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Biocompatible, Implantable tri-band PIFA Antenna for Biomedical Applications

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Biocompatible, Implantable tri-band PIFA Antenna for Biomedical Applications.

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***Abstract*— In this paper, a biocompatible tri-band inverted F antenna was proposed for wireless data telemetry and power transmission operation. This antenna will be implanted in human body. This surrounding medium witch having the properties of biological tissues will be considered. The proposed antenna covers three bands: MedRadio (401 – 405)MHz, and ISM (902.8 – 928)MHz, and ISM (2.4 – 2.5) GHz. The antenna is inserted in the biological tissue, The dimensions of the proposed antenna are $16 \times 11 \times 1.27mm^3$. The presented antenna is printed on Roger RO3210 substrate with dielectric constant $\varepsilon_r = 10.2$ and tanδ=0.003.**

Keywords*— *PIFA antenna, Implanted antenna, MedRadio band, ISM band, Biological tissue.

I. INTRODUCTION

With the rapid development of wireless medical field, implantable devices has received much attention of the researchers due to their applications for the continuous monitoring of human health [1]. The implantable medical device is an electronic component which is inserted, surgically, inside a human or an animal body. This device is composed of several components such as a battery, sensors, and an antenna. Among all these components, the antenna plays the most important role to ensure the communication link from the implant inside the body to the external receiver [2]. The implant requires a wireless communication link because the wired links are uncomfortable and may cause infection to the patient [2]. Previously, inductive coupling was most popular and effective means to realize link in biomedical devices for low frequencies. Actually, the link between the monitoring system outside the human body and the implant is ensured using implantable antennas. In [3], a complete wireless power transfer system (WPTS) has been proposed for medical applications to transmitting data and recharging the batteries of the device. An ultra-wideband with bandwidth of 1533MHz implantable antenna has been designed for biomedical applications in [4]. A MIMO implantable antenna based on meandered resonators has been introduced in [5] to be used in medical implantable devices. In |6], M. Singh proposed a dual-antenna operating at 2.4-2.48 GHz ISM band for biotelemetry application.

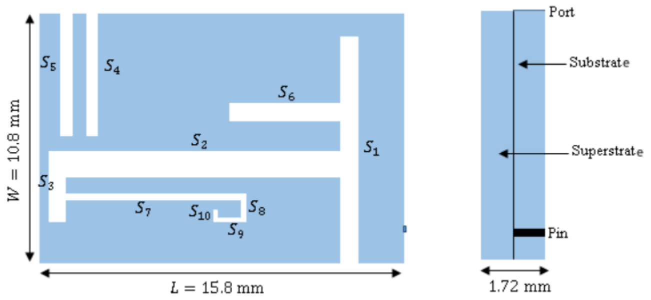
The medical implant requires a miniature antenna for wireless communication to ensure patient comfort. Planar inverted F antennas (PIFA) are typically used for implantable devices due to their convenience in miniaturization [7], [8]. In [9], a miniaturized PIFA antenna with a compact size of $10 \times 10 \times 1.905\ \text{mm}^3$ has been designed and fabricated for biotelemetry applications. A triple-band implantable PIFA antenna has been introduced in [10] to operate at MedRadio band (401–406 MHz) and ISM bands (902–928 MHz and 2400–2483.5 MHz). A PIFA antenna operating at ISM band (2.4 GHz) is designed and optimized in [11] to study the effect on the implantable antenna by placing it within the human body model, particularly in the arm.

In our paper, we present a novel tri-band PIFA antenna inserted in the human body radiating at three frequency bands: wireless data telemetry and power transmission operation in the radiocommunication service band of medical devices (MedRadio 402 – 405 MHz), power transmission (ISM Industrial Scientific and Medical) in the 902.8 – 928 MHz and 2.4 – 2.5 GHz bands.

II. ANTENNA DESIGN

The proposed tri-band implanted PIFA antenna is shown in Fig. 1. The radiating element is located between two identical dielectric layers: the substrate and the superstrate Rogers RO3210 , whose dielectric constant is $\varepsilon_r = 10.2$ and $\tan\delta = 0.003$ and a thickness of 0.635mm. The antenna is configured as a structure with a size of $16 \times 11 \times 1.27\ \text{mm}^3$. The rectangular radiating element has a surface area of $15.8 \times 10.8\ \text{mm}^2$ and contains ten slots.

The rectangular slot (S1) of length $l_1 = 10.2$ mm and width $w_1 = 0.9$ mm is split to have the antenna radiation in the MedRadio band at 402 MHz, Two other slots (S2, S3) are sampled to create radiation in the ISM band (915 MHz) with dimensions ($l_2 = 12.9$ mm, $l_3 = 1.9$ mm) and non-uniform width ($w_2 = 1.3$ mm, $w_3 = 0.8$ mm), a turn composed of four rectangular slots (S7, S8, S9 and S10) of total length of 10.8mm ($l_7 = 8.1$ mm, $l_8 = 1.3$ mm, $l_9 = 0.9$ mm, $l_{10} = 0.5$ mm) and irregular width ($w_7 = 0.35$ mm, $w_8 = 0.5$ mm; $w_9 = 0.19$ mm, $w_{10} = 0.2$ mm) and the slot (S6) with the length of $l_6 = 5$ mm and a width $w_6 = 0.9$ mm are removed to create a third resonance at the frequency (2.45GHz), it is important to mention that the slot (S7) plays a very important role in creating this resonance. The two identical apertures S4 and S5 are removed to introduce the feed through the transmission line, the width of the line is $w_4 = 0.58$ mm and its length is $l_4 = 5.4$ mm.



(a) (b)

Fig. 1. a). Top view. (b). Side view of the proposed tri-band implanted PIFA antenna

The PIFA antenna is placed inside the cylindrical arm tissue model at depth d = 10 mm. the arm consists of three layers: skin (thickness 2.5 mm), muscle (thickness 25 mm), and bone (thickness 22.5 mm). The properties of the 3 layers of tissue are given in the table I.

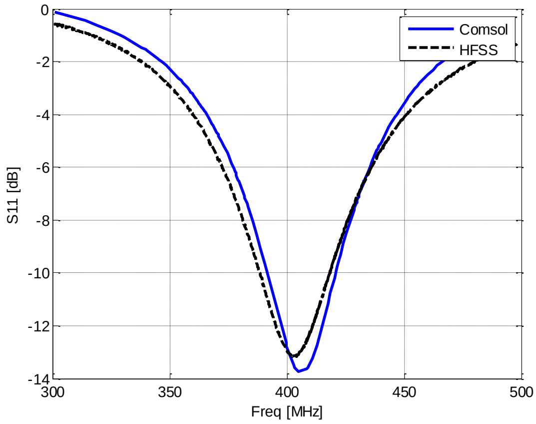
TABLE I. PROPERTIES OF THE TISSUE LAYERS

	402MHz		**915MHz**		**2.45GHz**	
	ε_r	σ	ε_r	σ	ε_r	σ
Skin	46.741	0.6889	41.329	0.8716	38	1.46
Muscle	57.112	0.7960	54.997	0.9480	52.72	1.73
Bone	13.143	0.0910	12.440	0.1450	18.54	0.8

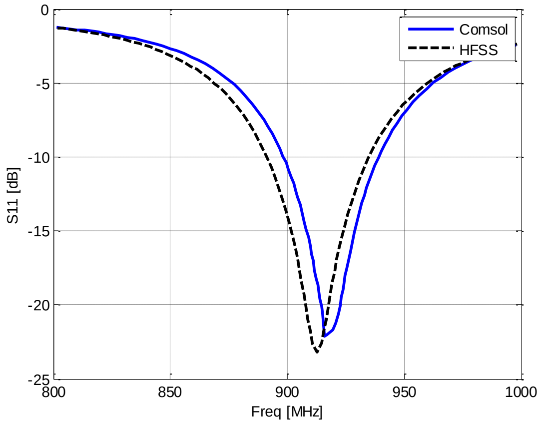
III. RESULTS AND DISCUSSION

A. *Reflection coefficient*

The antenna is designed and simulated using Ansys HFSS and Comsol Multyphisics. The simulated reflection coefficient is illustrated in Fig. 2. It can be seen that the simulated results using HFSS agree well with the results using Comsol. As seen, the proposed implanted antenna covers three bands MedRadio (402MHz), and ISM (915MHz and 2.45GHz), with impedance bandwidth of 30 MHz (7.46%), 40 MHz (9.95%) and 180 MHz (7.34%) respectively.



(a)



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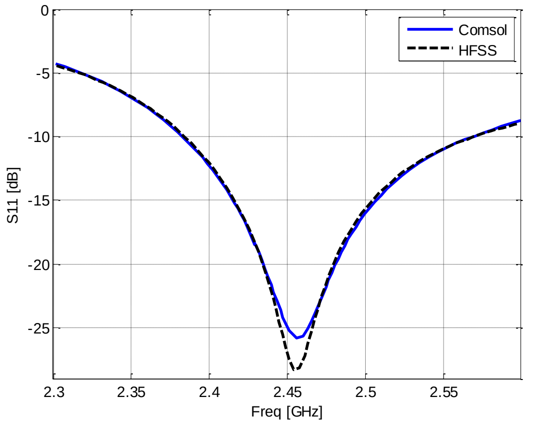
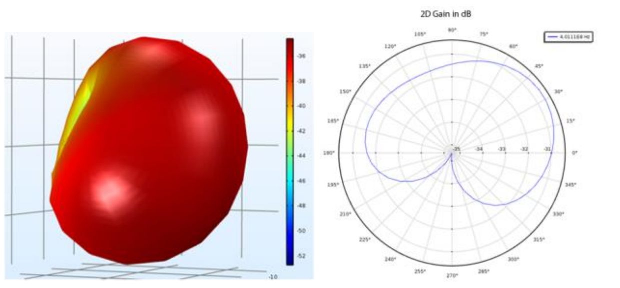


(c)

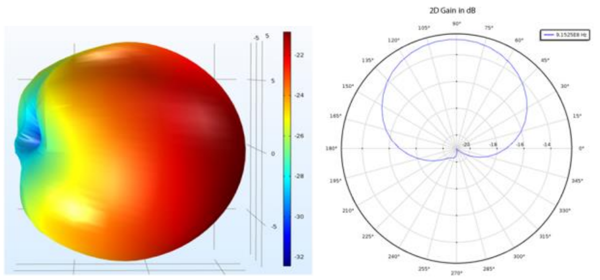
Fig. 2. Return loss of the proposed tri band implanted PIFA antenna in a). MedRadio, b) ISM (915 MHz) and c) ISM (2.45 GHz) band.

B. *Far Field Gain*

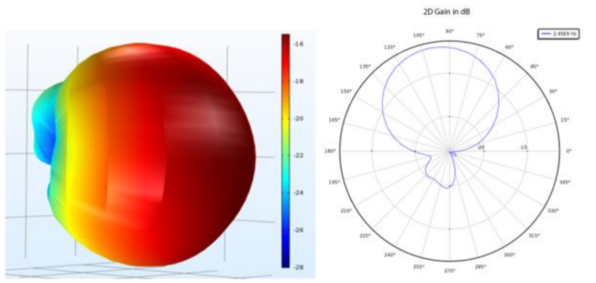
Fig. 3 shows the radiation pattern in 2D and 3D of the proposed implanted antenna in the different resonant frequencies. For the three frequencies, the radiation is in the off-body direction with maimum gain of -35 dB in the MedRadio band, -21 dB and -15 dB for the ISM band (915 MHz and 2.45 GHz respectively). These values of the gain are due to the height losses in the biological tissue surrounding the implantable antenna.



(a)



(b)



(c)

Fig. 3. Three (Right), Two (Left) dimensional gain pattern of the tri-band implanted PIFA antenna at a). MedRadio (402 MHz), b) ISM (915 MHz) c).ISM (2.45 GHz) band.

C. Biocampatibility

Biocompatibility is a term used to describe the capability of an implanted prosthesis to exist in harmony with surrounding tissues[12]. In order to insure the patient's safety, it is necessary to use the biocompatible implantable device for long life operation. Two ways are used to make device biocompatible: biocompatible encapsulation where the antenna is covered by a biocompatible layer. or use biocompatible substrate and superstrate. For our study, we use the second method to test the biocompatibility of our antenna. Two substrate and superstrate materials are used (Roger RO3210 ($\varepsilon_r = 10.2$ $\tan\delta = 0.003$) and Alumina ($\varepsilon_r = 9.4$ $\tan\delta = 0.006$)) without any changing in the antenna design.

Fig. 4 presents the return loss of the proposed antenna using the two biocompatible substrates and superstrates. A slight frequency increase is observed when we use the alumina material; which can be attributed to the slightly lower permittivity of alumina as compared to Rogers RO 3210.

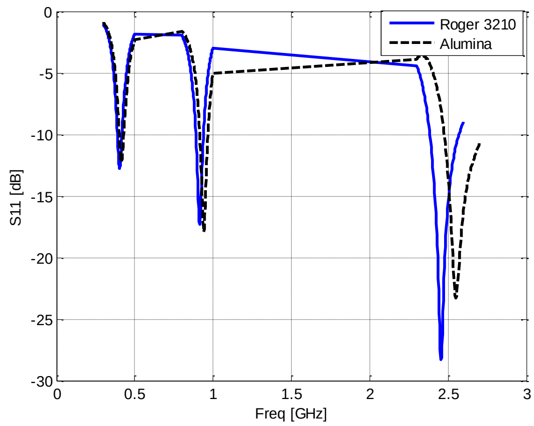


Fig. 4. Reflection coefficient (|S11|) frequency responses of the tri band proposed antenna, with two biocompatible materials Roger RO3210 and Alumina substrate/superstrate

IV. Conclusion

In this paper, a novel biocompatible tri-band implantable PIFA antenna is proposed and designed using COMSOL Multiphysics 5.2a and Ansys HFSS.

The obtained antenna is optimal in term of heigh performances presented and miniaturization size. To show the performance of the implantable tri-band PIFA antenna, some characteristics in term of reflection coefficient, far field gain, and biocompatibility are presented and discussed. Due to the height losses in the biological medium surrounding the implantable device which metagate the performances of the wireless system and reflect the difficulties of implantable antennas design. Indeed, despite the fact that the use of antennas within a living body goes back five decades, the subject remains open and with great interest for research. To enhance the performances of the implementable devices, smart antennas are used. For our future works, we plan to use implantable antennas for other applications such as localization of alzheimer's patient.

Acknowledgment

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