MEASUREMENT EVALUATION OF EMF EFFECT BY MOBILE PHONE ON HUMAN HEAD PHANTOM

Z. Pšenáková, M. Beňová

Department of Electromagnetic and Biomedical Engineering, Faculty of Electrical Engineering, University of Zilina, Veľký diel, 010 26 Žilina, tel.: +421 41 513 2142, 2119,e- mail: psenakova@fel.uniza.sk, benova@fel.uniza.sk

Summary Interaction of electromagnetic field (EMF) with environment and with tissue of human beings is still under discussion and many research teams are investigating it. One of electromagnetic devices is mobile phone. There are many simulations and measurements on models or phantoms of human body to biological effect of EMF acquirement. This paper deals with laboratory measurement evaluation of EMF effect by mobile phone on human head phantom.

1. INTRODUCTION

The human body exposure of the electromagnetic field (EMF) is very actual topic today. One of these electromagnetic devices is mobile phone. The use of wireless telecommunications devices, notably cellular phones, has increased dramatically in many countries over the past decade. Many studies want to show real results of this exposure on human models by using numerical methods and simulations. There are many measurements in labors with animals and models or phantoms of human body too. Mostly SAR measurements with human head phantoms are made to verify radiofrequency (RF) field effects. [1] - [6].

2. HEALTH EFFECTS

Many studies are speaking about effect detecting by sensitive measurements methods from temperature changes in the head to changes of memory and reaction speed. We can speak about two basic effects on human tissue: thermal effect and non-thermal effect.

Thermal effects of EMF appear with absorption of high frequency electromagnetic energy. Then intensity of power density of EMF evokes increasing of temperature. The thermal electromagnetic fields can be shown by measurement with thermovision camera, measurement with special phantoms of biological tissue or measurement with water phantoms. The organs most sensible on temperature are eye lens, brain and seminal vesicles. Many researches are interested in these thermal effects.

Non-thermal effects include non-specific symptoms, which are caused by mobile radiation. There are for example: headache, dizziness and insomnia. This type of symptoms might result from a unilateral influence on the vestibular system in the middle ear arising from absorption of the telephone's EMF. Other studies have been made on a few human volunteers to prove influence on the volunteer's memory and their reaction speed [7]. Brain is the most important organ in our body that must be protected and all possible risks have to be studied; for example brain activity, brain tumors and blood brain barrier by influence of other factors. EMF may influence others parts of human body as cardiovascular and endocrinal system too.

3. THEORY

We come out from Maxwell equations to examine EMF effect [8]. One way is to use simulation program. This method is very safe, because examined object is not exposed. But real measurements are more accurate. Measurement with model of human body exists between these two approaches; especially measurement with human head phantom [8]. Figure 1 shows realized head phantom we use for laboratory measurements of EMF effect by mobile phone. This phantom has been realized with respect to the next assumption.

Fig. 1. Realized human head phantom

At RF and microwave frequencies, electromagnetic fields penetrate into human body. These fields interact with biological tissue in several ways. The most important interaction can be explained in terms of energy transfer from the electromagnetic field to the tissue material.

One measure of this macroscopic effect is the time-averaged absorbed power. A quantity usually used is known as SAR and has dimension W/kg. SAR can be defined as:

$$SAR = \frac{1}{2}\frac{\omega\varepsilon_0\varepsilon_r}{\rho}|E|^2 \qquad (1)$$

with ω the angular frequency , ε_0 the permittivity of free space, ε_r the imaginary part of the relative complex permittivity, ρ the tissue density in kg/m^3 and E is the peak value of the total field inside the tissue material. [9]

We can see that the SAR depends on dielectric parameters therefore the materials of phantoms have to have similar dielectric parameters as human tissues. The human head consists of several tissues, which have different electrical characteristics and form complex-shaped boundaries. The electrical characteristics of human tissues are very different from the normal propagation medium (air), but not so different between each other.

For values of SAR are recommended maximum values by committee INCRIP, this value is 2 W/kg in EU. [10]

4. EXPERIMENTAL

Measurements of EMF effect by mobile phone on human head phantom we have practiced in specially laboratory room - semianechoic room. Figure 2 shows the block diagram of realized measurements with human head phantom, where **BO** is anechoic (or semianechoic) room, **PC** is personal computer (notebook), **LWL** is signal converter (optical signal/electric signal), **MA** is measurement antenna, **A** is antenna, **µC** is microcontroller, **LS** is logarithmic sensor of EMF, **F** is phantom of human head with human tissue parameters and full of the physiological solution, **G** is high-frequency generator, **or** is optical interface, **rvf** is air-phantom interface, **sr** is serial interface RS232 and **er** is electrical interface (DC).

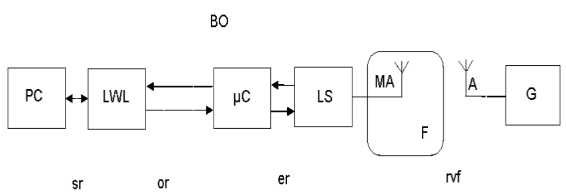

Fig. 2. Block diagram of measurements

The sensor of EMF that scans EMF power via measurement antenna and converts it to direct voltage (LS) is logarithmical type AD 8313. Wide dynamical range and good measurement accuracy for no calibrate frequencies are its advantages. There were made calibrations of this sensor via exact signal generator for two frequency bands - GSM (890 MHz - 915 MHz) and UMTS (1920 MHz – 2080 MHz). Final calibration of sensor in anechoic room enables to determine SAR values for every human tissue using equal 1.

Receiving antenna (A) of type Helix (screw) embodies good properties with minimal size. It was designed for GSM band use and it was calibrated via network analyzer. For its really measured pattern - were measurement error compensated.

Measurements have been realized for radiofrequency power in uplink band of wireless mobile system GSM. The transmitting antenna has been located near ear and simulates mobile phone (power level and frequency band). The measurements have been made for different angles considering ear. Transmitting power mode has been 2 W (33dBm). Figure 3 and figure 4 show these measurements with transmitting antenna rotation.

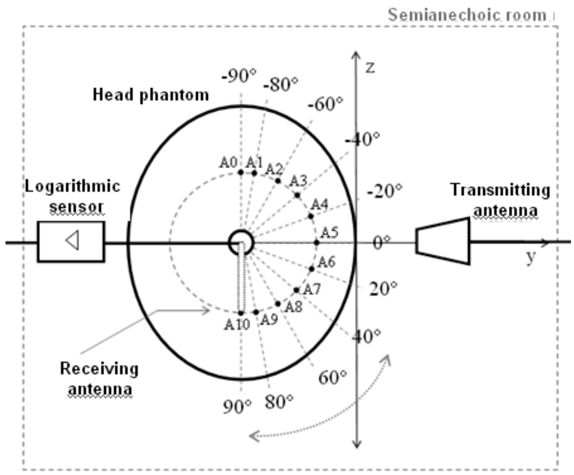

Fig. 3. Schematic representation of transmitting antenna rotation – top view

Fig. 4. Real transmitting antenna rotation – top view

5. MEASUREMENT RESULTS

Table 1 shows measured values for frequency 900MHz; there are ten points of measurements as shown Fig 3. Receiving antenna and transmitting antenna have been located in one axis – y and distance between transmitting antenna peak and phantom has been 5cm.

Tab. 1 Measured values for f_m=900MHz

Measuring point A_x	Angle of antenna rotation [°]	Received power P_m^{Ax} [dBm]	Standard deviation δ^{Ax} [dBm]	Measured values of $SAR_{AVG/10g}^{Ax}$ [W/kg]
A0	-90	-11,823	0,149	0,00657
A1	-80	-11,019	0,147	0,00791
A2	-60	-10,356	0,193	0,00921
A3	-40	-7,933	0,334	0,01609
A4	-20	-2,587	0,181	0,05512
A5	0	-0,578	0,212	0,08753
A6	20	-5,347	0,183	0,02919
A7	40	-9,032	0,236	0,01250
A8	60	-9,645	0,212	0,01085
A9	80	-10,245	0,147	0,00945
A10	90	-12,002	0,272	0,00631

Measured values of power shall be modified with regard to parameters of used receiving antenna to relevant results obtainment. The calculation of real $SAR_{AVG/10g}^{Ax}$ takes to know real power in measuring point. There are registered M values in 1 second interval. These values are calculated with regard to antenna parameters via correction coefficient Γ^{Ax} and then they are statistic evaluated. Received power in a measuring point P_m^{Ax} [dBm] is

$$P_m^{Ax} = \frac{1}{M}\sum_{n=0}^{M}(P_{m\,n}^{Ax} + \Gamma^{Ax}), \qquad (3)$$

were $P_{m\,n}^{Ax}$ is n-th value in measuring point A_x. The standard deviation δ^{Ax} of measured values is (for each measuring point A_x)

$$\delta^{Ax} = \sqrt{\frac{\sum_{n=0}^{M}\left[(P_{m\,n}^{Ax} + \Gamma^{Ax}) - P_m^{Ax}\right]^2}{M}}. \qquad (4)$$

Measured values of power a have small deviation from median that measured powers represent small variances as is shown in the Fig. 5.

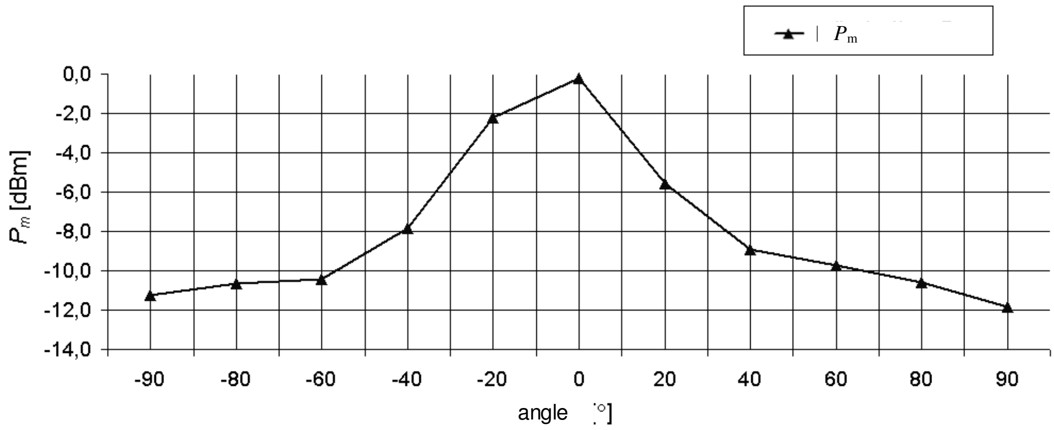

Fig. 5. Receiving power P_m^{Ax} (f = 900 MHz)

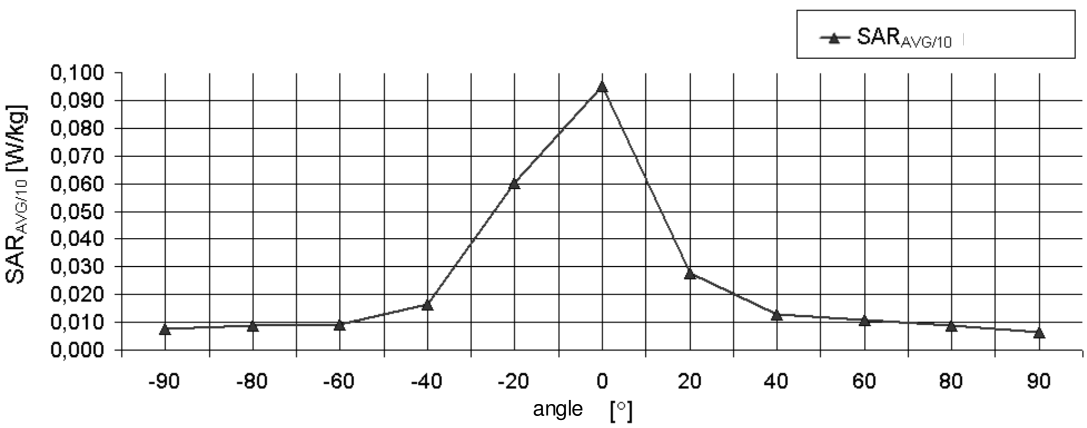

Fig. 6. Measured values of $SAR_{AVG/10g}^{Ax}$ (f = 900 MHz)

Figure 5 shows that measured values of receiving power have a maximum at zero angle antenna rotation Power declines with increasing values of angle.

Measured values of SAR have similar relations; maximum of it is at zero angle of transmitting antenna rotation. This point is at the same angle as maximum of receiving power. Neither of these values exceed limit value of $SAR_{AVG/10g}$ = 2 W/kg.

6. CONCLUSION

The goal of this article was measurement evaluation of EMF effect by mobile phone on human head phantom. This phantom is real model of human tissue and we were interested in specific absorption rate (SAR). Exposure limit of this quantity given by INCRIP is 2 W/kg. Our measurements showed that this maximum value was not exceeded.

The number of interested organizations and people increases in this area, but a lot of them are talking about EMF as about very dangerous. EMF and mobile phones has many positive sides, but we must learn to use safely this fantastic discovery, without which we can not imagine our modern life.

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