under the ICNIRP guidelines ,the maximum levels of exposure of the public are about five times less than those recommended for workers . The reason for this approach was the possibility that some members of the general public might be particularly sensitive to RF radiation. However, no detailed scientific evidence to justify this additional safety factor was provided.

Both the NRPB and ICNIRP guidelines are based on the need to avoid known adverse health effects. At the time these guidelines were drawn up , the only established adverse effects were those caused by the heating of the tissues.

6. CONCLUSIONS

The biological effect and health risk of mobile communication was explained and it was concluded that the effect consists of non-thermal and thermal effects, the thermal effect is more effective. It was concluded that the effect depends upon two main factors power and time, therefore, the biological effect exist in all cases but when this effect exceeds certain threshold limit the health hazard takes place, because a health hazard is a biological effect outside the normal range of physiological compensation, and the increase in core temperature of 1oc or more, certainly, lead to changes in the performance of well-learned tasks and other simple behaviours. It is recommended to keep mobile phones far from or out

of reach of children because it affect their nervous system and to let them use mobile telephones for as short of periods as possible ,only for essential purposes, with low SAR values and with hands-free devices provided they have been proved to reduce SAR exposure. Motorists should be strongly discouraged from using mobile phones while driving to overcome the risk of traffic accidents while the driver is using a mobile phone. Also the safety exposure distance from mobile phones is measured for each mobile model because different mobile phones have different output power and it is recommended to use mobile phones model with less output power. The safety distance from mobile station is measured and for practical purposes (i.e 60w antenna) the safety distance from the mobile station is 4.501 m and this distance will be increased with increasing the output power of mobile station.

7. REFERENCES

[1] Schwan, H.P., "Interaction of microwave and radiofrequency radiation with biological systems", IEEE Trans. on Microwave Theory and Tech. Vol NTT-19, PP 146-150, 1971.

[2] Igr Belyaev, "Non-Thermalbiological effect of microwaves", Microwaves Review, Nov.2005, PP 13-29.

[3] Henry Lai, "Neurological Effects of Radiofrequency Electromagnetic Radiation Relating to Wireless Communication Technology", IBC-UK Conference, Sept16-17 ,1997 ,Brussels ,Belgium.

[4] "The Possible Harmful Biological Effects Of Low-Level Electromagnetic Fields Of Frequencies Up To 300 GHz", IET Position statement –May 2006.

[5] Lai, H.,Singh,N.P., "Single And Double–Strand DNA Breaks In Rat Brain Cells After Acute Exposure To Radio Frequency Electromagnetic Radiation", Int.J.Radiat. Bio.69, PP 513.1995.

[6] M.H.Repacholi."Health Risks From The Use Of Mobile Phones", Toxicology letters, Vol.120, PP 323-331. 2001

[7] Lin,J.C, "Update of IEEE Radio Frequency Exposure Guidelines", Microwave Magazine, Vol.7, Issue 2 , PP 24-28 ,April 2006.

[8] Who, Who's agenda for EMF research, Report WHO/EHG/98.13. World Health Organization, Geneva Health; Mobile Phones and Their Base Stations, World Health Organization, Geneva, 1998.

[9] Kraus, J.D, "Antennas", McGraw Hill, New York, 1988 .

[10] Internet Websites.

Table 1. Different mobile models & their safety exposure distance

Mobile Model	Output Power(w)	Safety Exposure Distance(cm)
Bosch GSM-908	1.59	17.7
Philips Genie 900	1.52	17.39
Ericsson LX-588	1.51	17.33
Ericsson T28 World GSM	1.49	17.22
Nokia 3110	1.24	15.71
NEC DB4000	1.23	15.646
Nokia 6210	1.19	15.39
Siemens C-35	1.19	15.39
Nokia 3210	1.14	15.06
Ericsson SH888	0.91	13.45
Ericsson A1018s	0.88	13.23
Nokia 6110	0.87	13.15
Motorola d 160	0.81	12.69
Nokia 8110i	0.73	12.054
Ericsson GA-768 GSM	0.725	12.01
Nokia 8219	0.72	11.97
Siemens C- 25	0.72	11.97
Motorola CD930	0.70	11.803
Nokia 6150	0.69	11.71
Siemens M35	1.14	15.06
Bosch GSM-909	1.13	14.997
Philips Savy	1.11	14.864
Philips Diga	1.06	14.525
Philips Genie	1.05	14.456
Motorola Timeport I7089	1.00	14.10
Motorola Timeport P7389	1.00	14.10
Motorola Timeport 9250 GSM 1900	1.00	14.10
Siemens S35	0.99	14.037
Sony CMD-C1	0.41	9.033
Sony CMDX-1000	0.41	9.033
Mitsubishi Trium Galaxy G-130	0.35	8.346
Ericsson GH628	0.26	7.19
Nokia 8810	0.22	6.617
Nokia 8850	0.22	6.617
Motorola 130 Startac	0.10	4.461
Motorola StarTac70	0.02	3.98
Motorola v3688	0.02	3.98

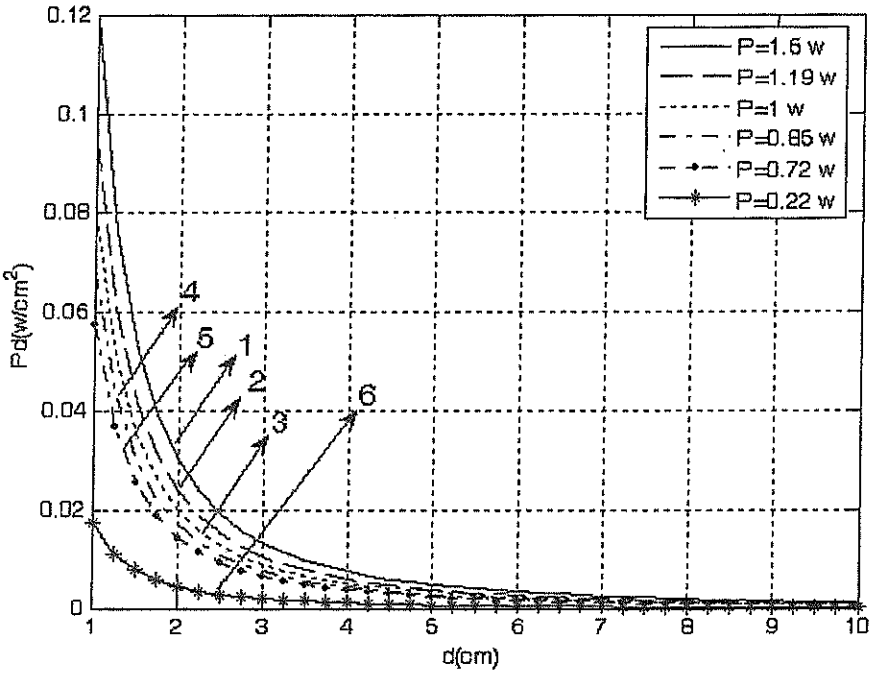
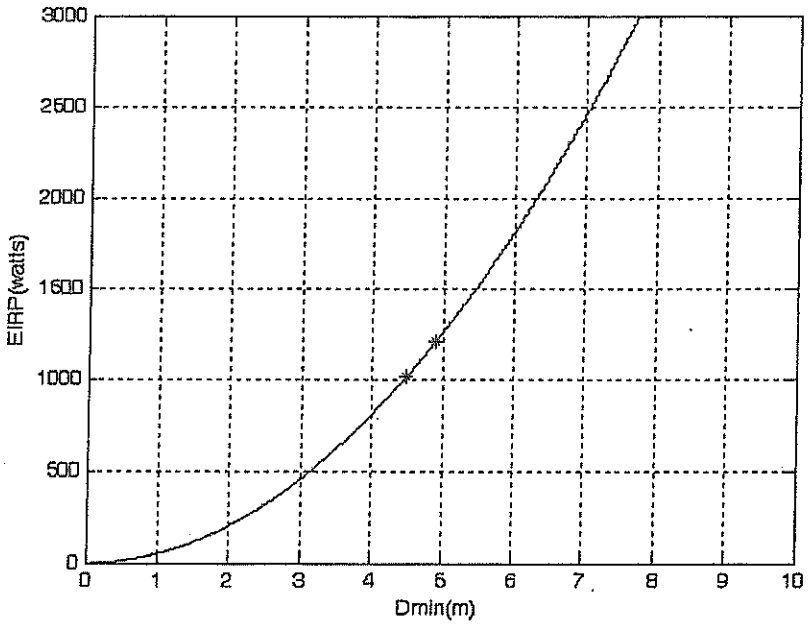


Figure (1) The power density and distance from the mobile phone for different mobile models.

Curve 1: Pt=1.5w For models (Bosch GSM-908,Philips Genic 900, Ericsson Lx588).
Curve 2: Pt=1.19w For models (Nokia6120,Siemens C-35, Nokia3120).
Curve 3: Pt=1w For models (Siemens S35,Motorolla timeport, Philliphs Diga).
Curve 4: Pt=0.85w For models (EricssonSH888,Nokia6110,Motorolla di60).
Curve 5: Pt=0.72w For models (Nokia 8219,Simens C-25, Motorolla CD930).
Curve 6: Pt=0.22w For models(Nokia 8810, Ericsson GH628, Nokia 8850)



Figure(2) The effective Isotropic Radiated power (EIRP) and minimum safety exposure distance from mobile station