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# A dual-band compact microstrip patch antenna for 403.5 MHz and 2.45 GHz on-body communications

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## Abstract

In this paper, a dual-band microstrip patch antenna (MPA) is designed as the wireless body-area networks (WBANs) sensor. The antenna working at 403.5 MHz and 2.45 GHz, located in the medical implant communication services (MICS) band and the industrial, scientific and medical (ISM) band, is presented and studied. The upper chest, a commonly implanted location within a realistic on-body environment, is selected to evaluate the antenna performance using the finite-difference time-domain (FDTD) and the genetic algorithm (GA) methods. Antenna characteristics such as the return loss are analyzed. Comparative results of simulations and measurements are presented.

*Keywords:* Implantable medical devices; implantable antenna; microstrip patch antenna.

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## 1. Introduction

Modern technologies such as smart devices and smart phones became the common tools for health care professionals to communicate with their clients. Moreover with better network infrastructure and ultra-high-speed internet, the biotelemetry technology combining wireless body-area networks (WBANs), wireless sensor networks (WSNs) or wireless personal area networks (WPANs) together has introduced. These smart devices are one of the keys for the future medical telemetry as their functions connectable to wearable medical devices, and thus enable the potential for the tele-home healthcare. With the better network systems and sensors, a patient or a healthcare provider can set up a telemetry link between the biosensor platform and a hospital information system (HIS) to upload and download data. Biotelemetry devices takes a huge benefit as they require frequently monitors or continuous records to set up or define parameters for information exchange, sharing, and retrieval of electronic health information. These include implants such as pacemakers, neurostimulator and therapeutic.

The WBANs basically have two modes, the on-body communication and the off-body communication. These two scenarios refer to the communication between the wearable electronic sensors on the human body, and the

communication between the sensor and the base station or external devices. Therefore the wearable biosensors need to be able to perform well for on-body and off-body scenarios. The wearable sensor has couple advantages over the conventional implantable sensor, especially on the specific absorption rate (SAR) level as an electromagnetic wave radiated from the wireless implanted devices have a potential to damage the surrounding body tissues. Traditional inductive coils with the coupling method have their disadvantage as the data rate and the communication range are very limited. In order to improve the telemetry performance, the European Telecommunications Standards Institute (ETSI) and the Federal Communications Commission (FCC) recommend two frequency bands for a better transmission range and a faster transfer rate. The 402–405-MHz, medical implant communication service (MICS) band, for ultra-low-power active medical implants and 2.45 GHz, industrial, scientific and medical (ISM) band, are chosen as the operating frequency to resolve the short-range issue.

To effectively take the advantage of WBANs and new allocated frequency bands, many researches have focused on designing the microstrip patch antenna (MPA) or planar inverted-F antenna (PIFA)<sup>1,2</sup>. These antenna types are small, durable, low SAR level and mountable on the existing implant hardware<sup>3</sup>. However, most of them were designed to operate a single-band frequency<sup>4</sup>. In addition to design a dual-band wearable sensor, the antenna structure should be able to bend slightly along with the human body surface. In this paper, we presented a dual-band MPA corresponding to 403.5 MHz and 2.45 GHz, in order to determine the radiation characteristics on the human body (i.e. chest or abdomen). The patch antenna was designed by using the finite-difference time-domain (FDTD) method, and the optimization technique is applied to tune its performance. The results of return loss characteristics are studied.

## 2. Method of Analysis and Evaluation

The main objective of this paper is to evaluate and compare the return loss characteristics of a dual-band MPA which have a potential to use for the wearable medical sensor with the off-body and on-body modes. The MPA was chosen instead of the planar inverted-F antenna (PIFA) due to the reason that the signal and ground pins can possibly be shorted. The antenna was designed and tested on a simplified two different simplified models, the 2/3 of muscle model and the simplified three-layer model, using the XFDTD software provided by Remcom. As the antenna was proposed for the on-body operation, the radiating side should be faced down on a skin area. Ideally to minimize the additional impedance at the contact surface, it is better for the antenna structure to be able to bend slightly. Therefore the RO3210 ( $\epsilon_r=10.2$ ,  $\tan\delta=0.003$ ) with the thickness of 1.28 mm was used. Household silicon (same dielectric properties as medical-grade silicon) with the thickness around 2 mm was covered as the superstrate to prevent the body on shorting out the antenna. The MPA was firstly simulated on a simplified homogenous material and then later on a three-layer model as shown in Fig. 1.

The general features of the geometry models are as follows: the substrate dimension is 46 x 60 x 1.28 mm<sup>3</sup> and the superstrate is 46 x 60 x 2 mm<sup>3</sup>. In order to design an antenna that worked for the body channel communication (BCC) and could perform the dual-mode communication well, the overall dimension has to become larger than the conventional size as the ground plane needs to get bigger. The patch is centered mounted on a 100 x 100 x 35 mm<sup>3</sup> simplified model. For three-layer model it consists of a skin layer, a fat layer and a muscle layer with thicknesses of 3 mm, 6 mm and 26 mm, respectively. The serpentine shape was chosen as it has advantages over the spiral shape and the waffle-type shape such as better field distributions<sup>5</sup>. The genetic algorithm (GA) is applied to optimize the antenna performance by adjusting each arm's length and width. The cost function of this study is the return loss ( $S_{11}$ ) equal to -10 dB on both frequency bands. The antenna was optimized in the simple homogeneous structure to reduce simulation time as the difference of the radiation characteristics and performance between in the homogeneous model and a simple four-layer model and the realistic human phantom are acceptable. The simulated body phantoms were defined as a homogenous material with a dielectric constant of 42.8 and a conductivity of 0.64 S/m (the electrical properties given are 2/3 those of pure muscle) and the simplified three-layer model. The dielectric properties of tissue materials are presented in Fig. 1. The effect of dry skin and moist skin was tested. As moistening skin provides a stronger coupling to an antenna and moreover it can possibly also reduces the effect of skin layers. This property can somewhat affect the whole WAN performance. Dry skin has a relative permittivity of 46.7 and a conductivity of 0.64, while moist skin has a dielectric constant of 50.2 and a conductivity of 0.7<sup>6</sup>. Therefore comparing the antenna parameters from the model for dry and saline-moistened skin was appropriated. The simulate

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