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Design of Mirror E-Shape Implantable Antenna For Biomedical Applications

Mahalakshmi Nachiappan[1,*], *Thenmozhi Alagarsamy*[2] *and Vijay Jeyakumar*[3]

[1] Department of Electronics and Communication Engineering, Vickram College of Engineering, Tamil Nadu, India
[2] Department of Electronics and Communication Engineering, Thiagarajar College of Engineering, Tamil Nadu, India
[3] Department of Biomedical Engineering, SSN College of Engineering, Tamil Nadu, India.

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Abstract: An antenna with new mirror E-shape implantable patch has been proposed for bio-medical application at ISM band (2.4GHz to 2.48GHz). CPW is a feeding method, that is utilized for the proposed antenna design to attain maximum frequency response. This proposed antenna is fabricated using Rogers as substrate material with the dielectric constant of 9.8 and thickness of 1 mm. The dimension of the mirror E-shaped antenna is 11*11*1 mm, and it is located inside the human tissue, which has different layers such as fat, muscle and skin. The important antenna parameters such as VSWR, gain, return loss and radiation pattern are analysed. The major advantage of this proposed work is its compact dimension and enlarged precision. Hence, this proposed mirror E-shape patch can be used for numerous biomedical implantable applications.

Keywords: Biomedical applications, CPW feed, Implantable antenna, Mirror E type antenna, Phantom model

1 Introduction

The recent research activities in biomedical applications assures that an implantable antenna provides a substantial growth in the health care of a patient and their life attributes [1]. Now, the research and theoretical studies of implantable antennas are very fascinating attracting certain scientific interest . The implantable antenna operates in the range of MICS (401-406 MHz) band and ISM band (2.4GHz-2.48 GHz)[2], it is just an example of electromagnetic field and radio frequency application range. The patch antennas are compact in size, so it is widely used in medical implantable devices particularly in telemetry applications [3]-[5]. It enhances the communication between patients and doctors which results into better treatment, minimum diagnosis time, and improved healthcare. By changing the operating frequency, the permittivity and conductivity of the human body tissue can be varied. The most important criteria's that has to be considered while designing implantable patch antenna are size, operating frequency and permittivity with human tissue [1]. To achieve an effective communication, the patch structure is designed with wireless links by amputating cables [6]. The feeding method to antenna is Coplanar Waveguide (CPW) that is designed for greater frequency response [7,8]. In such a way, the precision of the designed structure can be significantly increased and the back radiation is reduced. The designed antenna could inspect [9] upon human tissues like muscle, fat and skin with their relative dielectric constant, electrical conductivity, mass density and permittivity. Additionally, the antenna parameters such as VSWR, return loss, gain and radiation pattern are measured. Return loss is measured, as 28.4 dB at central frequency of 2.42 GHz. Dimension of the proposed design is 11*11*1 mm.

2 Antenna Design

An antenna design depends on the parameters like frequency, substrate material selection and relative permittivity of antenna material. Fig.1 illustrates the structure of the mirror E- shape patch with their dimension. It is designed for 2.42 GHz resonant frequency. Rogers volume is 11*11mm with the thickness of 1mm in which the antenna etches. The designed antenna has 9.8 relative permittivity. Dual strips of 1mm

* Corresponding author e-mail: ece.nmaha@gmail.com

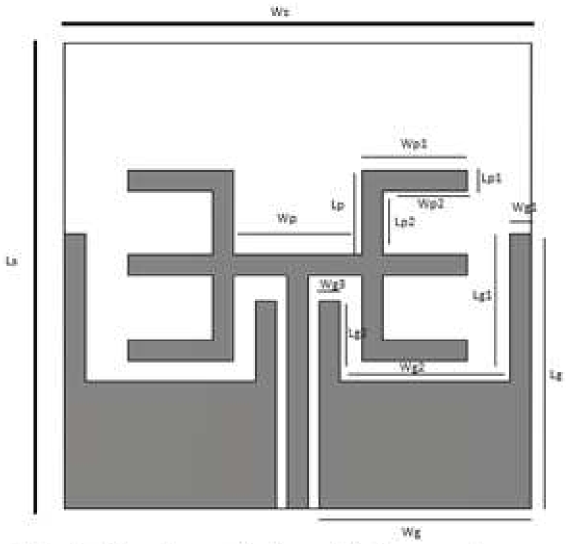

Fig.1. Structure of mirror E-shape antenna

Table 1: Dimensions of mirror E-shape antenna

Ws	Ls	Wp	Lp	Wg	Lg	Wp1	Lp1	Wp2	Lp2	Wg1	Lg2	Wg2	Lg2	Wg3
11	11	3	2	5	6.5	2.5	0.5	2	1.5	0.5	3.5	4	2	0.5

Table 2: Electrical Properties of Human Tissues

Tissue	Permittivity (ε_r)	Conductivity (σ)
Fat	5.28	0.10
Skin	38	1.46
Muscle	52.7	1.73

Table 3: Thickness of each Phantom Layers

Human tissue	Thickness (mm)
Antenna	1
Fat	4
Skin	4
Muscle	8

with 0.25mm gap bound the transmission line width. Coplanar ground plane feeding is used to excite the designed antenna. The mirror E-form patch is designed in ISM (2.4GHz-2.48GHz) for bio medical applications. The dimensions of the proposed mirror E-shape patch antenna are given in Table 1.All dimensions are in mm.
The designed antenna is simulated with the phantom model, which is developed for the human body composed of skin and fat material of length 4 mm respectively along with muscle length of 8 mm and this is used for experimental setup, with the help of relative dielectric constant. These electrical properties are listed in Table 2 and Table 3 respectively [12].
The flow of design requirements of proposed antenna are explained with the aid of flow chart as shown in Figure 2.

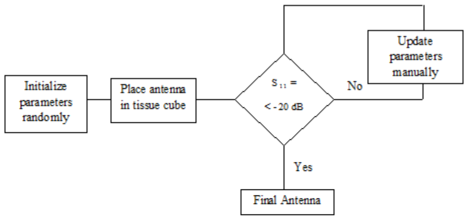

Fig.2. Flow diagram for proposed system

We randomly initialize the parameters like length, width, feed length and feed width of the proposed antenna. Initially designed antenna structure is placed in the multilayer phantom to ensure the biocompatibility of the antenna. Antenna along with phantom model is numerically analyzed with CST software (Computer Simulation Technology) and the corresponding S parameters are studied. Return loss S11 is obtained and verified for optimal value of -20dB .If the structure achieves -20dB return loss then it is said to be the final antenna design else we repeat the design process with different initial values until it achieve less than or equal to -20dB of return loss. The phantom reflection of proposed mirror E-shape patch is demonstrated in following Figure 3.

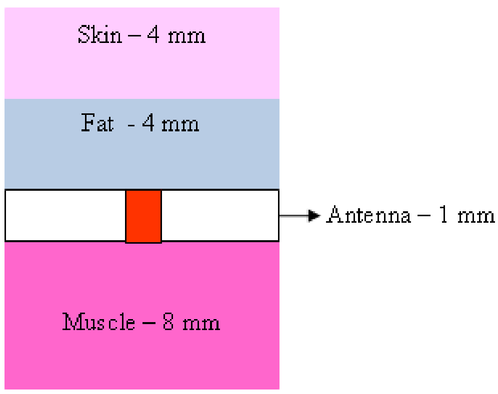

Fig.3. Phantom model

Fundamental requirement for phantom model can be understood by fig.3, where the tiny antenna of 1 mm thickness is placed above the muscle layer and upon the fat and skin layer of 4mm thickness respectively.

3 Results and Discussion

In this article, antenna specifications like VSWR, gain, radiation pattern and return loss and gain etc, are calculated with the help of CST software.

Return Loss: Return loss is measured as -28.4 dB at central frequency of 2.42 GHz. These results are shown in Fig 4. In the field of bio-medical application, the return loss is the important parameter, and it should be lower than -10dB.

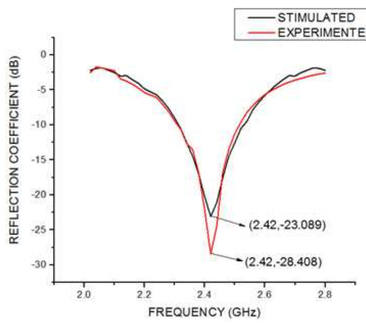

Fig.4. Comparison of simulated and experimented return loss of mirror E-shape antenna

Gain: The simulation results of designed antenna are shown in Fig.5. At lower band, the observed gain value is -14.5dB. In the case of higher band, the gain value is larger. The value of gain is directly proposed to radiation pattern, wavelength and current field distribution.

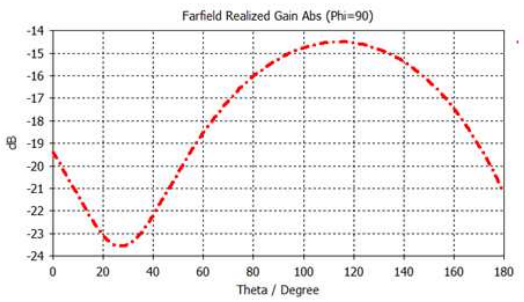

Fig.5. Gain of mirror E shape antenna

Radiation Pattern: radiation pattern of the antenna is generally obtained in E-field and H-field. These patterns of mirror E-shape patch are shown in Fig.6, which mainly illustrates its elevation outline at 2.42GHz. The both mentioned fields are called 2D radiation pattern, which shows that the antenna operates at a frequency of 2.42GHz and its highest gain is -14.5dB.

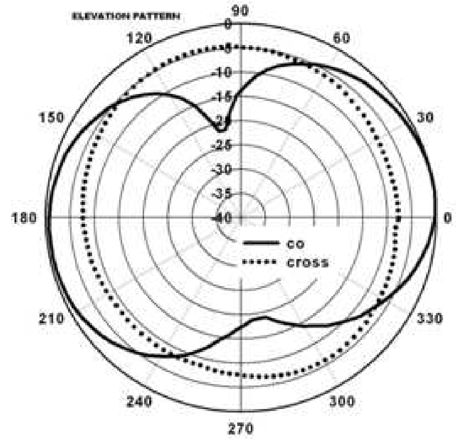

Fig.6 E-field pattern

The pattern of mirror E-shape patch is displayed in Fig .7.,it mainly depicts the azimuth outline at 2.42GHz.When phi=0,vertical polarisation is co-polarisation and horizontal polarisation is cross polarisation. When phi=90, vertical polarisation is cross polarisation and horizontal polarisation is co-polarisation. Fig 8 illustrates the 3D radiation pattern of proposed antenna. Radiation pattern is the graphical representation of the EM field. It is observed that the radiation spreads along with various directions.

Current Distribution

Fig.9.shows the current distribution and EM characteristics of mirror E-shape antenna at 2.42 GHz. The distribution of blue colour indicates minimum current distribution and the green colour indicates that the current distribution is more than the previous one .The scaling factor and sprinkling of current distribution are shown in the figure, which is at 89.8 dB and that creates a good environment for structuring the antenna.

Prototype of Proposed Antenna

Rogers's substrate is used for manufacturing the planned antenna. Antenna of 1mm thickness is constructed and measured with scale as shown in Fig. 10.Subminiaturized connector is connected and this fabricated antenna is attached to network analyser for measuring the

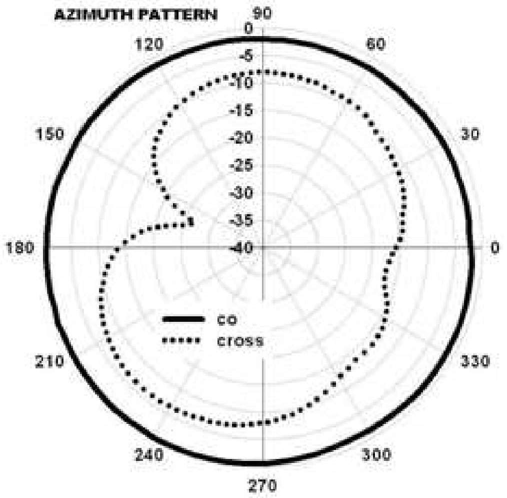

Fig.7.H-field pattern

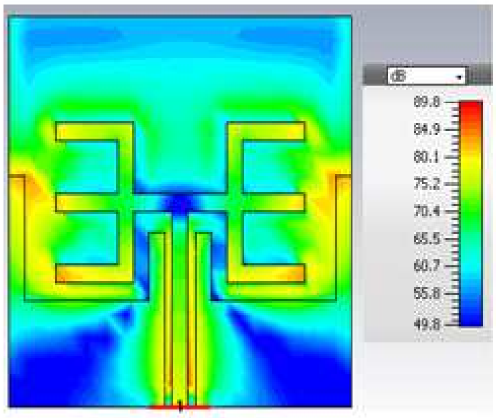

Fig.9. Current Distribution

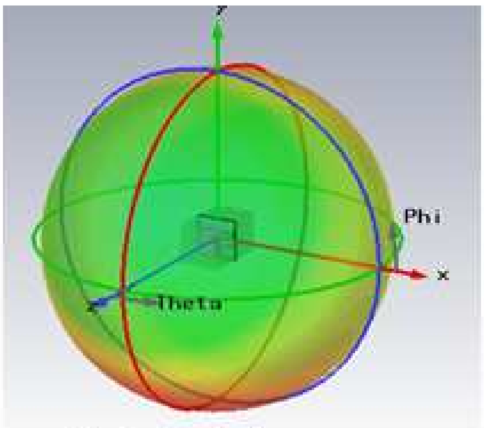

Fig.8. Radiation pattern

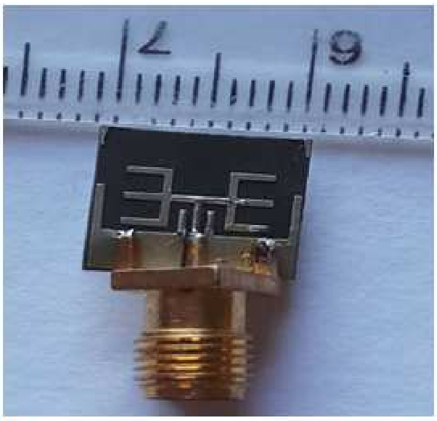

Fig.10.Prototype of the proposed mirror E-shape antenna

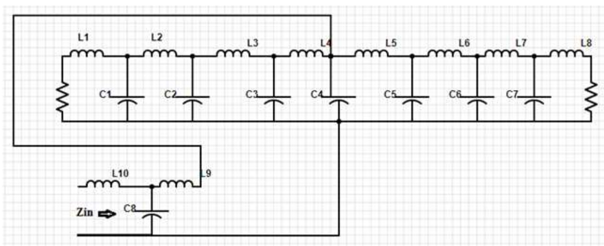

Fig.11.Equivalent circuit

parameters with and without phantom.

Equivalent circuit analysis:

The behaviour of antenna is studied by investigating various parameters and this gives a clear idea about equivalent circuit in antenna. The return loss of mirror E-shape can be schemed successfully using cascaded RLC circuit.

Fig.11.exhibits the equivalent circuit of mirror E which shows the perplexed circuit constitute of distibuted elements like capacitance, inductance, etc.that suits best for validating the design.

Using this equivalent circuit,one can foretell the attitude of an electrical circuit at high frequencies. At low frequency any circuit action as pure conductor and also high frequency parameters are inactive.When the frequency continuously increases distributed elements come into act and determination of high frequency parameters is made possible. From fig.11 it is evident that inductance effect is compensated equally by the capacitance and stablises the function of the mirror E antenna at high frequency ranges and make the circuit suitable for high frequency analysis.

4 Conclusion

In this paper, both equivalent circuit model and numerical analysis of dual E antenna is analysed for the frequency range of 2.42 GHz i.e. which is the ISM band for the application of implantable bio-medical industries. Designed antenna is validated with the parameters like radiation pattern, return loss, gain and VSWR. Then, the designed mirror E patch antenna is implanted in human tissue model developed with layers like skin, fat and muscle for the experimental purpose. The lower return loss -28.4 dB is achieved using high dielectric constant value of Rogers substrate which is designed with the thickness of 1mm. Comparison between numerical analysis and experimental analysis is carried out for proposed antenna and this shows good correlation between the simulated and experimented results, it is evidence the practical implementation of the same in bio-medical environment at ISM band .The measured results of proposed antenna renders good performance compared with other implantable antennas. Hence the current antenna structure is the most appropriate structure for bio-medical application at ISM band.

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Mahalakshmi Nachiappan She received B.E. degree in Electronics and Communication Engineering from Madurai kamaraj university, Madurai, India, in 1997, M.E. degree in communication systems from Sudharshan Engineering College, Anna University, Trichy, India, in 2011. She has Eighteen years of teaching experience in Polytechnic and Engineering Colleges in Tamilnadu, India. She is currently working towards the Associate Professor, Department of Electronics and Communication Engineering, Vickram College of Engineering, Tamilnadu, India. She has authored for 6 journals and conference papers. She is a member in professional bodies like ISTE and IET.

A. Thenmozhi is received B.E. degree in Electronics and Communication Engineering from Thiagarajar College of Engineering,madurai,in 1988, M.E. degree in communication systems from Thiagarajar College of Engineering,MKU,India,in 2004 and Ph.D in Department of Electronics Engineering, Thiagarajar College of Engineering,Anna university, Chennai, India, in 2010. She has twenty five years of teaching experience in Engineering Colleges in Tamilnadu, India. She is currently working towards the Professor, Department of Electronics and Communication Engineering,Thiagarajar College of Engineering,Madurai.She has authored for 10 journals and conference papers. Her current research interest includes Microwaves & RF filters and Antennas.

J. Vijay is an Associate Professor in the department of Biomedical Engineering and has 10 years of experience in the field of teaching. He completed his Bachelors degree in Electronics and Communication Engineering from Anna University in 2005 and obtained his master degree in Medical Electronics from College of Engineering, Guindy Campus in 2008. He has done his research in Medical Image Retrieval and obtained his Ph.D degree in medical informatics from Anna University in 2015. He has published more than 30 papers in peer reviewed journals and conferences. He is a recognized supervisor of Anna University, Chennai. He has authored two books titled “Image Retrieval Systems in PACS Environment” and “Basic Electrical and Electronics Engineering”. He has obtained funding from CSIR, TANSCST and ISTE to organize workshops, seminars and STTP. Dr. J. Vijay is an Editorial board member for three journals and peer reviewer forthe journals like Springer, Journal of Biomedical & Science Engineering and etc. He is an active member of IEEE, ISTE, IE and IAMI. He has filed one patent and his biography has been shortlisted by Marquis Who’s Who for its 2016 Anniversary edition. His areas of interest are Biological Signal and Image Processing, Medical Informatics, Soft Computing