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Influence of Electromagnetic Fields by Electronic Implants in Medicine

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Introduction

The paper deals with influence of electromagnetic field (EMF) from mobile phone by electronic implants used with requirement of substitute non-functional parts of human body.

There are many people, who can not live without implantable devices like pacemakers, defibrillators and cochlear implants. But they want to have full-value life, use all electronic devices despite they have to follow certain rules according to user manual for each electronic implant. In user manual for each implantable device or electronic implant is written about mobile phone as one source of disturbances and than by using not regular functionality of implant.

Radiofrequency EMF

At radiofrequencies, electromagnetic field penetrates in to human body. This field can interact and disturb other electronic devices too. All disturbances depend on communication signal, its intensity and SARs (Specific absorption rate [W.kg-1]), power from mobile phone which human body absorbs:

$$SAR = \frac{\sigma\left|\vec{E}\right|^2}{2\rho}; \qquad (1)$$

where $\vec{E}$ – maximal value of the electric field component [V/m], σ – electrical conductivity [S/m], ρ – mass densities [kg/m$_3$] [1,10].

The lower intensity of signal leads to the higher transmitting power, which mobile phone has to use. Standard mobile phone has full battery voltage U = 3,6V. In curb position mobile phone has current I= 15mA and by ringing current changes on 250mA. By taking call the current will be increase on 330-350mA. Mobile phone systems and handsets parameters are present in table 1.

EMF and electronic implants

One of the frequently used electronic implant is artificial pacemaker. It is a small electronic device that has its own battery. When it is connected to the heart muscle by a thin wire called a lead, can detect the heart beats. By too slow hart beat the pacemaker can send a signal to the heart to make it beat faster.

Table 1. Mobile phones systems and handsets parameters [7]

Mobile phone system	Type	Frequency Band [MHz]	Maximum time-averaged power [W]
NMT (Nordic Mobile Telephone)	Analogue	450, 900	1
ETACS (Extended Total Access Communication System)	Analogue	900	0,6
AMPS (Advanced Mobile phone System)	Analogue	800	0,6
D-APMS (Digital AMPS)	Digital	800, 1900	0,2
GSM 900 (Global System for Mobile communications)	Digital	900	0,25
GSM 1800/1900	Digital	1800, 1900	0,125
IS-95 (CDMA Code Division Multiple Access)	Digital	800, 1900	0,2
PDC (Personal Digital Cellular)	Digital	800/1500	0,2

Brands and models of cardiac pacemakers exhibit a wide range of immunity levels to GSM and other types of radio signals. Therefore, people who wear cardiac pacemakers and who want to use a GSM phone should seek the advice of their cardiologist. If, as a pacemaker users, they are still concerned about interaction with mobile phones, it has been suggested by national health authorities that they:

- always keep the phone at least 15 cm away from pacemaker; when the phone is turned on;
- do not hold the phone to the chest, e.g., don't carry the phone in a breast pocket;
- use the ear opposite the pacemaker;
- refer to the pacemaker product literature for information on this particular device;

- if you have any reason to suspect that interference is taking place, turn off the phone immediately;
- refer to the phone product literature for the technical parameters of the phone, [3].

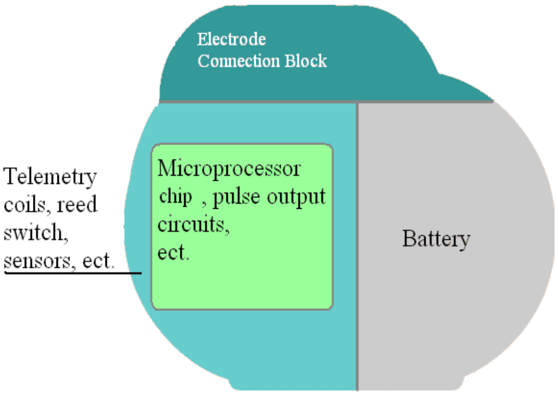

Fig. 1. Simple pacemaker diagram

Mobile or cellular phones may interact with pacemaker function by inhibiting the pacing output, asynchronous pacing and ventricular triggering [1,2]. When the antenna is located near the pulse generator header, interaction may occur very easily. New pacemakers have home monitoring system, when data from pacemaker can be transmitted, but patient has to follow system instruction and cooperate fully with transmitting data, [4].

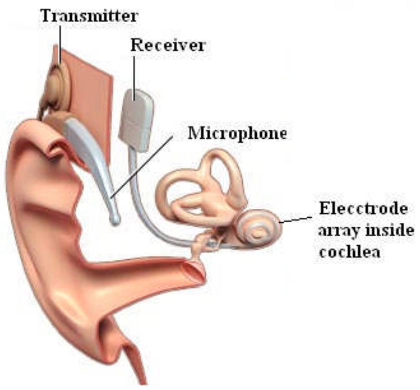

Fig. 2. Cochlear implant diagram

Other example of electronic implant is called "Brain pacemaker" is used to treat people who suffer from epilepsy, Parkinson's disease, major depression and other diseases. This kind of pacemaker is a medical device that is implanted into the brain to send electrical signals into the tissue (Fig. 1). Depending on the area of the brain that is targeted, the treatment is called deep brain stimulation, or cortical stimulation. Brain stimulation may be used both in treatment and prevention. Pacemakers may also be implanted outside the brain, on or near the spinal cord (spinal cord stimulation), and around cranial nerves such as the vagus nerve (vagus nerve stimulation), and on or near peripheral nerves, [6].

A cochlear implant (CI) is a surgically implanted electronic device that provides a sense of sound to a person who is profoundly deaf or severely hard of hearing. The cochlear implant is often referred to as a bionic ear. Unlike hearing aids, the cochlear implant does not amplify sound, but works by directly stimulating any functioning auditory nerves inside the cochlea with an electric field. External components of the cochlear implant include a microphone, speech processor and an RF transmitter (Fig. 2).

An RF receiver is implanted beneath the skull's skin. The transmitter has a magnet by which it attaches to another magnet placed beside the receiver. The receiver relays the incoming signal to the implanted electrodes in the cochlea. The speech processor allows an individual to adjust the sensitivity of the device. The implant gives recipients additional auditory information, which may include sound discrimination fine enough to understand speech in quiet environments. Post-implantation rehabilitative therapy is often critical to ensuring successful outcomes.

Methods

One of the most common methods used to analyze high frequency electromagnetic fields is the FDTD (*Finite-Difference Time-Domain*) method. It is directly used to time form of Maxwell equations. With the use of this method, curled equations of the electromagnetic field are solved simultaneously in time and space domains. The model was divided to many small parts-voxels by using FDTD (Finite Difference Time Domain) method. Calculation of this method is based on FFT (Fast Fourier Transformation), which advantage is minimal memory requirements. The areas of interest (model-environment interface) are covered by higher number of voxels, e.g. voxels are smaller to increase results resolution..

In the Fig. 3 electric field intensity resolution E(Ex, Ey, Ez) and magnetic field intensity resolution H(Hx, Hy , Hz) in grid is displayed.

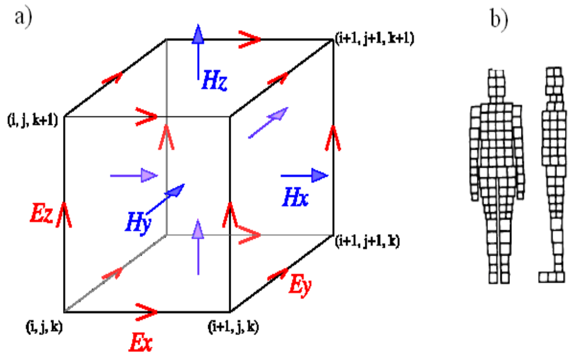

Fig. 3. a) Grid geometry by FDTD method, b) Interpretation of grid division of human body

These parameters are calculated in different points of space according to modified Maxwells equations (2–4).

$$\frac{\partial H_x}{\partial t} = \frac{1}{\mu}\left(\frac{\partial E_y}{\partial z} - \frac{\partial E_z}{\partial y}\right), \qquad (2)$$

$$\frac{\partial E_y}{\partial t} = \frac{1}{\varepsilon}\left(\frac{\partial H_x}{\partial z} - \sigma E_y\right), \qquad (3)$$

$$\frac{\partial E_z}{\partial z} = \frac{1}{\varepsilon}\left(-\frac{\partial H_x}{\partial z} - \sigma E_z\right). \qquad (4)$$

This method is applied by frequency ranges from MHz to GHz, [8]. Advantage of FDTD method in comparison with other numerical methods for modelling of EMF is rate of computation.

As investigation method can be performed simulation of influence of EMF. In numerical simulation can be used a model of 34-years-old male human body (Fig. 4).

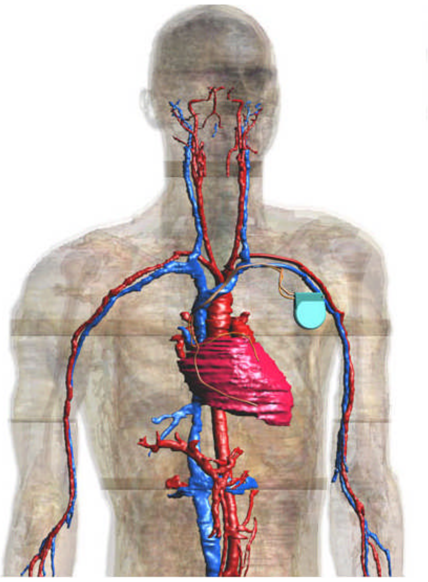

Fig. 4. Whole human body model with pacemaker

Simulation was made, where distance from source of radiation from body was changed. Simulation length was set to 10 periods of selected frequency, what double minimum number of periods to achieve reliable results. Parameters of EMF simulations are listed in Table 2.

Achieved SAR values recorded at far field sensor (FFS) have to be normalized to average tissue weight 10g. Normalized SAR results are comparable with specifications requirements [3]. Level 0dB is equal to SARAVG/10g=1,3973286W/kg (maximum SARAVG/10g = 2,84dB = 2,7842943W/kg) in presented simulation results [8,9].

Table 2. Simulation settings

Parameter	Value	Note
Nominal frequency	900 MHz	
ES, type of source of EMF	Dipole (Z=50Ω)	
Power supply / source of EMF	U_{max}=10V	U_{total}=20V
Harmonic mode		
Exposure simulation time	16 periods	
Period of time step	1,0138e-012s	
Number of calculation steps per period	1096	
Number of time steps	17536	
FFS, sensor mode	phase	
ESTDM, sensor mode	harmonic	

Maximal values SARAVG/10g reached by simulations with different distances between body and source of radiation are displayed in Fig. 5a. With increasing of distance is maximal value SARAVG/10g exponential decreasing to the zero value. Differences ΔSARAVG/10g [dB] for distances from 0 mm to 30mm (with step 5 mm) considering to the maximal value in mm are displayed in the Fig. 5b.

Conclusion

Modern medical electronic implant have special advantage called Medical Implant Communication Service (MICS).

MICS is the name of a specification for using a frequency band between 402 and 405 MHz in communication with medical implants. This service allows bi-directional radio communication with a pacemaker or other electronic implants. The maximum used bandwidth at one time is 300 kHz, which makes it a low bit rate system compared with WiFi or Bluetooth.

The main advantage is the additional flexibility compared to previously used inductive technologies, which required the external transceiver to touch the skin of the patient [5]. For this service can influence of radiofrequency EMF some negative effect and for single function of electronic implant too.

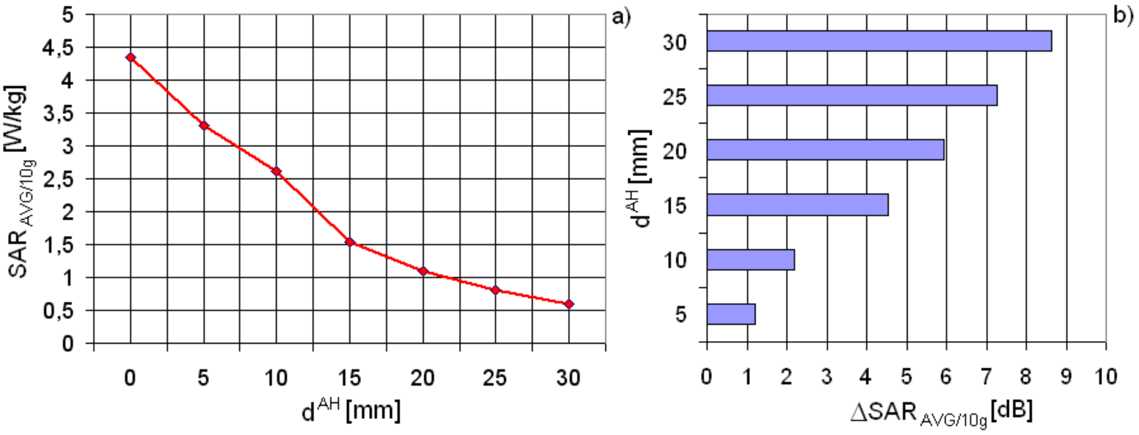

Fig. 5. Maximal values SARAVG/10g by increasing of distance between body and source of radiation (a); difference of reached values considering maximal value SARAVG/10g (b)

It is important to use hands-free package and to have mobile phone in minimal recommended distance (15 cm) from electronic device, what is presented in simulation too.

Acknowledgement

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B. Psenakova, J. Hudecova. Influence of Electromagnetic Fields by Electronic Implants in Medicine // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 7(95). – P. 37–40.

Influence of electromagnetic field (EMF) from mobile phone by electronic implants used to substitute non-functional parts of human body is analyzed. Minimal distance from radiation source published in user manuals of electronic devices (implants) is 15 cm. There is presented numerical simulation, where influence of radiation source on electronic implant is proved. Ill. 5, bibl. 10 (in English, summaries in English, Russian and Lithuanian).

Б. Псенакова, Ю. Гудецова. Исследование влияния электромагнитных полей на параметры электронных медицинских имплантов // Электроника и электротехника. – Каунас: Технология, 2009. – № 7(95). – С. 37–40.

Анализируется влияние электромагнитного поля, созданного мобильным телефоном, на работу электронных имплантов, помещенных в теле человека. Описываются результаты цифрового моделирования и влияние электромагнитного поля в зависимости от расстояния до медицинского импланта. Результаты сравниваются с данными технической документации. Ил. 5, библ. 10 (на английском языке; рефераты на английском, русском и литовском яз.).

B. Psenakova, J. Hudecova. Medicininių elektroninių implantų skleidžiamų elektromagnetinių laukų įtaka // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 7(95). – P. 37–40.

Analizuojama mobiliojo telefono skleidžiamo elektromagnetinio lauko įtaka žmogaus kūne esantiems elektroniniams implantams. Elektroninių implantų techninėje dokumentacijoje pateikiamas minimalus leistinas jų atstumas nuo spinduliuotės šaltinio yra 15 cm. Pateikiamas skaitmeninis modeliavimas, kuriuo įrodoma sąveikos tarp elektroninio implanto ir spinduliuotės šaltinio priklausomybė nuo atstumo. Il. 5, bibl. 10 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).