SAR Analysis Around an Implanted Cardiac Pacemaker Induced by EM Wave of VHF Band

Kazuyuki Saito and Soichi Watanabe
National Institute of Information and Communications Technology
4-5-1 Nukui-Kitamachi, Koganei, Tokyo 184-8795, Japan

Ryota Akiyama and Koichi Ito
Chiba University
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan

***Abstract*— Recently, electromagnetic interference (EMI) of an implanted cardiac pacemaker induced by a mobile radio terminal has been investigated. However, there are few studies of specific absorption rate (SAR) around the pacemaker induced by the mobile radio terminal. In particular, the SAR in such a case due to the electromagnetic wave of very high frequency (VHF) band has not been investigated. Therefore, the authors have been calculated the SAR distributions around the pacemaker model embedded into a torso model by a wireless radio terminal in VHF band. Moreover, the characteristic SAR distribution has been analyzed by the simplified model.**

Keywords—SAR; implanted cardiac pacemaker; VHF; plane wave; FDTD

I. Introduction

The implanted cardiac pacemaker is one of the medical devices for cardiac diseases such as irregular heartbeat, ventricular fibrillation, etc. and is implanted in the chest of patient (Fig. 1). Recently, electromagnetic interference (EMI) of the pacemaker with a mobile radio terminal has been investigated [1]-[3]. Based on these studies, national authorities have recommended that a mobile radio terminal should be kept 15 cm from the pacemaker in Japan. Meanwhile, SAR distribution in the body especially around the pacemaker, when the mobile radio terminal closes to chest of the pacemaker holder, has to be considered. In particular, in the case of using a wireless radio terminals in very high frequency (VHF) band, which are used in police officers, airport employees etc., it should be considered that the electromagnetic energy penetrates deep region of the operator body compared with the cellular phone because of longer wave length. Therefore, previously, the authors calculated the SAR distributions using a practical model based on a rectangular parallel pipe torso model. As a result of calculation, characteristic SAR distribution around the pacemaker was observed. In this study, the characteristic SAR distribution is analyzed by the simplify model constructed by an infinite torso model and plane wave.

II. Plactical Calculations

In the previous study, a rectangular parallel pipe torso model and a normal mode helical antenna operated at 150 MHz are employed. Figure 2 shows the analytical model. This model is precisely constructed using 0.1 × 0.1 × 0.1 mm voxels for representation of the helical antenna. Some other detailed information of the model are described in [4].

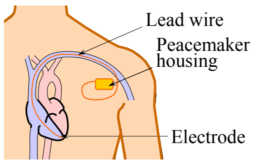


Fig. 1. Implanted cardiac pacemaker.

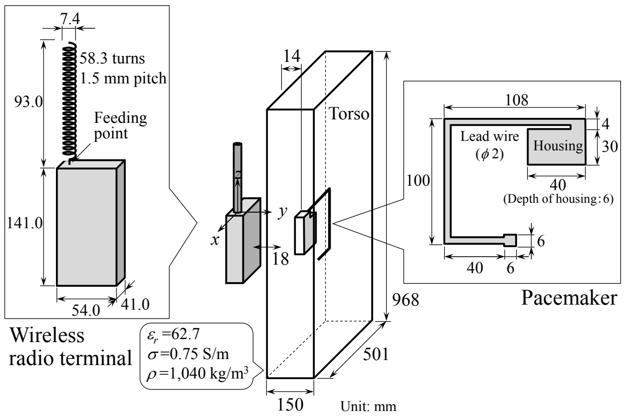
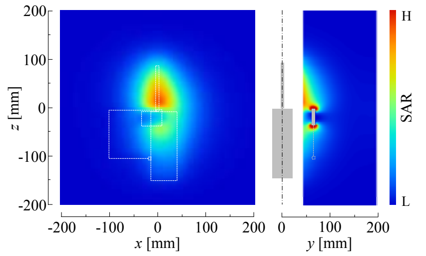


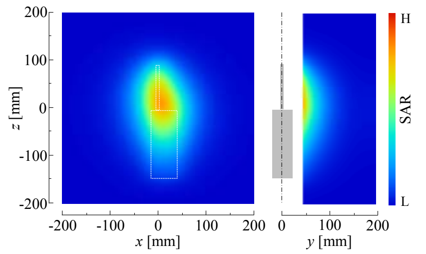
Fig. 2. Practical calculation model.

Figure 3 shows the calculated SAR distributions around pacemaker model. Here, SAR observation planes are *y*-*z* plane at *x* = 0 (including the feeding point of the VHF wireless radio terminal model) and *x*-*z* plane at *y* = 40 mm (surface of the torso model). Moreover, Fig. 3 (b) is the SAR distributions without pacemaker model for comparison.

From Fig. 3 (b), high SAR value is observed at the surface of the torso model just beneath the antenna feeding point. On the other hand, in Fig. 3 (a) (*y*-*z* plane), high SAR values appear at inside the torso model and are around both edges of the pacemaker model (around *y* = 70 mm, *z* = 0 and -30 mm at *x* = 0). Moreover, in the *x*-*z* plane, although the pacemaker model is not exposed on outside of the torso model, both surface SAR distributions are different. It is considered that the surface SAR distribution is affected by the reflected



(a) with pacemaker model.



(b) without pacemaker model.

Fig. 3. Calculated SAR distributions by practical calculation model.

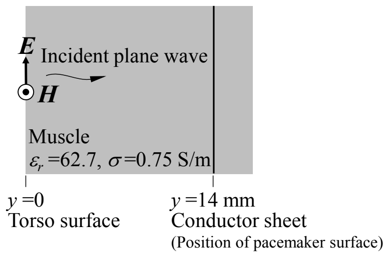


Fig. 4. Simlpified Calculation model.

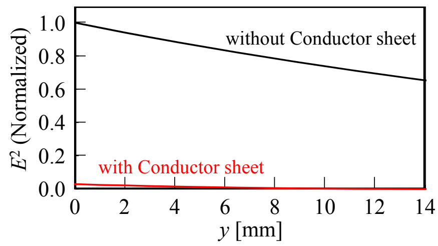


Fig. 5. Calculated E^2 distributions.

electromagnetic wave at the surface of the pacemaker model composed of the perfect electric conductor.

III. SAR Analyses

A. Simplified Model

In order to understand the mechanism of the SAR reduction at the torso surface, an analytical consideration will be employed. Figure 4 is a simplified calculation model for the analysis. This model is constructed an infinite muscle part and conductor sheet. The wave source is a plane wave for rough assumption. In addition, the pacemaker model is replaced by infinite conductor sheet.

In the model, incident plane wave can be expressed

$$E = E_0 \exp(-jky) \tag{1}$$

where, E_0: strength of electric field at the muscle surface [V/m], k: wave number [1/m], and y: position from the muscle surface [m]. At the surface of the conductor sheet, the incident wave reflects with phase reversal. Moreover, the reflected wave reflects at the muscle surface and the multiple reflected wave will be generated. In this way, it is considered until 3rd reflected wave.

B. Calculated Results

Figure 5 shows calculated E^2 distributions, which are proportional to the SAR. In this figure, vertical and horizontal axes indicate the E^2 and position from the muscle surface, respectively. From the results, the E^2 values without conductor sheet are completely larger than the case with conductor sheet. It is considered that the results of destructive interference between the incident and reflected waves. Therefore, it also can be said that the same phenomenon has been observed in Fig. 3 (a).

IV. Conclusion

In this study, the SAR distributions around the implanted cardiac pacemaker embedded into the torso model by the VHF wireless radio terminal model are introduced. Moreover, characteristic SAR distribution under the condition has been analyzed by the simplified model. From the result of analysis, it is found that the characteristic SAR distribution is generated by the reflected wave at the pacemaker surface. The SAR distributions under more practical situations will be calculated as our further study.

Acknowledgment

A part of this research is financially supported by the Ministry of Internal Affairs and Communications in the government of Japan.

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