Performance Analysis of Dual Band Micro Strip Patch Antenna in Varying Medical Implant Environments

Bimal Aryal
ME Graduate
Kathmandu University
Dhulikhel, Nepal
baryal86@gmail.com

Madhav Prasad Pandey
Assistant Professor
Kathmandu University
Dhulikhel, Nepal
mpp@ku.edu.np

Abstract: The design of implantable biomedical devices faces many obstacles, including developing and implanting antennas in a hostile environment due to the human body's surrounding tissues. This paper proposes the design, simulation, construction and analysis of Dual Band Rectangular Patch Antenna operating on 3.6 GHz and 5.8 GHz inside different implant environment .The two frequency bands were obtained by a pair of parallel slots in a copper patch and a rectangular ground plane separated by an FR-4 substrate with a dielectric constant of 4.2 and a thickness of 1.6 mm. Results illustrates primary frequency (3.6 GHz) performs better at the lower depth of implant whereas 5.8 GHz performs better at greater implant depth scenarios . As the implant depth increases the performance of antenna for primary frequency in terms of return loss and VSWR (Voltage Standing Wave Ratio) degrades.

Keywords: Implantable devices, rectangular patch antenna, implant environment, VSWR, Return Loss

I. Introduction

An active medical implant is a surgically implanted electronic device inside the body of a human or animal. Implants have been developed to treat a wide range of medical conditions, including pacemakers for cardiovascular disorders, cochlear implants for the deaf, and automated implantable medicine pumps to help with conditions requiring frequent intravenous drug delivery [1].

A number of frequency ranges have been proposed and are currently being investigated for use in various medical implant applications. The ITU-R Recommendation SA.1346 recommended that Medical Implant Communications Services use the 401 to 406 MHz band in 1998. (MICS). Other suggested frequency bands for biomedical applications include the Commercial, Research, and Medical (ISM) bands, 608 to 614 MHz, 868 to 868.6 MHz, 902.8 to 928 MHz, 1395 to 1400 MHz, 1427 to 1432 MHz, and 2.4 GHz to 2.5 GHz, as well as the Wireless Medical Telemetry Service (WMTS) [2].

The production of antenna patches has progressed significantly, as they can now be small enough to be printed straight on a circuit board. When compared to traditional antennas, they provide more benefits and better efficiency. This is due to its small scale, low volume, low cost, and ease of production [3].

This paper presents performance analysis of a microstrip patch antenna on three different medical implants environments.

II. Methods and Tools

This study is based on simulation analysis of implant antenna under three analysis parameters (Return Loss S_{11}, VSWR and Specific Absorption Ratio).

A. *Research Framework*

Figure 1 shows the block diagram of the research framework.

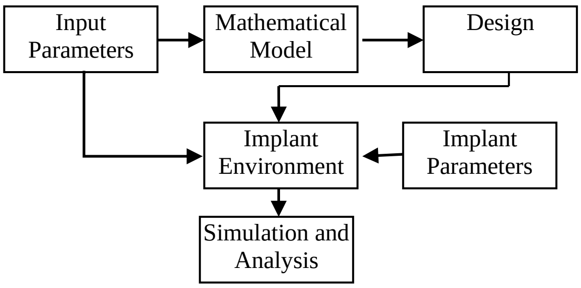

Fig. 1: Research Framework

B. *Antenna Design and Parameters*

The antenna dimensions were obtained using the mathematical model for rectangular patch antenna design. On the basis of operating frequency, with the help of mathematical model, the dimensions of antenna were generated. For dual band frequency, two rectangular slots are introduced on the patch.

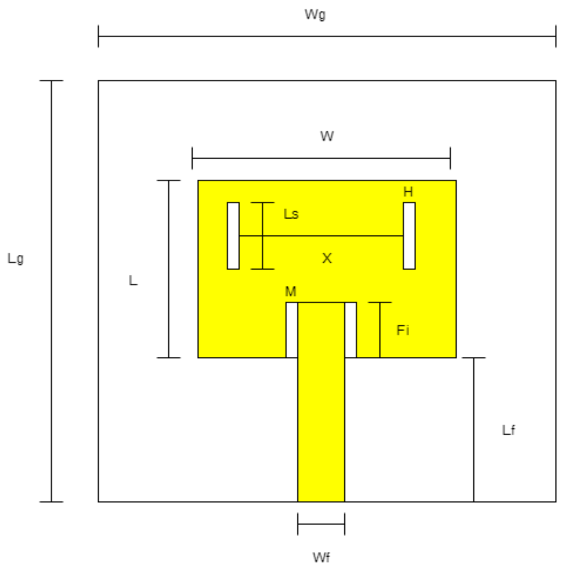

Fig. 2: Antenna Design

TABLE I: DESIGN PARAMETER VALUES

Parameters	Value(mm)
Lg (Ground length)	56
Wg (Ground Width)	62
L (Patch length)	19
W (Patch width)	25
h (Substrate Height)	1.6
Wf (Feed Width)	4.4
Lf (Feed Length)	20
Fi (Inset feed)	6.9
Ls (Slot Length)	6.9
X (Slot Separation)	9.4
M (Inset width)	0.5
ϵ (Permittivity)	4.2
H (Slot width)	0.6

C. *Implant Environments*

For this simulation dielectric constant of different layers were considered. Using the value of dielectric constant of different human tissue and their thickness, a simulation environment was modeled for simulation.

TABLE II: IMPLANT ENVIRONMENT PARAMETERS [4]

Frequency (MHz)	Relative Permittivity			Loss tangent		
	Fat	Muscle	Skin	Fat	Muscle	Skin
403	5.57	57.1	46.71	0.622	0.622	0.658
915	5.46	54.99	41.33	0.339	0.339	0.414
2400	5.28	52.73	38	0.242	0.242	0.283
5800	4.95	48.49	35.11	0.317	0.317	0.328

Three different implant positions (Arm, Thigh and Abdomen) have been considered for this research. On the basis of implant parameters implant parameters in table II implant environment are designed antenna is placed on given depth.

Figure 3 illustrates simulation modelling example for arm model.

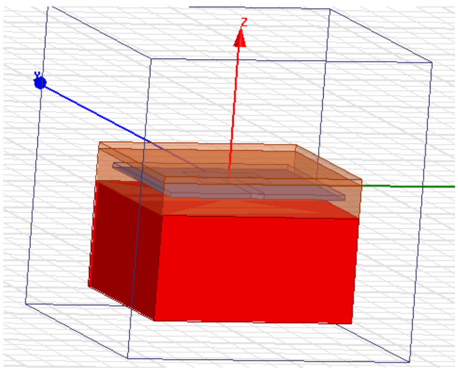

Fig. 3: Simulation Arm model (Antenna depth 7.7mm)

III. RESULTS AND ANALYSIS

A. *Arms Implant*

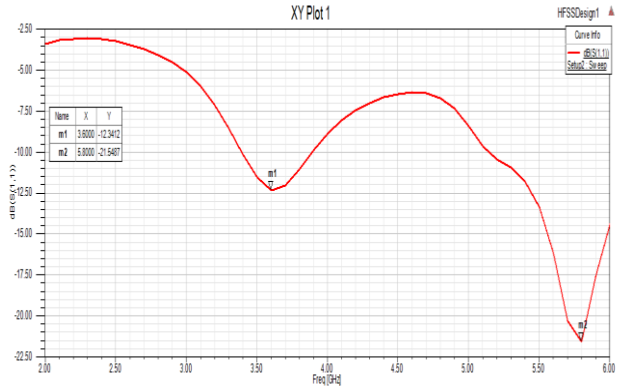

Fig. 4: S11 (Arm Model)

In arms model, both the frequencies meet the required analysis criteria in terms of performance. Both frequencies have Return loss less than -10dB and VSWR between 1 and 2(From table III). However higher frequency (5.8GHz) exhibited better performance compared to 3.6GHz band. The antenna placement in this model is shallower compared to other three models.

B. *Thigh Implant*

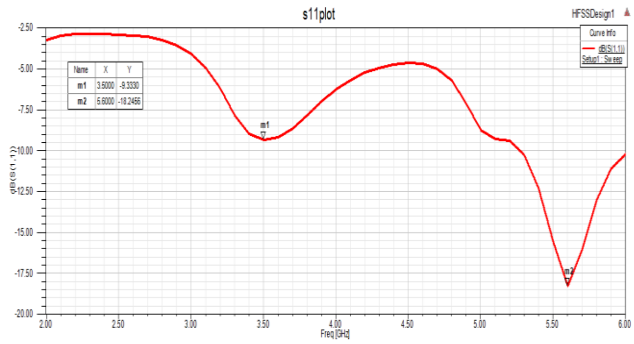

Fig. 5: S11 (Thigh Model)

In thigh model, we can observe slight detuning effect (3%) for both frequencies. In addition, 3.6GHz band shows higher values for both VSWR and return loss. This is due to the fact that antenna is placed at a greater depth compared to arms model. In this model lower frequency does not meet the minimal optimization criteria hence transmission can be shifted to higher frequency.

C. *Abdomen Implant*

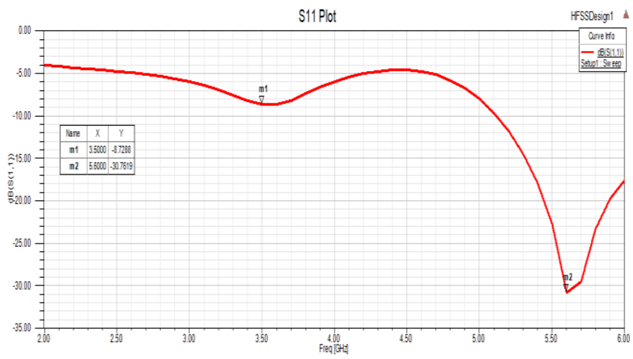

Fig. 6: S11(Abdomen Model)

In abdomen model, the detuning effect still persists due to the antenna height. The VSWR and return loss performance for 3.6GHz band further degrades but for 5.8GHz band both return loss and VSWR performance has improved. This is due to the fact that muscle thickness has decreased in this model.

D. VSWR Summary

TABLE III: VSWR SUMMARY FOR THREE IMPLANTS

	VSWR		Implant Depth(mm)
Frequency	**3.6 GHz**	**5.8 GHz**	
Arm	1.63	1.18	7.7
Thigh	2.03	1.27	12.3
Abdomen	2.15	1.05	16.1

E. SAR Summary

TABLE IV: SAR SUMMARY FOR THREE TISSUE LAYERS

	SAR (W/Kg)		
Layer	**SAR (Max)**	**SAR(Min)**	**SAR(Avg)**
Skin	0.371	0.341	0.356
Muscle	0.0357	0.0351	0.0354
Fat	3.31	0.053	1.88

IV. CONCLUSION AND FUTURE WORKS

From the results we can clearly visualize that the primary frequency (3.6 GHz) performs better at the lower depth of implant. As the implant depth increases the performance of antenna for primary frequency in terms of return loss and VSWR degrades. However, performance of secondary frequency (5.8 GHz) is consistent at higher depth implant scenario. From above observation we can conclude that the antenna has optimal performance on arms model but if used at higher depth, it has to be operated at higher frequency. Operating at higher frequency results in larger attenuation inside implant environment therefore requiring high power implant devices [5]. The antenna performance proves to be effective for lower implant depth scenarios with low tissue density surrounding it. Antenna performance can be improved using different feeding techniques. The dimensions of the antenna can be reduced considering the dielectric loading effect.

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