A Miniaturized Structure of Implantable Antenna for Biomedical Application

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Abstract:This paper proposes a miniaturized structure of microstrip patch antenna with the defected ground plane, for working over the range of the 2.4-2.6 GHz ISM (Industrial, Scientific, and Medical) band. Roger Duroid having dielectric constant 10.2 is used for the designing of the proposed antenna because this material biocompatible. The structure of patch and the position, shape and length of the defected ground are optimized for resonant on the ISM range and for the performance parameters to meet the optimum desirable value. High-Frequency Structural Simulator (HFSS) is used to analyze this novel structure. The optimized value of the reflection coefficient is -46.3517 dB on the resonant frequency 2.6 GHz of this proposed structure.

Keywords: Implantable antenna, Industrial, Scientific, and Medical Band (ISM), Defected Ground, Performance parameters.

1. INTRODUCTION

Medical devices that are implanted inside the human body for the surgical operations or diagnosis are known as implantable medical devices (IMDs). An implantable device has gained much attention as compared to the mammography and other treatments. These devices are used for various applications like diagnosis purpose, therapies, and monitoring of the patients. The range 2.4-2.6 GHz is the ISM band which is also used for the biomedical telemetry systems which comprise a biosensor powered, a transmitter and an antenna. This band will work as a wake-up signal for the antenna. An antenna is that device which minimizes the whole device.

In [1], Merve Usluer et.al. proposed the antenna with dimension 14*14*1.27mm^3. The proposed antenna is designed by etching three complementary split ring elements and this configuration provides a dual band performance at 400 MHz with 20% bandwidth and at 2.6 GHz with 60% bandwidth. In this dual band antenna, the main radiator of the antenna is concentric complementary split ring elements and a U-shaped slot is inserted into the ground plane for tuning with the desired frequency bands. In[2], Sahart Surapan et.al. , proposed the antenna for camera pill of biomedical applications. This camera consists of a small camera, transceiver chip, and dual band antenna. The dimension of the antenna is 26*8*1.25 mm^3. In the proposed antenna, ground pork is used instead of the human skin. The antenna consists of two layers of dielectric and they are superstrate and substrate. In [3], Erdem Uras et.al., proposed the implantable antenna in which radiating element is sandwiched between two thin substrates backed by the ground plane. For miniaturization purposed shorting pin used. The proposed antenna has dimensions 10.6*10*1.27mm^3. A spiral-shaped and bended microstrip line radiator is sandwiched between two thin substrates. The proposed antenna offers a dual band performance (VSWR<2) covering ISM and MICS band.

In [4],Wen Lei et.al. proposed a differentially fed dual-band implantable antenna which has a shorting strip which is used for size reduction. In this design, meandered arms are designed which resonate at 401 MHz and L-shaped resonate at 2.4 GHz. 27*9*1.27mm^3 is the dimension of the designed antenna and biocompatible substrate and superstrate are used. In this paper, the working principle of differentially fed has been discussed. Several parameters like effects of length of meandered arms, effect of length of L-shaped arms has been discussed and analyzed. In [5], Noor M. Awad et.al. , designed an ultra wideband (UWB) antenna consists of a rectangular patch etched on FR-4 substrate having dimension 35*30*1.6mm^3. There are several methods which are used to enhance the bandwidth of the antenna like adding the slots with different shapes in the patch, feed, and the ground plane or by using the defected ground structure (DGS) or by using quarter wavelength open ended slots. In this paper, the investigation has been done by cutting the corners of the patch and adding the slots in the ground. In [6], H. Nornikman et.al., proposed a dual layer rectangular patch antenna with H-slot. The dimension of the antenna is 41.44*36.62*1.6 mm^3. The H-shot patch is located in the upper layer of the patch antenna. The ground plane has the same length as the substrate and the width is the same as the patch width.

In [7], Li-Jie Xu et.al. proposed the antenna having the dimensions 19.8mm*19.4mm*1.27mm^3 which resonate at 2.4-2.45 GHz ISM band. According to this paper, a slotted ground has been used to improve the bandwidth without increasing the volume of the antenna. In this paper, a compact dual band implantable PIFA is proposed for telemetry communications. In [8], N. Prombutr et.al., presented the technique using a modified ground plane for the bandwidth enhancement. In the proposed design T-shaped slot is cut in the ground for the enhancement of the bandwidth. According to this paper, when

the ground plane is reduced in either length or in width, the first resonant frequency is shifted slightly to around 3 GHz. The second best approach to increase the operating band is to cut different slots in patch.

In [9], Damla Alptekin et.al., proposed antenna in the form of stacked Planar Inverted-F Antenna (PIFA) covered with the substrate. Stacked multilayers and PIFA structures were usually covered with superstrate for the purpose of the bandwidth of antenna and reducing the human tissue erosion. Designed antenna is achieved to wake up base station at ISM band and to send data at the MICS band in the range of 4m.

In this paper, microstrip patch antenna is design by introducing the defect in the ground and the patch is approximately cut in the form of alphabet S to investigate the reflection coefficient. Section 2 is related to the need of design and some properties of the material used in designing. Section 3 is regarding with formulae which are used to calculate the dimensions of the antenna, the designing, and dimensions of the microstrip antenna. Section 4 is related to the simulated result of the proposed antenna and discussion related to the result. Section 5 concludes the paper.

2. METHODOLOGY

For the implantable devices, the first requirement is that the dimension of the antenna is very small so that the device can easily implant in the human body. The second requirement is that the material which we use in the antenna design should be safe for the tissues when it is implanted in the body.

So, the dimension of the antenna is quite small as compared to other proposed antennas. The material which is used in the design is RT Duroid 6010. The dielectric constant of the material high is 10.2 and height is 1.27mm. The properties due to which it is used in the implantable devices are:

1. It has high dielectric constant for circuit reduction.
2. It has low loss which is ideal for operating at X-band or below.
3. Low moisture absorption i.e. it reduces the effects of moisture on the electrical loss.
4. It has tight ε_r and thickness control for repeatable circuit performance.

3. STRUCTURAL ANALYSIS

This section is about the structural analysis of the microstrip patch antenna. The dimensions of the antenna had been calculated by the basic formulae of antenna and they are:

(a) The width of the antenna:

$$W = \frac{c}{2f_o\sqrt{\varepsilon_r+1/2}} \quad (3.1)$$

(b) Effective dielectric constant:

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\frac{12h}{W}\right]^{\left(-\frac{1}{2}\right)} \quad (3.2)$$

(c) Length extension, ΔL:

$$\Delta L = \frac{0.412h(\varepsilon_{re}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{re}-0.258)\left(\frac{W}{h}+0.8\right)} (3.3)$$

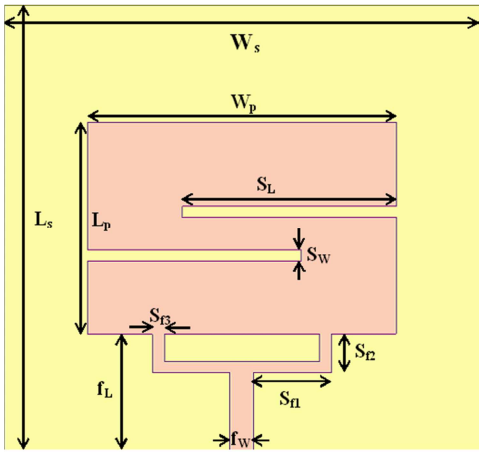
(d) Effective length, L_e:

$$L_e = \frac{c}{2f_o\sqrt{\varepsilon_{re}}} (3.4)$$

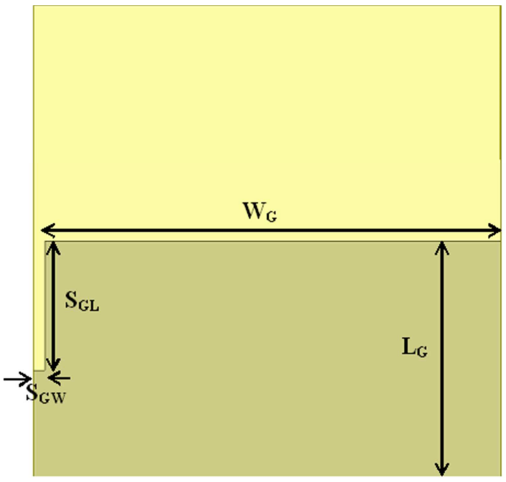
(e) Actual length, L:

$$L = L_e - 2\Delta L \quad (3.5)$$

The proposed antenna configuration with its parameters is described in figure 1. The dimension of the antenna is 9.5*13 mm^2. The substrate which is taken is RT Duroid 6010 having dielectric constant, ε_r=10.2, height, h=1.27mm and tanδ=0.0023. Due to the high dielectric constant this material is widely used for implantable antenna design.



(a)



(b)

Figure 1 : Geometrical parameters of the patch and the defected ground. (a)Dimension of patch (b) Dimension of the defected ground

Table 1 : Design parameters with their values.

Design Parameters	Values (mm)
Substrate Length (L_s)	20
Substrate Width (W_s)	20
Patch Length (L_p)	9.5
Patch Width (W_p)	13
Slot length (S_L)	9
Slot Width (S_w)	0.5
Feedline Length (f_L)	5.25
Feedline Width (f_W)	1
Feedline split 1(S_{f1})	3.25
Feedline split 2(S_{f2})	1.75
Feedline split 3(S_{f3})	0.5
Ground length (L_G)	10
Ground Width (W_G)	12.5
Ground Slot Length (S_{GL})	5.5
Ground Slot Width (S_{GW})	0.5

4. RESULTS AND DISCUSSIONS

This section is related about the result from the calculations and parametric analysis from the simulation. The simulated result is obtained by using the HFSS software. Reflection coefficient (dB) is the parameter which is simulated in this section.

5. CONCLUSION

In this paper, we presented a structure of microstrip patch antenna for the biomedical applications. In this design defected ground plane has been used to improve the bandwidth of the antenna. The return loss is -46.3517 dB for the band 2.4-2.6 GHz when the shape of the defected ground is L shape and the slots introduced on the patch is S shape.

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