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Original Research Article

Design and miniaturization of dual band implantable antennas

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ABSTRACT

Two types of miniaturized dual band implantable antennas are designed and presented, one of a meander type and the other is the so called comb antenna. In medical applications the electromagnetic characteristic changes of tissue in different situations and the corresponding resonant frequency shifts, should not disturb the data transmission. The objective is to design dual band antennas in 400 MHz and 2.4 GHz with suitable bandwidths and small sizes. The meander type antenna was fabricated and its S parameters were measured using an equivalent liquid phantom of skin, fat and muscle which included propanol, butanol, purified water and salt. The experimental results are shown and compared.

1. Introduction

Implantable antennas have remarkable impact on medical and engineering fields. Applications of implantable antennas in inbody and onbody communication systems are noticeable these days. The possibility of collecting vital data of a body such as blood pressure, sugar and heartbeat or reprogramming of implanted set through wireless communication made them unique. These medical fields have been discussed since 2004 and have reduced the need for operations in implantable devices [1–3]. These antennas are applied in many fields such as implantable medicine, excitation of nerve system and when communication is needed in medical applications. For example when it is needed to inform the doctor in emergency situations or when implantable devices such as pacemakers or implantable drug releasers need reprograming without a new surgery. Finding location of patients with Alzheimer's disease or recognition of people by these implantable devices using wireless connection (for example, instead of using debit cards in purchases) are other applications of these devices. All these applications need suitable antennas to connect the implanted devices to information center. To design these types of antennas, many conditions should be considered such as

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specific absorption rate (SAR) and dimensions' limits, bio compatibility and low consumption, due to small batteries in these systems. The most important criteria is the size of these types of antennas, since these sets should not disturb patients in any circumstances. Implantable antennas have advantages such as small size, more versatility and usable distance in comparison to old conductive sets.

Another factor before design of the antenna is the frequency band selection. Two frequency bands have usually been used since beginning of implantable antennas. These bands are 402–405 MHz and 2.4–2.485 GHz. Lower frequencies can be used for long distance and high frequencies correspond to high speeds. To design multiple band antennas, microstrips are the best, they are light, small and inexpensive.

As for previous works, a helix implantable antenna working in 400 MHz is illustrated with a 4 MHz bandwidth [5]. This narrow bandwidth (BW) is the weakness of the antenna since any condition that changes the resonant frequency makes the antenna useless. Some dual band antennas working in 400 MHz and 900 MHz with 40 MHz BW in both bands is shown in [6,7]. Other dual band radiators are discussed in [8], and operate at 400 MHz and 2.4 GHz with 50 MHz bandwidth in each frequency band. In this paper we designed two dual band antennas. Miniaturizing implantable antennas is of prime interest, since these implantable antennas should not disturb the person in movements. Both designs have improved BW in comparison to recent works. Because these antennas are implantable inside a body and due to variations in electromagnetic characteristics of tissues in different conditions and individuals, the center resonant frequency can change. As a result, a lower BW could affect impedance matching at the antenna terminals and disable the system. Therefore, more BW can guarantee stable data connection in any circumstances. Our designed antennas are smaller than most previous works, yet, they have more bandwidths. In next sections, design, implementation, the phantom, results and measurements are presented.

2. Environment and design

To design dual band antennas, one should choose the environment first. Our antennas are implantable in fat tissue of arm and chest. To design the antennas, three layers phantom including skin, fat and muscle is chosen. EM characteristics of these tissues are dispersive. Dispersive models are based on Gabriel articles in literature and are considered in the software. As an example characteristics of tissues at 2.4 GHz are given in Table 1 [9,10]. CST was used to design and the dimensions of the phantom are optimized for stable and reliable results. Increasing phantom dimensions results in better simulation accuracy but also increases simulation duration. Therefore, we have chosen the dimensions such that by increasing the dimension even twice, changes in the result remain lower than 0.1 percentage. The dimensions of phantoms are about 5 cm × 5 cm. Superstrate is used in addition to the substrate layer to avoid contact of antenna and conductive tissues. With the proper selection of feeding point, the input impedance of all both designs are 50 Ohms.

Table 1 – EM characteristics of tissues at 2.4 GHz.

Tissue	ϵ_r	σ (s/m)	μ_r	Thickness (mm)
Skin	32	2	1	4
Fat	4.6	0.84	1	4
Muscle	58	0.58	1	8

EM characteristics of substrate and superstrate at 2.4 GHz used are shown in Table 2 [11]. Rogers 3003 is used in our first design and Rogers 3210 is used in the second design. In each design, the first step is specifying the path corresponding to the first resonant frequency. The second resonance is added by extra branches to the structure. Other methods used in antennas, are previously reported [12–14].

2.1. Antenna I

This configuration was designed using Rogers 3003 with a height of 1.52 mm. The basis of the design is meandering the current path. The meander structure is bent to decrease, even further, the length and increase stiffness of the antenna. Extra branches are added to achieve dual band performance.Adding branches is chosen for miniaturizing the Antennas even more. Best location for inserting the branches are selected based on two matters. First the antenna is analyzed without extra branches. The points with maximum current and E field between existed branches are specified. Based on distances between the feeding point and the selected points we can manipulate each resonant frequency. Closer point to the feeding point influences more the resonant frequencies in higher frequencies. The impact of farther points is dominant on lower resonant frequency. Adding extra branches in the selected point increases the capacitance between previous branches of antenna and reduces the resonant frequency and consequently antenna size and tunes each resonant frequency. Although this method can miniaturize the structure about 40%, the antenna is slightly longer than next design due to the lower permittivity of the substrate [15]. The dimensions of the antenna are 3.04mm × 1 cm × 1.65 cm. The geometry of this antenna is shown in Fig. 1.

2.2. Antenna II

The idea of antenna II is new and the geometry is called comb antenna because of the antenna configuration. This configuration has a better bandwidth from the previous geometry. Rogers 3210 with a height of 0.7 mm is selected for the substrate. Unlike other geometries, in comb antenna the input port is located in the beginning of the geometry, where the input impedance is 50 ohm. The dimensions of this antenna are 1.4mm × 1.2 cm × 1.2 cm and its geometry is illustrated in Fig. 2.

Table 2 – EM characteristics of substrates.

Substrate	ϵ_r	μ_r	tgδ
Rogers 3003	3	1	0.0013
Rogers 3210	10.2	1	0.0027

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