Novel Interference Voltage Measurement for Beam-Type Wireless Power Transfer Using an Electro-Optical Converter for EMI Assessment of Active Implantable Medical Devices

Takashi Hikage, Suzune Ito, and Atsuki Ohtsuka

Abstract – In order to estimate electromagnetic interference characteristics on active implantable medical devices (implantable cardiac pacemakers or implantable cardioverter-defibrillators), we developed a novel measurement setup for the interference voltage using a directly modulated electrical-to-optical converter embedded in a pacemaker mock-up connecting actual pacemaker leads. Then interference voltage measurements in RF frequency band for beam-type wireless power transfer were taken using the proposed measurement setup.

1. Introduction

Wireless devices such as mobile phones, RFIDs systems, and wireless power transfer (WPT) systems are essential to creating the ubiquitous and universal network society. These devices emit electromagnetic fields (EMFs) that can potentially cause electromagnetic interference (EMI) for other electromagnetic devices.

The EMI on active implantable medical devices (AIMDs) such as implantable cardiac pacemakers and cardioverter-defibrillators (ICDs) is one of the most important issues needing detailed investigation [1–4]. This is because EMI on AIMDs can occur even with the potentially lower EMF level provided by the international safety standards for RF exposure. Furthermore, the number of AIMD users is increasing every year due to the aging of the population.

In this article, an interference voltage sensor for AIMD EMI assessment was developed using a directly modulated electrical-to-optical (EO) converter. Furthermore, measurement of the interference voltage of a pacemaker in the RF frequency band for beam-type wireless power transfer (RF-WPT) using the measurement setup is demonstrated.

2. Interference Voltage Sensor Using an EO Converter for AIMD EMI Assessment

EMI affects pacemakers/ICDs when the sensing circuit of the AIMD receives a signal similar to an electrocardiogram signal or noise and the signal's strength is higher than the sensing threshold of the device. The induced voltage on the internal circuit of the pacemaker/ICD by the received external signal is defined as *interference voltage*. If the interference voltage exceeds the pacemaker/ICD's sensing threshold, it may cause malfunctions. In order to assess pacemaker/ICD EMI from RF/EMF emitters, a human torso phantom, as shown in Figure 1, was used [4]. The torso phantom comprises a saline tank and electrodes. The saline tank is made of acrylic panels and is filled with a saline solution with an NaCl concentration of 1.8 g/L. The pacemaker was placed in the saline during the EMI assessment test in order to operate properly as if it were implanted in a human body.

It is very difficult to obtain the actual induced interference voltage on the internal circuit inside the pacemaker's enclosure (can) by measurement. We developed a novel interference voltage sensor by installing a small EO converter [5, 6] in the pacemaker can with a perfect waterproof structure. Figure 2 shows the configuration of the developed interference voltage sensor. Actual pacemaker leads can be connected to this sensor in unipolar mode. Induced voltage can be measured without disturbing electromagnetic fields, because the I/O signal of the sensor is made through

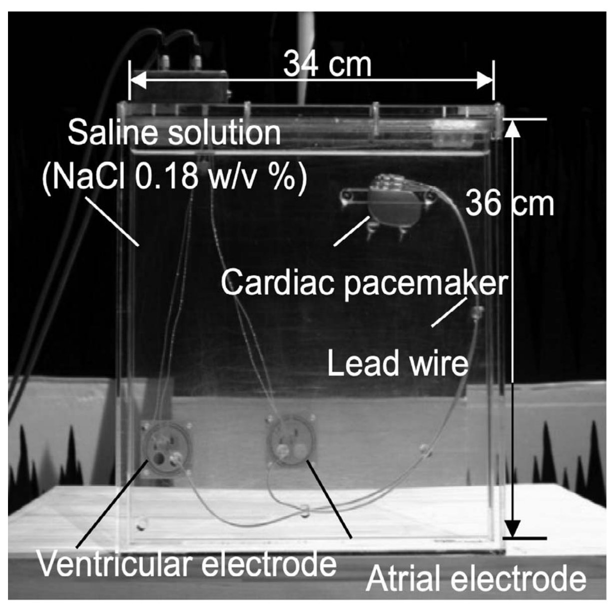

Figure 1. Torso phantom for AIMD EMI assessment.

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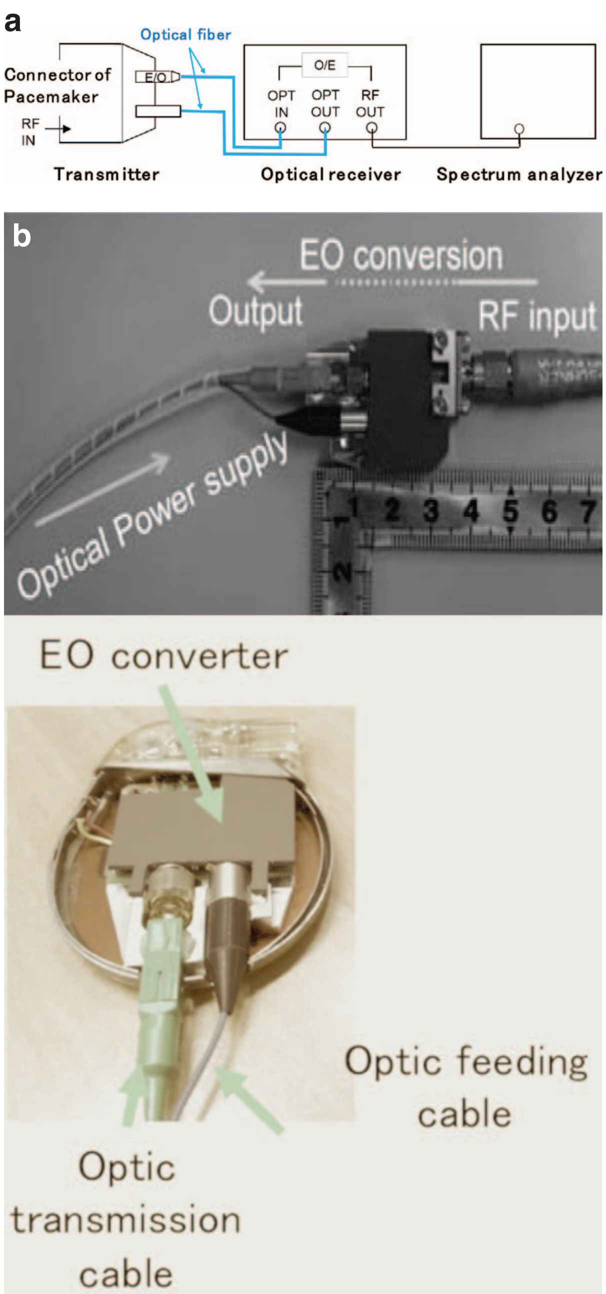

Figure 2. EO converter and developed interference voltage sensor. (a) Block diagram of EO converter; (b) overview of the developed interference voltage sensor for AIMD EMI.

optical fiber. The input impedance of the sensor is 50 Ω, and the minimum sensitivity is approximately –80 dBm. This sensor can be used in frequency ranges from 100 kHz to 6 GHz for WPT systems.

3. Measurement of Interference Voltage Due to a 915 MHz RF-WPT Antenna

As an example, we measured the interference voltage due to an RF-WPT base station emitting a 900 MHz–band RF wave using the developed sensor placed into the torso phantom. Figures 3 and 4 show the constructed measurement setup and the measured distance dependence of interference voltage, respectively. In the measurement, the antenna input power was 1.25 W and the antenna gain was 2 dBi. The interference voltages were measured with the RF-WPT station operating at 915 MHz in both vertical and horizontal polarization under near-field exposure. The error bars in Figure 4 represent the standard deviation of the data set of measurements repeated three times. Measured results confirmed that the developed sensor can obtain the interference voltage. From the figure, it was found that a vertically polarized signal produced interference voltage exceeding the threshold level for small distances from the antenna, while for the horizontally polarized signal the interference stayed under the threshold. These are the first data measuring the interference voltage signal due to 900 MHz–band beam-type WPT. Based on the measured data and AIMD EMI test data obtained using actual pacemakers and ICDs, we can simply predict the relationship between maximum exposure level and potential risk of AIMD EMI occurrence.

4. Conclusions

A novel interference voltage sensor for AIMD EMI assessment was developed by applying a directly modulated EO converter, and a novel measurement setup was constructed. To our knowledge, this is first report demonstrating measurement of interference voltage in the RF-WPT frequency band. In the future, the developed setup can be applied for other wireless systems.

5. References

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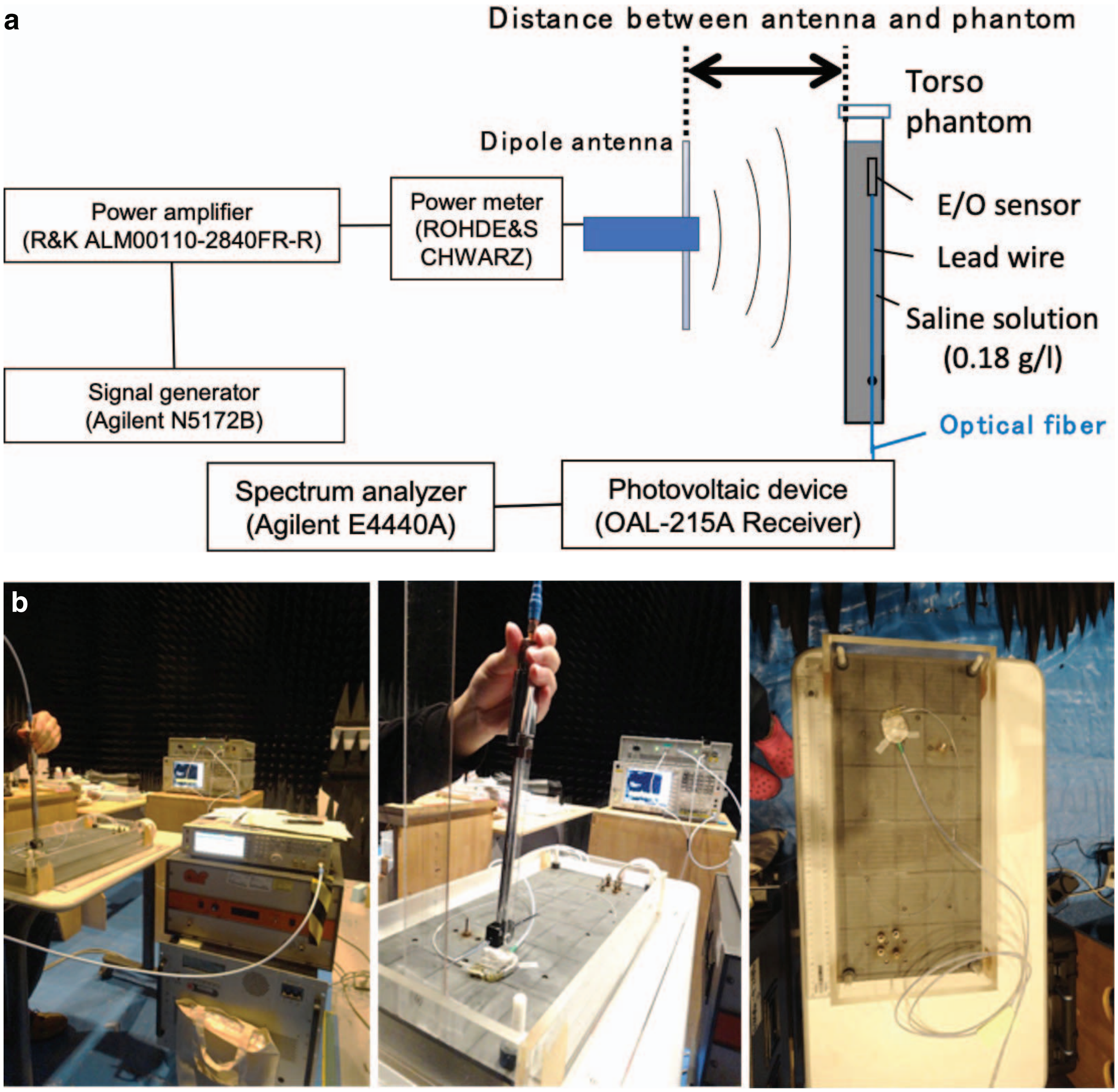

Figure 3. (a) Block diagram of measurement setup for interference voltage due to an RF frequency band for beam-type wireless power transfer; (b) overview of measurements of interference voltage.

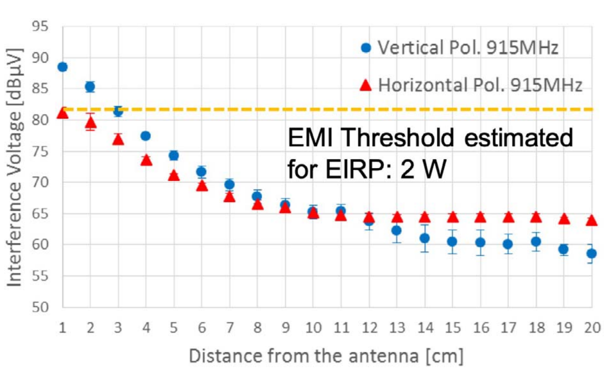

Figure 4. Measured distance dependence of interference voltage at RF-WPT frequency (915 MHz).