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Effects and Analysis of Electromagnetic Radiation from Mobile Phone on Human Body

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Abstract:
Mobile telephony became an essential instrument in our everyday life, and with dimensions of more than 60 million mobile phones, one counts some 50000 basic antennas or stations, where the surrounding inhabitants worry about the consequences that they could have on health. In this article, the dielectric human tissue properties and their evolution will be approached according to the variations of the frequency, as well as the resolution of the equations of Maxwell's in order to determine the expressions of the electromagnetic fields in the human body, thus broadcasting capacity of energy (RF) in the layers of the human head most exposed to these radiations, this by the observation of the variation of the power absorptive by tissue of the human head and also classify the electromagnetic radiation

Key words: dielectric parameters of tissue; specific flow of absorption SAR; incidental power on the head; power absorptive by the head.

I.INTRODUCTION

Communication networks have so much developed that they have become an essential tool of communication; however this communication puts more and more in sets of problems Since its creation, networks of mobile telephony and of effects on health. Field RF is the association of an electric field and a magnetic field which varies in time and is propagated in space. These fields are likely to move electric charges, and are characterized by several physical properties whose principal ones are: the frequency, the wavelength, intensity and power. Therefore any living matter contains electric charges (ions, molecules...) and insulating materials; it is thus a medium slightly conducting (called dielectric). According to the position of the mobile telephony compared to the human head figure (1 and 2), the tissue (layers of the head) is subjected to a field RF, part of the field is reflected, and the other penetrates in the organism. The radiation produced by this interaction must be quantified, because it can be at the origin of biological effects. The field which penetrates inside the tissue can be calculated using electromagnetic models, and the energy absorptive by transformation into heat proportions is quantified by the power absorptive per unit of exposed biomaterial mass. It is defined by specific absorption rate (SAR).

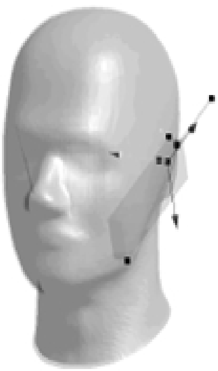

Figure 1 Position of the mobile on the human head (Reference 6)

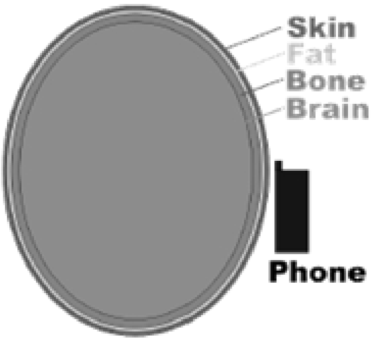

Figure 2 Simple models of the human head (Reference 6)

II.LITERATURE REVIEWS

From basic knowledge of cell phone electromagnetic fields, there are two variables: frequency and amplitude that will be considered. The frequency range is generally considered as 450 - 2,700 MHz, which is the range of non-ionizing radiation. Theoretically, non-ionizing radiation of electromagnetic field cannot damage deoxyribonucleic acid (DNA). On the other hand, ionizing radiation which has a higher frequency and shorter wavelength than non-ionizing radiation can be a health hazard. The usual frequencies: 800, 900, 1,800 and 2,100 MHz are for example used in cellular phone system. Although cell phone electromagnetic radiation is non-ionizing radiation, exposure limits to electromagnetic radiation is necessary to limit thermal effects. Electric field intensity (V/m) and magnetic field intensity (A/m) are both present electromagnetic power density (W/m2).

SAR Exposure limits (SAR in the frequency range of 100 kHz-10 GHz for general public group) to electromagnetic radiation from radio communication equipment, of which the radiation component is, in normal use, positioned close to the user's head, or less than 20 centimeters from the body of the user.

Table 1 SAR Limits

Average specific absorption rate, SAR	Specific absorption rate, SAR (W/kg)
Average SAR for whole body	0.08
Average SAR for the head and trunk	2
Average SAR for the limbs	4

Furthermore, the usual range of cell phone electromagnetic power is normally limited in a range of 0.1 - 2 W. From cell phone electromagnetic radiation, related diseases may be concerned as follows.

A. Effects on sight and hearing

A continuous use of long period of a cell phone may be caused to be worried about subjective hearing and vision symptoms. Health problems such as tired eyes, dry eyes, headaches, and blurred distant vision are investigated. Impaired hearing, ear ache, and warmth on the ear are also investigated. Risk of these symptoms with using a cell phone may be concerned; however, this depends on the behavior of users. In fact, the cell phone is very popular use, and many people do not only use the cell phone but also consume the cell phone. Someone can for example chat almost all day long.

B. Effects on hormones

In animal experiment, there is no evidence relative to an adverse effect of cell phone exposure on measures of testicular function or structure. The rats were confined in Plexiglas cages specially designed for this study. Also, influence of electromagnetic fields emitted by cellular telephones whether to affect human health is investigated in human experiment. From this research, data show that the 900 MHz electromagnetic field exposure does not appear to affect endocrine functions in men. However, evidences from designed animal and in-vitro studies may be different from in-vivo human exposure. In-vivo human research was conducted. Data show that no significant conclusions regarding cellular phone electromagnetic radiation effects on the human body.

C. Brain tumors

There is ongoing discussion whether cell phone has any effects on brain. Results show that use of a cell phone may cause high power beta waves, leading to anxiety, stress and other physical and mental discomforts. Furtherstudy, results suggest that cell phones may reversibly influence the human brain, as their use induced abnormal slow waves in electroencephalogram (EEG) of awake persons. Similar observation shows the slow-waves with higher amplitude appeared earlier in children than adults, and their frequency is lower with longer duration and shorter intervals. On the other hand, some results show that no increased risk is observed for having been a regular cell phone user.

However, this analysis restricted to regular users that may yield higher levels of exposure (e.g., heavy use in rural areas) shows consistently elevated risks. Case-control studies on adults point to an increased risk of brain tumors (glioma and acoustic neuroma) associated with the long-term use of mobile phones. The specific absorption rate (SAR) value of cell phones is obtained to be absorbed into human head. Nevertheless, cell phones are designed with low power and operate at high frequency, resulted in lower SAR value comparing to 2W/kg that stated by International Commission on Non-Ionization Radiation Protection (ICNIRP) . When the limit (SAR)exceeds, it may produces adverse human health effects that contribute to reverse cell membrane polarity, alter brain waves and damage DNA. This can lead to cancer and memory loss.

D. Leukemia

Leukemia mortality among children and adults, living near high-power radio transmitters, was evaluated. The risk of childhood leukemia was higher than expected. However, the study has limitations because of the small number of cases and the lack of exposure data. As the potentially greater susceptibility of developing nervous systems, childhood is concerned to radio frequency fields. In addition, child's brain tissue is more conductive to radio frequency penetration relative to head size. There is conducted a large record-based case-control study testing associations between childhood cancer and natural background radiation. Associations for other childhood cancers were not significant for exposure. A case-control study of radio frequency electromagnetic fields and childhood leukemia was conducted. The data did not show any increased risks of leukemia relative to amplitude-modulated and frequency-modulated transmitters.

E. Effects on a fetus-topic

26th-gestational week pregnant woman models, which fetuses were positioned in the left occiput anterior and right sacra anterior of the model's pelvis, were employed. The data show that the SAR can be changed with changing positions of fetus. Furthermore, the SAR can be changed with changing the inherent tissues relative to the standard reference values at 12- and 20-weeks' gestation. The studies by building body models show that specific tissues such as peripheral brain tissues can have higher electromagnetic field exposure with children than with adults. Preliminary results show that the pre-birth exposure is lower than the post-birth exposure. Hyperactivity in children has been postulated in mice experiment, but there is no convincing evidence in human that maternal cell phone use has an adverse effect on the neurocognitive development of young children. An in-vitro study on the effects of low level radio frequency (RF) fields from mobile radio base stations in order to test the hypothesis that modulated RF fields may act as a DNA damaging agent. Under the RF field exposure conditions, no significant differences in the DNA strand breaks were observed.

Table II. Exposure limits (for general public group) to electromagnetic radiation from wireless communication transmission equipment, of which the radiation component is, in normal use, positioned at least 20 centimeters from the human body, and that in fixed location and with broad area of electromagnetic radiation.

Table 2 SAR Limit for general public group

Frequency range	E-field intensity (V/m)	H-field intensity (A/m)	Equivalent plane wave power density (W/m^2)
9 kHz – 150 kHz	87	5	-
150 kHz – 1 MHz	87	$0.73/f$	-
1 MHz – 10 MHz	$87/f^{1/2}$	$0.73/f$	-
10 MHz – 400 MHz	28	0.073	2
400 MHz – 2 GHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$f/200$
2 GHz – 300 GHz	61	0.16	10

III. PROPRIETES DIELECTRIC OF TISSUE

The electromagnetic wave penetrated in the tissue depends on the following electric properties [4]: the electric permittivity ε, the magnetic permeability μ and the electric conductivity σ of various tissues, as well as the thickness of tissue, incidental power and the frequency of operation. The electric properties of tissue vary with their water content; the water content in fatty tissue is much larger than in non-fatty tissue, the human biomass can be regarded as dielectric:

$$\varepsilon = \varepsilon_0(\varepsilon' - j\varepsilon'') = \varepsilon_0(\varepsilon' - j(\sigma / \omega\varepsilon_0)) \quad (1)$$

ε_0 : Electric permittivity in the space, ε' and σ are

Dependent on the frequency, and this frequency has two significant values [0.9 GHz and 1.8 GHz] at a temperature of 37°, as illustrated in the equations (1), (2) & (3) [5] :

$$\varepsilon' = 1.71 f^{-1.13} + (\varepsilon_S^m - 4) / [1 + (f/25)^2] + 4 \quad (2)$$

$$\sigma = 1.35 f^{0.13} \sigma_{0.1} + [0.00222(\varepsilon_S^m - 4) f^2] / [1 + (f/25)^2] \quad (3)$$

f is the frequency in GHz, and $\sigma_{0.1}$ = 0.05 is the conductivity in 0.1 GHz, ε_S^m = 8.5 is the extrapolated permittivity of the electromagnetic wave [6].

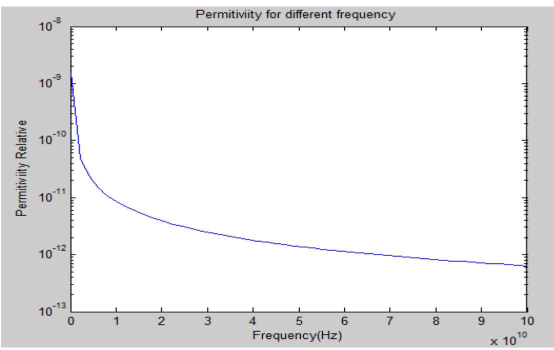

Figure 3. Relative permittivity in function to the frequency

Figures (3) and (4) are identical by contribution to practical measurements, and small variation between f = 1 GHz and f = 10 GHz is due to the water content in the biomass are shown in the above graph.

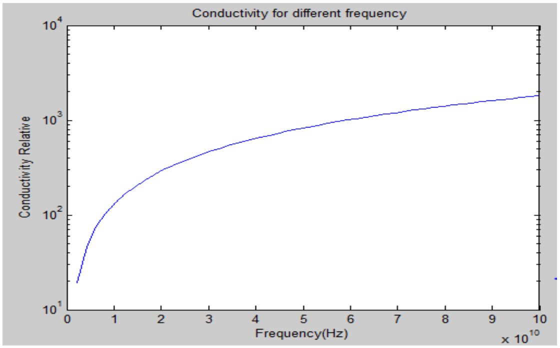

Figure 4 Conductivity in funfunction to the frequency.

IV. EXPRESSIONS OF THE FIELDS E/MIN THE HUMAN BODY

The expressions of the electromagnetic field in the human body can be obtained by the resolution of the equation of Maxwell's, on the assumption of a wave with uniform incidents and being propagated along direction Z.

$$E_Y = E_O \exp(-\alpha z) \exp(j(\omega t - \beta z)) \quad (4)$$

$$H_Z = -(K_Z / \omega\mu_0) E_Y \quad (5)$$

With: $K_Z = \frac{\omega}{c}\sqrt{\varepsilon_r - j\frac{\sigma}{\omega\varepsilon_0}} = \beta + j\alpha \quad (6)$

K_Z is the complex constant of propagation, α represent the coefficient attenuation and β is the constant of phase.

A. *Coefficients of the attenuations*

The solution (E_Y / H_Z) of the equations of Maxwell's led to calculate the constant of attenuation (α), the constant of phase (β), intrinsic impedance of the wave (η) and the propagation speed V, represented in the relations (7), (8), (9) & (10).

$$\alpha = \frac{\sigma}{2}\sqrt{\frac{\mu_0}{\varepsilon_0\varepsilon}} \quad (7)$$

$$\beta = \omega\sqrt{\mu_0\varepsilon_0\varepsilon}\left(1 + 0.125\left(\frac{\varepsilon''}{\varepsilon'}\right)^2\right) \quad (8)$$

$$\eta = \sqrt{\frac{\mu_0}{\varepsilon_0\varepsilon}}\left(1 + j\frac{\sigma}{2\omega\varepsilon_0\varepsilon'}\right) \quad (9)$$

$$V = \frac{1}{\sqrt{\mu_0\varepsilon_0\varepsilon'}}\left(1 - \frac{1}{8}\left(\frac{\sigma}{\omega\varepsilon_0\varepsilon'}\right)^2\right) \quad (10)$$

B. *Penetration depth*

The penetration depth is defined as being the distance so that the density of power is reduced to 13% of its initial value, the distance z = 1/α is called penetration depth.

$$SAR = \frac{1}{\alpha} = 2\sqrt{\frac{\varepsilon_0}{\mu_0}}\frac{\sqrt{\varepsilon'}}{\sigma} \quad (11)$$

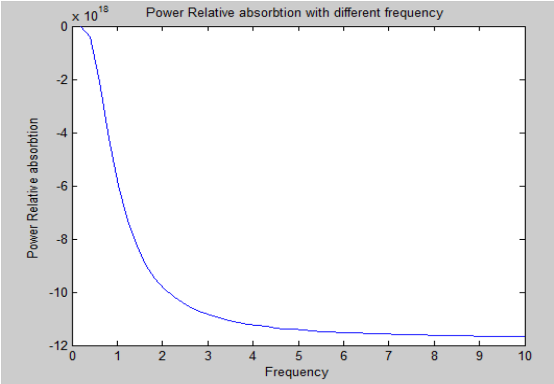

Figure 5Power Relative absorption with different frequency

As the above graph (Fig :5) indicates it above, the SAR of the man depends on the frequency of operation, the SAR decreases quickly when the frequency increases, that means that quantity of incidental energy is absorbed by the human body, although the evaluated SAR is lower than the limits ofhealth protection recommended in official regulations .

IV. RF ENERGY PROPAGATION THROUGH THE HUMAN HEAD

Properties of reflection and transmission in various tissues are in function dielectric properties of these various tissues: frequency of operation, angle of incidence, type of polarization and the thickness of each layer.

A. Model of the human head

It is more practical to take the human head like a model simple to study in the form of four layers : Skin, Fat, Bone and Brain (figure 5), as well as their density and electric properties for the two significant frequencies 0.9 GHz and 1.8 GHz, table 1

	Frequency $[GHz]$	Skin	Fat	Bone	Brain
$\varepsilon_r[-]$	0.9	43.74	5.46	12.45	52.73
	1.8	42.36	5.35	11.78	50.08
σ $[Sm^{-1}]$	0.9	0.855	0.051	0.143	0.942
	1.8	1.21	0.078	0.275	1.391
μ_r[-]	All	1	1	1	1
ρ $[Kgm^{-3}]$	all	1100	920	1850	1050

Table1. Characteristics and electric properties of the layers of the human head

Thus ε_r the relative permittivity, σ the electric conductivity $[Sm^{-1}]$, μ_r the relative permeability, ρ density $[kgm^{-3}]$.

B. Incidental power

The flow of the incidental power can be calculated by using the theorem of Poynting, the vector of Poynting p G is equal to the average power which crosses the unit of area of the plan of wave, therefore the flow of p G represents a power, in our case a wave which is propagated in direction OZ, the vector p G only one component has z p who is written:

$$P(Z) = -\frac{1}{2} Re\,[\,E_V Hx^*]$$

Therefore the incidental power is written:

$$P_i(z) = \frac{1}{2}\sqrt{\frac{\varepsilon_0 \varepsilon'}{\mu_0}}\left(1 + 0.125\left(\frac{\varepsilon''}{\varepsilon'}\right)^2\right) E_0{}^2 \exp(-2\alpha z) \qquad (13)$$

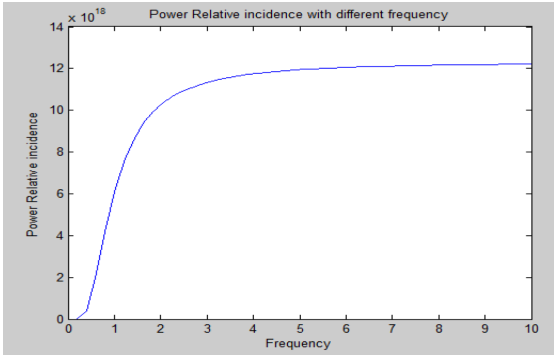

Figure 6 Incidental Power in function to the freq with z=0

As above graph (Fig : 6) incidental power reaches a maximum level, and then decreases quickly according to the increase in the frequency.

C. Reflected power

$$P_r = P_i |R_c{}^2| \qquad (14)$$

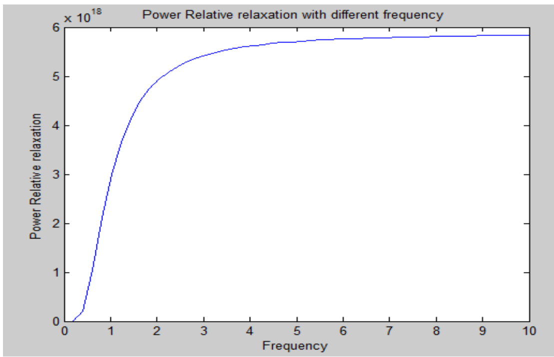

Figure 7 Power Relative relaxations with different frequency

D. Transmitted power

$$P_t = P_i |T_c{}^2| \qquad (15)$$

$|R_c|$ *and* $|T_c|$arethe coefficients of reflation and transmission in tissues [9] – [10], for a wave with uniform incidence ($\theta = 0$).

$$R = \frac{\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}}{\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}},\ T = 1 + \frac{\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}}{\sqrt{\varepsilon_2} + \sqrt{\varepsilon_1}} \qquad (16)$$

ε_1 *and* ε_2 are the permittivity of medium 1 and medium 2.

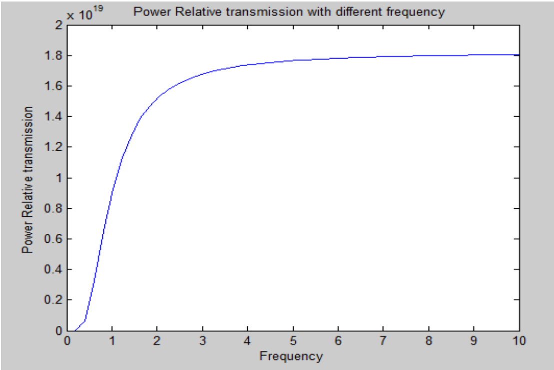

Figure 8 power Relative transmission with different frequency

1) Absorptive power with Z = 0

By the application of the principle of conservation of energy

$$P_\alpha(0) = P_i - P_r - P_t = 2|R|(1 + |R|)P_i \qquad (17)$$

2) Absorptive power with Z ≠ 0

$$P_\alpha(Z) = P_\alpha(0)\exp(-2\alpha h) \qquad (18)$$

H represents the thickness of the layer in question.

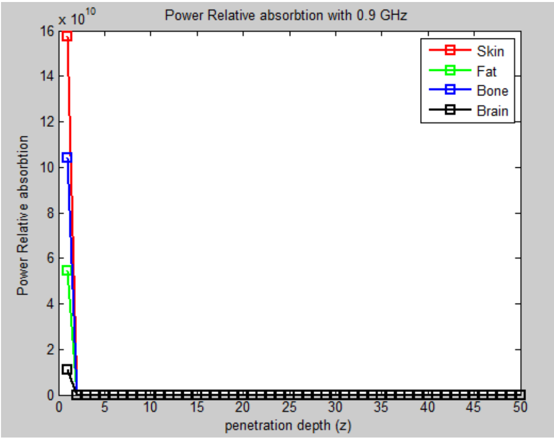

Figure 9. Power absorptive in function to depth z for*f*=0.9GHz.

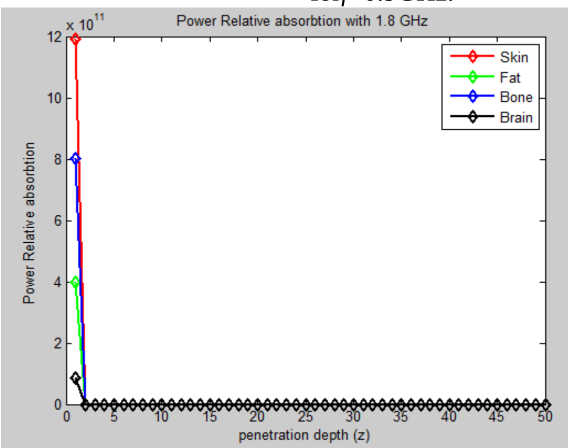

Figure10. Power absorptive in function to depth z for*f*=1.8GHz.

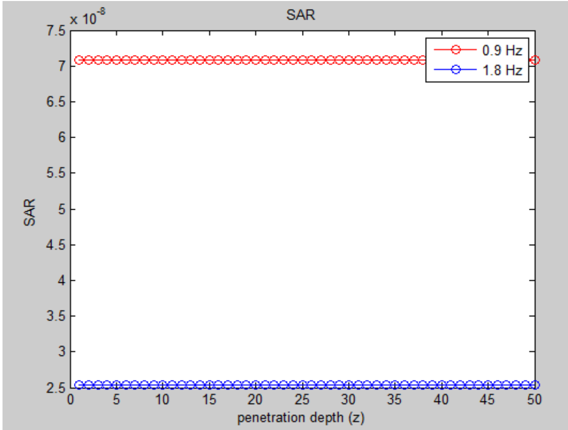

Figure11. Comparison of SAR in 0.9 and 1.8 Hz

V CONCLUSION

Thus the Effects and analysis of electromagnetic radiation from mobile phone on human body is found through SAR value. If the SAR value exceeds, it result in damage to human body from skin to cellular level even cause damage in brain such as insomnia, fatigue, mental disorder and cancer.
Analysis of the relative power absorptive in function to the penetration depth (z) leads to the following results:

1- With Z = 0 (surface head): two figures (6) and (7) are identical on the form and not on the amplitude (absorptive energy < incidental energy), this justifies that the human head absorbs a some quantity of energy.

2- with Z ≠ 0 (inside the head): in various tissues appears above graph (figure 8), figure (9) and figure (10), when the frequency increases (f = 0.9GHz, f = 1.8 GHz and f = 3 GHz): the amplitude of the absorptive power undergoes a light reduction, and the penetration depth (z) undergoes a very fast reduction.

When the frequency increases, the wave with a less penetration is due to the obstacles (living matter) on the course of the wave, what is called the interaction (wave / living matter), which produces an incidental energy absorption along the wave propagation until the complete weakening of the wave.

The analysis carried out shows that the absorptive energy by the human head is weak; however, the interaction wave / living matter is not negligible. This can induce physiological changes on the brain which results in unpleasant moods which on the long term can influence the metabolism at the level of the brain. Recent work starts to clarify the problems of the electromagnetic environment. The aspect of pollution E/M starts to be posed with acuity by [12]. Theoretical and experimental works were born, they pose the problem of the human behavior subjected to an electromagnetic influence in a clear way.

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