

Cardiac Pacemaker and Base Station Interaction

Dr inż. Anna Pławiak-Mowna

Autorka pracuje na stanowisku adiunkta w Instytucie Informatyki i Elektroniki na Uniwersytecie Zielonogórskim. W 2005 roku otrzymała tytuł doktora nauk technicznych w dyscyplinie Elektrotechnika (Instytut Elektrotechniki w Warszawie). Od czterech lat, wraz z zespołem lekarzy elektrofizjologów oraz naukowcami z Polskiego Towarzystwa Zastosowań Elektromagnetyzmu, prowadzi badania elektromedycznych implantów kardiologicznych (m.in. stymulatory serca, kardiowertery-defibrylatory) eksponowanych na sztucznie generowane pole elektromagnetyczne.



e-mail: A.Mowna@iie.uz.zgora.pl

Abstract

The paper presents preliminary findings from examinations cardiac pacemakers and base station interaction. Cardiac pacemaker exposes to electromagnetic field at wireless telecommunication devices can results in improperly implants function. The literature survey allows recognize the possible pacemaker responses to external interference from base station antenna. The preliminary results analysis base station antenna – cardiac pacemaker interaction are discussed.

Keywords: electromagnetic field, cardiac pacemaker, electromagnetic interference.

Streszczenie

Artykuł przedstawia wstępne wnioski, sformułowane na podstawie doniesień naukowców badających problem oddziaływania stacji bazowych telefonii komórkowej na pracę stymulatorów serca. W kardiointplantach eksponowanych na sztucznie generowane pole elektromagnetyczne (przez urządzenia telefonii komórkowej) mogą występować zaburzenia w prawidłowej pracy implantów. Przegląd wyników badań pozwoli rozpoznać potencjalne zaburzenia w pracy stymulatorów serca będące odpowiedzią na zewnętrzne interferencje od anteny stacji bazowej. W pracy przedyskutowano wstępne wyniki analizy problemu interakcji antena stacji bazowej – stymulator serca.

Słowa kluczowe: pole elektromagnetyczne, stymulator serca, interferencje elektromagnetyczne.

1. Introduction

Cardiac pacemaker is a medical instrument generating electric impulses to simulate the heart muscle artificially. Manufacturers design medical devices to be immune to electromagnetic fields up to 10 V/m for life-support medical electrical equipment and 3 V/m for non-life-support medical electrical equipment, as proposed in international standards. Meeting these standards would reduce the potential hazards of EMI. Specific EMC standards for implantable cardiac pacemakers and defibrillators are defined in ISO [2].

The exposure to electromagnetic field cardiac pacemaker might be affected by EMI. The range of responses from the pacemaker system to EMI and other forms of interference is wide and largely depends on the interference signal characteristics. Electromagnetic field at environment comes mainly from public available sources, like the home appliances, power lines or base station antenna which occur near places where people live or mobile phones and other wireless communication devices [1,8].

The documented sources of electromagnetic field at daily life situations are:

- transmission lines of different voltage, including multivoltage lines, electrical devices – electromagnetic field frequency of 50/60 Hz,
- devices generate magnetostatic fields – magnetic resonance image scanners and direct current transmission installations,
- electromedic devices, radio/television transmitters – electromagnetic field frequency of 10 - 100 MHz,
- high frequency electromedic devices, wireless telecommunication – electromagnetic field frequency of 100 MHz - 2GHz.

2. The method of exam pacemaker EMI

To examine the operation of cardiac pacemaker exposed to electromagnetic field four approaches are used:

- examination of isolated pacemaker in phantom (*in vitro* in phantom) is performed with the implantable device submerged in a saline filled tank and with the source of radiated EMI in close proximity. This method of investigations allows study of interactions between various EMI sources and devices. Multiple iterations of the experiment permit examination of the effects of distance, position, field strength, and device programming on the frequency and severity of the interaction,
- examination of isolated pacemaker (*in vitro*) is performed similar to *in vitro* in phantom study. Device testing *in vitro* study is not submerged in a saline filled tank,
- examination of pacemaker implanted in the human body (or animal body – *in vivo*) – the study with patient volunteers (or animal) requires control patient exposure to potential sources of EMI. The fact that many sources of EMI might interfere complicates that studies. The recorded electrocardiogram is the ideal method to evaluate device behavior during exposure to potential sources of EMI,
- numerical simulation allows to predict the possible hazards might occur in examination of pacemaker implanted in the human body that method allows to quantify the relationship between an external electromagnetic field and the voltage induced in the leads of an implantable device.

3. EMI resulting in pacemaker malfunction

Electromagnetic fields may interfere with implanted cardiac pacemakers causing a life-threatening malfunction of the device.

There are number of possible pacemaker responses to external interference:

- inhibition of pacemaker output (total inhibition, one-beat inhibition),
- inappropriate triggering of pacemaker output, asynchronous pacing (noise),
- reprogramming to different parameters, rate increase and damage of the pacemaker circuitry.

4 Study of cardiac pacemaker and base station interaction

The author and colleagues [5,9,12-14] at present performing investigation with base station antenna (GSM operated). This project is consisted of investigations grouped by sources of disturbance:

- **mobile phones and base stations (GSM, UMTS operated);**
- devices including the power frequencies of 50 Hz;
- therapeutic, diagnostic medical devices.

The aims of the work are: to develop effective methods to identify the electromagnetic disturbances in cardiac pacemakers, to identify malfunction of cardiac pacemaker exposed on electromagnetic field and to determine the health effect of these interaction.

The research project including all the examinations specified above.

The research project is performing in cooperation with scientific society – Polish Society of Applied Electromagnetic, University of Zielona Góra, GSM operators and Military Institute of Hygiene and Epidemiology in Warsaw, the medical community - Collegium Medicum UJ and physicians of Medical University in Warsaw and Japanese scientifics from Doshiha University [4-6,9-15].

5. The results of EMI examination of pacemaker at electromagnetic field generated by base station

At present Author and colleagues are performing investigation with base station antenna (GSM operated) [5,9,13,14]. The study comprises 230 patients, till now we tested 70 patients. Twenty three were dual chamber and the remaining were single chamber pacemakers. The following companies manufactured were tested: Biotronik, Medtronic, St. Jude Medical, Siemens.

All the patients were tested in the same place of investigations situated in hallway of Medical University hospital (Warsaw, Banacha Street) (Fig. 1). Place of investigation is marked at special place, where intensity EMF is equal: 7 V/m, 20 V/m, 30 V/m, 40 V/m, 100 V/m. These values correspond to European standards. Patients can't cross line marks place, where EMF intensity is equal 100 V/m. Research procedure steps: (1) patient is qualified to take part in examination; (2) cardiac pacemaker is controlled; (3) Holter's recorder is set up (device makes possible to record signal generate by cardiac pacemaker); (4) estimate if base station antenna functions with maximum power influences cardiac pacemaker – patient (insured by doctor) coming up step by step to base station antenna (follow marked route), time of crossing special mark place is noted; (4a) if interaction is detected – estimate distance to base station antenna; (5) test is finished at place where EMF intensity is equaled to 100 V/m (6) after 24 hour from the beginning of investigation estimates signal recorded by Holter recorder to identify kind of pacemaker disturbances; (6a) if disturbances of pacemaker function are observed relate this event to: expose to electromagnetic field, distance between tested device and source of disturbance, value of intensity of EMF. It was analyzed 70 recorded electrocardiograms.

We didn't observe any disturb of pacemaker function relevant with exposing pacemakers to electromagnetic field generated by base station antenna (Allgon 7330 S/N 531, 900MHz).



Fig.1. Investigation determine whether incompatibility with base station antenna may exist, examination of cardiac pacemaker implanted in the human body – study with patient volunteers [14]

Rys.1. Badanie kompatybilności (antena stacji bazowej, stymulator serca) – badania z udziałem pacjentów wolontariuszy

Kubacki *et al.* [6] found severe malfunctions of cardiac pacemaker exposed to EMF generated by microwave base station (Kathrein K – 738573, 940MHz). Base station antenna caused the most pronounced effect – one-beat inhibition of pacemaker output, asynchronous pacing and damage of the pacemaker circuitry. This electromagnetic interference (EMI) occurred for averaged power density equaled 90 W/m^2 (**restricted area** condition). Two models of cardiac pacemakers (Biotronik) were subjected to EMI susceptibility. The one-beat inhibition of pacemaker output and asynchronous pacing occurred in dual-chamber pacemaker. Base station radiation can cause permanent single-chamber pacemaker damage. The Scientifics from Poland focused on examination of isolated pacemaker in order to identify malfunction of cardiac pacemaker exposed on base station electromagnetic field (power density range $0 - 100 \text{ W/m}^2$). The aim of investigations was to determine the kind of this interaction – the effects of distance, position, field strength, and device programming on the frequency and severity of the interaction.

Fig.2. Investigation determine whether incompatibility with base station antenna may exist, examination of isolated pacemaker implanted – *in vitro* measuring setup [6]

Rys. 2. Badanie kompatybilności (antena stacji bazowej, stymulator serca) – zestaw badawczy *in vitro*



Scientifics from Japan (Tarusawa *et al.* [16]) presented results of investigation the interference of implantable cardiac pacemaker by cellular base station (BS) antennas. The estimation of the impact was based on *in vitro* experiments. Critical interference to the electric field strength was revealed with respect to the 800-MHz band second-generation and 2-GHz band third-generation cellular systems. The researchers concluded that “the pacemaker EMI depends on the average power of the transmission signals and does not depend on the peak-to-average power ratios of the transmission signals, which

increase with the number of multicarriers and multicodes". They noted that the boundary of the EMI area (where malfunctions occur closely) approximates the contour of a 25-V/m electric field that "is exited from a commercially available collinear array antenna typically used in BSs". **No pacemaker EMI** was detected in the immediate vicinity under the BS antenna at an input power level for typical operation.

Table 1. The results of EMI examination of pacemaker at antenna base station electromagnetic field [4-6,9,13,14,16]

Tabela 1. Wyniki badań interferencji elektromagnetycznych (stymulator serca, antena stacji bazowej)

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An examination of isolated cardiac pacemaker (<i>in vitro</i>)	Tarusawa <i>et al.</i> [16] 1. The pacemaker EMI depends on the average power of the transmission signals and does not depend on the peak-to-average power ratios of the transmission signals, which increase with the number of multicarriers and multicodes. 2. The boundary of the EMI area where malfunctions occur closely approximates the contour of a 25 V/m electric field that is exited from a commercially available collinear array antenna typically used in BSs 3. No pacemaker EMI was detected in the immediate vicinity under the BS antenna at an input power level for typical operation
	Kubacki <i>et al.</i> [6] 1. Base station antenna caused the most pronounced effect: a. one-beat inhibition of pacemaker output, asynchronous pacing (dual-chamber pacemaker), b. damage of the pacemaker circuitry (single-chamber pacemaker). 2. EMI occurred for averaged power density equaled 90 W/m² (restricted area condition).
An examination of cardiac pacemaker implanted in the human body – study with patient volunteers	Plawiak-Mowna <i>et al.</i> [4,5,9,13,14] 1. It was analyzed 70 recorded electrocardiograms. 2. "We did not observe any disturb of pacemaker function relevant with exposing pacemakers to electromagnetic field generated by base station antenna".

6. Summary

The aim of the article is to provide an overview of published studies regarding the electromagnetic interferences resulting in cardiac pacemaker malfunction. Author has focused on wireless telecommunication EMF source – base station antenna. The available literature was sorted according to types of investigation. In general experiments concerning the susceptibility of pacemakers to mobile phones have been performed. The results of these experiments suggested "6-inch rules" [11] to prevent the disturbance of pacemakers.

Not many studies were found in literature in case of determine whether incompatibility with base station antenna (and cardiac pacemaker) may exist [2,7,8]. The investigations results allowed to formulate preliminary conclusions that cardiac pacemakers are not influenced by base station antenna signal (in daily life situation).

7. Literature

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Tytuł: Oddziaływanie pola elektromagnetycznego generowanego przez stacje bazowe na stymulatory serca.

Artykuł recenzowany