

Investigations on Impalnted Anetnnas for Various Medical Applications in Human Structure

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1. INTRODUCTION

The use of advanced technology to deliver healthcare from a distance has the potential to be one of the defining medical revolutions of the 21st century. It is commonly recognized that modern wireless technology will play an important role in making advanced telemedicine possible.

The development of implantable medical devices (IMDs) is one of the most important aspects towards establishing such an advanced healthcare system. Essential elements of implantable devices are antennas embedded in such systems, which enable the exchange of data between implantable devices and external environment. Challenges faced by the designer of implantable antennas are considered and the subject of this thesis is presented, which is the design of an optimized implantable antenna, for wireless radiation dosimetry, for usage within external-beam radiotherapy.

2. DESCRIPTION:

The Biological implantable medical device. Then the basic operating principles of microstrip, PIFA (Planar Inverted F Antenna) Tissue Properties are presented since the biological environment is crucial to the operation an MICS and loop antennas as well as the Antenna Performance Parameters are described following by standard Miniaturization techniques. Finally, several antenna designs in Literature Review are reported as well as a brief description about the Simulation Software HFSS (High Frequency Structure Simulator).

3. MICRO STRIP ANTENNA FEEDING TECHNIQUES

1.Edge Feed

2.Inset Feed

3.Coaxial Feed

4.Aperture coupling and

5.Proximity coupling

1,2 and 3 being the contacting feed techniques and 4, 5 being non-contacting feed techniques

FEEDING TECHNIQUES

Co-axial feed:- In this feed, electric field is directly connected to patch from the bottom.

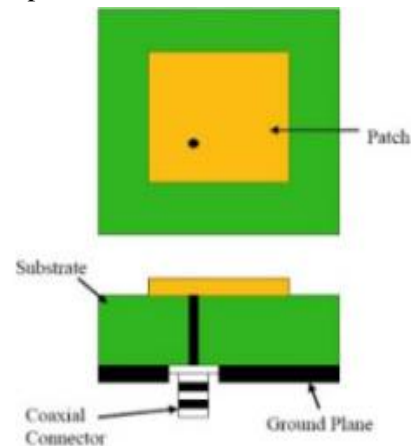
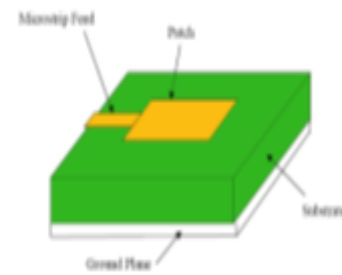


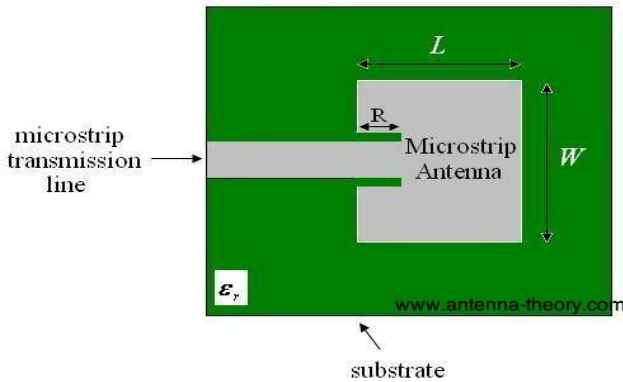
Fig:1

Edge feed:- In this feed, electric field is directly connected to the side of the patch

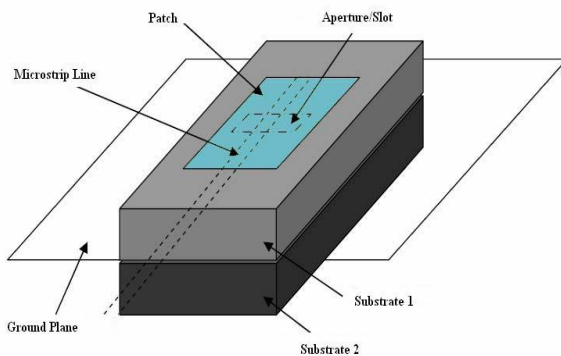


• Fig.2

Inset-feed: -In this feed, electric field is connected to side of the patch by inserting micro strip into the patch.

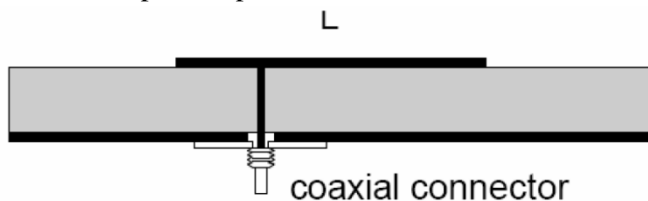


Aperture coupled feed: -here the patch and the micro strip feed line are being divided by the ground plane.



CO-AXIAL FEEDING

Patch antennas can also be fed from underneath via a probe. The outer conductor of the coaxial cable is connected to the ground plane, and the center conductor is extended up to the patch antenna.



4.ANTENNA BOUNDARY CONDITION

- Substrate Dielectric Constant: $-2.2 \leq \epsilon_r \leq 12$.
- Height of substrate: $-0.003\lambda_0 < h < 0.05\lambda_0$.
- Thickness of patch: $-t \ll \lambda_0$.
- Normally $W < 2L$ because of geometry constraints.
- Length of patch: $-0.3333\lambda_0 < L < 0.5\lambda_0$.
- Here $\lambda_0 = c/f_0$, $\lambda_0 =$ free space wave length.
 $c =$ velocity of light in free space.
 $f_0 =$ operating frequency.

4.1 ANTENNA DESIGN EQUATIONS

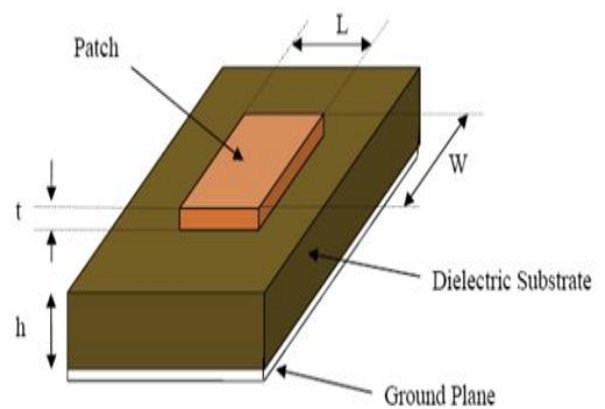
Frequency of operation = 2.4 GHz

Dielectric substrate = RT-Duroid-5880

Dielectric thickness (h) = 1.5 mm

Dielectric Constant (ϵ_r) = 10.2

Length(L) , Width(W) ,ground Length(Lg) and ground Width(Wg)of the Rectangular patch are calculated using the following equations



$$W = \frac{1}{2f_r \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r + 1}} = \frac{v_0}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}$$

$$\epsilon_{re\text{ff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}}$$

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{re\text{ff}} + 0.3) \left(\frac{w}{h} + 0.264 \right)}{(\epsilon_{re\text{ff}} - 0.258) \left(\frac{w}{h} + 0.8 \right)}$$

$$L = \frac{1}{2f_r \sqrt{\epsilon_{re\text{ff}}} \sqrt{\mu_0 \epsilon_0}} - 2\Delta L$$

$$B.W = \frac{f_{\text{max}} - f_{\text{min}}}{f_r} \times 100\%$$

Length and width of ground plane are:

$$L_g = L + 6h$$

$$W_g = W + 6h$$

Feed Location

$$X_f = \frac{L}{2\sqrt{\epsilon_{\text{reff}}}}$$

$$Y_f = \frac{W}{2}$$

Medical Implanted Communication Service

The Medical Device Radio Communications Service (MedRadio) or Medical Implanted Communication Service is a specification and communication spectrum created for and set aside by the U.S. Federal Communications Commission (FCC) for the communication needs of diagnostic and therapeutic medical implants and body-worn medical devices. Devices operating on MedRadio include cardiac pacemakers, defibrillators, neuromuscular stimulators, and drug delivery systems.

The Medical Device Radio Communications Service (MedRadio) is in the 401 – 406, 413 – 419, 426 – 432, 438 – 444, and 451 – 457 MHz range. MedRadio spectrum is used for diagnostic and therapeutic purposes in implanted medical devices as well as devices worn on a body. For example, MedRadio devices include implanted cardiac pacemakers and defibrillators as well as neuromuscular stimulators that help restore sensation, mobility, and other functions to limbs and organs. The FCC created the Medical Implant Communication Service (MICS) in 1999 "in response to a petition for rule making by to permit use of a mobile radio device, implanted in a patient, for transmitting data in support of the diagnostic and/or therapeutic functions associated with an implanted medical device.

MICS provided additional flexibility to medical device developers compared to previously used inductive technologies, which required the external transceiver to touch the skin of the patient. MICS was later adopted by

the ETSI in 2002. This set aside the 402–405 MHz band and designated a low maximum transmit power, EIRP=25 microwatt, in order to reduce the risk of interfering with other users of the same band. Ten channels of 300 kHz each were assigned to the bandwidth. Additional modifications to the MBAN rules were released in August 2014, including the "narrowing of the definition of health care facilities that may use MBAN devices in the 2360-2390 MHz band" and relaxing MBAN network topology restrictions among others

5. OBJECTIVE AND TASK CARRIED OUT

The work proposed in the thesis focuses on several aspects of implantable antenna design for bio medical applications. Considering the constrains and further the demand of wireless disimetry the following objectives are drawn.

Design of implantable antenna structures suitable for bio-medical applications

- Explore characteristics of implantable antenna with modified boundary conditions.
- Developing an implantable antenna design that is smaller in size which operates at MICS band
- Optimize the chosen implantable antenna for bandwidth, return loss, radiation pattern, etc.

Methodology

HFSS is an interactive software for calculating the electromagnetic behavior of a structure. The software includes post-processing commands for analyzing this behavior in detail.

Using HFSS, you can compute:

- Basic electromagnetic field quantities and, for open boundary problems, radiated near and far fields.
- Characteristic port impedances and propagation constants.
- Generalized S-parameters and S-parameters renormalized to specific port impedances.
- The Eigen modes, or resonances, of a structure.

System Requirements

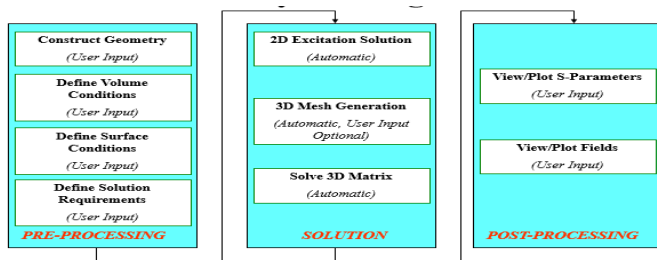
- HFSS supports the following operating systems:
- Windows
- Linux

6. SETTING UP AN HFSS DESIGN

To set up an HFSS design, follow this general procedure. Note that after you insert a design, you do not need to perform the steps sequentially, but they must be completed before a solution can be generated.

1. Insert an HFSS or HFSS-IE design into a project.
2. Select the solution type.
3. Set the model's units of measurement.
4. Draw the model geometry and assign material characteristics to objects.
5. Assign boundaries, which specify the field behavior at the edges of the problem region and object interfaces.
6. For Driven solution-type designs, assign excitations - sources of electromagnetic fields and charges, currents, or voltages on objects or surfaces.
7. Specify how HFSS or HFSS-IE will compute the solution.
8. (Optional) Set up any Optimetrics you want to run.
9. Run the simulation.
10. View solution results, post-process results, view reports, and create field overlays.

7.HFSS ANALYSIS DESIGN FLOWCHART



In this chapter, the simulation technique, Finite Element Method (FEM) and the software tool, High Frequency Simulation Software (HFSS) which are used for the design and simulation of the antenna, are described.

HFSS is high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes the advantage of the familiar Microsoft Windows user interface. It is an interactive

software package for calculating the electromagnetic behavior of a structure. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give unparalleled performance and insight to all 3D EM problems.

Ansoft HFSS can be used to compute:

- Basic electromagnetic field quantities.
- Characteristic port impedances and propagation constants.

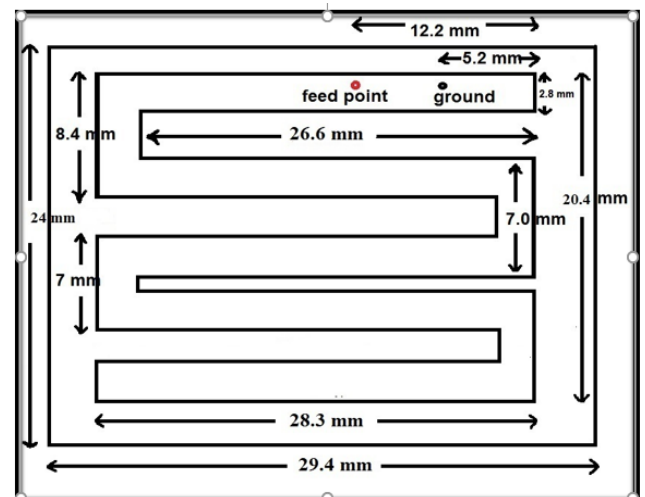
Generalized S-parameters and S-parameters renormalized to specific port impedances

Patch Antenna Designing's

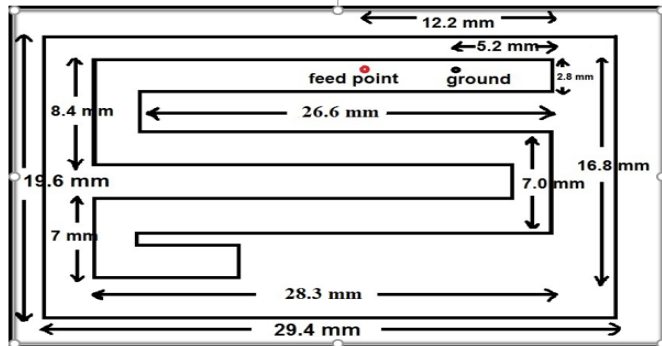
Figure Numbers	Name of the Patch Antenna	Dielectric Constant (ϵ_r)	Thickness	substrate
Fig.8	Spiral Microstrip Antenna - 1	10.2	1 mm	Rogers-RO3210(tm)
Fig.9	Spiral Microstrip Antenna - 2	10.2	1mm	Rogers-RO3210(tm)
Fig.10	Rectangular Microstrip Antenna - 1	10.2	1mm	Rogers-RO3210(tm)
Fig.11	Rectangular Microstrip Antenna - 1	10.2	1mm	Rogers-RO3210(tm)
Fig.12	Spiral Microstrip Antenna - 3	10.2	1mm	Rogers-RO3210(tm)
Fig.13	Spiral Microstrip Antenna - 4	10.2	1mm	Rogers-RO3210(tm)

Table-1

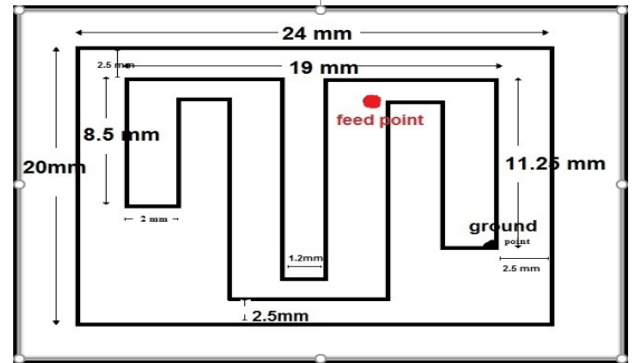
Spiral Microstrip Antenna – 1



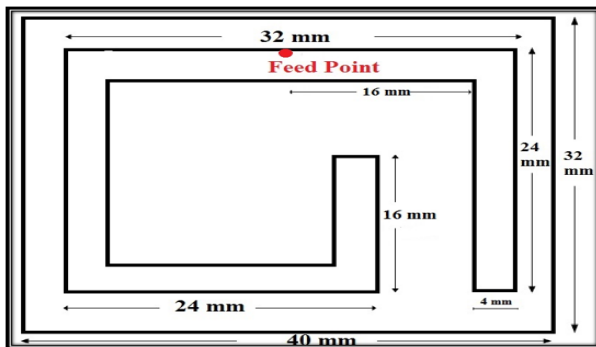
Spiral Microstrip Antenna -2



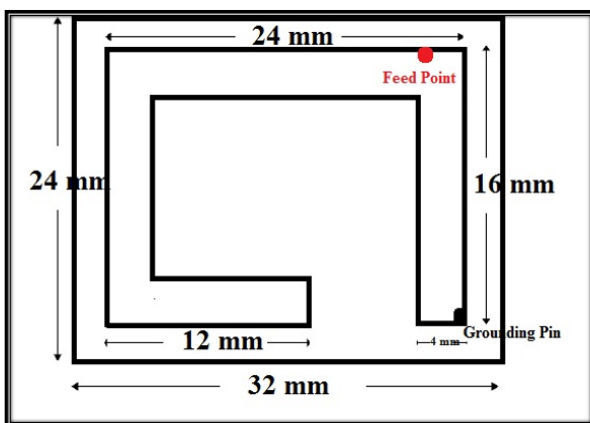
Spiral Microstrip Antenna -4



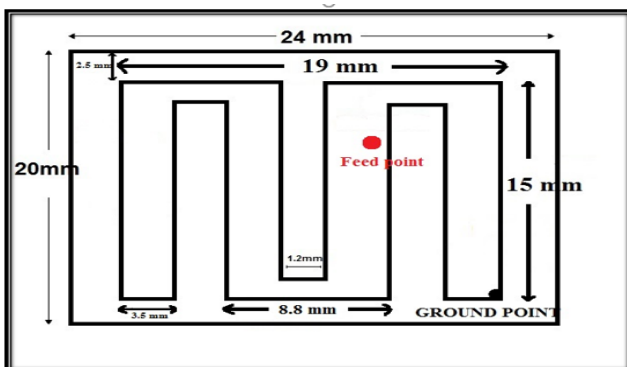
Rectangular Microstrip Antenna - 1



Rectangular Microstrip Antenna -2



Spiral Microstrip Antenna -4



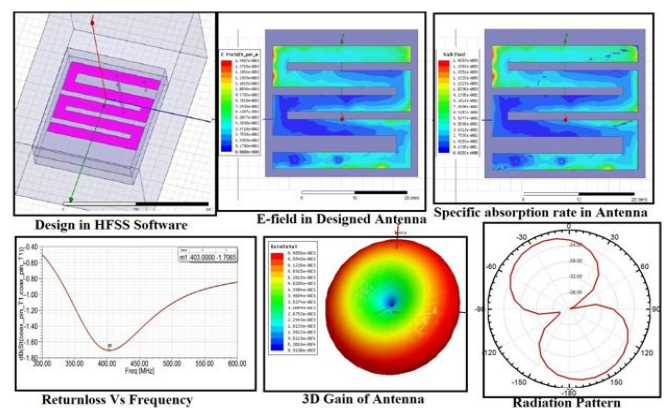
Designing's Dimensions:

S.no	Fig no	Dimensions (Including ground Plane)	Patch Dimensions (After Tuning or Optimization)
1	Fig . 1	29.4 mm X 24 mm	28.3 mm X 20.4 mm
2	Fig . 2	29.4 mm X 19.8 mm	28.3 mm X 16.8 mm
3	Fig . 3	40 mm X 32 mm	32 mm X 24 mm
4	Fig . 4	32 mm X 24 mm	24 mm X 16 mm
5	Fig . 5	20 mm X 24 mm	19 mm X 15 mm
6	Fig . 6	20 mm X 24 mm	19 mm X 11.25 mm

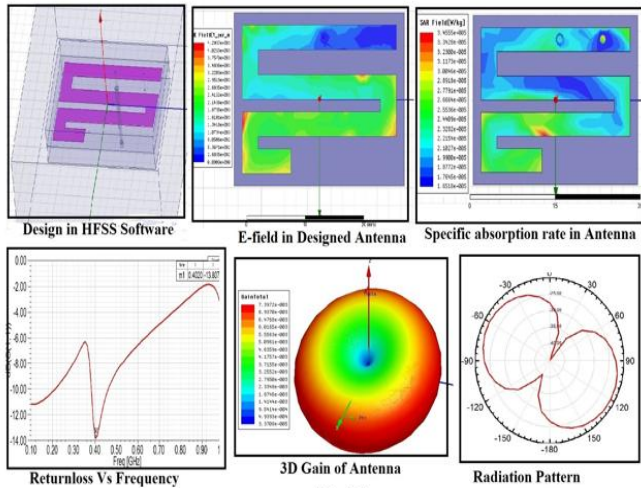
ANTENNA PERFORMANCE CHARACTERISTICS

- DESIGNED ANTENNA IN HFSS
- CURRENT DISTRIBUTION
- SPECIFIC ABSORPTION RATE(SAR)
- RETURN LOSS(S11)
- GAIN IN 3D
- RADIATION PATTERN

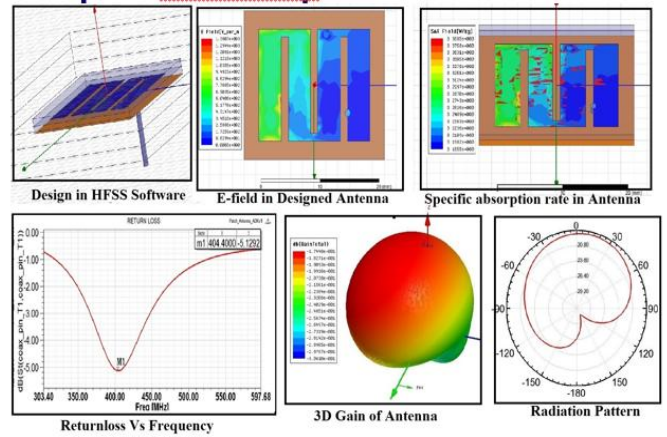
8.SPIRAL MICROSTRIP ANTENNA - 1RESULTS



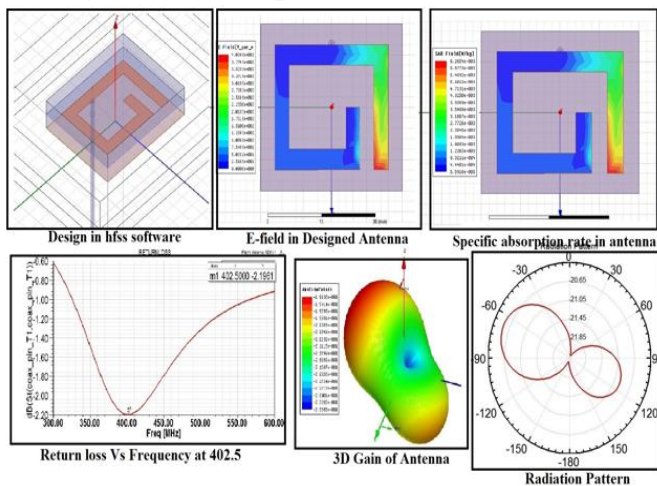
Spiral Microstrip Antenna – 2 Results



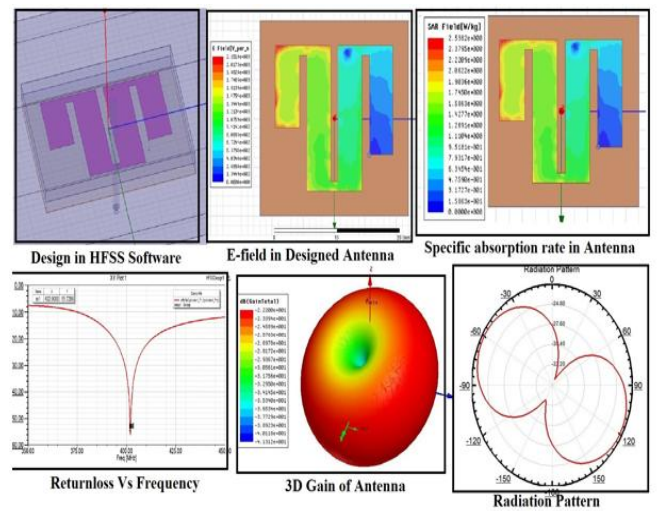
Spiral Microstrip Antenna – 3 Results



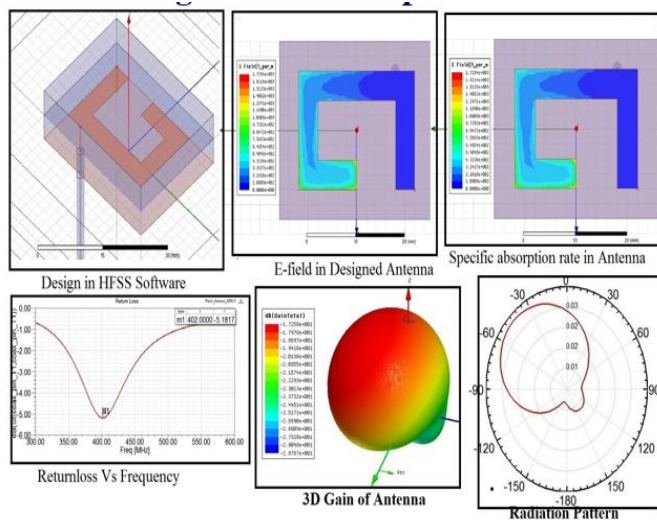
Rectangular Microstrip Antenna - 1



Spiral Microstrip Antenna – 4 Results



Rectangular Microstrip Antenna - 2



Comparison of Results with all Designed antennas:

Figure Numbrs	Name of the Patch Antenna	Frequency	reflection coefficient s11
Fig.8	<u>Spiral Microstrip Antenna - 1</u>	403 MHz	-1.706 dB
Fig.9	<u>Spiral Microstrip Antenna - 2</u>	402 MHz	-13.807 dB
Fig.10	<u>Rectangular Microstrip Antenna - 1</u>	402.5 MHz	-2.190 dB
Fig.11	<u>Rectangular Microstrip Antenna - 1</u>	402 MHz	-5.18 dB
Fig.12	<u>Spiral Microstrip Antenna - 3</u>	404.4 MHz	5.129 dB
Fig.13	<u>Spiral Microstrip Antenna - 4</u>	402 MHz	-55.77 dB

9. CONCLUSION

Six types of implantable antenna structures, which are suitable for miniaturization, were designed, which include a meandered PIFA, Spiral PIFA and Rectangular PIFA. A parametric analysis of the proposed geometries is performed. In order to understand the performance of these antennas when implanted in a lossy material (phantom). This study also allows to achieve miniaturization and the impact of these parameters.

The initial geometry of the proposed PIFA design has a diminutions of 28.3 X 20.4 mm. applying the parametric analysis of the antenna dimensions are reduced in steps through 28.3 X 16.8, 32 X 24 mm, 24 X 16 mm, 19 X 16mm and finally to 19 X 11.25 mm. when compared the final antenna design. Observe a reduction in size with respect to initial design. The proposed spiral antenna is well matched at 402 MHz with -14.65 dB reflection coefficient. The Radiated Power is enough for communication outside of the body.

10. FUTURE SCOPE

However, future scope of the work could be to improve the Radiation Efficiency. While managing miniaturization concerning to the 1 X 1 mm design.

11. REFERENCES:

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