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Design of Compact Dual Band Slot Antenna at MICS and ISM for Bio-Medical Applications

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ABSTRACT: The design proposes a bandwidth, miniaturization and gain enhancement design for an implantable slot antenna for biomedical applications. The proposed antenna resonates at 403MHz in MICS (401-405 MHz) band and 2.45 GHz in ISM (2.4-2.48 GHz) band. Miniaturization of an antenna can be achieved by etching the top surface of radiating patch with open meander line. A micro-strip line excitation along with shorting pin connected to the radiator. Two U- shaped stubs are used to enhance the gain and bandwidth on ground surface. The dimensions of the proposed antenna are 10x10x1.27 mm. The antenna is measured on a human arm phantom model with permittivity, conductivity and loss tangent mimic to human tissue. From the measured one layer skin model result, it is found that the bandwidth of the implantable slot antenna is covered entire MICS and ISM bands (S_{11}< -10 dB achieved), the size of antenna reduced from 139 mm^3 to 127mm^3, and also improved the gain 3.9dBi from -27.6 to -23.7dBi. The proposed antenna is simulated in three layer skin model. The optimistic results are obtained by varying depth of the antenna from skin surface. Simulation is done in Ansoft HFSS**.**

KEYWORDS: Miniaturization, Implantable slot antenna, Medical implant communications service (MICS), Industrial, Scientific, Medical (ISM), Micro-strip line, Phantoms, Mimic, Human tissue.

I. INTRODUCTION

Over the past few years, rapid development of wireless communications makes effect every aspect. In wireless communication, antennas are playing key role and essential part of it. It shows enforcement to Medical Body Area Network (MBAN). It is a new wireless communications technology design for human body wirelessly [1, 2]. Implantable medical devices have capability to communicate wirelessly with external devices. They are using different application fields for both human and animals. Some applications are monitoring blood pressure, glucose levels, Potential Hydrogen(pH), temperature and tracking as well as detecting pets [3, 4, 5, 6]. Implantable device placed into human body may improve the lives of patients. We have to focus few characteristics for designing of implantable antennas. Those characteristics are bandwidth, size of antenna and radiation. An implantable antenna main objective is minimizing the volume occupation. Some researches worked on miniaturization of antenna [7, 8]. Some researches focused design of antenna operating at dual band or multi band [9, 10].

The miniaturization is adopted several types antennas such as a planer inverted-F antenna (PIFA), spiral or meander dipole, a micro-strip and slot antenna. Here we chose slot antenna for compact dual band at MICS and ISM. Medical Implant Communications Service (MICS) frequency range is 401-405MHz [11, 12]. For low frequencies is more challenging to minimize the size of the antenna but it can be achieve etching the top surface of the radiating patch with open meander line [13, 14]. Industrial, Scientific, and medical (ISM) frequency range is 2.4-2.48GHz [11, 12]. It is quite confortable to achieve the miniaturization. Meander lines and Two U- shaped sheets are used to enhance the antenna parameters [15]. The bandwidth coverage also most important parameter in implantable antenna due to each and every human has different tissue. The tissue properties changes with age, gender, position of antenna and etc. It is most difficult to mimic the properties of human phantoms. To select substrate material based on the permittivity, conductivity and loss tangent of tissue. If tissue is having high water content, it has high conductivity, permittivity otherwise low conductivity and permittivity.

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Insulation is mandatory for any implant devices so as to avoid any adverse reaction of the living tissues for bio-compatible [16]. Such insulation is to paramount from antenna point of view, the human body is a hostile environment for Radio Frequency (RF) Radiation. Insulation layer either placed around the antenna or on the surface of human skin [17].

In the presence of biological tissue, power dissipation is main drawback in the lossy surrounding media. It creates heat which may be hazardous, therefore the Specific Absorption Rate (SAR) introduced for analysis of Electro Magnetic (EM) wave in biological tissues. The evaluation of SAR is a way to compute the dissipation of EM power per unit mass, in order to estimate the heating of the tissues that may have harmful effects. The maximum transmission power for any implantable device must comply with the SAR limitations 1.6 W/Kg per 1-g averaging and 2 W/Kg per 10-g averaging [18].

In this, the proposed antenna is implant on the human arm. The human arm consists of three layer, they are skin, fat and muscle. The layers have different thicknesses as shown in Fig 1.

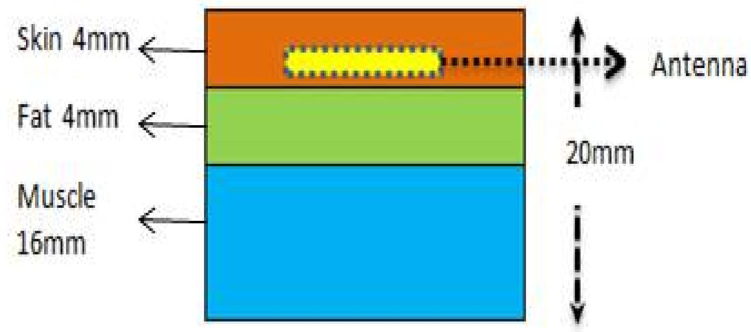

Fig 1: Human arm tissue model

II. RELATED WORK

In paper [13], author adopted both open end slot at patch surface and U shaped planar stubs at ground plane. Owing to open end slot, it reduces the size of antenna. U shaped planar stubs are used to increase the electric path as well as to match feeding impedance. In paper [14], author is used both open end slot at ground and shorting pin. Threecloselyspacedresonantfrequencies are created at the lower band by adding open-end slots in the groundplane,resultinginabroadbandwidth. A shorting pin was used to improve the electrical length and reduce the size of antenna. In paper [15], author used U-shaped stubs. The dimensions of antenna are shirked and enhance the wide band width of antenna due to U shaped stubs at ground plane. In paper [19] author is adopted a shorting pin, adding a shorting pin can reduce the required size of the antenna for given frequency.

III. ANTENNA DESIGN

The proposed slot antenna is fabricated on Rogers RO3010 (tm) substrate with permittivity of 10.2, loss tangent of 0.0035 and height of 1.27 mm [13]. The parameters of proposed antenna listed in table 1. The implemented antenna is operating at MICS and ISM band for bio-medical applications.

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Table.1. Detailed dimensions of designed antenna

Parameter	Size in mm	Parameter	Size in mm
L1	10	W1	9
L2	2.1	W2	5.7
L3	1	W3	0.3
L4	4	W4	10
L5	2	W5	6.3
L6	4	W6	4
L7	0.5	W7	3.5

The patch of the antenna and its dimensions are 10 mm x 9 mm is shown in Fig 2a. The top of substrate is etched such a way that, a meander line having 5.7mm of length and 0.3mm of width at one end is open. Generally, a standard slot antenna physical size is λ/2. The dimensions of proposed antenna are λ/12(10 x 10 x 1.27 mm) using with one end open.

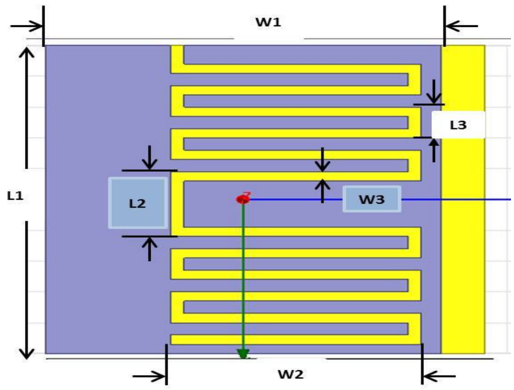

Fig 2a: Design of patch

Two U-shaped tubes are used to enhance the radiation at MICS band but it degrades the radiation pattern at ISM band. The ground surface of antenna and its dimensions are 10 mm x 10 mm is shown in Fig 2b. The bottom surface of the substrate is etched such a way that to improve the current distribution. So, it enhances the gain. A micro-strip line feeding is applied along with a short pin having 0.6mm diameter and height 1.27 mm at centre to limit the dimensions of antenna at low frequencies (MICS band)[19].

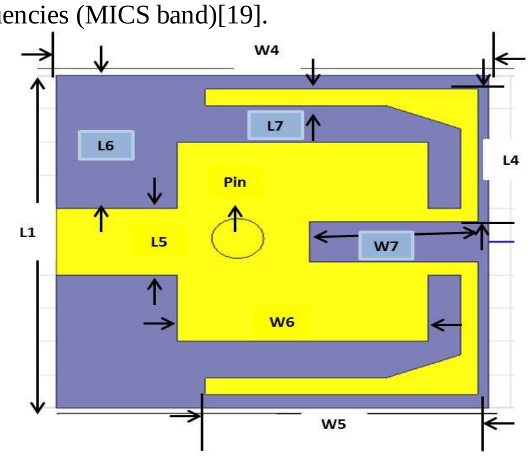

Fig 2b: Design of ground plane.

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The proposed antenna is simulated in one layer skin model and three layer skin models. Three layered skin model consists of Skin, Fat and Muscle tissues. The design of three layer skin model is shown in Fig 3. We have to mimic these tissues with their dielectric properties, which are taken from [20]. Based on the depth (d) of the antenna from surface of the skin gave different simulation results.

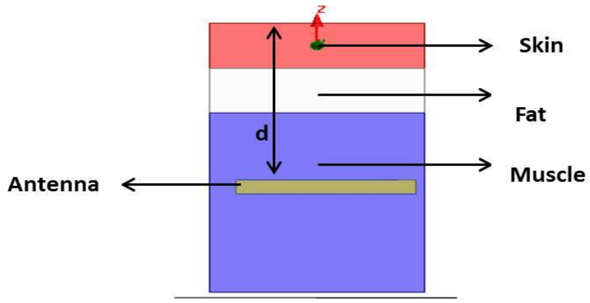

Fig 3: Three layer skin model

IV. RESULTS

One Layer Skin Model:

In this section, the proposed antenna is simulated in one layer skin model.The antenna proposed in [13], covered 29.9% at MICS band only and gain is -27.7dBi. The proposed antenna return loss plot is shown in Fig 4a and 4b at MICS and ISM bands respectively and return loss < - 10 dB for entire MICS and ISM bands. The radiation pattern is almost Omni directionaland gain is -23.77dBi as shown in Fig 5a and 5b. Gain improved by 3.9dBi and bandwidth is improved by 169.35% with respect to [13].

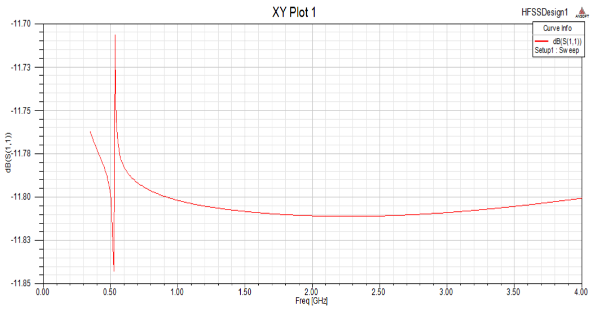

Fig 4a: Return loss at 403MHz

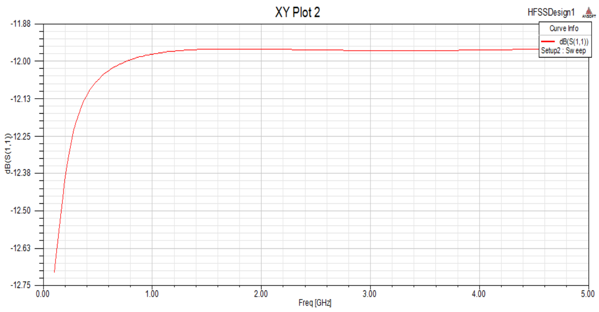

Fig 4b: Return loss at 2.45GHz

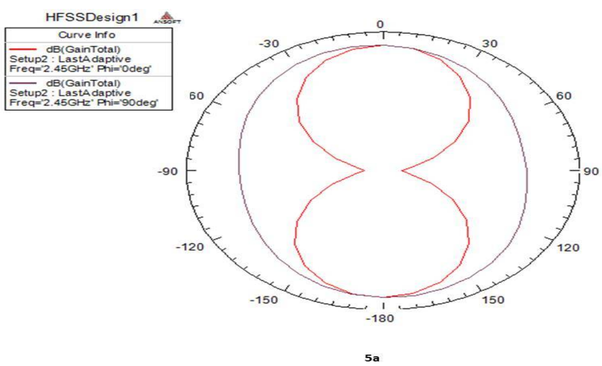

Fig 5a: Radiation pattern at 403MHz

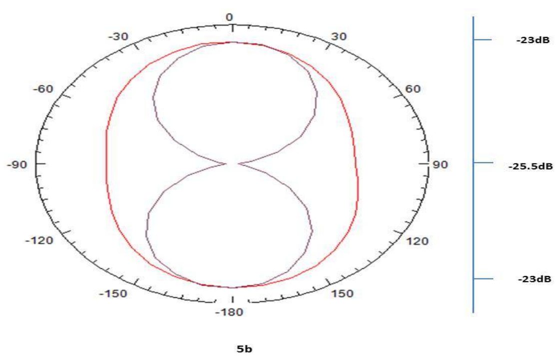

Fig 5b: Radiation pattern at 2.45GHz

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Three Layer Skin Model:

In this section, the proposed antenna is simulated in three layer skin model. The antenna performance is shown in Fig 6a, 6b and 7 by varying the depth (d) at skin (d=2.7mm), at fat (d=6mm), and at muscle (16mm).

Return loss of the antenna is almost similar at any depth and it covered entirely MICS and ISM bands. Return loss at 403MHz and 2.45GHz is shown in below Fig 6a and 6b at different depths (d) 2.7mm, 6mm, and 16mm are indicated blue, red and pink colors respectively.

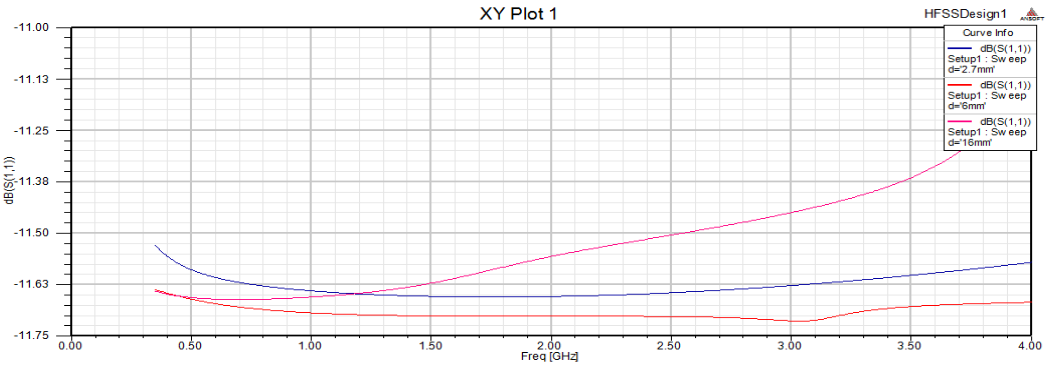

Fig 6a: Return loss at 403MHz

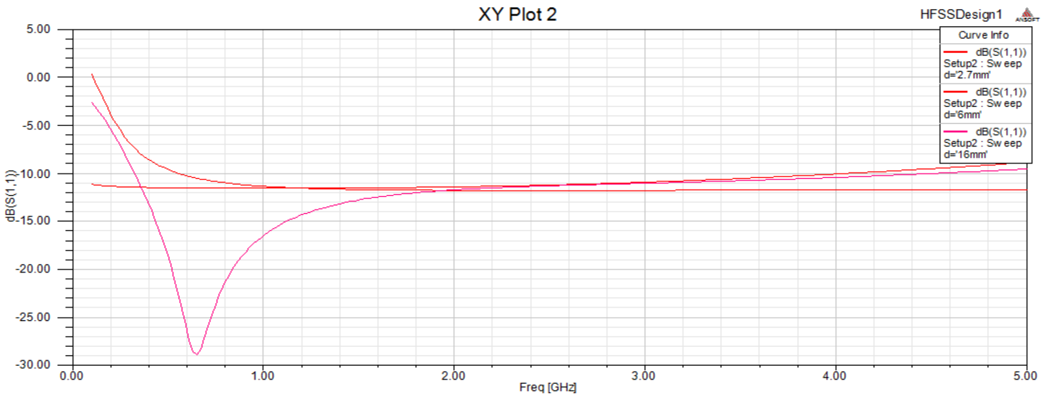

Fig 6b: Return loss at 2.45GHz

Radiation pattern of proposed antennaat different depth is shown in Fig.7. Gain is -24.9dBi when proposed antenna placed into skin at a depth d=2.7mm.Gain is -22.9dBi, when it is placed into fat layer at a depth d=6mm. Gain is -26.4dBi, when it is placed into muscle layer at a depth d=16mm. The radiation patterns at 403MHz and 2.45GHz is shown in Fig 7a and 7b respectively, blue color denotes d=2.7mm, pink color denotes d=16mm and red color denotes d=6mm.

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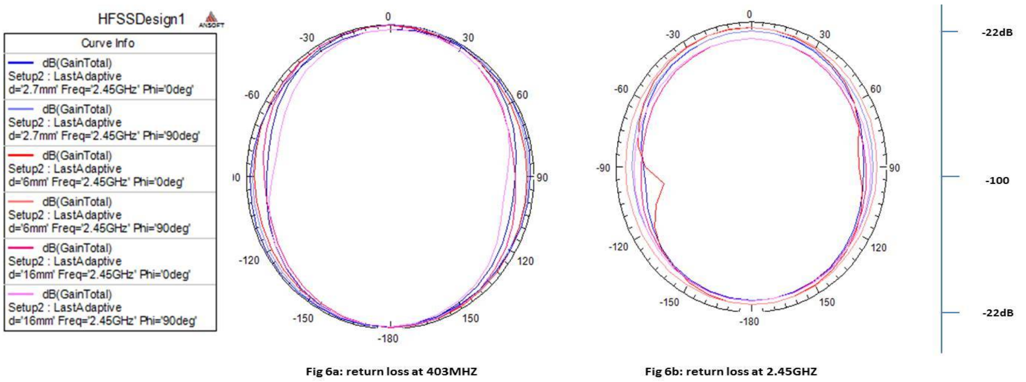

Fig 7: Radiation pattern of proposed antenna (a) at 403MHz and (b) at 2.45GHz

V. Conclusion

A Miniaturized slot antenna at MICS and ISM bands for bio-medical applications is designed with dimensions 10x10x1.27 mm (127mm^3). The antenna optimized to one layer skin model and three layer skin model. The antenna covered entire MICS and ISM bandwidth in all the cases. The best optimum implant position of proposed antenna in human arm at a depth d=6mm (Fat layer) with a gain of -22.9dBi.The antenna size is reduced to 8.5%, bandwidth is improved by 169.35%, and gain is improved by 21.14%.

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