Implantable Circular Patch Antenna in Medical Devices

A report submitted in partial fulfilment of the

requirement for the award of certification of

MINOR PROJECT

in
Implantable Circular Patch Antenna

By

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DECEMBER, 2022

Table of Contents

LIST OF FIGURES

LIST OF TABLE

Certificate

I hereby certify that the work which is being submitted in this report titled "Implantable Circular Patch Antenna in Medical Devices", in partial fulfilment of the requirement for the award of certification of "Minor project" submitted in Bharati Vidyapeeth's College of Engineering, New Delhi, is an authentic record of our own work carried out under the supervision of "Mr Rajiv Nehra" and refers to other researchers work which are duly listed in the reference section.

The matter presented in this report has not been submitted for the award of any other certificate of this or any other institution.

Vikram Kumar, Prince Sareen, Raja Ahmed, Jatin, Alnoor Parveen

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This is to certify that the statements made above by the candidate are correct and true to the best of our knowledge.

The Viva-Voce Examination of has been held on 20 January 2023 tentatively.

Internal Examiner External Examiner

ACKNOWLEDGEMENT

We express our deep gratitude to Mr. Rajiv Nehra for his valuable guidance and suggestion throughout our project work. We are thankful to him for his valuable guidance. We would like to extend our sincere thanks to Head of the Department, Prof. Kirti Gupta for her time-to-time suggestions to complete our project work. We are thankful to Dharmendra Saini, Principal for providing us the facilities to carry out our project work.

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Abstract

In this Report we discussed about the implantable circular patch antenna in medical devices, after the review of this Report reader will understand what implantable antenna is and how these implantable antennas become boon for medical industry. Majorly these antennas used in implantable devices i.e., the instruments that is either wholly or partially implant into the body. Implantable antenna is an antenna which is implanted in humans or simply placed across the torso (tissue) to establish a bio-communication system between medical equipment and external devices for short-range biotelemetry purposes. The main purpose of these antennas is to set up the communication between internal environment and external environment, Different types of body-centric wireless communications include on-body, off-body, and in-body communications. On-body communication is demonstrated via wearable tech. Off-body communication is the term used to describe communication between on-body devices and external devices. An implanted device and an external health-monitoring device make up the in-body communication system. Because an antenna may function as a transmitting or receiving antenna, it is crucial for body-centric wireless communication networks. These implantable antennas used in implantable devices which helps in to effectively monitor or examine different bodily diseases and then transfer this information to the server or base station. Antenna design is crucial for effective communication between the implant and the base station. IMDs have a variety of uses in these systems, including remote drug delivery, hyperthermia for the treatment of cancer, and monitoring of vital signs. The implantable devices are placed inside the body where they track bio-signals (like blood pressure and temperature signals) and transmit the data to the external device. Industrial, Scientific, and Medical (ISM) (2.45 GHz) band frequencies or the Medical Device Radio band (401-406, 413-419, 426-432, 438-444, 451-457 MHz) or Medical Implantable Communication Service (MICS) (402-405 MHz) are where they function. The use of circular microstrip patch antennas is extensive, particularly in the domains of pharmaceutical, military, mobile, and planetoid communications. The impedance of microstrip antennas varies depending on the frequency, polarity, prototype, and explicit patch composition.

Keywords – Implantable Medical Devices (IMDs), circular Polarization (CP), Metamaterial (MTM), Axial ratio bandwidth, Impedance , Miniaturization , ISM Band.

Chapter 1

Introduction

Wireless communication technologies have experienced a huge development in recent years. Growthin portable and wearable wireless devices has made Body-centric applications an integral part of our daily life resulting in vastly growing field of Body-centric Wireless Networks (BCWNs). On-body, off-body and in-body communications are different forms of body centric wireless communications

1.1 Introduction to Implantable Antenna

Wearable devices exhibit on-body communication. The communication between an on-body device and external device is referred as off-body communication. The in-body communication consists of an implantable device and an external device for health monitoring. For Body-centric wireless communication networks, antennas, and propagation play an important role because the antenna either work as transmitting or receiving antenna. So, if the performance of the antenna is not good it will affect the performance of whole system. In biomedical telemetry, the IMDs are capable of monitoring patient physiological data wirelessly in real time [3], [4]. IMDs have many applications in these systems such as hyperthermia for cancer treatment, remote drug delivery and vital signs monitoring. The implantable devices are placed inside the body where they monitor bio-signals (such as blood pressure and temperature signals) and send the information to the external device. They operate at either of Medical Device Radio band (MedRad) (401-406, 413-419, 426-432, 438-444, 451-457 MHz, Medical Implantable Communication Service (MICS) (402-405 MHz) or Industrial, Scientific and Medical (ISM) (2.45 GHz) band frequencies. The external device can be used to process the information, transmit signal to implantable device such as wakeup signals and wireless power transfer for RF energy harvesting. It receives the information from the implantable device and send it to the monitoring unit where post processing is done to analyze the patient data by medical experts for an appropriate treatment. These health monitoring systems are very useful in diagnosing some life-threatening diseases such as cancer and diabetes in their early stages and reduce the cost and trouble of keeping the patient in hospitals significantly.

1.2 Importance of Antenna in Implantable Devices

In recent research activities in biomedical applications, an implantable antenna assures the substantial growth in patient’s health and their life. The implantable antennas are operated in the range of MICS (401–406 MHz) and ISM band (2.45 GHz), it just a few examples of electromagnetic field and radio frequency application. The patch antennas have compact size and low profile so it makes the necessary use of medical implant devices mostly telemetry application the patch antennas place the important role. It makes the communication between patients and doctors, so the treatment performance is so easy. The implantable patch antenna makes the easy communication between doctor and patient. Researchers have so far examined a variety of methods. By prolonging the current route on the patch surface, miniaturization is accomplished. It can be challenging for researchers to achieve the greatest efficiency from implanted antennas in the lossy condition of the human body. SAR is hence a key factor in assessing the performance of implanted antenna. SAR is the body's rate of heat absorption per kilo gram of mass. Because a rise in body temperature may alter the relative permittivity of human tissue, a very high antenna radiation absorption may result in a major issue (temperature rise). Providing a wireless charging capability for the battery in BMDs is another significant difficulty. DC biassing energy is required to operate all electrical equipment. The only way to guarantee the proper operation of BMDs is with a charged DC battery. It would be difficult for patients frequently undergo surgery in order to recharge or replace the BMDs' battery. Therefore, appropriate wireless battery charging techniques are very necessary.

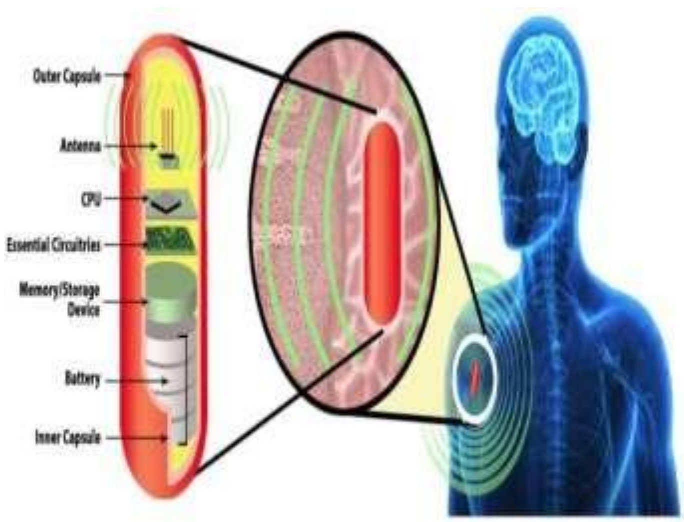

Figure 1: Structure of Antenna

The implanted antenna must be created with two bands to perform wireless charging (ISM bands). Here, the two bands are used so that one band is used for data transmission during telemetry sessions and the other band uses radiation and converts it into DC voltage using a rectifier and filter (integral parts of BMDs) for wireless charging without changing the placement of IMDs in the humanbody. The IMDs are intended to wirelessly interact with receiver equipment outside the human body while continually monitoring a variety of processes inside the human body. Consequently, animplanted antenna is required. Unlike conventional antennas, which function in open space, antennasused within the body have distinct radiation properties, must adhere to a number of requirements, andmust consider patient safety. Different medical implant applications presently utilize permittedfrequency ranges in a variety of ways. Industrial Scientific Medical (ISM) (433-238 MHz), Medical Device Radio Communication Service (Med Radio, 401-406 MHz), 886-906 MHz, 2.4-2.48GHz, 5.725-5.875 GHz, and Wireless

1.3 Different types of implantable antennas

Different types of implantable antennas are **Planar Antennas**: The achieved gain of the antenna, which has a 2.42 GHz center frequency, is -20.8 dB. Its bandwidth is 10.4%, however its efficiency is unknown. A single layer tissue model with dimensions of 150 150 90 mm3 and parameters of _r=37.88 and _=1.44 S/m at 2.42 GHz was used to measure the antenna, **Wire Antenna**: a helical implanted antenna with circular polarization (CP) for use in capsules shaped antenna. The antenna has a 290 MHz bandwidth, a gain of -19.83 dBi, and works at 2.4 GHz. **Conformal Antennas**: It uses a Rogers RO6010 substrate with _r =10.2 and tan =0.0023 and runs at 2.45 GHz. The antenna measures 14.2 16.64 0.254 mm3 in size. Gain and bandwidth for the antenna are -29.1 dBi and 31%,respectively. Antenna effectiveness is unreported. Muscle phantom measuring 100 100 100 mm3 with _r=52.74 and _=1.74 S/m is used to test the antenna. **Spiral Antennas:** It is an antenna with CP. The antenna measures __52 1.27 mm3 and works at 2.45 GHz. The substrate is Rogers 3010, which has a _r = 10.23, tan = 0.0035, and a thickness of 0.635 mm. Muscle tissue is used to test the antenna with _r=52.7 and _=1.74 S/m. Gain of 22.7 dBi and bandwidth of 12.4% are also provided. There is no information on the antenna's effectiveness. **Slot Antennas**: The antenna is 10 10 0.65 mm3 in size and has a 2.45 GHz resonant frequency. The antenna is tested in a liquid phantom with an Al2O3 substrate and has a peak gain of -6 dBi and a bandwidth of 8.2%. Antenna radiation efficiency is 0.4%. **Planar Inverted F Antennas (PIFA):** A modest, 402 MHz, compact, broadband implanted PIFA with a dimension of 23 16.4 1.27 mm3. The substrate has a tan of 0.0023 and a r of 10.2. The antenna achieves a gain of -34.9 dBi and a bandwidth of 52 MHz.

Table 1: Different types of implantable antennas

Antenna type	Frequency	Dimensions of antenna (mm^3)	Model used	References
PIFA	402 MHz	32 × 24 × 4	Skin	63
Dipole	402 MHz	16.5 × 15.7 × 0.27	Skin	64
PIFA	402 MHz	22.7 × 49 × 1.9	Skin	65
Dipole	542 MHz	27 × 14 × 1.27	Skin	66
PIFA	402 MHz	8 × 8 × 1.9	Skin	67
Monopole	402 MHz	18 × 16 × 1	Skin	68
Slot	402 MHz	10 × 11 × 27	Skin	69

1.4 EFFECTS ON IMPLANTABLE ANTENNA ON HUMAN BODY

The human body is a crucial component of IMDs. The high conductivity and permittivity of human body tissues generate attenuation loss within the human because it is a very lossy medium where the electric characteristics of the tissues alter with the change in functioning.

Human Body Effects on Antenna Bandwidth: The implanted antennas have a small footprint and a limited bandwidth. However, due to absorption and reflection by bodily tissues, not all the radiation's strength reaches the recipient. For implanted antennas, the absorbed power is significantlymore than the reflected power, resulting in a broader bandwidth at the expense of a reduced radiationefficiency. As was previously said, these losses can be decreased by employing bio-encapsulation andimpedance matching, which would narrow the bandwidth. The narrow bandwidth implanted antennas,however, experience frequency detuning inside the human body. Therefore, it is necessary to approach this problem with caution.

Human Body Effect on Antenna Radiation Pattern: Because of reflections, refractions, and scattering that occur within or from the bodily tissues, the lossy human body may cause the radiation pattern to become more diffuse. If mounting circumstances and in-body placements vary, an implanted antenna's radiation pattern would similarly vary in the same material.

Measuring Human Body Effects: The design of implanted antennas is extremely challenging since they must function under challenging circumstances. These antennas are created using a variety of devices and programs.

Chapter 2

Literature Review

In recent research activities in biomedical applications, an implantable antenna assures the substantial growth in patient's health and their life. The implantable antennas are operated in the range of MICS (401–406 MHz) and ISM band (2.45 GHz), it just a few examples of electromagnetic field and radio frequency application.

2.1 Study

The literature showed no positive effect of the type of attachments on patient satisfaction with implant-supported overdentures. Burns *et al* suggested no difference in patient satisfaction with mandibular implant-supported overdentures when 2 types of attachments (*i.e.*, magnets and O-rings) were used. In addition, Wismeijer *et al*23 reported no difference in the levels of patient satisfaction with either ball or bar attachments when they were used to anchor the implant-supported overdentures. Similarly, in a randomized study, Naert *et al* assessed patient satisfaction 5 years following the provision of overdentures that were anchored to implants *via* 3 different attachment systems and found similar levels of satisfaction regardless of the type of the attachment used. Accordingly, Ambard *et al*4reported a similar conclusion when they compared direct ERA (Sterngold, Attleboro, MA) attachments and Hader bars that were used to anchor implant-supported overdentures.

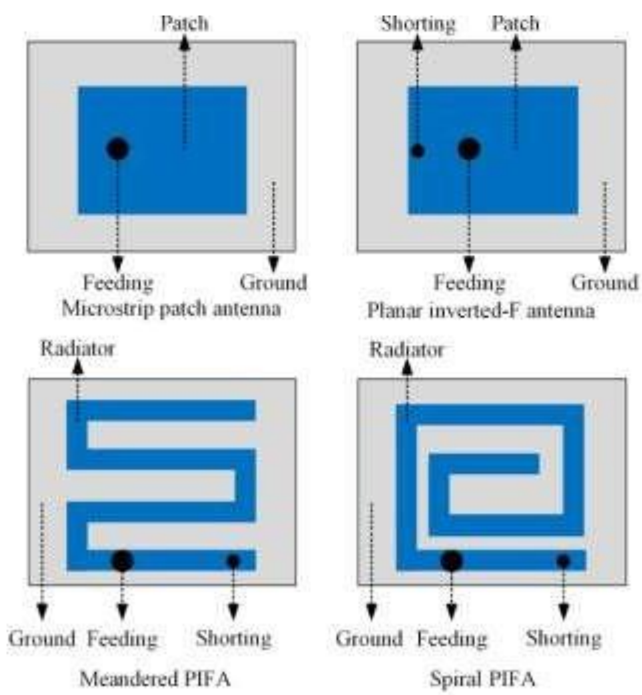

Figure 2: Different Antenna Designs

2.2 Typical Requirements of Implant Systems

When designing an implantable electronic system, several general requirements are to be addressed, namely minimal size and weight, low power consumption, good reliability, high biocompatibility and minimal toxicity, high data rate and data latency. As the case with any commercial product, the design of the implantable devices is heavily influenced by the demands and preferences of their consumers. In addition to being less invasive to the body of the patient during the implantation, smaller and lighter devices are likely to result in less pain and discomfort to the host during healing and use. The excessive size and weight may be detrimental to the healing process by putting pressure on the adjacent tissues that have already been damaged as a result of surgery, contributing to the inflammatory processes within the peri-implant space. Small and light devices are less restrictive in terms of normal level of human activity, and thus afford better quality of life to the patients. The power source and encapsulation components remain the major contributors to the overall weight and size of the device, whereas the electric circuitry components have decreased dramatically with the advancements in MEMS and nanotechnology. Coupling capacitors used to ensure charge-balance and effectively minimize current leakage may further increase the volume of the implantable module

2.3 DUAL-BAND USE

To transition between sleep and wake-up modes, therefore conserving energy and increasing the lifespan of the implanted devices, a dual-band implantable antenna was developed [15]. Medical implant communications are most frequently conducted in the MICS (402-405 MHz) band. The dual-band implantable system normally operates in the ISM (2.4-2.48 GHz) band's sleep mode and won't wirelessly send data to the MICS band until it gets a wake-up signal from the ISM band

Chapter 3

Work Carried Out

Architecture

This model consists of four sub-models like design antenna using HFSS software, Optimize the co-axial field for impedance matching, apply techniques to get best performance and Fabrication and testing.

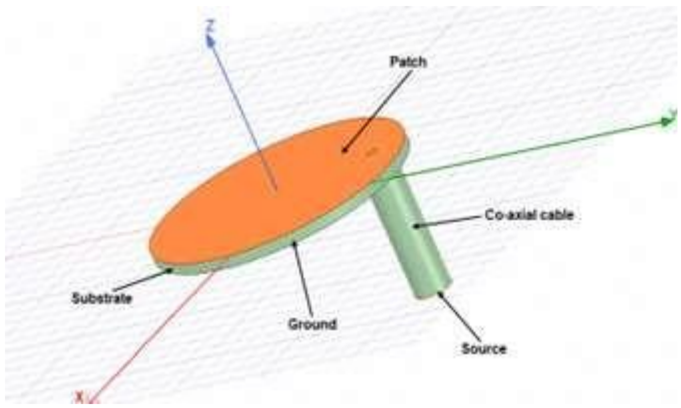

Figure 3: Circular Patch Antenna

Design antenna using HFSS

Antennas are used for different applications and electronic devices to serve the basic function of facilitating communication. However, with different applications, there are different types of antennas which can be built. With the technological advancements in the field of electronics and electromagnetics, the researchers are constantly trying to come up with innovative antenna designs to fit different purposes. Ansys HFSS is a software which is specifically known for its radio electronic frequencies and developing antennas. Therefore, when we got this project from our client from a student pursuing their PhD degree in Australia, our experts came up with different ideas and topic suggestions as per the current standards and innovations in the field. HFSS can be used to develop parametric studies about the changes and experimenting process so that the insights regarding the parameters of antenna and feed geometry can be optimized. The parameters of the antenna include radiation pattern, return loss, gain or/and VSWR. The design of the antenna needs to be developed in a way that is applicable for WLAN and then the proposed design of the antenna needs to be fabricated in accordance with the HFSS simulation software. After optimizing the parameters and simulating the design, the optimum feeding system is decided for the better performance. The results which came after testing and trying different frequencies are then compared and experimented to evaluate the properties of antenna like high radiation efficiency, high gain or whether these antenna are suitable for Wi-Fi applications or not.

Procedure

First, we made a circular ground of radius 3mm, after that we made a circular substrate of same radius and height of 0.25mm and material of substrate is FR4-epoxy. Because It has dielectric constant of 3.8 to 4.8 and has excellent thermal mechanical and electrical properties. After that we made a circular patch named as patch and the color will be different from substrate and the radius 3mm. after that we made ground and patch to perfect E for making the perfect conductor and then we made a coaxial cable. It has 3 parts inner outer and middle, so we made inner cylinder of radius 0.125 mm and then we subtract this from substrate for making the hole in substrate and then we draw a circle name ground cut on the ground of antenna having radius same as outer cylinder that is 0.431 mm and subtract this from the ground and after that we draw an outer cylinder of radius 0.431 mm and material is of copper outer cylinder has positive potential related to the inner cylinder and then we draw another cylinder named as middle and the radius of middle cylinder will be 0.278 mm . And the material is Teflon. After that we draw another cylinder named as inner having the radius 0.125 mm and the material is of copper now we have to subtract inner and middle cylinder from the outer cylinder to remove the 3D Error. After subtracting we must draw againa middle cylinder having the radius of 0.278 mm and material is of Teflon and then we draw another inner cylinder. Of radius 0.125 mm and material is of copper. Now again for removing 3Derror. We subtract inner cylinder from the middle one. And now the finally we draw the inner cylinder of radius 0.125 mm and material is of copper.

Step by step approach:

- Design Antenna Using HFSS Software
- Optimize the Co-Axial Field for Impedance Matching
- Apply Techniques to Get Best Performance (In Body, Off Body, Or On Body)
- Fabrication And Testing

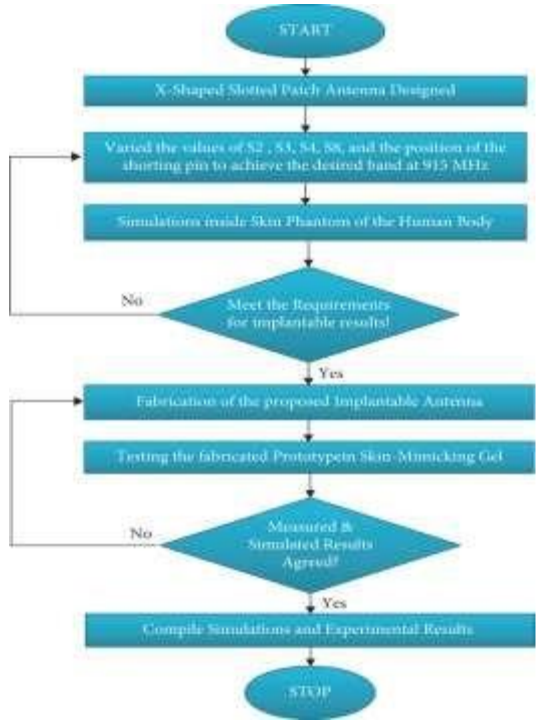

Figure 4: Procedure

Optimize the Co-Axial Field for Impedance Matching

For getting the better result we optimize the position of our coaxial cable for impedance matching and check where will the antenna take feed and produce better results. After that we validate and check the rectangular wave plot of designed antenna that is shown in Figure 5. Rectangular plot shows the return loss value and an antenna's Return Loss is a figure that indicates the proportion of radio waves arriving at the antenna input that are rejected as a ratio against those that are accepted. It should be lower then -10db

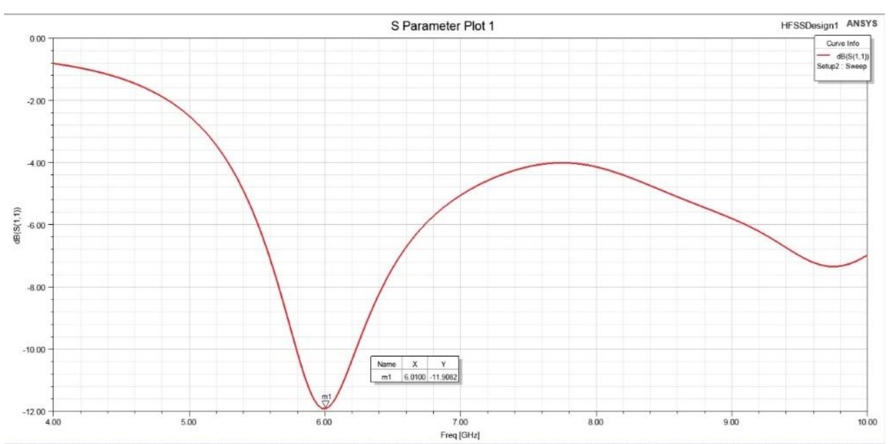

Figure 5: Return loss

Apply Techniques to Get Best Performance (In Body, Off Body, Or On Body)

After getting in which frequency our antenna works properly we put the antenna inside different bodies Or different radiation material like skin, bone, ligament etc. for checking where the antenna works properly in Body-centric wireless communications systems. Body-centric wireless communication consists of on-body, off-body and in-body communications, as shown in Figure 4.On-body communication means communication between on-body/wearable devices. Off-body communication can be defined as communication from off body to an on-body device. In-body can be simplified as communication to an implantable device or instrument.

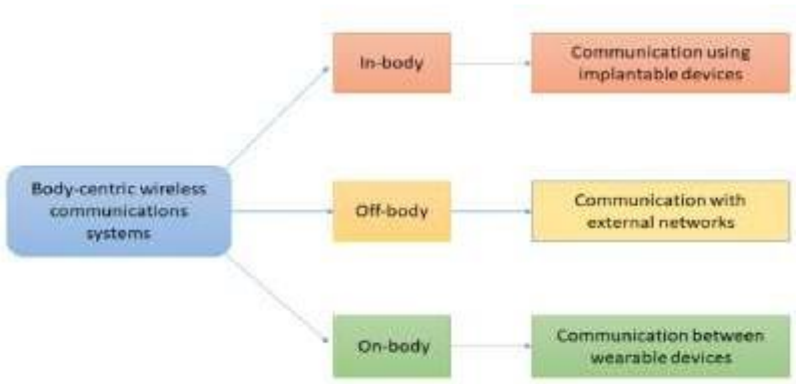

Figure 6: Descriptions of body-centric wireless communications.

- ## Fabrication And Testing

After getting the results that where the antenna works properly like in body, on body or off body the antenna will be ready for the testing all the conditions once it satisfied all the condition then fabricate the same

Chapter 4

Experimental Results and Comparison

Antenna measurement techniques refers to the testing of antennas to ensure that the antenna meets specifications or simply to characterize it. Typical parameters of antennas are gain, bandwidth, radiation pattern, beamwidth, polarization, and impedance.
The antenna pattern is the response of the antenna to a plane wave incident from a given direction or the relative power density of the wave transmitted by the antenna in a given direction.

- ## Radiation pattern

The radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna and shows sidelobes and back lobes. As antennas radiate in space often several curves are necessary to describe the antenna. If the radiation of the antenna is symmetrical about an axis (as is the case in dipole, helical and some parabolic antennas) a unique graph is sufficient.
Each antenna supplier/user has different standards as well as plotting formats. Each format has its own advantages and disadvantages. Radiation pattern of an antenna can be defined as the locus of all points where the emitted power per unit surface is the same. The radiated power per unit surface is proportional to the squared electrical field of the electromagnetic wave. The radiation pattern is the locus of points with the same electrical field. In this representation, the reference is usually the best angle of emission. It is also possible to depict the directive gain of the antenna as a function of the direction. Often the gain is given in decibels.

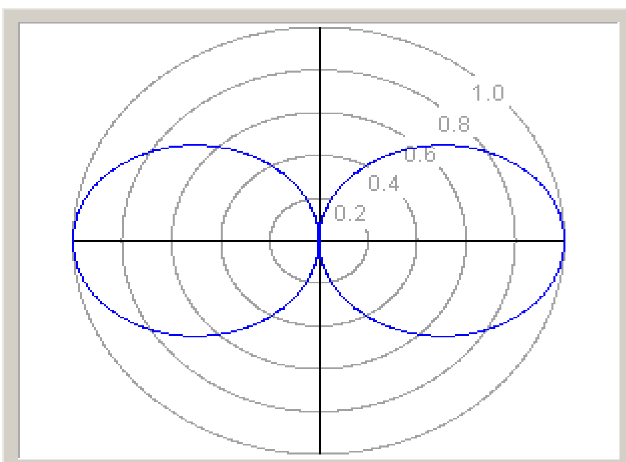

Figure 7: Radiation pattern of a half-wave dipole antenna Linear scale.

Efficiency

Efficiency is the ratio of power radiated by an antenna to the electrical power it receives from a transmitter. A dummy load may have an SWR of 1:1 but an efficiency of 0, as it absorbs all the incident power, producing heat but radiating no RF energy; SWR is not a measure of an antenna's efficiency. Radiation in an antenna is caused by radiation resistance which cannot be directly measured but is a component of the total resistance which includes the loss resistance. Loss resistance results in heat generation rather than radiation, thus reducing efficiency. Mathematically, efficiency is equal to the radiation resistance divided by total resistance (real part) of the feed-point impedance. Efficiency is defined as the ratio of the power that is radiated to the total power used by the antenna; Total power = power radiated + power loss.

Bandwidth

IEEE defines bandwidth as "The range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard."[4] In other words, bandwidth depends on the overall effectiveness of the antenna through a range of frequencies, so all of these parameters must be understood to fully characterize the bandwidth capabilities of an antenna. This definition may serve as a practical definition, however, in practice, bandwidth is typically determined by measuring a characteristic such as SWR or radiated power over the frequency range of interest. For example, the SWR bandwidth is typically determined by measuring the frequency range where the SWR is less than 2:1. Another frequently used value for determining bandwidth for resonant antennas is the -3dB Return Loss value, since loss due to SWR is -10log10(2:1) = -3dB.

Directivity

Antenna directivity is the ratio of maximum radiation intensity (power per unit surface) radiated by the antenna in the maximum direction divided by the intensity radiated by a hypothetical isotropic antenna radiating the same total power as that antenna. For example, a hypothetical antenna which had a radiated pattern of a hemisphere (1/2 sphere) would have a directivity of 2. Directivity is a dimensionless ratio and may be expressed numerically orin decibels (dB). Directivity is identical to the peak value of the directive gain; these values are specified without respect to antenna efficiency thus differing from the power gain (or simply "gain") whose value is reduced by an antenna's efficiency.

Gain

Gain as a parameter measures the directionality of a given antenna. An antenna with a low gain emits radiation in all directions equally, whereas a high-gain antenna will preferentially radiate directions. Specifically, the Gain or Power gain of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in a given direction at an arbitrary distance divided by the intensity radiated at the same distance by an hypothetical isotropic antenna: We write "hypothetical" because a perfect isotropic antenna cannot be constructed.

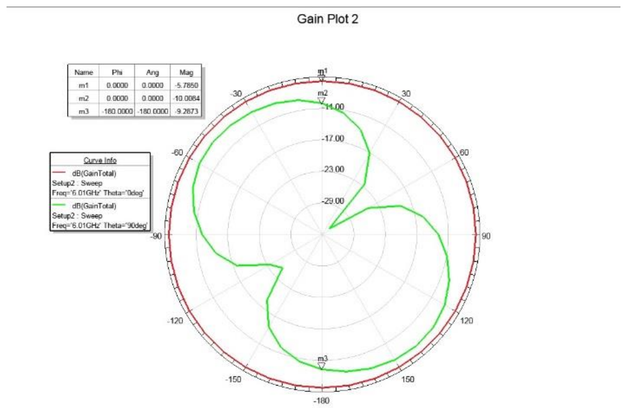

Figure 8: Gain of Reference Antenna

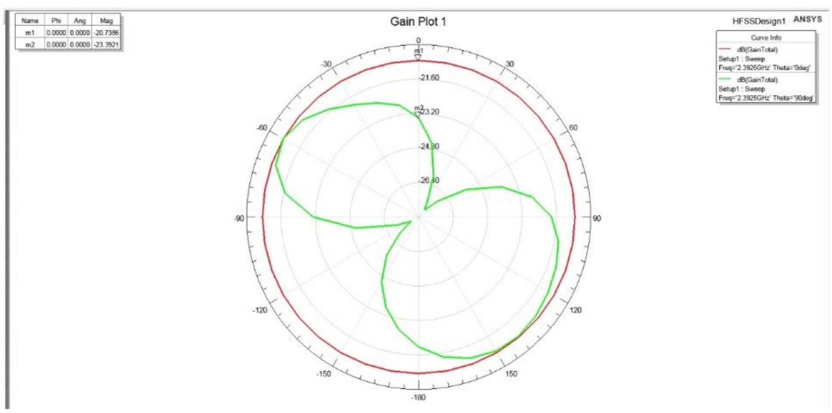

Figure 9: Gain of Proposed Antenna

Return loss

An antenna's Return Loss is a figure that indicates the proportion of radio waves arriving at the antenna input that are rejected as a ratio against those that are accepted. It is specified in decibels (dB) relative to a short circuit (100 percent rejection). Consider the antenna being used in transmit mode.

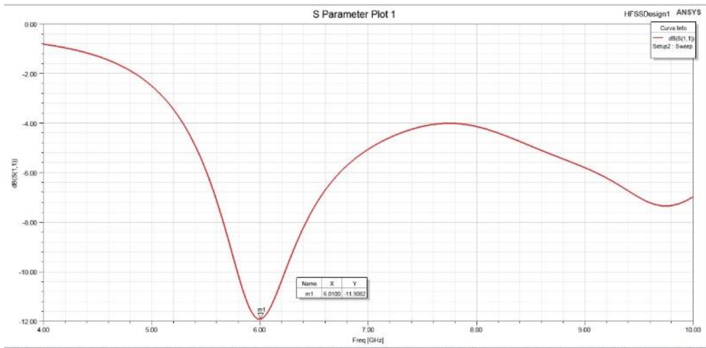

Figure 10 : Reference Antenna Return loss

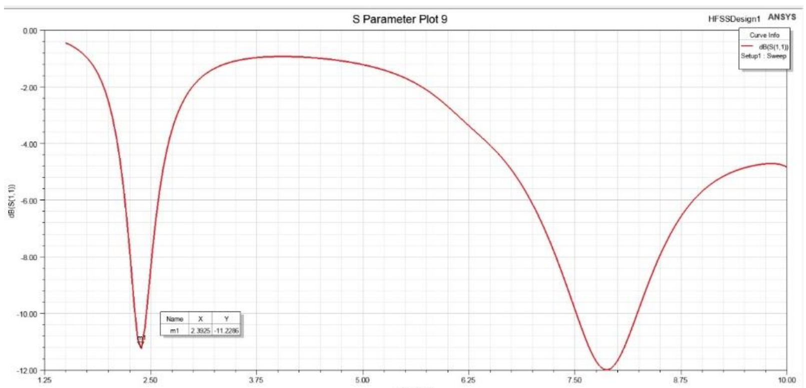

Figure 11 : Proposed Antenna Return loss

Axial ratio

The Axial Ratio (AR) of an antenna is defined as the ratio between the major and minor axis of a circularly polarized antenna pattern. If an antenna has perfect circular polarization, then this ratio would be 1 (0 dB). However, if the antenna has an elliptical polarization, then this ratio would be greater than 1 (>0 dB). This ratio tells us the deviation of an antenna from the ideal case of circular polarization over a specified angular range. For example: ‘Axial Ratio: <1.25 dB for +-20° from main beam’- this indicated that the antenna deviation from the main beam is less than 1.25 dB in the that given 20°.

Typically, axial ratios are quoted for circularly polarised antennas. Since a circularly polarised field is made up of two orthogonal electric field components of equal amplitude and 90 degrees out of phase, the closer the axial ratio is to 0 dB, the better. On the other hand, if two plane waves are of different amplitude and exhibit a 90° phase difference, that wave is said to be in an elliptical polarization. Therefore, it is always larger than 1 (>0 dB) in an ellipse.

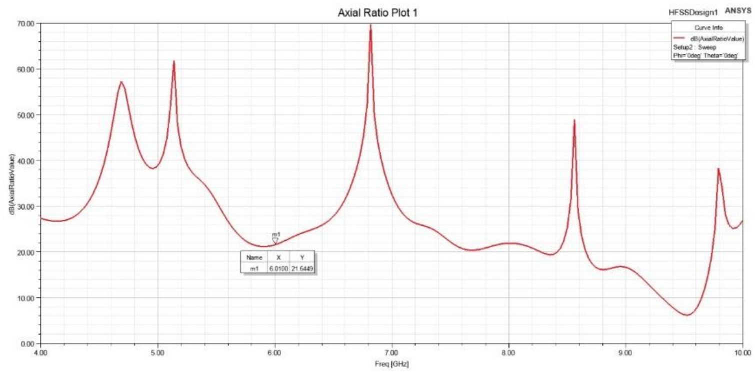

Figure 12: Axial Ratio Reference Antenna

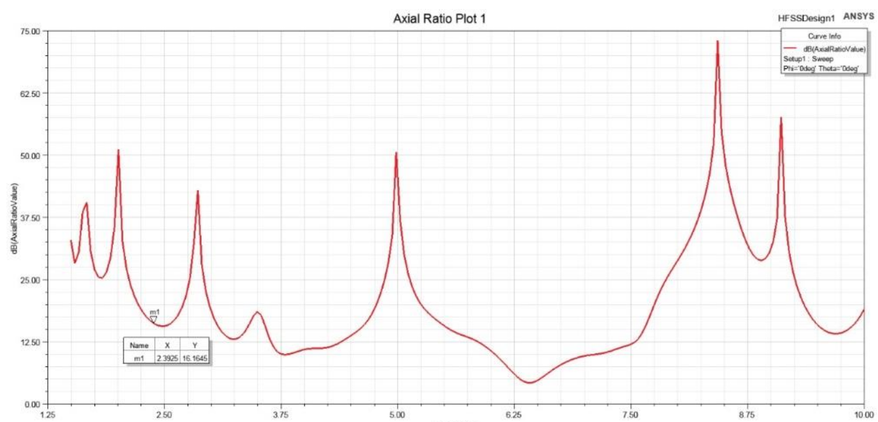

Figure 13: Axial Ratio Propose Antenna

Chapter 5

Conclusions, Summary and Future Scope

Since the days of first pacemakers, implantable electronics systems have undergone a major transformation. The advent of micro-, nano- and molecular scale technologies have brought upon tremendous miniaturization of all components of the indwelling module, from sensors to actuators and electrodes. The very-large-scale integration enabled small yet efficient low-power implantable microsystems that can support increasingly complex processing. The advancement of battery technologies has allowed for the development of long-term implantable devices with high reliability, multiple functions, and improved performance. Device powering via short range wireless links has been used to extend the lifetime of the electronic system, with in vivo energy generation and harvesting being an area of active research. The use of wireless communication technologies has extended from biomedical research to clinical health care, by enabling remote monitoring and control. Significant progress has been made about the stability and biocompatibility of the packaging and encapsulation used to shield the indwelling electronics from the aggressive physiological environment. Additional functionalities, such as ability to retard bacterial attachmentor encourage tissue growth, have been imparted onto these encapsulants. Together, these technologies have contributed significantly to the quality of life of the patient, preventing critical incidents and decreasing patient mortality. Given the ageing population, increased longevity and anever-increasing number of patients admitted into hospital care every year, the technologies that support individualized out-of-clinic automated monitoring and patient status-responsive treatment will continue to be an area of great interest and concentrated research effort. Further miniaturizationof the sensing and stimulating devices will enable on-organ monitoring and highly specific treatment delivery, without compromising normal functioning of surrounding organs and tissues. The advancement of closed loop systems will facilitate simultaneous stimulation and high-resolution sensing of both natural and evoked activity, with utility in intricate surgical procedures and neuromodulation. In addition to more sophisticated neuroproteins and artificial organs that will improve patient survival and quality of life, further developments in brain-computer interfacing will enhance our ability to investigate and alter cognitive or sensory-motor functions in humans

A significant amount of absorption results in low radiation efficiency and inefficient antenna operation. The radiating wave travels through the near field and far field to reach the outside receiver antenna since the absorption in the far-field is unavoidable. However, the absorption of a radio wave can be avoided if the biocompatibility of the implant antenna is covered near the field.

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