

CALCULATION OF THE SAFE TIME OF GSM MOBILE PHONES USAGE

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مستخلص

أصبحت تكنولوجيا الراديو الخلوي النقال جزءا مهما في حياتنا اليومية لكونها توفر خدمات الاتصالات الملائمة خلال حركة المستخدم. تلك المميزات نتج عنها زيادة أعداد المستخدمين لتلك التكنولوجيا بنسبة اكبر من الاعتيادية. أدى الانتشار الواسع لاستخدام الهواتف الخلوية النقالة قلعا شعبيا عاما من التأثيرات البيئية والطبية المحتملة الناتجة عن الإشعاعات الصادرة عن محطات القاعدة وعن الهواتف النقالة لان قسما من طاقة تلك الإشعاعات يتم امتصاصه من قبل جسم الإنسان الذي يعمل كهوائي استلام كفاء. يناقش هذا البحث الآثار الطبية المحتملة للانبعثات الصادرة من الهواتف النقالة، ويقدم طريقتين مقترحتين لحساب الزمن الآمن لاستخدام الهواتف النقالة التي تعمل بنظام الـ (GSM).

Abstract

A cellular mobile radio technology has become an important part of our everyday life as it provides a convenient communication services during user's mobility. These facilities result in increasing the user numbers of this technology at an extra ordinary rates. Widespread usage of cellular mobile communication systems has generated public concern about the possible environmental, and health effects of human exposure to electromagnetic energy emitted by base stations and cellular phones as an amount of this energy is absorbed by the human body which works as an efficient receiving antenna.

This paper discusses the probable health effects of cellular mobile system emissions, and presents two proposed methods to calculate the time of the safe usage of the mobile phones that operate under the Global System for Mobile Communications (GSM).

Key Words: cellular mobile communication systems, GSM phones, SAR, Mobile effects on human health.

I. Introduction

The cellular mobile communication system is a wireless system designed by dividing a large area into several small cells, with a single, low-power transmitter in each cell

that is served by one base station whose antennas send and receive radio signals to and from the cellular phones. In cellular mobile communication networks the frequency of a cell is reused to another cell after skipping several cells[1].

A cellular mobile radio technology has become an important part of our everyday life, as it provides a convenient communication services with the other communication networks including the wire telephone network. It provides mobility to the users, that enables users to make communications anytime, anywhere, with anyone.

The Global System for Mobile Communication (GSM) is the most widely used mobile standard in many countries. GSM operates in two main frequency bands: one between 880MHz and 960MHz, the other between 1710MHz and 1880MHz[2].

II. Cellular Mobile Phones Effectc

Radio waves used in cellular mobile communications, belong to the part of the electromagnetic spectrum, which is called **non-ionizing** radiation, as their energy is too low to damage the human tissues.

In cellular mobile communication systems, there are two different sources of radiofrequency (RF) radiation that may affect the environment and the public health; cellular phones (mobile units), and fixed transmitters(base stations).

Growing demand for cellular mobile communication services in an extra ordinary rate results in large number of base stations over a limited area, accompanied by public concern for possible health effect as these base stations occupy the public environment where people live and work. At the same time, there is significantly less concern over the mobile phones themselves, although RF exposures from the phones are greater as the common position of use (the head of the user), receives the highest exposure[3][4].

Biological Effects

When a person is exposed to the radio waves from mobile phones or base stations, most of

the energy will be reflected by the body, while some of the energy will be absorbed in the tissues at the surface of the body. The absorption of power from electromagnetic fields causes temperature rise in tissues as the RF fields penetrate exposed tissues, and may cause tissue damage[5][6]. This effect is called thermal effect. The antennas of the cellular phone systems are designed to radiate energy horizontally so that only small amounts of RF are directed down to the ground. The power density (S) produced by any RF source is given as

$$S = \frac{P_t G_t}{4 \pi r^2}$$

where P_t is the transmitted power, G_t is the antenna gain, and r is the distance between the RF source and the exposure point.

The magnitude of the electric field strength (E), and magnetic field strength (H) are related to the power density(S) as follows[7]:

$$S = \frac{E^2}{377} = 377 H^2$$

The amount of radiofrequency power absorbed in the body is measured in watts per kilogram, known as Specific Absorption Rate (SAR). SAR has a peak value near the body surface and closest to the radiating antenna. SAR is the parameter that is used to evaluate the possible risk for human health due to mobile phone usage. It can be given as[8]

$$SAR = \frac{d}{dt} \left(\frac{dW}{dm} \right) = \frac{\sigma E^2}{2 \rho}$$

where W is the absorbed energy in joule, t is the time in second, m is the tissue mass in kilograms, E is the induced electric field strength (V/m) in tissue, σ is the material conductivity (S/m), and ρ is the tissue density (kg/m^3).

The other effect of GSM mobile phones is called a non-thermal effect. The cellular phones perform transmission of the information by pulses combined in block, and each block consists of eight pulses. Hence, signals which are able to interact with human brain bioelectric activity and may distort its functions.

Environment Effects

Cell phones are made from materials whose manufacture is harmful to the environment as well as workers who produce them. In the Western world, the price of cell phones is masked and are therefore treated as nearly disposable. As a result, most cell phones get land-filled where their toxins can affect the environment.

Mobile phones can cause electromagnetic interference in other electrical equipment. Therefore, caution should be exercised when using mobile telephones around sensitive electro-medical equipment such as pacemakers and hearing aids.

Currently, there are more than two billion mobile-phone users in the world, and this lead to an increased level of disruption in public areas due to the diverse ringing tones, and people carrying on mobile phone conversations at an elevated volume. Furthermore, research has demonstrated an increase in the risk of traffic accidents when mobile phones are used while driving.

III. Interational Protection Guidelines

Many authorities provide protection for the public from any electromagnetic field (EMF) sources, and set the permitted maximum exposure (PME) levels that protect all individuals from RF fields. These safety guidelines are usually given in terms of the maximum possible exposure of electric and magnetic fields, or of RF power density. In the near-field region of cellular phones, the safety guidelines, are based on the specific absorption rate (SAR) instead of the incident RF fields.

There are many proposed international standards, but the most respected standard levels of (RF) radiation are those recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) which has been adopted by more than 80 countries, those developed by American National Standards Institute and the Institute of Electrical and Electronics Engineers (ANSI/IEEE), and the guide lines issued by the federal communication commission (FCC).

All the safety guidelines are based on large amounts of scientific data and experiments[5][9]. All exposure limits are frequency dependent and time averaged. The limit values implicit that those values are the average of a specific time period. Therefore, the actual exposure level(s) multiplied by the actual time(s) of exposure must not be greater than the allowed (average) exposure limit times the specified averaging time. This concept can be applied with power density or SAR limits. This condition can be expressed as[10]:

$$\sum (\text{Actual Expouser level} \times \text{Expouser Period}) \leq (\text{Exposure Limit} \times \text{Average time})$$

For frequencies above 100 kHz, the general recommendation is 30 minutes averaging for whole-body exposure[4].

1- ICNIRP Safety Limits

The (ICNIRP) has established international guidelines on human exposure limits for all electromagnetic fields. ICNIRP suggests the following equations to determine the plane wave power density and field intensities.

$$\text{Power Density in (mW / cm}^2\text{)} = S = 0.00051 f$$

$$\text{Effective Electric Field Strength in (V / m)} = E = 1.375 \sqrt{f}$$

$$\text{Effective Magnetic Field Strength in (A / m)} = H = 0.0037 \sqrt{f}$$

$$\text{SAR Limit} = 2.0 \text{ W/kg in 10 g of tissue}$$

where f in equations 4,5, and 6 is the frequency expressed in MHz.

2- ANSI / IEEE Safety Limits

The ANSI/IEEE exposure standard for the general public is 1.2 mW/Cm² for antennas operating in the 1800-2000 MHz range, and 0.57 mW/Cm² for antennas operating in the 900 MHz range [3].

The ANSI/IEEE standard C95.1-1992 RF Safety Guideline suggests that the 1-g averaged peak SAR should not exceed 1.6 W/kg and the whole body averaged peak SAR should be less than 0.08 W/kg. These guidelines are applicable to uncontrolled situations (the public) and must be satisfied for personal handsets[4][7].

These equations can be applied to calculate the exposure limits for the public in the frequency range between (400-2000 MHz)[5][11].

(4)

3- FCC Safety Limits

FCC is the authority who is responsible for the most RF telecommunications services in the United States. The development of the FCC limits that are used in the United States was heavily influenced by the standards has been developed by the Institute of Electrical and Electronics Engineers (IEEE).

The FCC exposure limits for uncontrolled environments that can be applied in situations where persons may not be aware of their exposure. Table 1, shows the FCC maximum permissible exposure (MPE) limits in mW/cm² versus frequency in MHz for uncontrolled environments. The current FCC exposure guidelines were adopted in 1996. The guidelines are based on specific absorption rate (SAR) and use a time-averaged whole-body exposure SAR of 4W/kg as this value of SAR can result in a maximum tolerable temperature rise is 1° C in human tissue within 30 minutes [8][9][12].

Table 1. FCC Limits for General Population(Uncontrolled Exposure) [6]

Frequency (MHz)	Electric Field E (V/m)	Magnetic Field H (V/m)	Power Density (mW/cm ²)	Time (min)	SAR (W/kg)
0.3-1.34	614	1.63	100	30	< 0.08 whole -body -- ≤ 1.6 partial – body
1.34-30	824/f	2.19/f	$180 / f^2$	30	
30-300	27.5	0.073	0.2	30	
300-1500	--	--	f/1500	30	
1500-100000	--	--	1.0	30	

IV. Power Densty In Human Head Calculation

Mobile phone users are exposed to RF radiation in the microwave range, and this can result in increasing body temperature, and may damage the head and brain tissues of the user. The cellular telephone is usually held against the side of the head when the telephone is in use. Therefore, the cellular phone antenna (RF source) is just a few centimeters away from the brain, that is equivalent to the penetration depth in human head tissue. The penetration depth in user's head is given as the depth where the incident power density has been reduced by a factor of e^{-2} , i.e. down to about 13.53% of the incident power density.

In the GSM system up to eight users share the same frequency channel and each phone transmits only one eighth of the time. This means that the average power is one eighth of the peak power. The peak power

$$(S_{900})_{in} = 4.973 \times 13.53\% = 0.672 \text{ mW/cm}^2$$

$$(S_{1800})_{in} = 2.486 \times 13.53\% = 0.336 \text{ mW/cm}^2$$

V. Safe Usage Time Calculation

Two proposed methods will be presented to calculate the approximated time of the safe usage of a mobile phone. Both of these methods depend on the guide lines explained

transmitted by GSM-900 and GSM-1800 cellular phones are 2W, and 1W respectively.

Assuming, that antenna has a unidirectional radiation towards the user's head ($G_t = 1$), and the separation distance between the phone and the head surface of the user 2.0 cm, the power density near the head (outside), produced during the GSM phone usage can be calculated as:

$$(S_{900})_{out} = \frac{(2/8) \times 1000 \times 1}{4\pi \times (2)^2} = 4.973 \text{ mW/cm}^2$$

$$(S_{1800})_{out} = \frac{(1/8) \times 1000 \times 1}{4\pi \times (2)^2} = 2.486 \text{ mW/cm}^2$$

The power density inside the head up to the penetration depth will be 13.53% of the incident power density, therefore,

above. The first method depends on the maximum permissible power density, and the other depends on the admissible SAR values.

1- Using The Admissible Levels of Power Density

The GSM-900 system uses the frequency band (890-915) MHz for up-link and the band (935-969)MHz for down-link. While, The GSM-1800 system uses the frequency band (1710-1785)MHz for up-link and the band (1805-1880)MHz for down-link. The medium up-link frequency (when the phone in transmit mode), can be calculated as:

$$(f_{med})_{900} = \frac{890 + 915}{2} = 902.5 \text{ MHz},$$

$$(f_{med})_{1800} = \frac{1710 + 1785}{2} = 1747.5 \text{ MHz}$$

The admissible power densities for GSM systems, expressed in mW/cm^2 for 30

minutes according to limits explained above are calculated, and the results are shown in Table 2.

As all the given admissible power density limits are time-averaged for 30 minutes for the public, we can write the following equation

$$\text{Admissible Power Density} \times (30 \text{ min}) =$$

$$\text{Calculated Power Density} \times (t \text{ min})$$

$$(t)_{\min} = \frac{\text{Admissible Power Density} \times (30 \text{ min})}{\text{Calculated Power Density}}$$

Using equation 8, the safe usage time for GSM-900 phones can be calculated according to the power density safe limits calculated in Table 2,

Table 2. The Calculated Admissible Power Density For GSM

	GSM-900		GSM-1800	
Safety Guide Lines	Medium Up-Link Frequency = 902.5 MHz		Medium Up-Link Frequency = 1747.5 MHz	
	Admissible Power Density mW/cm ²		Admissible Power Density mW/cm ²	
ICNIRP	0.00051 f	0.46	0.00051 f	0.891
ANSI/IEEE	-	0.57	-	1.2
FCC	f/1500	0.601	-	1.165

$$t = \frac{0.46 \times (30 \text{ min})}{0.672} = 20.535 \text{ min} \quad \text{according to ICNIRP limits}$$

$$t = \frac{0.57 \times (30 \text{ min})}{0.672} = 25.446 \text{ min} \quad \text{according to ANSI/IEEE limits}$$

$$t = \frac{0.601 \times (30 \text{ min})}{0.672} = 26.83 \text{ min} \quad \text{according to FCC limits}$$

The same method can be followed to determine the safe usage time for GSM-1800 phones. It was calculated to be 79.55 min, 107.14min, and 104.01 min, according to ICNIRP, ANSI/IEEE, and FCC standards respectively.

2- Using The Admissible Levels of Specific Absorption Rate (SAR)

In order to determine the thresholds for harmful effects and develop exposure limits to protect against health effects, it is necessary to know the magnitude of the SAR within the exposed object. A worst- The specific energy absorption J is equal to the (SAR) multiplied by the exposure time(t)

case expression to relate specific energy absorption and temperature providing that the effect of cooling is neglected is given by the National Radiological Protection Board (NRPB) report as [4][13]:

$$\Delta T = \frac{J}{4186 \times c}$$

where ΔT is the temperature rise ($^{\circ}\text{C}$), J is the specific energy absorption (J/kg), c is the relative heat capacity (0.85 for human body).

in seconds, hence equation 9, can be written as

$$\Delta T = \frac{SAR \times t}{4186 \times c}$$

Based on RF exposure experiments with volunteers, a maximum tolerable temperature rise is 1° C in human tissue. This effect is harmful for any organ and it can occur if SAR value is 4 W/kg during 30 min[9][11].

Equation 10, can be used to calculate the safe usage time by considering the maximum admissible limits of SAR values (1.6-2.0 w/kg):

$$t = \frac{4186 \times c \times (1.0^{\circ}C)}{\text{Admissible SAR}}$$

$$t = \frac{4186 \times 0.85 \times 1}{2.0} = 1779.05 \text{ s} = 29.657 \text{ min}$$

with ICNIRP limits.

$$t = \frac{4186 \times 0.85 \times 1}{1.6} = 2223.81 \text{ s} = 37.06 \text{ min}$$

with ANSI/IEEE& FCC limits

3- Using Cell Phone Rated SAR

The rated SAR for any phone (as an RF source) should be given in its catalogue. The SAR parameter should be kept as small as possible to verify that the RF exposure of the user is within safe limits. This rated value can be also used to calculate the safe usage time with the help of the following equation:

$$t = \frac{\text{Admissible SAR Limit} \times \text{Specified Averaging Time}}{\text{Mobile Phone Rated SAR}} \quad (11)$$

For example, the iPhone has SAR levels ranging from 0.79W/kg to 1.38W/kg, depending on the model (the iPhone 4 is the

highest)^[14]. Therefore, the safe usage time was calculated to be 43.47 minutes with ICNIRP limits, and 60.76 minutes with FCC limits.

VI. Conclusions

The most known biological effects of RF energy to human health are due to heating caused by cellular phone radiations that is delivered by the antennas close to the user's head.

There are many international limits have been set to protect public from the probable health effects associated due to the mobile phone radiations. These limits are all time averaged.

Depending on these limits, two main methods for cellular phone safety time usage are presented in this study. The first depend on the limits of power density and the other depends on the limits of the specific absorption rate (SAR). The study shows that the user can operate a mobile phone in the open air safely for a time of 21-37 minutes for GSM-900 phones and for a time of 37-107 minutes for GSM-1800 phones. However these values depend on the limits used, the cellular system, the head-phone separation distance, and the rated SAR values of the cell phone used.

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