DESIGN OF PIFA ANTENNA FOR MEDICAL APPLICATIONS

S.Shaheen[#1] S.Dharanya[#2] V.Divya[#3] A.Umamakeswari[*4]

[#]M.Tech Embedded Systems, School of Computing, SASTRA University, Thanjavur, Tamil Nadu, India
[*]Associate Dean, School of Computing, SASTRA University, Thanjavur, Tamil Nadu, India
[1]shaheenece@gmail.com
[2]dharanyasubramanian@gmail.com
[3]divyavijay.ece11@gmail.com
[4]aum@cse.sastra.edu

***Abstract* - The emerging techniques in the medical field include the use of bio implantable antennas to diagnose the diseases. The major disadvantage of these techniques is the side-effects caused by the radiations in the human body. There have been a lot of advancements in this area to reduce the radiation emitted. One among them is the use of PIFA antenna inside an indestructible capsule (Polyetheretherketones) which is helpful in both short and long range communications. The work includes the design of PIFA antenna using IE3D and MATLAB software. The characteristics of the antenna are analyzed with the aim to reduce the size and radiation effect of antenna and to increase the gain, efficiency and data rate.**

Keywords- PIFA Antenna, IE3D, MATLAB Software, PEEK, Medical application.

I.INTRODUCTION

Wireless communication and Satellite communication play an important role in human life. The current development in medical and communication systems focus on low cost, low profile antennas to facilitate high performance over a wide frequency range which lead to the design of Microstrip (patch) antennas. Since the invention of the microstrip antenna, the demand for its application has been increasing rapidly, especially from the last two decades. A microstrip antenna is a thin metallic conductor bonded to a thin grounded dielectric substrate. The dielectric slab on the radiating patch is on one side of the antenna with a grounded plane at the other. The patch is a copper plate with rectangular / circular (elliptic) shapes. These shapes provide better efficiency with respect to bandwidth, pattern and polarization. The microstrip antenna exhibits an enormous flexibility ranging from 4 to 10dBi with respect to gain. The basic patch configurations have simple analysis and performance prediction.

There are many advantages of microstrip antennas, the foremost being lightweight, low volume, low profile than their waveguide or coaxial counterparts or conventional antennas. Also there are certain drawbacks like being bulky at low frequencies (~100MHz) to achieve given thickness (in terms of λ). Also microstrip antennas are narrowband antennas since their radiation is a result of resonance. Since the advantages overrule the disadvantages, the microstrip antennas are used in many applications which are as follows:

- Mobile and Satellite communications
- Remote sensing
- Global Positioning System (GPS)
- Direct Broadcast Satellite (DBS) Systems
- Medical applications

The microstrip antenna designed in this work is PIFA (Planar Inverted F Antenna) antenna which is mainly useful in medical applications.

II. EXISTING SYSTEM

An implantable glucose sensor was designed using MICS (Medical Implanted Communication Systems) to reduce the wave attenuation in PIFA antenna due to human body [1]. Reconfigurable antennas with L-shaped slots were designed to achieve ample bandwidth. This included the use of circular polarization and is applicable in licensed and unlicensed WiMAX, WLAN and satellite communications [2]. The radiation pattern and impedance bandwidth were calculated for a CPW (Coplanar Waveguide) with a U-shaped tuning stub to achieve higher bandwidth [3]. An electromagnetic field in a spherical multi-layered lossy media was analyzed and computed to reduce the power radiation of implanted antennas in human body [4]. The CMCBCPW (Conductor-Backed Coplanar Wavelength) characteristics were examined by using CAD (Computer Aided Design) and based on ANN (Artificial Neural Networks) approach. This approach is simple since it excludes complex mathematical technique [5]. A.K.Skrivervik *et al.* explained the method to design the miniaturized antennas in the PCS (Personal Communication System) [6]. M.Fernando *et al.* studied various antenna designs used in microwave medical imaging applications like cancer detection [7]. Anja K Skrivervik *et al.* analyzed and designed bio-implantable electrically small antenna for telemetry application [8]. Kenneth.P *et al.* designed underwater antennas (loop, dipole and folded dipole) for biological sensor networks [9].

III. PROPOSED SYSTEM

PIFA antenna is designed using IE3D software and MATLAB. The PIFA antenna being an omni directional antenna produces a low radiation effect which does not cause any side effects to the patients.

A. PIFA ANTENNA

Planar Inverted F Antenna (PIFA) is a linear Inverted F antenna (IFA). In order to increase the bandwidth, the radiator element is replaced by a plate. PIFA which has reduced backward radiation enhance antenna performance and minimizes the wave produced due to power absorption. It has maximum gain in terms of polarization states like horizontal and vertical. By changing the size of the ground plane the bandwidth can be tuned. To decrease the quality factor and to boost the bandwidth, many slits are inserted in the ground plane. In medical applications, the main aim is to reduce the size of PIFA antenna. This approach can have an effect on the impedance of the antenna terminals and it can be compensated with capacitive top loading. An equivalent circuit is replaced for the missing antenna height which improves the efficiency and impedance match. At the expense of fine matching and bandwidth, the resonance length can be reduced to less than λ/8 from λ/4 by the capacitive loading. To produce a parallel plate capacitor, the capacitive load can be placed by an additional plate which is equivalent to the ground. The geometrical shape of PIFA antenna is shown below in Fig.1.

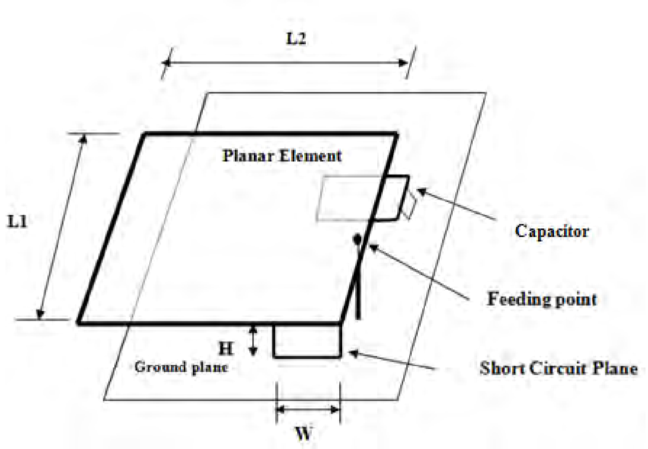


Fig . 1. Geometrical shape of PIFA antenna

The approximate resonant frequency of PIFA is:

$$L1 + L2 = \lambda/4 \quad (1)$$

$$\text{When } W/L1=1, \quad L1 + H = \lambda/4 \quad (2)$$

$$\text{When } W=0, \quad L1 + L2 + H = \lambda/4 \quad (3)$$

Where L1, L2 are the lengths of PIFA and W is width of PIFA.

When the width W decreases, the resonant frequency also decreases. Usually the micro-strip antennas are half wavelength dimensions, whereas the PIFA is a quarter-wavelength dimension. Hence it is best suitable for the medical applications. The impedance matching is obtained by reducing the gap between feed and shorting pins. The shorting pin and single feed are placed inside the slot for better impedance matching. The radiation pattern of this antenna is a function of direction in space with the relative distribution of radiated power. Radiation properties consist of field strength, power flux density, polarization and phase. The quality factor Q is inversely proportional to the impedance bandwidth of antenna as follows:

$$Q = \text{Energy Stored} / \text{Power Lost} \quad (4)$$

As shown in Fig. 2, the basic PIFA consists of a DC-shorting plate, a plate at the top of resonating patch, feed wire which feeds the resonating top plate and a ground plane that connects the ground and the top plate. Thus, the Planar Inverted-F Antenna is used in applications which has a low profile and an omnidirectional pattern.

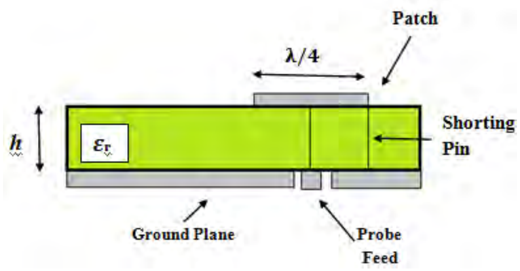


Fig . 2. The Planar Inverted-F Antenna (PIFA)

The feed is positioned between the open and short end. The feed location controls the input impedance. In PIFA, a plate forms the shorting pin as shown in Fig .3. Here L1 is the length and L2 is width. The feed is at a distance of D from the shorting pin and height h from the ground. The patch is a dielectric with permittivity ε_r. The distance between the feed and the short pin is adjusted to set the impedance. Based on *W*, the resonant frequency varies. If *W=L2*, the entire width of the patch is equal to the shorting pin. The resonant which has a maximum radiation efficiency when:

$$W=L2 \Rightarrow L1=\lambda/4 \quad (5)$$

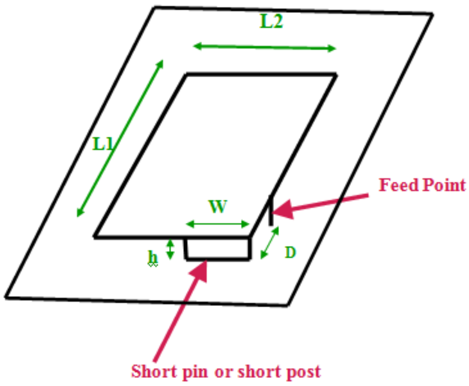


Fig . 3. The Planar Inverted-F Antenna with a shorting Plane

In general, the PIFA resonant length is

$$L1+L2-W=\lambda/4 \quad (6)$$

When *W=0*,

$$L1+L2=\lambda/4 \quad (7)$$

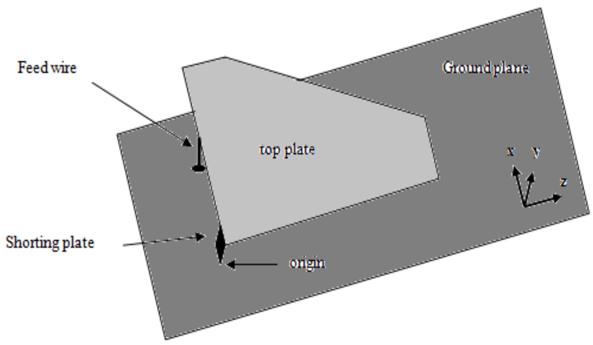
The relating wavelength, speed of light and permittivity can be defined by:

$$C=\lambda/4 \quad (8)$$

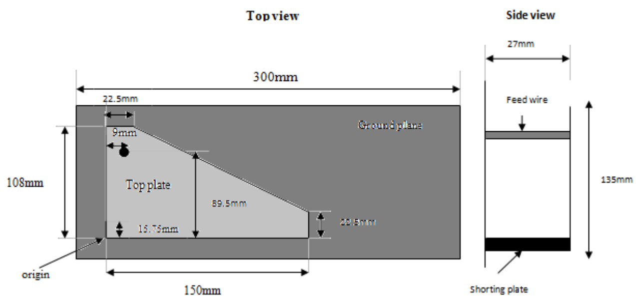
$$f=c_o/(\lambda*\sqrt{\varepsilon_r}) \quad (9)$$

Hence $$f=(3*10^8)/(\lambda*\sqrt{\varepsilon_r}) \quad (10)$$

Fig. 4. shows the geometric view of the quarter PIFA element for 440MHz.



(a)



(b)

Fig . 4. The PIFA structure optimized for 440 MHz. a) the isometric view; b) the top view

As shown in Fig. 5 the maximum return loss is -36.45 dB at 441 MHz. The upper and lower band frequencies are 410 MHz and 474 MHz with a bandwidth of 64 MHz. Therefore, the bandwidth obtained is 14.55%. The frequency range is between 1500 - 2500 MHz. The impedance value is 50Ω. The peak gain of an antenna is 1.5dB. The temperature value is between -30 to +85 degree Celsius. The maximum VSWR (Voltage Standing Wave Ratio) is 2.

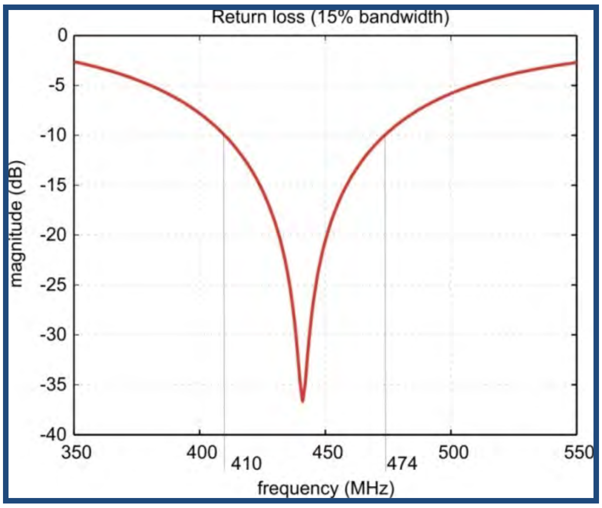


Fig .5. Return loss of the PIFA structure

IV. RESULTS

By substituting ε_r=4 in the above formulas (Eq.7 - Eq.10), the output is as follows:

$$d=0.04 \qquad (11)$$

$$\lambda/4 = 0.0650 \qquad (12)$$

$$L1=0.0650 \qquad (13)$$

$$L2=0.0400 \qquad (14)$$

By using these parameter values in the IE3D software, the result of Current distribution, Directivity, Gain, Return loss and the Structure view of PIFA antenna is as shown in Fig. 6 to 11.

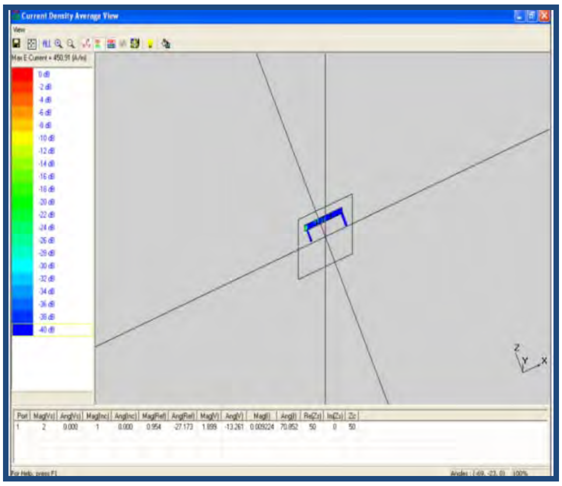


Fig. 6. Current distribution

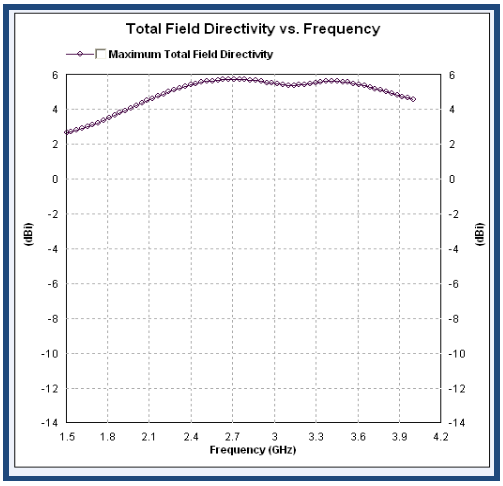


Fig. 7. Directivity

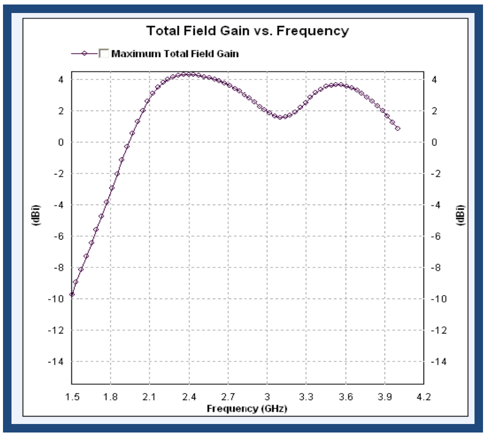


Fig .8. Gain

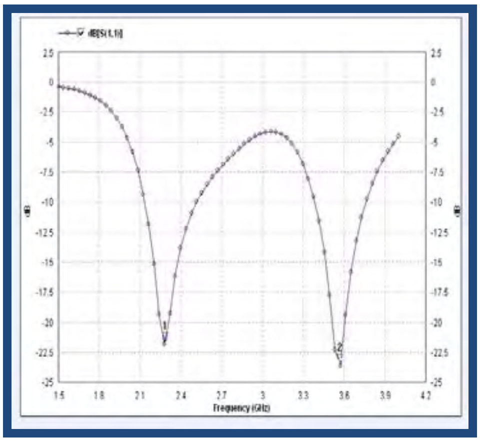


Fig. 9. Return loss

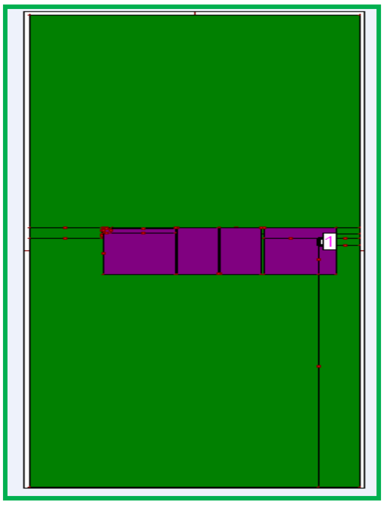


Fig. 10. Structure

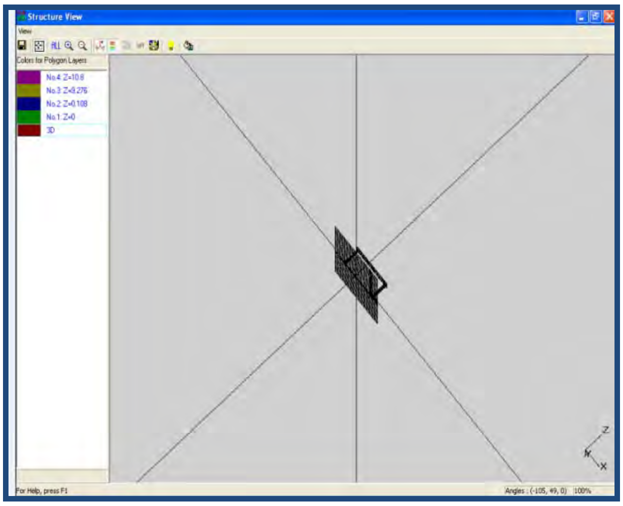


Fig .11. Structure view

The Smith chart for the Zo=50 Ohm is shown below in Fig.12.

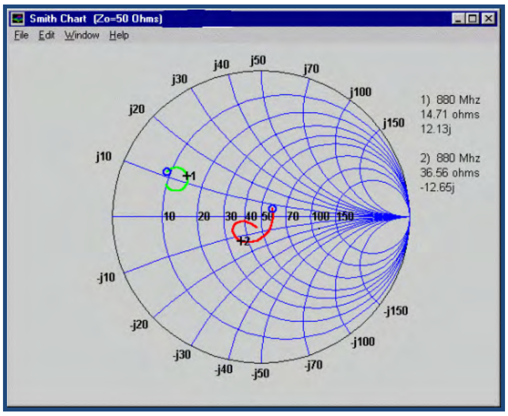


Fig .12. Smith Chart

V. CONCLUSION

The Bio-implantable PIFA antenna (Microstrip antenna) is designed in MATLAB and IE3D software and its characteristics are obtained. The PIFA has high gain and minimal size. An indestructible capsule made up of PEEK covers the antenna which doesn't cause any radiation effect to the patient. It is an omni-directional antenna plays an effective role in the long range communication for medical application. So the doctors can easily take care of their patients from a remote place. Thus, the PIFA antenna based medical application plays a vital boon for both doctors and patients in any emergency situations.

REFERENCES

[1] Merli. F, L. Bolomey, Meurville. E, and Skrivervik. A.K, "Implanted Antenna for Biomedical Applications", *IEEE Antennas and Propagation Society International Symposium,* San Diego, CA,1-4, 2008.

[2] Raghavan. S, Sriram Kumar. D, Kishore Kumar. M.S , " Reconfigurable Patch Slot Antenna for Circular Polarization Diversity", *International Journal of Microwave And Optical Technology,* Vol *3, No. 4*, 96-98 ,2008.

[3] Shanmuganantham. T ,Raghavan. S , "CPW Fed Rectangular Slot Antenna for Wideband Applications", *International Journal of Computer Applications (0975 – 8887)* Vol *39– No.12,* Newyork USA, 40-43, 2012.

[4] Francesco Merli, Benjamin Fuchs and Anja K. Skrivervik "Influence of Insulation for Implanted Antennas", *IEEE Antennas and Propagation, EuCAP:3rd European Conference,* Berlin ,196-199 , 2009.

[5] Thiruvalar. P Selvan and Raghavan. S , "Neural Model For Circular-Shaped Microshield And Conductor-Backed Coplanar Waveguide", *Progress In Electromagnetics Research M,* Vol *8*, 119-129, 2009.

[6] Skrivervik. A.K, Zurcher. J.F, 0. Staub and Mosig. J.R, "PCS Antenna Design:The Challenge of Miniaturization", *IEEE Antennas and Propagation Magazine,* Vol *43 No. 4,* 12-27, 2001.

[7] Fernando. M, K. Busawon, Elsdon. M and Smith. D, "Fundamental Issues in Antenna design for Microwave Medical Imaging Applications", *Communication Systems Networks and Digital Signal Processing (CSNDSP),* NewCastle upon Tyne UK, 795-800, 2010.

[8] Anja K. Skrivervik , Francesco Merli "On the efficient design, analysis and measurement of bio-implantable electrically small antennas", *IEEE URSI International Symposium on Electromagnetic Theory,* Switzerland, 853-856, 2010.

[9] Kenneth P. Hunt James J. Niemeier Anton Kruger, "Short Paper: Antennas for Mussel-Based Underwater Biological Sensor Networks in Rivers", *WUWNet Proceedings of the Fifth ACM International Workshop on UnderWater Networks,* Newyork USA, 2010.