An Assessment Methodology of Implantable Medical Device EMI due to RFID Reader/Writers Based Upon the Three-Dimensional EMF Distribution Measurement

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Abstract

Electromagnetic interference (EMI) from commercially available RFID reader/writers on implantable cardiac pacemakers and cardioverter-defibrillator (ICD) were investigated. We have carried out detailed in-vitro experiments to assess the EMI due to RFID reader/writers for implantable medical devices (RFID/IMD-EMI). In this paper, an assessment methodology for the RFID/IMD-EMI based on three-dimensional EMF measurement of the RFID reader/writer antenna is proposed. The assessment results obtained by the new methodology are presented.

1. Introduction

The implantable medical device EMI is one of the most important issues to investigate for the improvement of their patients' quality of life. It is required to ensure safe environments regarding the EMI from various kinds of radio devices and electronic devices, which emit electromagnetic fields. There is a lot of research being carried out to investigate the EMI [1]. We have carried out detailed in-vitro experiments to assess the EMI due to RFID reader/writers for implantable medical devices (RFID/IMD-EMI) [2]. In addition, a novel experimental assessment methodology for RFID/IMD-EMI that is based upon magnetic field distribution is proposed [3]. By using the results of the in-vitro experiments and magnetic field distribution measurement, applicability of the proposed methodology have been confirmed. In this paper, a newly developed three-dimensional EMF measurement system for the RFID/IMD-EMI assessment methodology is presented. Firstly, in-vitro experiments to assess RFID/IMD-EMI are explained. Next, an RFID/IMD-EMI assessment methodology proposed so far is introduced. And, a developed three-dimensional automatic EMF measurement system is explained. Finally, accuracy of the assessment results obtained by using the measurement system is discussed.

2. In-vitro Experiments to Assess EMI Due to RFID reader/writers

To investigate characteristics of RFID/IMD-EMI, detailed in-vitro EMI test experiments have been carried out [2]. RFID/IMD-EMI occurs when the following two conditions are satisfied. First, the sensing circuit of pacemakers and ICDs receives a signal similar to an electrocardiogram (ECG) signal or receives obvious noise. Then, the disturbing signals' strength must be higher than the sensing threshold level. EMI due to low-band RFID reader/writers such as 125 kHz and HF (13.56 MHz) is assumed to be caused by alternating magnetic field from antennas. As shown in Table 1 and Table 2, EMI characteristics of 10 types of pacemakers and 3 types of ICDs from 6 types of commercially available low-band RFID reader/writer antennas are examined so far. The torso phantom employed for the experiments is a modification of Irnich's model as described in [2]. In the experiments, the maximum interference distance (distance where EMI disappears) is determined and recorded in centimetres.

3. EMI Assessment Methodology Based Upon 3-D Magnetic Field Distribution

Since the tissues of the human body are electric conductors, it is supposed that "one turn coil" is connected between different electrodes and indifferent electrodes of pacemakers and ICDs as shown in Fig. 1. The magnetic flux density through the coil varies when the alternating magnetic field is generated from RFID reader/writer antennas. Then, by following Faraday's law of induction, an electromotive force arises between the electrodes. When this electromotive force exceeds the pacemakers' sensing threshold level, they no longer detect ECG signals. To estimate this disturbing

noise voltage, the methodology calculates the total magnetic flux integrated across the pacemaker and lead wire cross-section [3]. A developed three-dimensional automatic measurement system is shown in Fig. 2. The constructed system enables fully automated measurements in high-throughput rate by controlling simultaneously the three-dimensional probe positioner and measurement instruments such as spectrum analyzer and probe amplifier. In addition, since the probe positioner is consists mostly of dry wood, absorption/reflection effects for EMF due to the probe positioner is very low. RFID reader/writer antennas usually have different shapes and field distributions depending on their purpose, operating frequency bands and their manufacturers. To measure EMF distribution generated around these various RFID reader/writer antenna, the measurement area used is 100 cm × 100 cm × 100 cm (width × height × depth). In addition, minimum spatial resolutions of all axes are 2 mm.

4. Results & Conclusion

The estimated induced voltage calculated from the measurement results using the three-dimensional automatic measurement system is shown in Fig. 3. The induced voltage of each antenna is slightly different in the area 0 to 10 cm from the antenna surface. To evaluate these differences quantitatively, statistical processing is carried out. As shown in Fig. 3, maximum interference distances plotted on the lines of induced voltage are almost the same. Standard deviations of induced voltage for each pacemaker's test mode are calculated. The evaluations are conducted for the 90 test modes, which are affected by more than two antennas. Test modes which are not affected, or affected by only one antenna are excluded from the evaluations. By using the automatic measurement system, frequency of standard deviation has a peak of 0.07 to 0.09 and the average value of standard deviation is 0.069, respectively.

To achieve more detailed EMI assessment, investigation of uncertainties of the proposed EMI estimation methodology will be carried out. Furthermore, to develop a computer simulation based EMI assessment method, the numerical modeling of the EMI test system and the EMF analysis will also be carried out. The Further results and discussions are shown in later.

6. Acknowledgments

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7. References

1. W. Irnich, L. Batz, R. Muller, and R. Tobisch, "Electromagnetic interference of pacemaker by mobile phones," PACE, vol. 19, pp.1431-1446, 1996.
2. S. Futatsumori, T. Hikage, T. Nojima, B. Koike, H. Fujimoto and T. Toyoshima, "In vitro experiments to assess electromagnetic fields exposure effects from RFID reader/writer for pacemaker patients," in Proc. BIOLOGICAL EFFECTS of EMFs 4th International Workshop, pp. 494-500, 2006.
3. S. Futatsumori, T. Hikage, T. Nojima, B. Koike, H. Fujimoto, and T. Toyoshima, "An experimental assessment on implantable medical devices EMI caused by magnetic flux distributions of low-band RFID reader/writers", in Proc. the 2006 International Symposium on Antennas and Propagation, TC1-4, p6, 2006.

Table 1: Implantable medical devices

Tested devices	Type of chambers	Number of devices
Pacemaker	Single chamber	5
	Dual chamber	5
Implantable Cardioverter-Defibrillator	Single chamber	1
	Dual chamber	2
Total		13

Table 2: RFID reader/writer antennas

Frequency bands	125 kHz	HF
Specifications	-	ISO/IEC 15693
Modulation method	ASK	ASK
Number of antennas	4	2

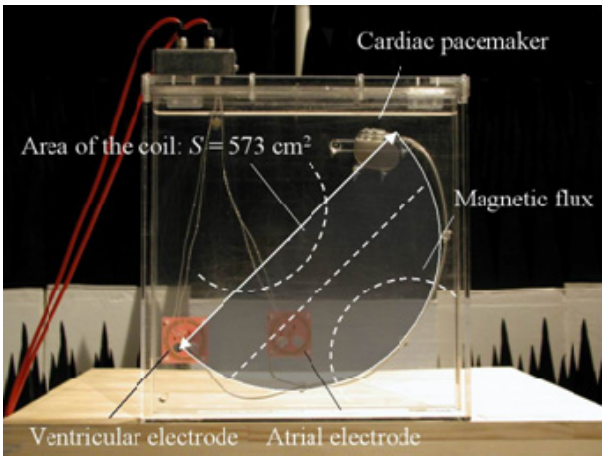

Figure 1: The torso phantom

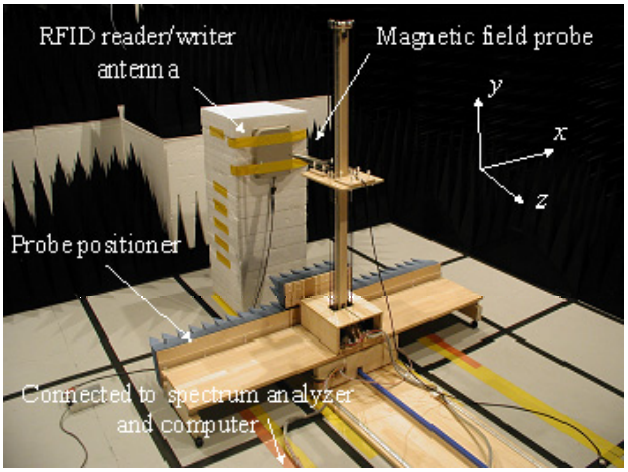

Figure 2: The three-dimensional automatic EMF measurement system

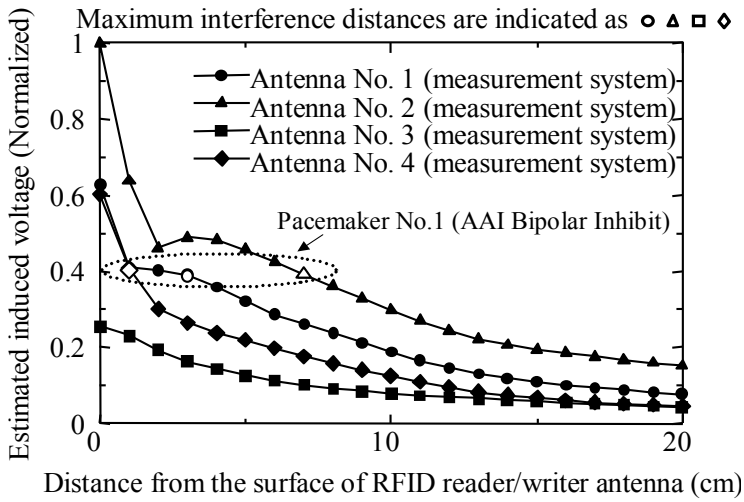

Figure 3: An example of a maximum interference distance plotted on the lines of induced voltage