COMPARITIVE ANALYSIS OF AN IMPLANTABLE PATCH WITH AND WITHOUT DGS

T. Rubesh Kumar [1], Moorthi Madhavan[2], E.MuthuKumaran[3]

[1] Research Scholar Anna University - Chennai & Assistant Professor (SG), Department of Biomedical Engineering, Rajalakshmi Engineering College, Chennai, India

[2] Professor, Saveetha Engineering College, Chennai, India

[3] Assistant Professor, Dr.B.R.Ambedkar Institute of Technology, PortBlair, Andaman & Nicobar Islands, 744103-India.

Corresponding author: T Rubesh Kumar (rubesh2131@gmail.com)

ABSTRACT

In today's scenario developing an implantable device plays a vital role in modern health care system. In most of the existing system the identification of critical situation is very difficult, subject oriented and subjective in nature. But in the proposed system the implantable device can sense bio-signals parameters such as temperature, pressure from the subject and it can be sent to the outside world. The receiver in the outside world can be placed either close to the subject or even at a distance of few meters. The device helps us to identify the critical conditions such as heart attack or stroke. The goal of our exploration is to optimize an implantable patch antenna with the defective ground structure (DGS) for biomedical application. The traditional approach to analyzing DGS relied primarily on iterative trial and error methods. This DGS can be achieved by incorporating shape errors at a level that disturbs the isolated distribution primarily due to the shape and structure of the error. Both the input resistance and the controlled antenna current are affected by the interference of the shield distribution. This allows you to adjust the excitation and propagation of the electromagnetic field throughout the substrate material. The slow wave effect of the high resistance hold zone is two characteristics of DGS. Proposed antenna is simulated using a composite material which comprises of fiber glass cloth with an epoxy resin and it is made to operate at 2.9 GHz frequency range, which is closer to the unlicensed band.

***Keywords**: DGS, Implantable antenna, FR-4 substrate.*

DOI Number: 10.14704/nq.2022.20.8.NQ44454 **NeuroQuantology 2022; 20(6): 4198-4207**

Introduction

Biotelemetry plays a vital role in health care industry in our today's situation. It is a technique where subject biological parameters can be monitored and controlled from remote. The measured data are transmitted through wireless channel. To obtain this service, Radio frequency and microwave signal plays a vital role. Wireless biotelemetry permits us minimum invasive method of monitoring the physiological parameters and provides the patients comfort and care that overcomes the hospital expenditure. Today sugar level monitoring, endoscopy, EEG and EMG are the few applications of medical industry that highlights the necessity of remote monitoring and control of implantable unit. The overall architecture of the proposed system is represented in Figure 1.

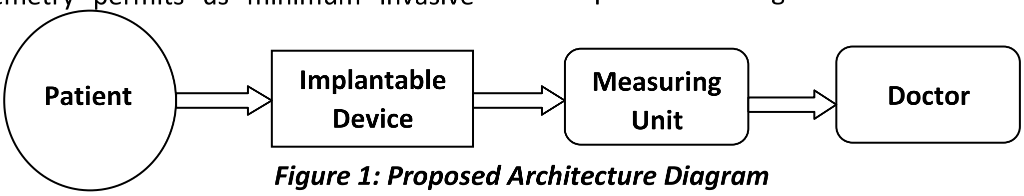

Figure 1: Proposed Architecture Diagram

In biomedical field pacemakers and radio pills has witnessed the greater necessity of implantable devices in monitoring and treating the human body. Since the devices are implantable, the material selection for designing the patch and the shape of the antenna are the key points to be considered for providing a medical device with wireless capabilities. The goal of our antenna is to provide high efficiency and to operate with an optimum frequency. The implantable device is composed of several components such as battery, sensors and antenna. Among all these components antenna plays the most significant role in building the communication link from inside of a subject to the external receiver.

Our objective is to minimize the SAR in the implantable antenna. It is achieved with the help of DGS technique. The use of implantable medical devices as part of healthcare treatment is an increasingly attractive response to the growing need for non-invasive surgery. As a result, it may be possible to use transplanted techniques in place of existing invasive methods of collecting biological or physical information.

Surgically embedded antennas were physically smaller antennas comparable to those used in common wireless systems, including smartphones, but with the additional challenge of being embedded in a complex lossy medium. The lightweight construction with extended bandwidth is designed using DGS. The manufacturing process is also simple compared to other approaches to increasing bandwidth. DGS designs typically contain one or fewer segments. The proposed FR4 substrate antenna with two or more slots was sought after by DGS, enabling biotelemetry applications with an elevated antenna structure. DGS modifies the characteristic impedance of the feeder line by calculating the impedance, capacitance, and inductance of the slots under the microstrip.

Most of the health studies of embedded antennas rely on medical properties such as hyperglycemia, inflatable angiography and other similar procedures, and optical sensors. In both cases, the antenna operates in the visible range, so long-range propagation is not an issue.

Microstrip antennas consist of a mixture of distributed resistance, capacitors, and resonances within each important parameter. This allows each concept to be explained with equivalent circuit modeling. DGS is achieved by introducing shape errors into the ground plane that disturb the isolated distribution based on the shape and structure of the error. Both the input impedance and the control current of the antenna are affected by the interference of the isolated distribution. This allows you to adjust the excitation and propagation of electrical signals throughout the substrate material. Both the slow wave effect of the hold zone and the high impedance are the two characteristics of DGS. By integrating some slot properties, such as transmission line attributes, such interference modifies the transmission line attributes. In other words, if the bottom layer under each microstrip antenna is defective, the effective inductance and effective capacitors of the microstrip line are improved by integrating slot capacitors, inductors, and resistors, causing resonance at specific frequencies. To do. The effective capacitor is inversely proportional to the slot space, but the effective inductance is directly related. Even if the slot size is small, the effective capacitor is small, and even if the slot area is large, the resonance is large.

Every DGS form does have its unique properties and, depending on over its shape or dimensions, does have an impact on the device's effectiveness. DGS was already added to enhance the efficiency of filtering, ground plane optics, microwave circuits, as well as antennae. DGS can be used to minimize density, increase operational gain and directivity, reduce impedance matching across network entities, decrease high - frequency components and undesired cross-polarization, or create a sloped zone to avoid issues for any spectrum.To provide a filter, a dumbbell-shaped DGS was initially placed on the ground plane beneath a microstrip transmission line. This capacitor effect is achieved by the perturbation of the electromagnetic fields surrounding the defect, whereas the induction impact is caused by the surface waves near the defect. As a consequence, resonance properties of a DGS emerge, resulting in a filtration impact.

1. Literature Review

Paikhomba, Loktongbam researched a paper on twisted antenna array that can be implanted has been discovered. This antenna consists of a (2.4–2.5) GHz bandwidth. Such an antenna, with a dimension measuring (15 21.5 1.5) mm3, is an illustration of substantial size downsizing. A meandering patch print antennas were being used to reduce the antenna's size. In comparison toward other current antennas, it's able to operate across all sectors of human body, particularly simulated using various body imaging. This gain is usually always larger as 3.2 impedance bandwidth on working frequency. It can operate with very minimal input power. The antenna in question is tiny and has good radiation properties. Surgically implanted antennae in those other frequencies are designed using the suggested array method.

Gurprince Singhintroduced a paper ontiny patches dimensioned implanted microstrip line enabling biotelemetry purposes are presented, that operates in the Industry, Research, and Healthcare (2400 MHz) spectrum. Like a substrate, Rodgers RO Duroid 3010 is utilized, and is a fr4 substrate material with a dielectric permittivity of 10.2 and a depth of 0.64 mm. This antenna's measurements were 13.3 x 14.6 mm2. This antenna's switching frequency is 2.26 to 2.71 GHz, with such a bandwidth of 18.10 percent and a resonant frequency of 2.45 GHz, with such a path loss of 20.7 dB within the skin. Their antenna performance was evaluated in the in-vitro mixture containing skin imitating fluids to test the reliability and validity. As a result, a skin-implantable tiny antennae for bio-telemetry purposes are presented.

X. Maichael Madona researched the paper on Among the most significant parts of developing an improved health service is the invention of implantable devices. Technology that measures physiological parameters within the body now hold enormous potential for making substantial improvements to prevention of illness, detection, and treatment, lowering treatment times and enhancing patient's life quality.

Another goal of the proposed study is to create a Skin Surgically implanted Antenna with such a DGS in order to lower the Particular Absorption. The study compares several faulty ground geometric shapes: a circular heading spiral, a folding construction, and a Hex framework, all of which have a rectangular patch like a radiation patch. Their performance has been analyzed in terms of Specific Absorption Rate, Effective Isotropic Radiated Power, Voltage Standing Wave Ratio, return loss and Radiation efficiency by placing the antenna inside the skin model to operate at the ISM band of 2.45GHz. The proposed work fulfils the requirements given by the International Telecommunication Union Standards for a Skin Implantable Antenna.

Adel W. Damaj proposed the paper on implantable biomaterials, there is a lot of focus on seeking information about chronic illnesses. The development of implanted biomaterials has several obstacles, include developing and transplanting antennae in a dangerous environment based on the human skin's surrounding structures. Transplanted antennae have to be small, effective, and secure, as well being able to operate within relevant treatment resonance frequencies. This study provides an outline of major characteristics from in vivo implant antenna is designed and problems. This analysis will look at the possibilities, design procedures, problems, modeling techniques, evaluation and production of implanted biomedical antennas, among other things.

M. K. Khandelwal proposed Defected Ground Structure refers to slots or faults incorporated on the ground plane for microwave antenna arrays. DGS is being used to improve the many properties of microstrip antenna, including such limited bandwidth, cross-polarization, as well as minimal amplification, among other aspects. This study discusses the historical development of DGS, as well as how it differs to previous technologies such as PBG as well as EBG. The core principle underlying DGS systems can be described, as well as numerous methodologies for analysing the Defected Ground Structure. DGS can be used in the fields of filtering, plane waveguides, amplification, and antennae, among other things.

Gurveer Kaur proposed biological telematics provides for the remote monitoring of physiological data using existing telecommunications systems. Physical signals are acquired using suitable sensors, post-processed, and then delivered to monitoring and surveillance devices on the outside. Implantable medical devices are among the most recent advancements within biological informatics. A most common approach of bio-telemetry using surgically implanted devices has historically utilized low-frequency induction linkages. Nevertheless, these have modest data speeds (1-30 kbps), a short communication distance (less than 10 cm), and are more sensitive to inter-coil placement. Development was presently focused on radio frequency (RF)-linked surgically implanted devices to circumvent such restrictions.

2. Design Methodology

Rectangular microstrips with 2.45 GHz resonance have already been developed. The intermediate frequency of the ISM band was actually selected from 2.45GHz, which is the resonant frequency of the antenna. Attempts have been made to minimize the reflectance coefficient as close as possible to the resonant frequency. As a result, the DGS approach was used to maximize antenna performance.

To achieve the required overall efficiency, most of the same slot was placed vertically and horizontally to the dipole antenna under the rectangular slot.The proposed antenna layout is very versatile in terms of structure, shape, and ease of integration, and is popular as an embedded antenna because it is relatively easy to miniaturize and integrate into the structure of embedded medical devices. Is increasing. In such a real-world scenario, the embedded patch antenna sits on top of an existing embedded medical device and acts as a ground plane.

Functionalization, miniaturization, quality care, and improved connectivity through environmental changes have all attracted research attention to the concept of embedded radiation patches.The detector, power source, implanted antenna, as well as insulators are all part of the wirelessly implanted device in biomedical monitoring. Their major goal is to send data from such an inner region of the body to such an exterior staging point, so vital signs are acquired using an appropriate detector and afterwards communicated mostly by user using an implanted antenna. These design issues that antennas undergo are examined, as well as the many ways that may be utilized to minimize its antenna's length so that it is inserted properly within the body.

The design specifications required for the proposed compact patch antenna is shown in Table 3.1. For better compatibility, best fit for the application proposed and to attain maximum competence several efforts have been used to increase the efficiency of the antenna, such as patch slots, various dielectric properties, feeding techniques, and defective grounding structure (DGS).

Table 3.1: Design Specifications

Parameters	Proposed Base Design Specifications
Operating Frequency	2.9 GHz
Tangent Factor	0.018
Dielectric constant	4.4
Feeding impedance	50 ohms
Substrate to be used	FR-4

Base Design

Here, the operating frequency is assumed to be 2.9 GHz, with substrate height (h) of 0.13 mm and dielectric permittivity (ε_r)as 4.4. The substrate used is FR-4and the speed of light (v) is 3×10^8m/s. The following equations are used to estimate the size of the proposed antenna.

Design calculations

1. The thickness of the patch is estimated using the following equation

$$W = \frac{v}{2f_0}\left[\sqrt{\frac{2}{\epsilon_r+1}}\right] \text{ ------------------1}$$

where, W - thickness of the patch

v - velocity of light

$f_0 = resonantfrequeny$

$$W = \frac{3\times10^8}{2\times2.4\times10^9}\left[\sqrt{\frac{2}{4.4+1}}\right] \quad =\mathbf{38}\boldsymbol{mm}$$

2. Calculate effective dielectric constant.

$$\epsilon_{reff} = \frac{\epsilon_{r+1}}{2} + \frac{\epsilon_{r-1}}{2}\,[1 + 12(\frac{h}{w})]^{-1/2} \text{ --2}$$

where, ϵ_{reff} = effective dielectric constant

$\epsilon_{reff} = \mathbf{3.97}$

3. The effective height of the patch is found using the following equation

$$L_{eff} = \frac{v}{2f_0[\sqrt{\epsilon_{reff}}]} \quad \text{-------------3}$$

Where, Leff = effective height of the patch

$$L_{eff} = \frac{3\times10^8}{2\times2.4\times10^9\times\sqrt{3.97}} \quad = 31\text{mm}$$

4. Calculate extension of length

$$\Delta L = 0.412h\left[\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}\right]$$

$L = 0.0011$ mm

5. The final patch length L is given as: $L = L_{eff} - 2\Delta_L = 29mm$
6. The substrate used here is FR4 Substrate.
7. The port is fixed at the reference plane of the patch.
8. The patch is simulated at a resonant frequency of 2.9 GHz.

4. Construction

DGS

Defects are imprinted on the antenna array under the DGS microstrip and change the distribution of the ground plane. By introducing the effects of dipole antenna slot inductance and capacitance into the microstrip antenna, this leads to fluctuations in the capacitors and inductance of the microstrip line. This fractal DGS shape is of particular interest among DGS-based methods because it helps achieve a higher degree of compression than a simple DGS structure.The fundamental principles behind DGS systems, as well as a variety of approaches for analysing the Defected Ground Structure, can be outlined. Filtering, plane waveguides, amplifying, and antennas are only a few of the applications for DGS.

Implantable Patch

Implantable devices are vital for healthcare systems, but designing them poses significant hurdles. Significant advancements in microelectronics as well as sensor technologies have improved implantable gadgets, although antennae difficulties persist. Since many human physical tissues get an elevated transmittance and conductance, this lossy channel of the body has a considerable effect on the construction and efficiency of implantable antennas.Transmitters, batteries, and detectors are amongst the multiple elements included in implantable devices. The implanted antenna plays a big role in the transmission medium in between internally and externally devices reliability and durability. The antennas would be a critical component of an implant surface since it is responsible for the fundamental operating requirements of message transmission and receiving. It has an impact on the implanted device's total height and weight. In addition, this electrically charged hostile as well as the lossy atmosphere within the body contributes towards the designing difficulty.

5. Experimental Results

The implanted antenna is typically small and has a limited bandwidth. Nevertheless, owing of absorption by body's tissues, many of the emitted power doesn't really contact the recipient. With implanted antennas, the absorbing energy is substantially higher than the reflected light, resulting in a larger spectrum at the expense of decreased radiation efficiency. As previously noted, such loss can be decreased by employing bio-encapsulation and resistance balancing to restrict the spectrum. Implantable antennas with such a limited bandwidth, on the other hand, incur from frequencies interference pattern within the human.

Patch without Defective Ground: The design of basic patch is shown in fig 5.1 as

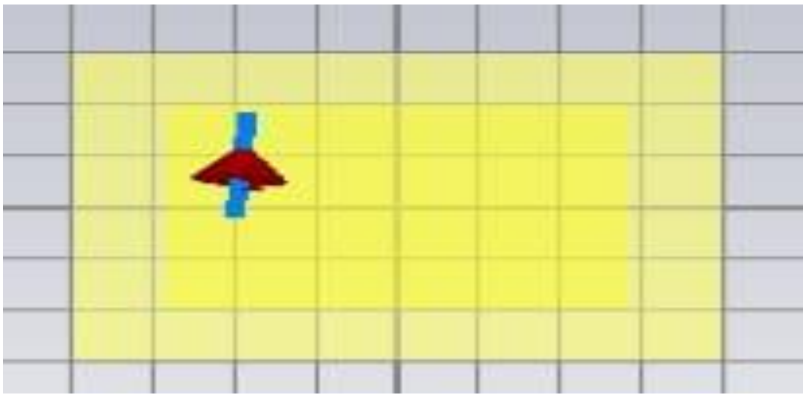

Fig 5.1 Design of patch without defective ground

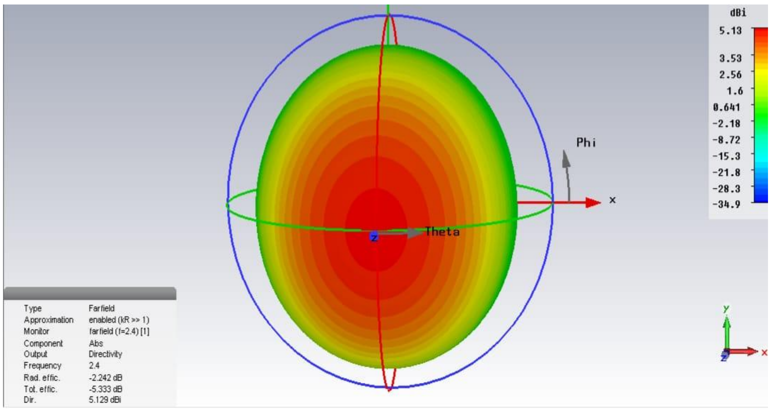

Fig 5.2 Radiation pattern of the patch without DGS

The fig 5.2 shows the radiation pattern of the patch in the far field region. The patch's highest emission comes from the centre (inside this plane of angle θ), whereas lesser lobe come from the opposite end. The directivity obtained here is 5.129 dBi.

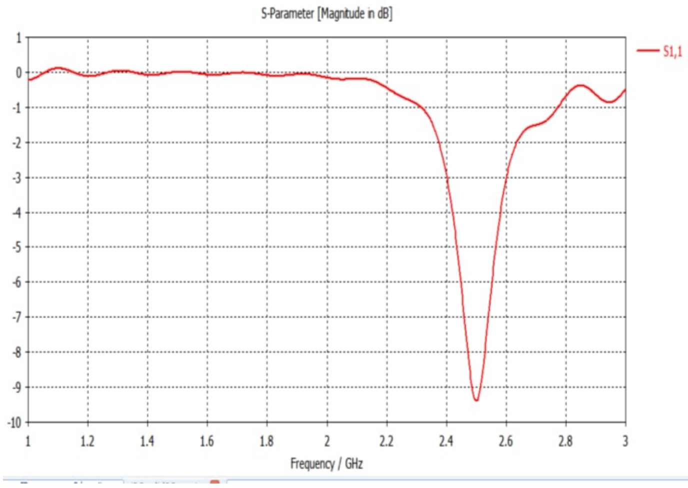

Fig 5.3 S-Parameter

The fig 5.3 shows the reflection coefficients of the patch. The return loss of the antenna is minimum at -10 dB.

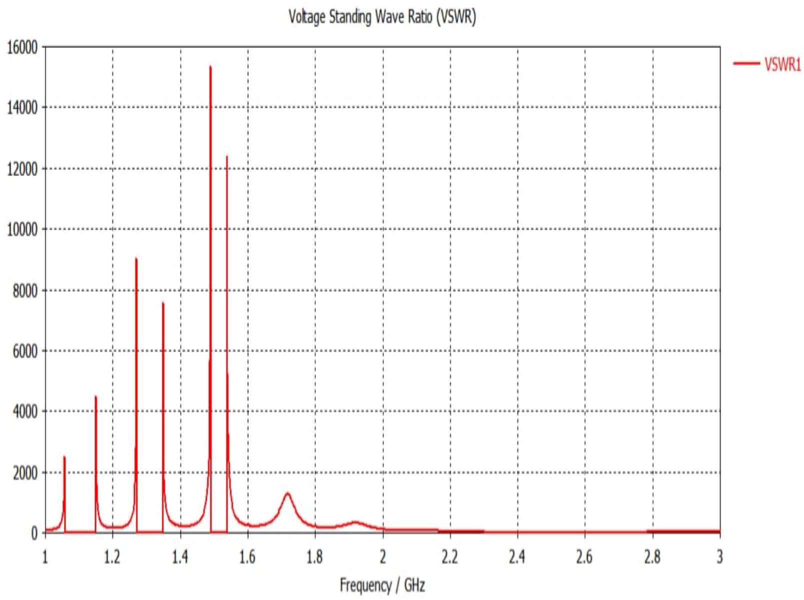

Fig 5.4 VSWR

The fig 5.4 shows the Voltage Standing Wave Ratio (VSWR) versus frequency graph of the designed antenna. The VSWR is minimum at 2.4 GHz.

Patch Antenna with Defective Ground: The design of basic antenna is shown in fig 5.5 as

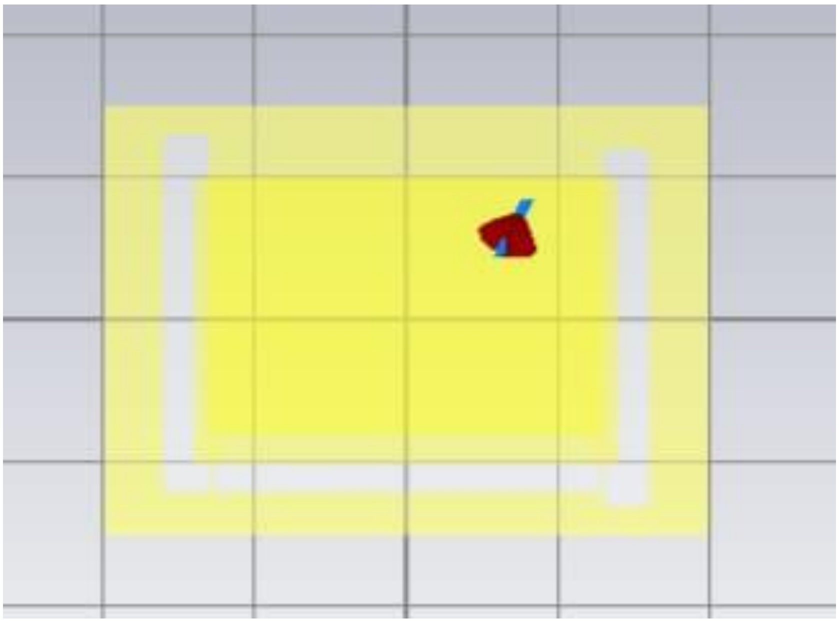

Fig 5.5 Design of patch antenna with DGS

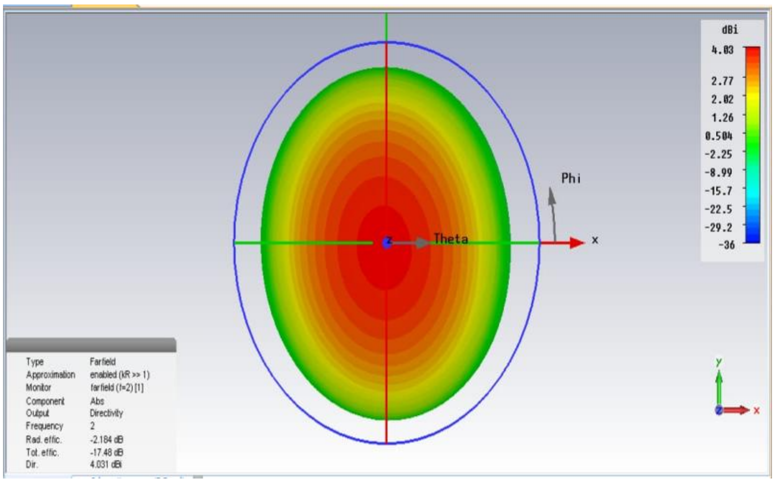

Fig 5.6 Radiation pattern of patch with DGS

The fig 5.6 shows the radiation pattern of the antenna in the far-field is 4.031dBi.

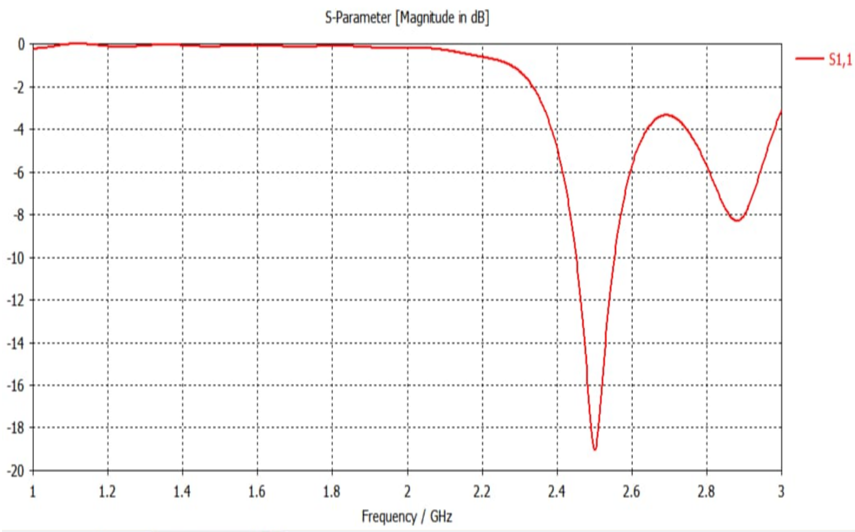

Fig 5.7 S-Parameter

The fig 5.7 shows the S-Parameter of the antenna. The return loss of the antenna is minimum at -18dB.

6. CONCLUSION:

A Microstrip Patch Antenna is designed to analyze the biological parameters of the subject and it has provided major contributions in identifying the sign in the initial stage itself. The proposed paper fulfills the requirement given by the ITU Standard for an Implantable antenna by comparing the patches with and without DGS. Surgically implanted antennae have to be biodegradable in necessary to defend the patient's health by preventing the implantation from being rejected. Moreover, transplanted cells are sensitive, so if permitted to come into interacting directly with implanted antenna's metal substrate, it will fault conditions them. As in event of antennae designed for long-term deployment, bio - compatibility as well as the avoidance of unwanted short-circuits were incredibly significant. Thus, an implantable antenna that detects the multiple physiological parameters without Defective Ground and with Defective Ground is simulated and its performance was analyzed. The antenna is designed using FR-4 substrate in the 2.4 GHz frequency range, which is an ISM band to implant in skin for monitoring physiological parameters while maintaining safety regulation of the patient under test.

7. REFERENCES:

1. Paikhomba, Loktongbam and Debashish pal June 2019. “Design of an Implantable antenna for Biotelemetry Applications” in Microsystem Technologies

2. Gurprince Singh, Jaswinder Kaur, August 2018. “Skin and brain implantable inset fed antenna at ISM band for wireless biotelemetry applications.”

3. “Design of a Skin Implantable Antenna with the Defective Ground Structure Aiming at the Reduction of Specific Absorption Rate.”

4. Adel damaj, hilal m. el misilmani, and soubhi abou chahine, july 2018. “Implantable antennas for biomedical applications: an overview on alternative antenna design methods and challenges.”

5. Mukesh Kumar, Khandelwal, Binod kumar, Kanaujia and Sachin kumar 2017. “Defected ground structure fundamentals, analysis and applications win modern wireless trends” in international journal of antennas and propagation.

6. Paikhomba Loktongbam, Romesh Laishram, June 2017 Performance and Design Analysis of an Implantable Antenna for Biotelemetry”

7. Manjulatha V and K. Cch.Sri Kavya May 2016. “Implantable antennas for Biomedial Applications” in APRN journal of Engineering.

8. Gurveer kaur, Amandeep chauhan and Gurpreet kaur June 2015. “Implantable antennas for Biomedical applications” in International Journal of Engineering Sciene and advanced tehnology.

9. Asimina Kiourti, Jorge R Costa, Carlos A Fernandes, Andre G Santiago, Konstantina Nikita, June 2012. “Miniature Implantable Antennas for Biomedical Telemetry from Simulation to Realization.”

10. A. Balanis, Antenna Theory Analysis and Design, New Jersey,2005.