FEM Simulation of Induced Interference Voltage at Implantable Cardiac Pacemaker Due to Wireless Power Transfer in HF-band

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Abstract – **A novel numerical Wireless Power Transfer (WPT)/Active Implantable Medical Device-EMI estimation methodology based upon finite element method analysis is presented. This assessment methodology can be applied to both Mobile/Portable-WPT system and electric-vehicle-WPT system. Here, an example for HF-band magnetic resonance type WPT is introduced. Simulated example includes different exposure scenarios in order to estimate the maximum interference voltage.**

Index Terms —**Implantable Cardiac Pacemaker, Wireless Power Transfer, Electromagnetic Interference (EMI), Finite element method (FEM).**

1. Introduction

Electromagnetic interference (EMI) on implantable medical devices such as implantable cardiac pacemakers and implantable cardioverter defibrillators (ICDs) is one of the most important issues needing investigation [1-4]. Recently, wireless power transfer (WPT) technologies using magnetic resonant coupling have been attracting attention [5]. The technologies are expected to achieve charging and power supply functions for home appliances, electric vehicles (EVs), and other electric systems and devices. Investigations of compliance with the basic restrictions for human exposure, induced currents and electric fields have been conducted [6, 7]. However, there is still concern that, when an implantable medical device patient is close to WPT system, the electromagnetic fields (EMF) may be strong enough to impact pacemaker operation.

This paper presents a numerical assessment methodology and some exemplary results for pacemaker EMI triggered by a HF-band WPT. The interference voltage induced at the connector of the pacemaker is calculated using the finite element method (FEM). We assume some exposure scenarios, when orientation and location of the torso phantom are varied, in order to estimate the maximum interference voltage. FEM analyses are performed using commercially available software [8].

2. Numerical model for pacemaker EMI assessment set-up

In order to measure the pacemaker EMI from RF/EMF emitters operating in various frequency bands such as those used by cellular phones and RFID readers, the human torso phantom has been widely used. An example of a vertical torso phantom is shown in Fig. 1 (a). The torso phantom is comprised of a saline tank and electrodes, as shown in the figure. The saline tank is filled with a saline solution, with the density (1.8 g/l NaCl concentration). The positions of the pacemaker and the lead wires are fixed. Based on this experimental torso phantom, we construct a numerical EMI estimation model consisting of the torso phantom and WPT [9,10]. The human torso phantom model for numerical estimation, which contains the implantable-cardiac pacemaker model, is shown in Fig. 1(b). As shown in the figure, the leads are connected to the pacemaker's terminals. The interference voltage is evaluated at the register (1 M-Ohm) on the terminal. The dielectric constants and electric conductivities of each material used in the phantom model summarized in Table 1 are for 10 MHz operations.

Here, an example for HF-band magnetic resonance type WPTS proposed by a research group of MIT [5] is used. The input and output loops are placed close to the coils, spacing is 13 cm. When the distance between the Tx and Rx coils is 1 m, the resonance of the coils occurs close to 10 MHz and the resonant frequency splits into two peaks under this coupling condition. Simulated power transfer efficiency was approximately 70 % at 10.3 MHz and 80 % at 10.4 MHz. The two resonant modes create different distributions of magnetic field around the coils. When the distance between the Tx and Rx coils is 1.5 m, the resonant frequency occurs at 10.35 MHz and efficiency decreases to approximately 60 %.

3. Results and conclusions

As shown in Fig. 2, the wireless power transfer coils and the human torso phantom were combined to obtain the interference voltage. The voltage at both ends of the resistor, connected to the terminals, is determined. The analysis used a 1 M-Ohm resistor to obtain a stable computed voltage.

Figure 3 plots the calculated interference voltages at the terminal versus distance L from the surface of Tx-coil (normalized by the maximum value in the simulation data), for the cases of Fig. 2 (a) and (b). Tx-coil input powers were the same for both scenarios. When distance L is 0 cm, the

induced voltage for scenario (a) is more than twice that of scenario (b), even though its input power is the same. This is because the difference in the magnetic field distribution strongly affects the induced voltage. By using FEM simulation to evaluate the interference voltage, accurate estimations can be achieved.

The results described herein clarified that the interference voltages due to the EMF generated around WPT can be estimated by the precise numerical analysis methodology.
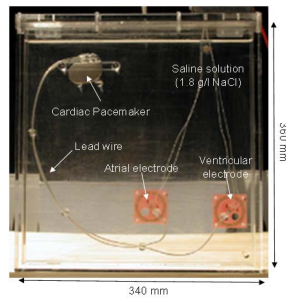
(a) Torso phantom for pacemaker EMI assessment
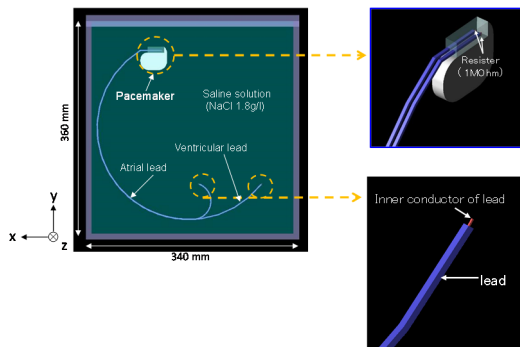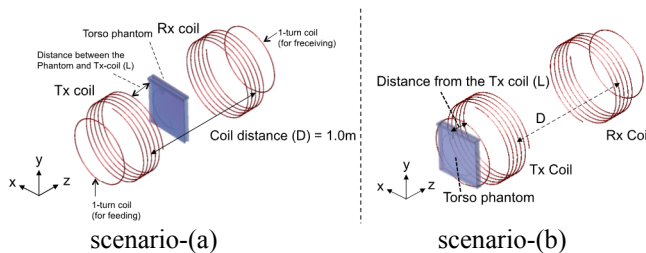

(b) Numerical model

Fig. 1. Torso phantom for pacemaker EMI estimation.

TABLE I
Dielectric constant and electric conductivity
of each material used in phantom model.

	ε	σ (S/m)
Pace maker, Lead	Perfect electric conductor	
Saline solution(1.8 g/l)	86.7	0.32
Silicon	2.7	0
Acrylic case	3	0

TABLE II
Simulation parameters.

Solver	Direct Solver
Frequency	8 ~ 13 MHz

scenario-(a)   scenario-(b)
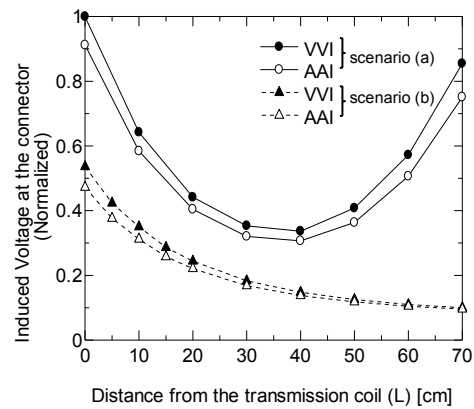
Fig. 2. HF-band wireless power transfer coils and human torso phantom.

Fig. 3. Simulation results of interference voltages in scenario-(a) and (b) when the position of the phantom is varied.

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