Design And Analysis Of X-Ma Implantable Antenna For Bio-Medical Applications

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***Abstract*—Patch antenna is used in our paper, it has an advantages of flexibility, comfortability and also a biocompatibility, miniaturization, power consumption etc., The main objective is to design a miniaturized X-MA implantable antenna for bio application at frequency range from 2.4 to 2.45 GHz in ISM band. The phantom layer is designed such as muscle, fat, skin and analyzed its return loss, VSWR ,impedance matching, gain and radiation pattern etc., The size of our implantable antenna is 10mm x 10mm and thickness of substrate is 0.635mm.The material used for substrate is Rogers.The CPW feed is used for our antenna.The X-MA slot implantable antenna is used for many implantations and ISM band application.We designed two different layer of antenna one is multilayer (muscle,fat,skin) and another one is single layer (muscle). The antenna is designed by using CST software.**

***Keywords*—Implantable antenna, CST, CPW feed, ism band, IMD.**

I. INTRODUCTION

Nowadays Implantable medical devices (IMDs) are widely used to perform an expanding variety of diagnostic and therapeutic functions. By means of an integrated implantable antenna the Bidirectional telemetry between the implantable medical device and exterior Monitoring/control equipment is most commonly performedwirelessly. Patch designs are preferred for implantable antenna design, because of their flexibility in conformability and shape. Communication is generally performed in the Industrial, Medical, and Scientific (ISM) band (2.4GHz to 2.45 GHZ).

The powerful measurement of physiological signals near to a distance, through either wired or wireless communication technologies are carried by biomedical telemetry. Physiological signals are measured by means of transducers, post-processed, eventually broadcast exterior monitoring/control equipment. In bio medical telemetrythe latest developments are in the field of mplantable medical devices (IMDs).Low-frequency inductive links are the most prevalent method of research and it is currently oriented towards radiofrequency (RF)-linked implantable medical devices. Millions of people worldwide depend upon implantable medical devices to support and improve the quality of their lives. RF-linked implantable medical devices are already in use for a wide variety of applications, including temperature monitors, pacemakers and cardioverter defibrillators, functional. As technology continues to evolve, new implantable medical devices are being developed, and their use is expected to rapidly increase from an already large base.

II. ANTENNA DESIGN

A. Numerical design of proposed antenna

Antenna designed by using cpw feed is designed for biomedical applications. The design is done by using CST software for simulation and then it is analyzed by using XFDTD and also fabricated as a hardware device. This proposed antenna is designed by using standard bio telemetry for implantable medical devices. However we design, they suffer from low data rates from (1-30 kbps), restricted range of communication at (< 10 cm), and increased sensitivity to inter-coil positioning. These limitations can be reduced by, formulas and then it is optimized for the expected output.

B. CPW feed

The CPW has low dispersion and hence gives the potential to construct wide band circuits and components. The gain can be enhanced by CPW.

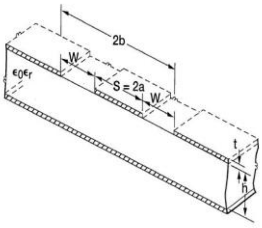

Fig.1. CPW feed

C. Width

$$W = \left(\frac{Co}{2f0}\right)\sqrt{\frac{2}{\varepsilon_r}+1}$$

D. Effective permittivity

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{n}{w}\right]$$

E. Length

$$L=\frac{C_o}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

F. Feedstrip

$$Z_0 = \frac{30\pi^2}{\sqrt{\varepsilon_{reff}}} = \left[ln_2\frac{(1+\sqrt{K})}{(1-\sqrt{K})}\right]^{\wedge} - 1$$

$$K=\frac{w_f}{w_{f+}w_s}$$

Where,

w_f = Feed width

w_s = Slot width

G. Geometric design of proposed antenna

By the inspiration of the structure of X-MAS TREE, the antenna is named as X-MA.

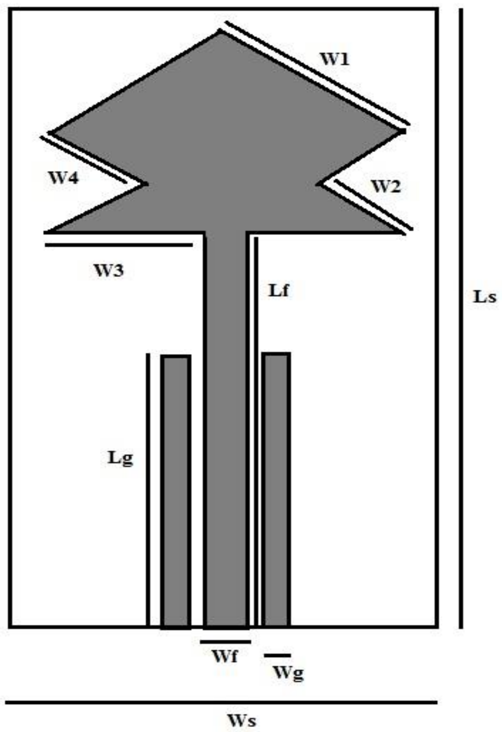

Fig 2. Geometry of proposed antenna

H. Dimension table

The dimensions of proposed antenna is

TABLE I

DIMENSIONS OF PROPOSED ANTENNA IN THE TABLE 1 GIVEN BELOW

Tissue	Permittivity	Conductivity
Skin	**ε_r = 38**	**σ = 1.46**
Fat	**ε_r = 5.28**	**σ = 0.10**
Muscle	**ε_r = 52.7**	**σ = 1.73**

I. Flow chart

The flow of design requirements are showed as flow chart which shown in fig. 2.

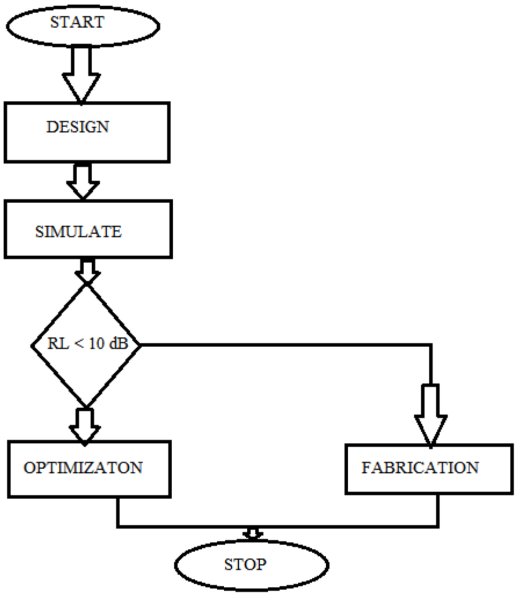

Fig 3. Flow chart of proposed antenna

J. *Phantom layer*

For wearable or implantable antenna the structure should be radiated on or off body without damaging tissues. For that the structure is placed above or inside a model which represent the human body tissues. Such a model is known as Phanthom model. Phanthom model consists of Skin , Fat , Muscle , Bone layers which is defined by its Dielectric Constants. Each of the layers has different Dielectric Constant value. Phanthom model for the structure is in the dimensions of length 10mm and width 10mm. According to the relative dielectric constant of human tissues, the parametric model of skin, fat and muscle are designed, which is shown in table 2. The table 3 shows thickness of human tissues.

TABLE 2

ELECTRICAL PROPERTIES OF HUMAN TISSUE

Width of substrate-Ws	**10**
Length of substrate-Ls	**10**
Width of feed line-Wf	**0.5**
Length of feed line-Lf	**6**
Width of ground-Wg	**0.5**
Length of ground-Lg	**4.35**
Gap between feed line and ground	**0.25**
W1	**2.2**
W2	**1.8**
W3	**1.75** [?]
W4	**1.9**

TABLE 3

THICKNESS OF EACH PANTHOM LAYER

Human tissue	**Thickness**
Skin	**4mm**
Fat	**4mm**
Antenna	**0.635mm**
Muscle	**8mm**

The proposed X-MA antenna with phantom model is shown in fig 3.

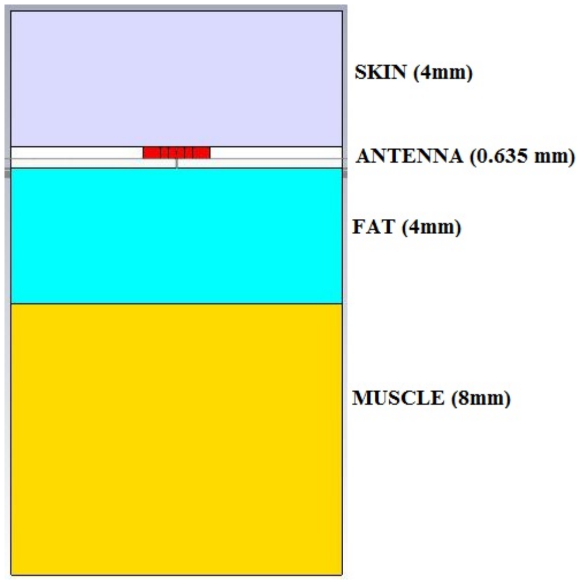

Fig.4 Phantom model

III. SIMULATION RESULT

The required parameters of an antenna like return loss, VSWR, radiation pattern and gain etc, aremeasured using CST software(computer simulation technology).

A. Return loss

RL (dB) = 10 $log_{10}\frac{P_i}{P_r}$

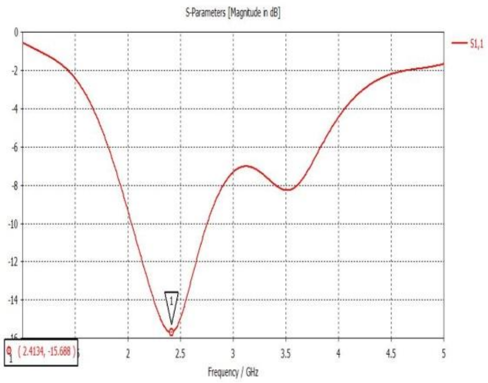

Fig 5. Graph of return loss.

The graph is drawn between frequency and s-parameter. The return loss is -15.688 in 2.4134GHz .

B. VSWR

VSWR = $\frac{1+S}{1-S}$

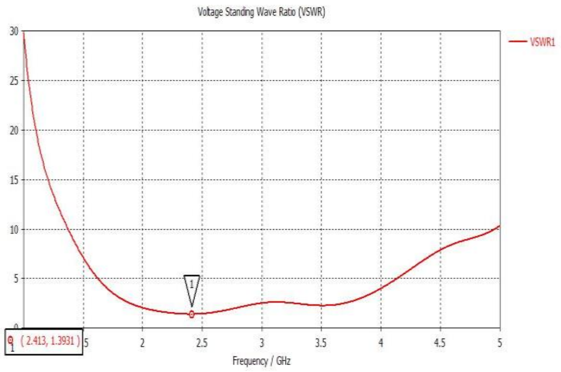

Fig.6. graph of VSWR curve.

The graph is drawn between frequency and Voltage Standing Wave Ratio (VSWR).The VSWR is 1.3931 in 2.4134 GHz .

C. 3D Radiation Pattern

The simulated radiation pattern of azimuth pattern at 2.4134 GHz is shown in fig. At the ISM band, the radiation pattern of proposed antenna is obtained in the E-plane and H-plane.

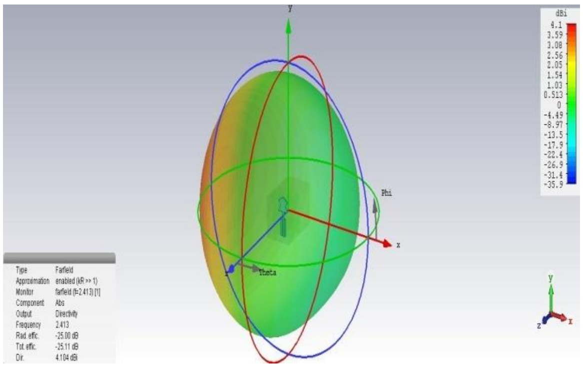

Fig 7. Radiation pattern of proposed antenna.

The radiation pattern is shown and the radiation efficiency is -25.00 dB in 2.4134 GHz.

D. E-field

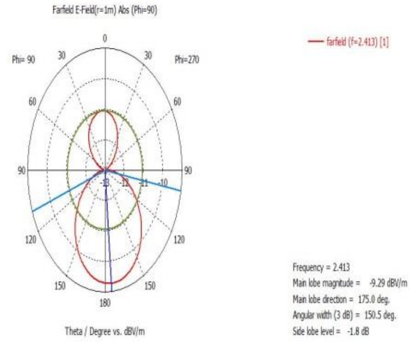

Fig 8. E- field pattern of designed antenna.

The E-Field shows the magnitude, direction and side lobe level and angular width in 2.4134 GHz .

E. H-field

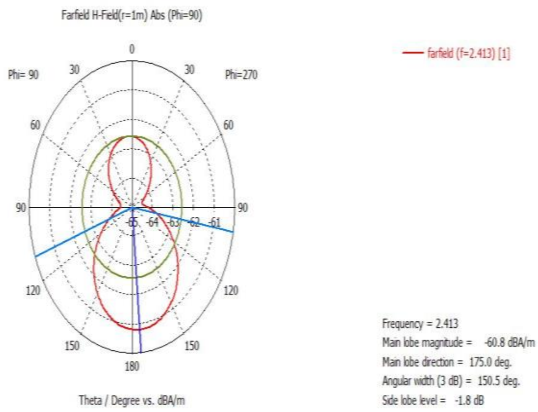

Fig 8. H-field of designed antenna.

The H-Field shows the magnitude, direction and side lobe level and angular width in 2.4134 GHz.

F. Directivity

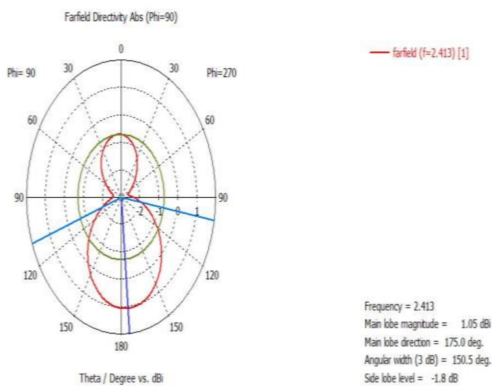

Fig. 9 Directivity of proposed antenna.

The directivity shows the magnitude, direction and side lobe level and angular width in 2.4134 GHz.

G. Current distribution

The EM characteristics of proposed antenna simulated and the current distribution generated in the antenna at 2.4134 GHz.

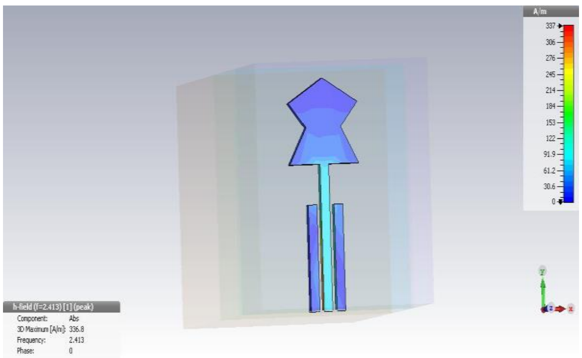

Figure 10. current distribution of proposed design.

IV. ANALYSIS

The proposed antenna is analyzed using transmission line equivalent circuit. The equivalent circuit of the antenna is drawn and simulated using ADS.(Advanced Design System). The results of analysis is nearly similar to the simulated results of the proposed antenna.

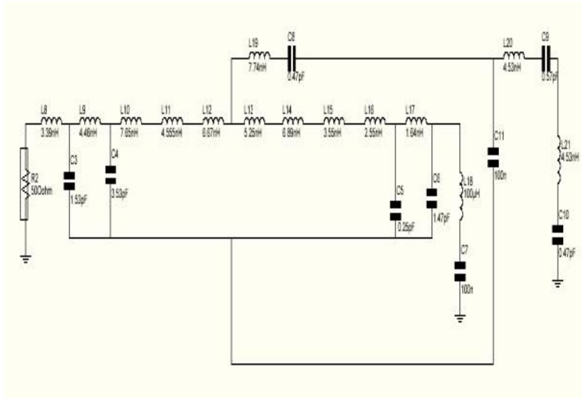

Fig. 11 Equivalent circuit.

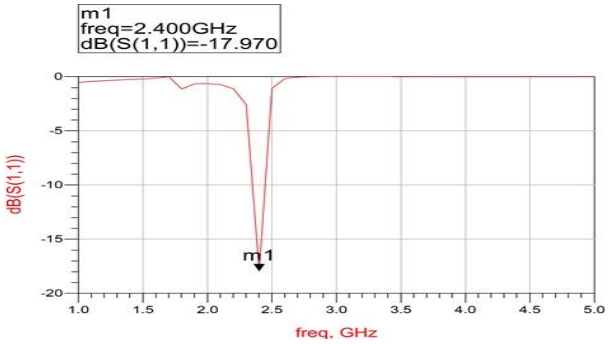

Fig. 12 Ssimulated results for equivalent circuit.

V. MEASUREMENT

The proposed antenna structure is fabricated and tested in the real time replica of human tissues called BSF (Body Simulating Fluid). The following figures shows the measured result of x-ma antenna with and without dipping in the phantom model. The following figure shows the return loss of antenna without dip in BSF solution and measured.

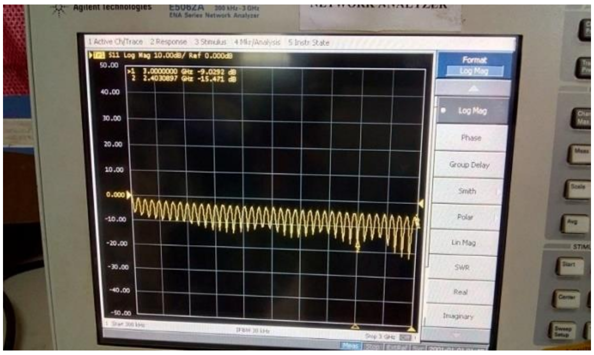

Fig. 13 Image of return loss testing result.

This figure shows the return loss of testing result. The return loss is -25.471 dB in 2.40 GHz.

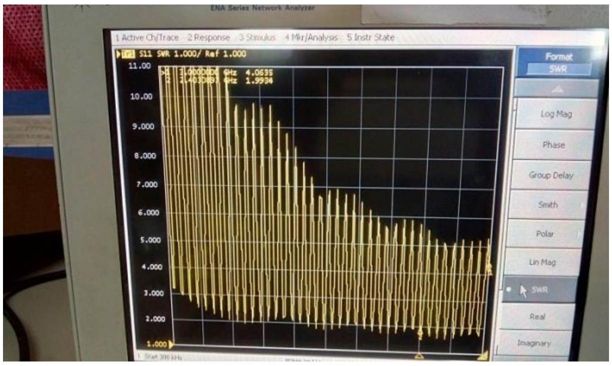

Fig14.VSWR

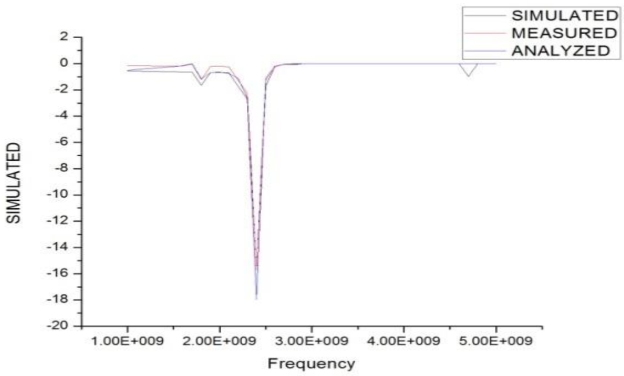

Fig. 15 Graphical analysis btw frq vs simulated &measured results.

The graph drawn between frequency and simulated, measured and analyzed. The figure shows the return loss of testing result. The VSWR is 1.599 in 2.40 GHz.

A. *Compared results*

The content includes the compared results of x-ma antenna comparing the simulated, analyzed and measured results of the proposed antenna structure.

B. *Comparision table*

The results of proposed x-ma antenna and its parameters are,

TABLE 4

COMPARISION TABLE

PARAMETERS	SIMULATION RESULTS	MEASURED RESULT	ANALYSIS RESULT
Frequeny	**2.421**	**2.403**	**2.400**
Return loss	**-15.551**	**-15.471**	**-17.9070**
VSWR	**1.4007**	**1.4388**	**-**

VI. CONCLUSION

An implantable CPW feed X-MA antenna for bio-medical applications is presented in this paper with the compact size of 10*10mm with the thickness of 0.635mm. The proposed antenna was simulated with human phantom model like skin, fat and muscle by CST (computer simulation software). Since the Rogers substrate is suitable for implantable application as it has highest dielectric constant. So, this designed antenna has lower return loss, VSWR, good impedance matching and high gain. Hence, the proposed antenna is completely suitable for ISM band frequency of 2.4-2.45GHz.

REFERENCES

[1] Asimina Kiourti and Konstantina S. Nikita (2014), Implantable Antennas 1527-3342/14/$31.00©2014IEEE.

[2] Jaehoon Kim, Student Member, IEEE, and Yahya Rahmat-Samii, Fellow, IEEE, Implanted Antennas in Human Body , Designs, and Characterizations (2004), VOL. 52, NO. 8, AUGUST 2004.

[3] Zhu Duan, Student Member, IEEE, Yong-Xin Guo, Senior Member, IEEE, Minkyu Je, Senior Member, IEEE, Dim-Lee Kwong, Fellow, IEEE,(2014), Design and Vitro Test of Differentially Fed Dual-Band Implantable Antenna which is Operating at MICS and ISM Bands, VOL. 62, NO. 5, MAY 2014.

[4] Changrong Liu, Student Members, IEEE, Yong-Xin Guo, Senior Members, IEEE, and Shaoqiu Xiao, Members, IEEE, (2014), Capacitively Loaded and Circularly Polarized.

[5] Implantable Patch Antenna for ISM Band in Biomedical Applications, VOL. 62, NO. 5, MAY 2014.

[6] *Toni Björninen,Member, IEEE, Rikky Muller, StudentMember, IEEE, Peter Ledochowitsch, StudentMember, IEEE, Lauri Sydänheimo, Member, IEEE, Leena Ukkonen, Member, IEEE, Michel M.Maharbiz, Senior Member, IEEE, and Jan M. Rabaey, Fellow, IEEE, (2012), "Design of Wireless Links to Implanted Brain–Machine Interface Microelectronic Systems", VOL. 11, 2012.*

[7] *Asimina Kiourti and Konstantina S. Nikita, (2012), "A Review of Implantable Patch Antennas for Biomedical Telemetry Challenges and Solutions", Vol. 54, No. 3, June 2012.*

[8] *Anatoly Yakovlev, Sanghoek Kim, and Ada Poon, Stanford University, (2012), "Implantable Biomedical Devices Wireless Powering and Communication", 0163-6804/12/$25.00 © 2012 IEEE.*

[9] *S. Ashok Kumar & T. Shanmuganantham (2014), CPW fed monopole implantable antenna.*

[10] *Antenna for 2.45 GHz ISM band applications,10.1080/21681724.2014.917712.*

[11] *X.L.Travasso, D.A.G.Vieira, and A.C.Lisboa (2011), Antenna Optimization Using Multi objective Algorithms, 10.5402/2012/369293.*

[12] *S. Ashok Kumar, T. Shanmuganantham (2013), "Design and analysis of implantable CPW fed bowtie antenna for ISM band applications", 10.1016/j.aeue.20.*