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Design of implanted PIFA for implantable biotelemetry locations: chest and abdomen

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Abstract

This paper presents a planar inverted-F antenna (PIFA) worked for implanted biotelemetry medical devices such as cardiac pacemaker. The implantable antenna operates in the 403.5 MHz, MICS band. Two commonly implanted locations, the upper chest and the center of abdomen, are selected to evaluate the antenna performances. The specific absorption rate (SAR) and radiation characteristics have been studied to determine the effect on the human tissue. The distances between an implanted antenna and the skin have been studied. The PIFA are implanted first in the three-layer phantom and then the realistic man model later. The comparative results of simulations and measurements are analyzed and presented in this study.

Keywords: Biotelemetry medical devices; Pacemaker; the three-layer phantom; Specific absorption rate (SAR).

1. Introduction

Implanted biotelemetry has become one of the important roles for medical treatment to improve the quality of human life and minimize restrictions on daily activities. Considerable researches have been done on the telemedicine and wireless implanted devices[1,2]. Some platforms have been designed for healthcare providers to monitor physical conditions, while some units are used for tuning the medical devices inside the patients[3,4]. Because medical implants such as pacemakers, implantable defibrillators and therapeutic have wireless medical sensors inside their package, there are concerns regarding on the safety from a radio wave that could possibly harm biological human tissues surrounding the implanted area. Many researches have been done to investigate the effect of the specific absorption rate (SAR) from both electric and magnetic fields[5]. Various exposure models with different scenarios and conditions were carried out such as gender, age, and size. Moreover, the effects from different implanted locations have been tested to justify the rate of energy absorbed in biological tissue.

To effectively minimize the radiation effect from electromagnetic field, the degree of power handling must be limited. According to the regulators such as European telecommunications standards institute (ETSI) and the federal

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communications commission (FCC), two frequency bands were evaluated for the possible maximum field strength with respected to SAR limits. The first band is the Medical Implant Communication System (MICS), at 402-405 MHz. This band has the benefit of being reserved mainly for medical and metrological applications. For safety, the international telecommunication union-radiocommunication sector (ITU-R) recommends that the maximum EIRP must be limited to the power set in each standard. The standard of telemetry system for the implanted antenna has margins of 17.5 to the MICS.

For the implantable wireless sensor for implanted medical devices, the antenna must be small, durable, efficient and attachable on the existing unit. Anther necessity is the antenna must provide the low SAR level for both frequency bands. Miniaturized antennas are definitely needed in the near future, as the dimension of implanted biotelemetry becomes smaller and smaller. Consequently in this paper, we designed a miniature implantable planar inverted-F antenna (PIFA) corresponding to 403.5 MHz band. The optimization technique such as artificial intelligent (AI) was applied, and performances such as the operating frequency and the return loss were tuned to meet the requirements. In order to determine the antenna performance and its radiation characteristics, two common implanted areas, chest and abdomen have been chosen. The results of radiation characteristics such as SAR, temperature rise, and far fields are studied.

2. Method of Analysis and Evaluation

To evaluate and compare the radiation characteristics of a smaller miniature implantable antenna are the objectives of this study as it has a potential use for the future biotelemetry devices. The genetic algorithm (GA) is applied to tune a serpentine shape because it has a smaller dimension when compared to other antennas. The simulant locations are around the upper chest and the center of the abdomen area as shown in Fig. 1. The antenna was first simulated in a simple rectangular 100 x 100 x 35 mm^3 model representing the realistic human tissue to achieve the desired frequency bands. Later it was embedded in the realistic chest and abdomen models to verify the effect of human tissues to the radiation characteristics and performance of the antenna. The realistic phantom has a dimension of 500 x 450 x 280 mm^3 with the grid size of 1 x 1 x 1 mm^3. The mesh has 22 different tissues. The substrate and superstrate materials are the RO3210 woven-glass reinforced PTFE laminate (εr=10.2, tanδ=0.003) from Rogers Corporation. All simulations were done by using the finite different time domain (FDTD) method from the XFDTD software provided by Remcom Corporation.

Compared to the previous model, which has the size of 27 x 22 mm^2, the antenna dimension was 22 x 20 mm^2 for matching the new pacemaker unit (which is 30 x 26 x 10 mm^3). Few constrains were applied to enhance the optimization process and its convergence speed. The numbers of GA chromosome parameters are totally 18, as each arm has its own width and length. The iteration is 100, unless the requirement, which is the return loss (S11) equal to -15 dB, is met. Both substrate and superstrate have dimensions of 30 x 26 x 1.27 mm^3. The implanted unit was analyzed in two different locations to interpret the SAR responses. Instead of using the realistic phantom, which provides the similar results to a three–layer structure, but process much longer simulation time, the stimulant geometry is built based on a three–layer structure as following; a skin layer followed by a fat layer, and finally a muscle layer. The thickness for each layer is 3 mm, 6 mm, and 26 mm for the chest, and 2 mm, 8 mm, and 25 mm for the abdomen. The simplified three-layer model is shown in Fig. 1. The PIFA was placed between the skin and muscle tissues within the superstrate layer underneath the skin. The practical distances between the antenna and the chest or abdomen skins were evaluated and made at 3 mm and 5mm. The gaps with each of the various combinations of tissue thickness were aim to obtain the location effects.

The prototyped PIFA was build, and tested in a simulated fluid, which has the dielectric permittivity of 42.8 and the conductivity of 0.64 S/m. It is slightly off from the 2/3 of muscle used in the simulation. Various parameters such as the operating frequency and the radiated power were compared and verified. The absorbed power equation with the conductivity and the electric-field intensity is calculated for the 1-g averaged SAR distributions.