INTERFERECE OF ACTIVE MEDICAL IMPLANTS WITH GSM AND UMTS MOBILE PHONES AND BASE STATIONS

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SUMMARY: This paper presents numerical calculations of the field-to-voltage transfer function, i.e. the coupling between GSM and UMTS mobile phones and base stations and the voltage induced at the sensing input of cardiac pacemakers. Furthermore the source impedance of a unipolar electrode is determined numerically. The numerical method is successfully validated by measurements using a homogeneous phantom with tissue simulating liquid. The numerical model considers implantation of the pacemaker in the right pectoral area using a realistic model of the human body as well as different exposure scenarios. The maximum amplitudes of the interference voltage range from 420 mV at 900 MHz for mobile phone use (P = 1 W) in front of the chest and 2.9 mV at 950 MHz for plane wave exposure (E = 1 V/m). The source impedance of a unipolar electrode varies from (44 – j 36) Ω at 900 MHz to (20 – j 12) Ω at 1950 MHz.

INTRODUCTION

In 2002 the German Ministry of Economics and Labour launched a 2-year project in order to investigate the interference of active medical implants by different mobile technologies like DECT, GSM and UMTS. The phenomenon of electromagnetic interference can be divided into two parts: The first part, which is described in this paper, deals with the field-to-voltage transfer function, i.e. the coupling between external field sources like mobile phones and base stations and the voltage induced at the sensing input of the implantable medical device. Furthermore the source impedance of the electrode has to be determined. In the second part, which is not discussed in the scope of this paper, the high frequency electromagnetic immunity of implantable medical devices and the input impedance of real pacemakers are investigated. Combining the results of both parts enables risk assessment of persons with implanted medical devices in the vicinity of mobile equipment.

This paper starts with an introduction to the numerical approach and presents the validation of the numerical code by measurements. Based of this an overview to open-circuit interference voltages for standard situations of unipolar electrode configurations is given in the range from 900 MHz to 2150 MHz. Finally source impedances are calculated numerically.

METHOD

The numerical investigation of the coupling model (i.e. field-to-voltage transfer function) is carried out using the commercially available electromagnetic field solver EMPIRE [1] from IMST GmbH. The software is based on the Finite-Difference Time-Domain (FDTD) method (e.g. [2]). For the representation of the human body the model from the US Air Force Research Laboratory (AFRL) [3] is used with a spatial resolution of 1 mm and about 40 different types of biological tissue including a parametric model of the dielectric properties.

For the numerical investigation a CAD model of a single chamber pacemaker with a unipolar electrode is generated (see Fig. 1). The size of the cardiac pacemaker is approximately 51 mm × 42 mm × 9 mm. The pacemaker electronics is neglected i.e. replaced by an open-circuit.

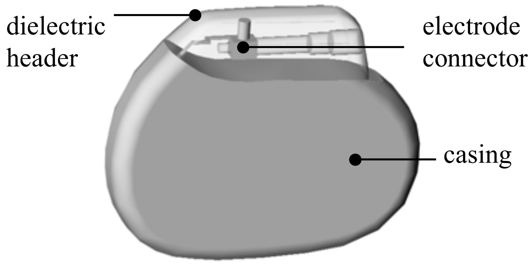

Fig. 1: Numerical model of a unipolar pacemaker

Fig. 2 shows the cardiac pacemaker in the right pectoral area and the tip of the lead in the ventricle of the heart. The implantable pulse generator is located under the subcutaneous fat layer. The electrode is bend around the pacemaker housing, passes the muscle tissue, enters the venous system, follows the vessels and goes through the atrium to the ventricle.

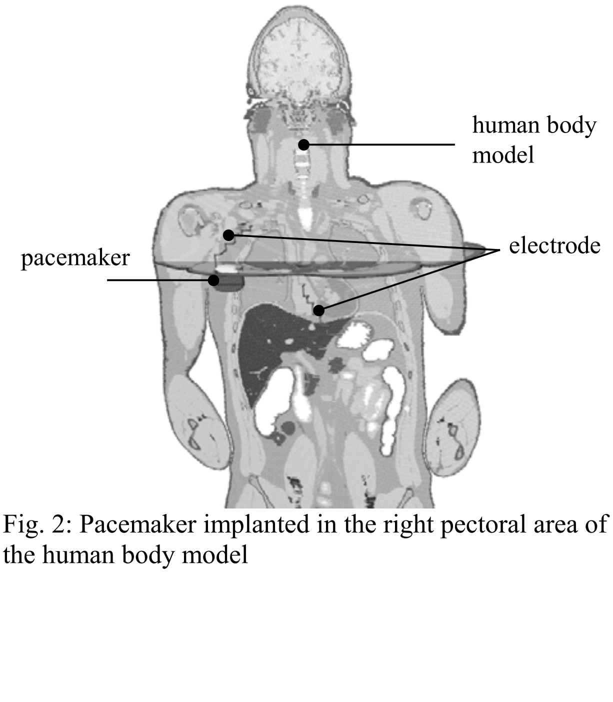

Fig. 2: Pacemaker implanted in the right pectoral area of the human body model

The following scenarios are investigated:

- Mobile phone in front of the chest (the distance between pacemaker and mobile phone is 5 cm)
- Mobile phone in head position (right and left ear)
- Frontal incident plane wave with two polarizations (vertical and horizontal)

The frequencies under investigation are 900 MHz, 1750 MHz, 1950 MHz for mobile phone use at head and chest (uplink) and 950 MHz, 1850 MHz, 2150 MHz for plane wave exposure (downlink).
In the scenarios discussed above the electrode acts as a receiving antenna with an open-circuit voltage u and a source impedance Z. Z_{PM} is the input impedance of the pacemaker electronics. The voltage u_{PM} at the input of the pacemaker can be determined by the equivalent circuit given in Fig. 3.

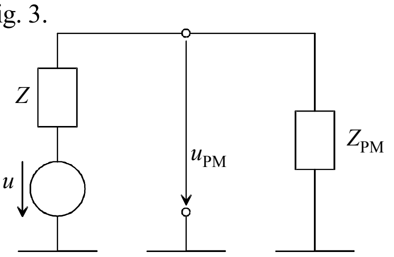

Fig. 3: Equivalent circuit for voltage transformation

VALIDATION

In order to validate the numerical simulations measurements are performed. Fig. 4 shows a schematic representation of the experimental set-up.

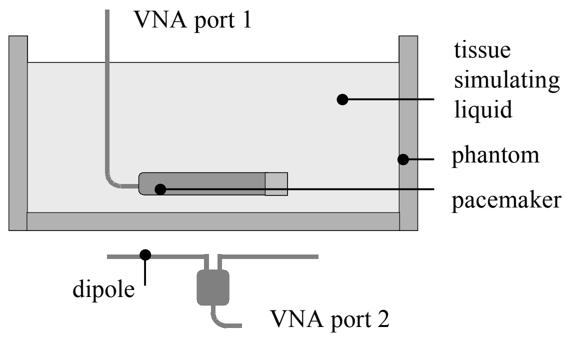

Fig. 4: Schematic representation of the experimental set-up for validation

A cardiac pacemaker is immersed into a rectangular phantom filled with tissue simulating liquid. Different sources (dipole and generic mobile phones) are located under the phantom. S-Parameters are measured by a vector network analyzor (VNA). The interference voltage is calculated by the following equation from the measured s-parameters, the impedance Z_L=50 Ω and the active power P of the VNA.

$$u = 2\sqrt{\frac{2PZ_L}{1-|s_{11}|^2}}\left|\frac{s_{21}}{1-s_{22}}\right| \qquad (1)$$

The measurement results and the FDTD simulations are in good agreement. The differences between measurements and simulations are within -3.1 dB to +0.3 dB. Simulations show slightly higher values for the interference voltage due to non-lossy metallic structures. Therefore simulations represent a worst-case scenario.

RESULTS

Table 1 lists the maximum interference voltages u (open -circuit) for the scenarios listed above. The results for chest and head position are scaled to an active input power of P = 1 W. The results for plane wave exposure are scaled to an incident plane wave of E = 1 V/m (rms) with vertical and horizontal polarization.

Tab. 1: Maximum interference voltages (amplitudes) for different scenarios (chest and head positions scaled to P = 1 W, plane wave exposure scaled to E = 1 V/m with vertical (v.) and horizontal (h.) polarization)

Configuration	GSM 900	GSM 1800	UMTS
Chest	420 mV	121 mV	67.5 mV
Head (left)	5.5 mV	2.3 mV	0.825 mV
Head (right)	32.0 mV	20.3 mV	15.9 mV
Plane wave v.	2.5 mV	0.98 mV	0.52 mV
Plane wave h.	2.9 mV	0.67 mV	0.52 mV

Table 2 lists the real and imaginary part of the source impedance Z of the unipolar electrode at different frequencies.

Tab. 2: Source impedance Z of a unipolar electrode at different frequencies

Source imp.	900 MHz	1750 MHz	1950 MHz
Re{Z}	44 Ω	24 Ω	20 Ω
Im{Z}	-36 Ω	-17 Ω	-12 Ω

DISCUSSION

Scaled to the same output power of P = 1W the interference voltage u decreases with increasing frequency due to absorption of electromagnetic energy in the superficial tissue. The same applies to plane wave exposure scaled to an incident plane wave of E = 1 V/m. The highest interference voltage occurs when the mobile phone is positioned in front of the chest. During normal usage of the mobile telephone at the human head the interference voltages are significantly smaller. Since the pacemaker is implanted in the right pectoral area the voltages for right ear usage are greater than for left ear usage.

REFERENCES

[1] EMPIRE. *User and Reference Manual*. IMST GmbH, 2002
[2] K. S. Kunz, R. J. Luebbers. *The Finite Difference Time Domain Method for Electromagnetics*. CRC Press, Boca Raton, 1993
[3] URL: http://www.brooks.af.mil/AFRL/HED/hedr/hedr.html

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