PERFORMANCE ANALYSIS OF MICROSTRIP ANTENNAS FOR DIFFERENT MATERIALS

A Dissertation

Submitted to the Department of Physics, Amrit Science Campus affiliated to Tribhuvan University, Kirtipur in the Partial Fulfillment for the Requirement of Master's Degree of Science in Physics.

By

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Recommendation

This is to certify that this thesis work entitled "**Performance Analysis of Microstrip Antennas for different materials**" submitted by Mr. Ramesh Simkhada is a bonafide thesis work carried out under our supervision and guidance fulfilling the nature and standard required for the partial fulfillment of the degree of Master of Science in Physics.

I recommend this project for the partial fulfillment of "**Master's Degree of Science in Physics.**"

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Evaluation

This is to certify that the accompanying dissertaion "**Performance Analysis of Microstrip Antennas for different materials**" by **Mr. Ramesh Simkhada** has been accepted after appropriate examination and comparing the standards met for the partial fulfillment of the requirements for Master's Degree of Science in Physics by Tribhuvan University.

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Abstract

The Micro-strip antennas are widely used due to its compactness, simple manufacturing process, budget friendly and versatility. Here, carbon, abundant and easily available element is utilized in the process for the design and fabrication of antenna patch. Seeds of lapsi (Choerospondias axillaris), the indigenous plant of Nepal is used to extract carbon. The seeds are powered and activated chemically. The presence of carbon is verified using XRD technique. Resistance of dry powdered activated carbon is in the range Mega-ohm (MΩ) but after the coating of the paste of activated carbon in a polycarbonate substrate and acted by a laser of light-scribe drive various light and dark patterns were. The darker patches were found to be conducting and lighter patches were found to be non-conducting. After the activation by laser in activated carbon in a polycarbonate substrate resistance hugely dropped from Mega-ohm (MΩ) to the range of Kilo-ohm (KΩ). For simulation part, High Frequency Structural Simulator (HFSS) software was used. First the basic rectangular antenna is designed and its properties were studied. Fractal swastika shape slot was later introduced in the design. The performance of antenna is optimized using the genetic algorithm. The optimized copper patch antenna with copper as ground in a polycarbonate substrate with no slot resonates at a frequency of 13.80 GHz with VSWR 1.34 and S11 parameter as -22.24 dB. On changing the patch as graphite in firstly mentioned identical conditions, antenna resonates at dual frequency of 15.40 GHz and 17.40 GHz with S11 parameters of -22.04 dB and -20.97 dB resp., VSWR of 1.17 and 1.19 resp. After the introduction of slot in copper patch antenna, multiple resonating frequencies were obtained as 9.0000, 13.8000, 15.0000, 17.4000 and 18.20000 GHz. In Graphite patch antenna also, there were multiple resonating frequencies. In comparison to cooper patch, graphite patch antennas showed better performance. After the introduction of swastika slot also, polycarbonate substrate has shown better performance for copper-copper patch-ground as antenna whereas properties were comparable in polycarbonate and corning glass substrate for graphite-copper as patch-ground antenna.

Keywords: Micro-strip antenna, Swastika slot, Resonating frequency, VSWR, S- parameter

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List of abbreviations

IEEE	=	Institute of Electrical and Electronics Engineers
mm	=	Millimeter
nm	=	Nanometer
eV	=	Electron Volt
Å	=	Angstrom
CD	=	Compact Disc
GHz	=	Giga- Hertz
VSWR	=	Voltage Standing Wave Ratio
dB	=	Decibel
HFSS	=	High Frequency Simulation Software

CHAPTER 1

INTRODUCTION

1.1 Background

An antenna is a piece of equipment used for receiving or transmitting radio and television signals that is made of wire or long, straight pieces of metal, according to the Oxford Learner's Dictionary. An antenna is "a mechanism for transmitting or receiving radio waves," according to IEEE.

The intermediate structure between free space and a guiding device is an antenna. The guiding device or transmission line may be in the form co-axial line or a hollow pipe, and it is used to transport electromagnetic energy from the transmitting source to the antenna and vice versa.

One of the most important parts of wireless communication systems is the antenna. Antenna performance can be increased by properly designing the antenna, which can also ease system requirements. The antenna serves to a communication system the same purpose that eyes and eye glasses serve to a human.

The field of antenna is lively and dynamic, many significant advances have happened till date; nonetheless, a lot more issues and testing are confronting us today, particularly since technology is moving ahead faster and faster.

Among various antennas, micro-strip antennas are popular and commonly used. These antennas consist of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. they are low-profile, comfortable to planar and non-coplanar surfaces, simple and inexpensive to fabricate using modern printed circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and very versatile in terms of resonant frequency, polarization, pattern and impedance [1].

Special antennas which cannot be realized using a single antenna are very often achieved via antenna combinations. Very often a combination is designed in order to achieve a higher gain [2].

Various factors are responsible for an antenna to work efficiently. Some of them are substrate we chose to design antenna, area of the patch, shape and size of the antenna, etc. Slots and fractals can be introduced in the antenna for better performance. Slot is a regular metallic antenna with one or more holes at the patch. The shape and size of the slot, as well as the driving frequency, determine the radiation pattern. Micro-strip patch antennas using different slots help in the reduction of return loss as well as increase of bandwidth significantly. Also dual bandwidths have low return loss and VSWR at low frequency as compared to single slot and having no slot [3]. The term 'fractal' was formulated by

Mandelbrot [4] to describe a set of intricate figure that possess inherent self-similarity in their geometrical structures. The fractal -antennas occupy a small surface area and often incorporate effective footprint leading to the miniaturization of micro-strip antennas. These antennas are used for multiband or WB applications [5] due to their resonant at multiple frequencies. A multiband swastika fractal slot antenna is purposed.

Design, simulation and analysis of antenna can be done in HFSS which is a commercial finite element method solver for electromagnetic structures from Ansys. It is a high performance full wave electromagnetic field simulator for modeling. It integrates simulation, solid modeling and automation in an easy to learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the Finite Element Method, adaptive meshing and brilliant graphics [6].

All designs does not give desired results, so certain optimization/improvement is needed to be done. Genetic algorithms are capable of handling a large number of design parameters and work for optimization of bandwidth of a patch antenna is very important area of research. Genetic algorithm is also required for miniaturization of the patch antenna [7].

1.2 Statement of the problem

Wireless communications has deep rooted in our life. Our expectations and service quality towards these are growing continuously. Use of these technologies involves more use of data and traffic and its demand is increasing day by day. Present day antennas and technologies are only providing a limited band-width and slower data transfer rates. In order to fill this void to some extent, antennas with high band width, high coverage area, energy efficient and portable are required.

1.3 Objectives

Major objective of this work is to analyze the performance of swastika fractal slot antenna.

CHAPTER 2

LITERATURE REVIEW

Micro-strip antennas are the promising candidates for microwave and millimeter wave applications with low cost, low profile conformability and ease of manufacture. Their uses printed technology because this technology has rapid growth in the development of antennas having patches of conducting materials etched on one side of dielectric substrate and the other side of the board is metal plane, such antennas are commonly referred as micro-strip patch antennas.

A triangular patch antenna with area of 3.5 cm * 4 cm with triangular slots for multiband applications is designed and analyzed on a substrate rogers RT duroid 5870 of thickness 1.575 mm and ε_r = 2.33 using HFSS simulator software that uses the finite element approach. At 5.8 GHz, 6.4 GHz, and 7.3 GHz, respectively, the simulated return losses obtained are more than -10dB, and it produces a nice radiation pattern that may not be possible with just one antenna element. The gain of 7.69dB is a good for C-band applications [8].

Performance comparison of micro-strip antennas with different shape of the patch was studied. Square, elliptical, annular ring and triangular patches at a frequency of 2.43 GHz were analyzed and compared by HFSS software. When there is need of miniaturization then square shaped patch antenna is mostly preferred then elliptical and triangular, annular rings to be least preferred ones [9].

A new multiband antenna based on a triangular monopole over a modified ground plane has been presented. It has been shown that the use of the fractal based plane introduces new matched bands and can improve the existing ones [10].

Antenna made of a circular monopole that was transformed into a dotted swastika-shaped monopole by adding slots to the planar circular monopole has increased bandwidth and gain. Disc monopole antenna, Swastika shaped monopole antenna and Swastika shaped monopole antenna with dots has a impedance bandwidth of 10.56 GHz, 9.47 GHz and 11.53 GHz with a gain of 2.17 dB, 5.16 dB and 6.18 dB respectively [11].

Hepta-band swastika arm antenna with multiple-input-multiple-output (MIMO) is proposed. the antenna operates at the bands of 0.95-1.02 GHz(GSM), 1.73-1.79 GHz(GSM 1800), 2.68-2.85 GHz(LTE-A), 3.66-3.7(UWB), 4.20-4.40 GHz(UWB), 5.50-5.65 GHz(worldwide interoperability for microwave access) and 5.93-6.13 GHz(UWB). Due to diagonal feed, circular polarization is achieved [5].

Antenna arrays are several antennas connected and arranged in a regular structure to form a single antenna. In modern days, communication systems, these antenna arrays play an important role to create a communication link. The main benefits of antenna arrays are that they boost overall gain, offer diversity reception, eliminate interference from a specific set of directions, have linear and circular polarization, and are multiband frequency competent.

The dual band micro-strip patch antenna with fractal swastika slot is created and tested in HFSS using a genetic algorithm. The developed antenna can function at 2.4 GHz and 4.7 GHz frequencies [3].

For the purpose of performing broadband micro-strip antenna optimization, a method based on the integration of HFSS and genetic algorithms is described. When the original patch and the improved patch were compared, the latter showed a fourfold increase in the possible bandwidth [12].

The coplanar DGS-based UWB antenna with quadruple band notches is introduced in its design. The feed line resistance of the antenna is 50 ohms. For a frequency range between 1.5 and 12 GHz, the antenna's characteristics are tuned to achieve VSWR less than two [13].

Slots, interdigital capacitors, spiral and meander line shaped stubs, and via-holes can all be included into the design of antennas to produce very broad frequency ranges with excellent performance [14].

Impedance of feeding point of microstrip patch antenna can be controlled by changing the location of feed point. Correct selection of feed point decreases the input impedance and raises return loss, gain, efficiency and directivity [17].

Several algorithms are used in antenna designs in order to further improve the antenna functionality such as particle swarm algorithm, genetic algorithm (GA), and quantum genetic algorithm (QGA). GA is used to determine the best configuration of the metal cells on the antenna structure in order to miniaturize the antenna. A miniaturization of 42% is achieved [19].

GA is described as a search algorithm. It works on a set of elements, called population. This population will progress through crossover and mutation, towards a maximum of the fitness function [20].

Particle-swarm optimization (PSO) algorithm is used in order to achieve an excellent performance for its tapered slot antenna. This PSO optimization reduces return loss, side lobes, and cross polarization below −18 dB and enables a symmetric circular beam. A VSWR < 1.6 and side lobes below −16 dB are also obtained [21].

A GA optimization can be used to minimize the resonant frequency of a rectangular patch antenna without changing its size and after the optimization, the resonant frequency is reduced from 3 to 1.8 GHz [19].

CHAPTER 3

RELATED THEORY

3.1 General Structure of Micro-strip Antenna

Generally, micro-strip patch consists of conducting surface on a top also known as patch and a ground plane on the next side. The patch used can be of any shape and sizes. It very well might be either round, curved, roundabout or rectangular. In light of these structures distinctive radiation designs and various properties of antenna can be examined. Between these layers a dielectric material is kept which goes about as a substrate.

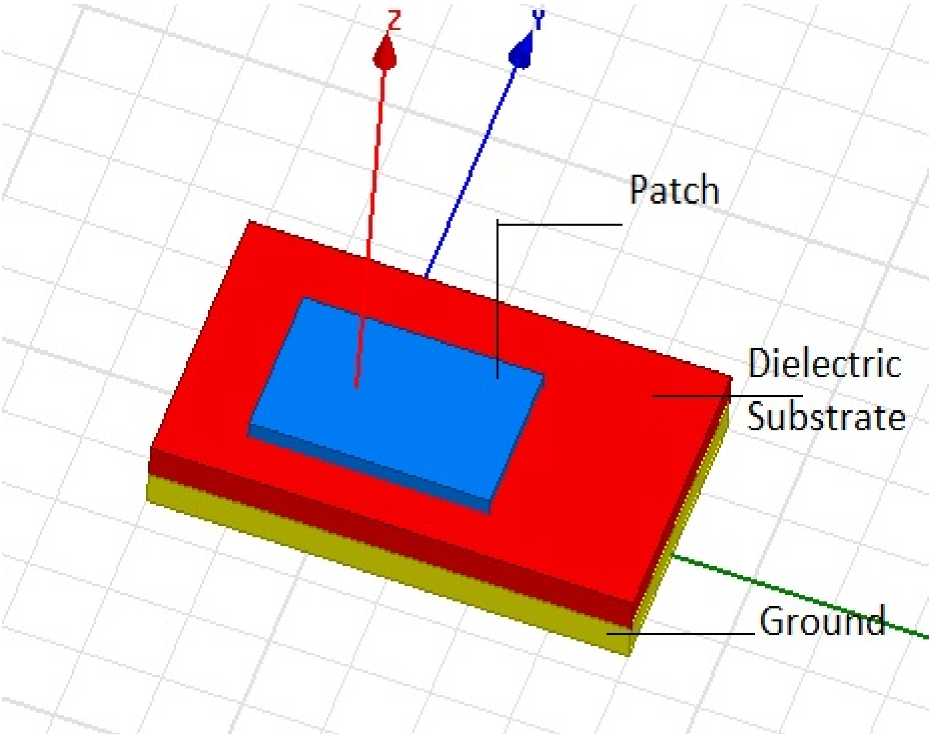


Figure 3.1 Structure of micro-strip antennas

3.2. Feeding techniques

An edge of a patch is connected with a connector directly by a conducting line also known as feeding line. Such technique is known as micro-strip line feeding technique. This line can be connected directly with the edge of the patch or a certain cut can be made into the patch. This other technique is called as inset feed technique. The line can be straight or either inset cut can be made. The advantage of inset cut is that the antenna can be matched by properly choosing the position of inset and width of the inset.

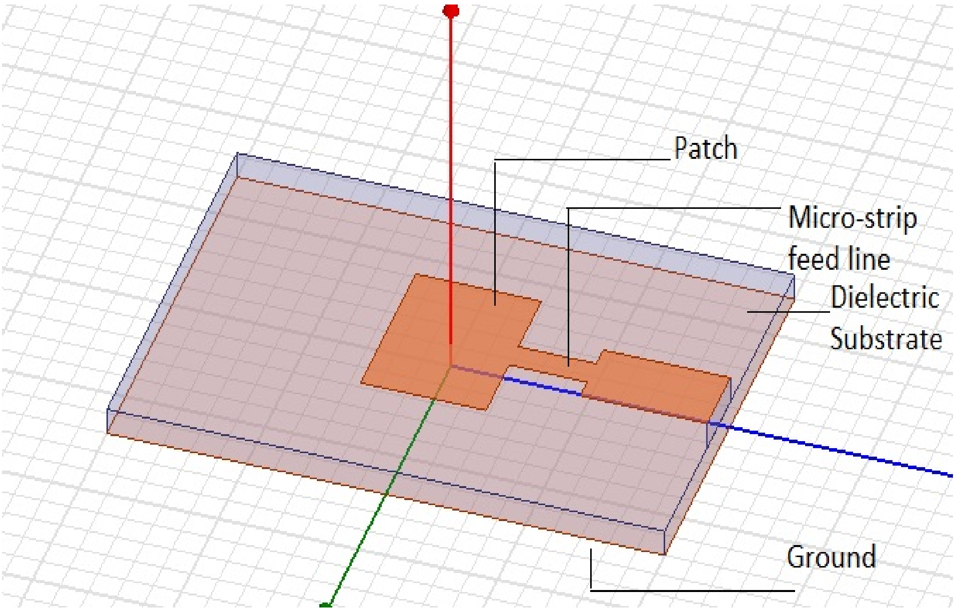


Figure 3.2 Rectangular Edge feed technique

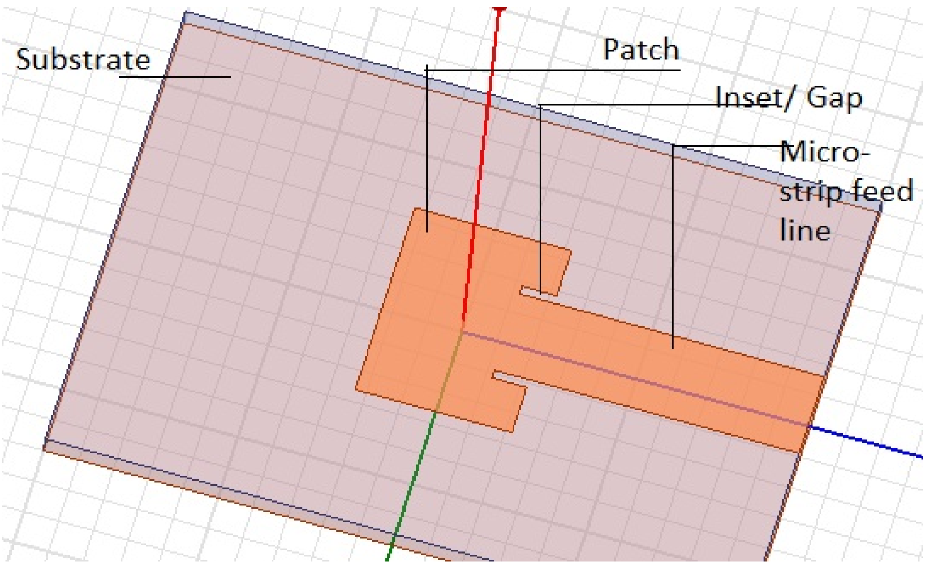
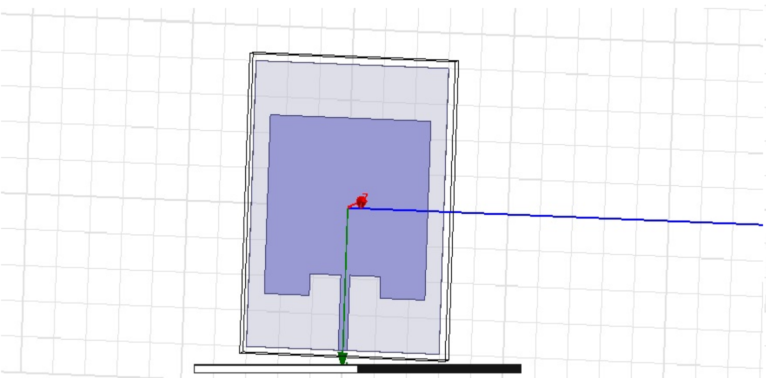


Figure 3.3 Rectangular Inset feed technique

3.3 Fractal Slot Antenna

In 1970, B.B. Mandelbrot introduced the term "fractal" meaning fragmented geometric shape. Fractal slot consists of a metal surface with a certain cuts of geometrical shape or figures in it.

They can be either of same shape repeated or a different one. The use of fractal antennas helps in reducing the cross section of the patch, also the antenna resonates in multiple frequencies.



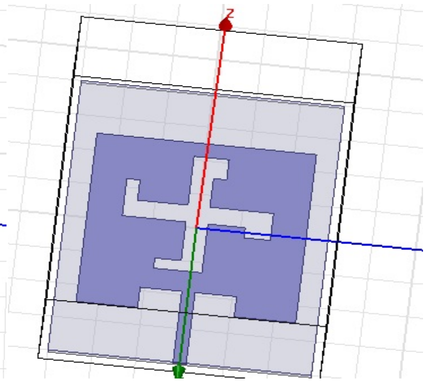


Figure 3.4 Reference antenna **Figure 3.5 Antenna with swastika slot**

The geometric patterns can be drawn and its properties can be further enhanced using the technique of Genetic Algorithm.

3.4 Genetic Algorithm

To solve complex issues with a greater number of variables and potential outcomes/solutions, a genetic algorithm is used. To select the best answers, combinations of several solutions are run through a Darwinian-based algorithm. The progeny of the superior solutions then take the place of the inferior ones. The Darwinian idea underlies everything, according to which only most fit individuals are selected for reproduction. The numerous solutions are viewed as the population's components, and only most fit solutions are permitted to procreate (to create better solutions). The solutions to each particular challenge can be optimized with the use of genetic algorithms.

3.5 Antenna Parameters

a) Frequency Bandwidth

The frequency range where an antenna performs in accordance with a given standard for a given characteristic is known as its frequency bandwidth. The frequency range on each side of the center frequency where the antenna properties are within a reasonable range of those at the center frequency is referred to as the bandwidth. In wireless communications, the antenna is required to provide a return loss as less as possible over its frequency bandwidth.

b) Return Loss Return loss

The effectiveness of power distribution from a transmission line to a load is gauged by return loss (antenna). The ratio P_{in}/P_{ref} indicates the degree of mismatch between the incident and the reflected power in the travelling waves if the power incident on the antenna under test is P_{in} and the power reflected back to the source is P_{ref} . The higher this power ratio is, the better the load and the line are matched. Return loss is the negative of the magnitude of the reflection coefficient in dB. The return loss in antenna is given by its S_{11} parameter. It is also called the return loss. It is expressed in terms of dB as:

$$S_{11}(dB) = -20log_{10}\frac{P_{ref}}{P_{in}} \qquad (3.1)$$

S_{11} is the reflected power that an antenna is trying to deliver (how much power is reflected from the antenna).

c) Radiation Pattern

A variation in the power radiated by an antenna depending on the direction in which the antenna is pointed defines a radiation pattern. It is a diagram that shows how the antenna's radiation characteristics change with the spatial coordinates. Additionally, the antenna's radiation pattern measures the power or radiation distribution relative to a specific set of coordinates. Since the ideal antenna should emit in a spherically symmetrical manner, we typically take spherical coordinates into account. The radiation pattern is almost always determined in the far field.

d) Antenna Gain

The relative gain is the ratio of the power gain in a given direction to the power gain of a reference antenna in its referenced direction. In most of cases the reference antenna is a lossless isotropic source. When the direction is not specified, the power gain is usually taken in the direction of maximum radiation**.** The mathematical representation of gain is:

$$\textbf{Gain} = \epsilon_r \textbf{D} \qquad (3.2)$$

where, ϵ_r = relative dielectric constant, D = directivity

e) VSWR

VSWR stands for Voltage Standing Wave Ratio. It is determined from the voltage measured along a transmission line leading to an antenna.

$$\boldsymbol{VSWR} = \frac{\textbf{peak amplitude of standing wave}}{\textbf{minimum amplitude of the standing wave}} \tag{3.3}$$

An impedance match between the antenna and the radio or transmission line to which it is linked is expressed numerically as VSWR. It is also called SWR and is a function of reflection coefficient. Smaller VSWR, better the performance.

f) Radiation Resistance and Efficiency

Antenna impedance's resistive component is divided into two parts: a radiation resistance Rr and a loss resistance R_1. The power that is really radiated by the antenna is dissipated in the radiation resistance, while the power that is lost in loss resistance is power that is lost within the antenna. Losses in the antenna's conducting or dielectric components could be the cause of this. Radiation efficiency of antenna is ratio of power radiated to power accepted by antenna. Antenna with high radiation efficiency therefore has high associated radiation resistance compared with the losses.

g) Compact Disc

A CD is made from 1.2-millimetre (0.047 in) thick, polycarbonate plastic and weighs 14–33 grams. From the center outward, components are: the center spindle hole (15 mm), the first-transition area (clamping ring), the clamping area (stacking ring), the second-transition area (mirror band), the program (data) area, and the rim. The inner program region has a radius between 25 and 58 mm [15].

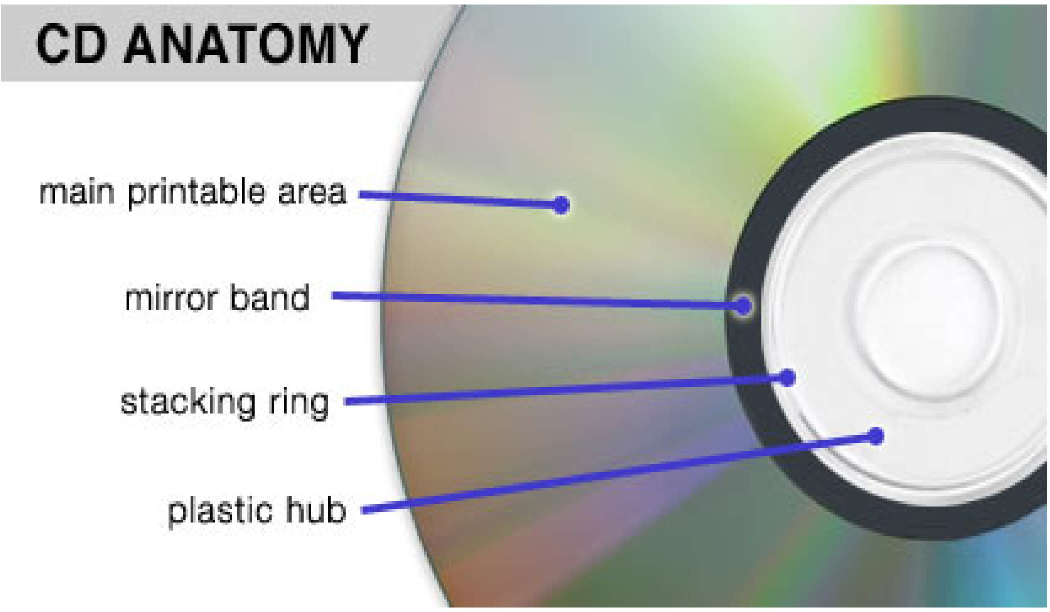


Figure 3.6 Compact Disc

The surface is coated with a small layer of aluminum or, less frequently, gold to make it reflective. A layer of lacquer is often spin coated directly on the reflective layer, shielding the metal from damage. The label is typically produced using offset or screen printing on the lacquer layer.

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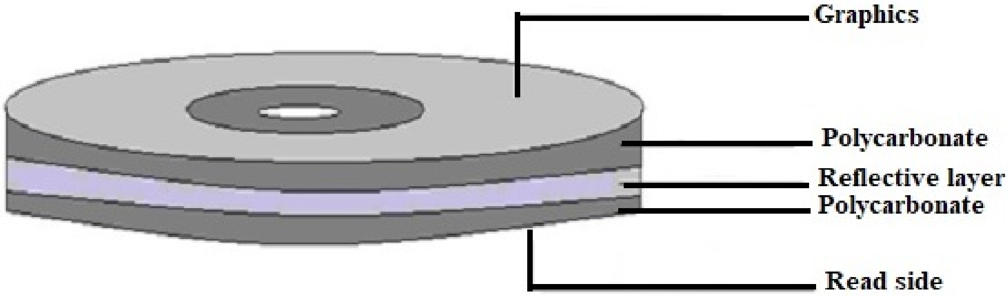


Figure 3.7 Different Layers of CD (Side View)

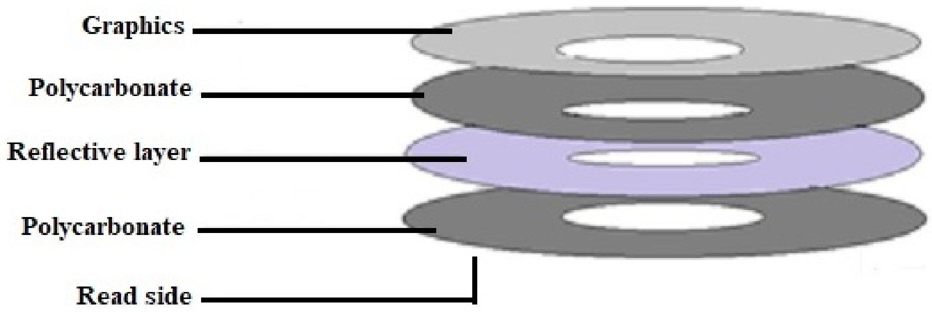


Figure 3.8 Stacking different layers of compact disc

h) How lightscribe works?

LightScribe is a direct disc-labeling technology that provides a simple way to create precise silkscreen-quality labels for discs [16].

Hewlett-Packard developed the optical disc recording technology known as LightScribe. Instead of stick-on labels and printable discs, it employs specially coated recordable CD and DVD media to create laser-etched labels with text or pictures. A reactive dye that changes color when it absorbs infrared laser light with a wavelength of 780 nm is applied to the surface of a LightScribe disc. A LightScribe label cannot be replaced with a different one (i.e., the disc's surface cannot be erased), however a label that has already been burned can have more content added to it. Every LightScribe disc has a center with a special code that, when combined with a sensor in the drive, enables the drive to know the exact rotational position of the disc. It can label the disc while spinning at a fast speed using these references because this, along with the drive hardware, enables it to know the precise position from the center outwards. It also offers the secondary function of allowing several labels with the same image to be placed on the same disc. The image contrast will grow and the blacks will get darker with each additional labeling. The successive burns are also aligned with the old ones [17].

CHAPTER 4

METHODOLOGY

4.1 Activated carbon sample Preparation

a. Carbon sample preparation

Firstly whole plum of Lapsi (Choerospondias axillaris), an indigenous plant of Nepal is taken. Its outer cover is removed, only seeds are taken. Then the seeds are washed, cleaned and other impurities are removed and dried in sunlight for 3 days for the removal of moisture and other volatile impurities. After that the seeds are crushed and made into powder form using crusher**.**

Figure 4.1 Lapsi original seed (left) and powdered form (right) [2]

b. Activation of the carbon sample

Chemically the obtained carbon powder is mixed with phosphoric acid. The mixture is then heated into the Quartz tube of tube furnace at about 400^{o}C with controlled supply of nitrogen gas. Nitrogen being an inert gas does not react with acid and carbon. **.**After this procedure other unwanted dust and chemicals are separated leaving behind the carbon only.

c. Characterization of the sample

To know whether the obtained sample contains carbon or not, characterization of sample is most important one. X-ray diffractometer helps in determining the crystallography of a material. It is used to measure the average crystal size, strain or microstrain effects in carbon sample. Here, Brunker D2 Phaser Diffract Meter is used for X-ray diffraction.

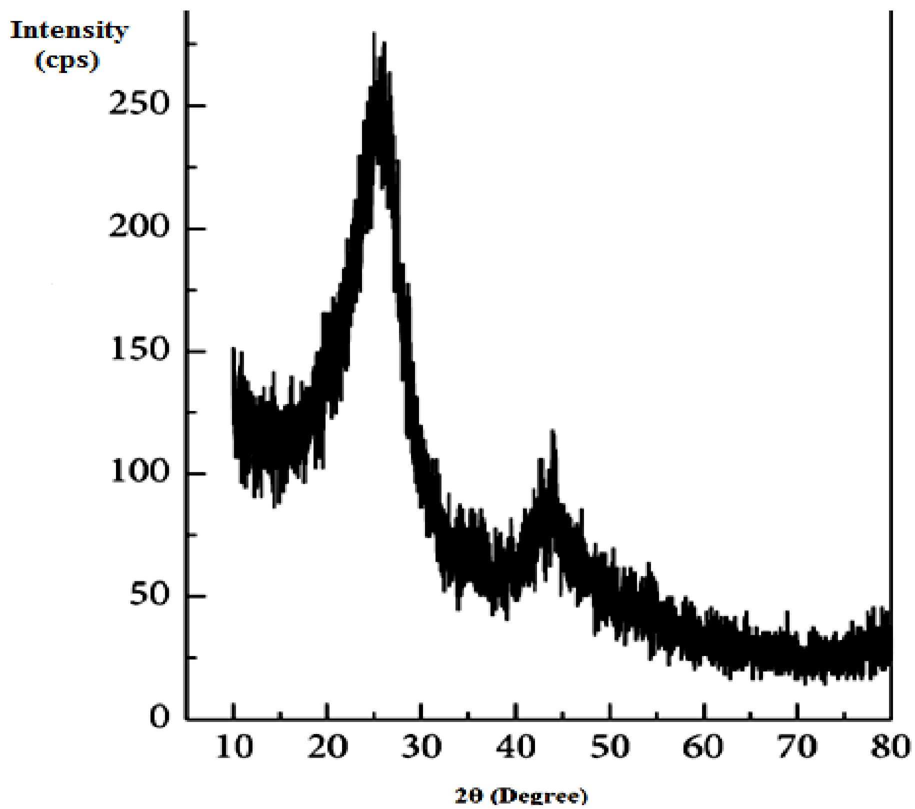


Figure 4.2 XRD of Activated Carbon [2]

The appearance of a broad peak between 22^o and 24^o in the XRD spectra of the activated carbon indicates the presence of carbon. The peak value of intensity in the range is about 275 cps. The absence of extra peaks shows the absence of any other x-ray traceable compounds in the activated carbon sample. Small peaks in the XRD spectra is because of minor presence of other impurities in the activated carbon sample [2].

4.2 Antenna Design

Firstly, the reference antenna is designed with square patch of 4cm*4cm in a substrate of 6cm*6cm of polycarbonate in Ansoft HFSS. Then, it is optimized using genetic algorithm (GA).

4.3 Formulation of swastika shape

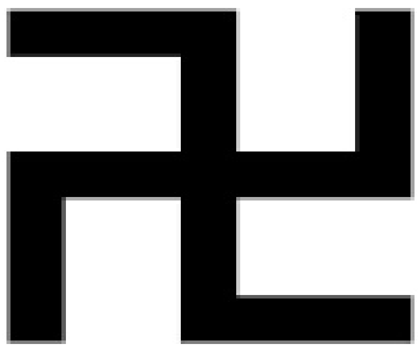


Figure 4.3 Swastika Shape

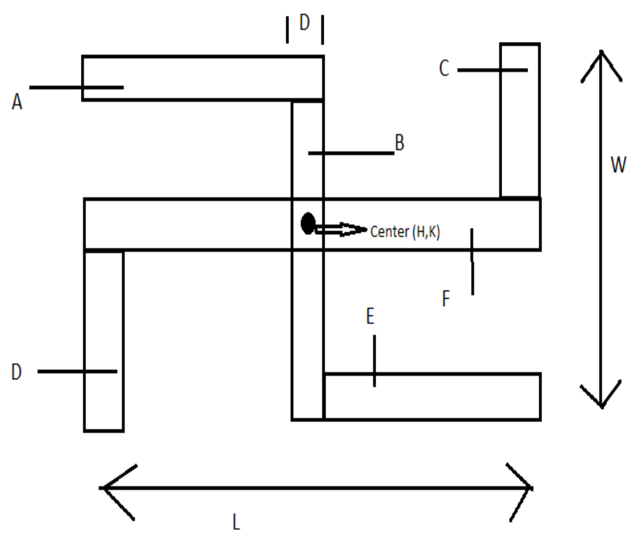


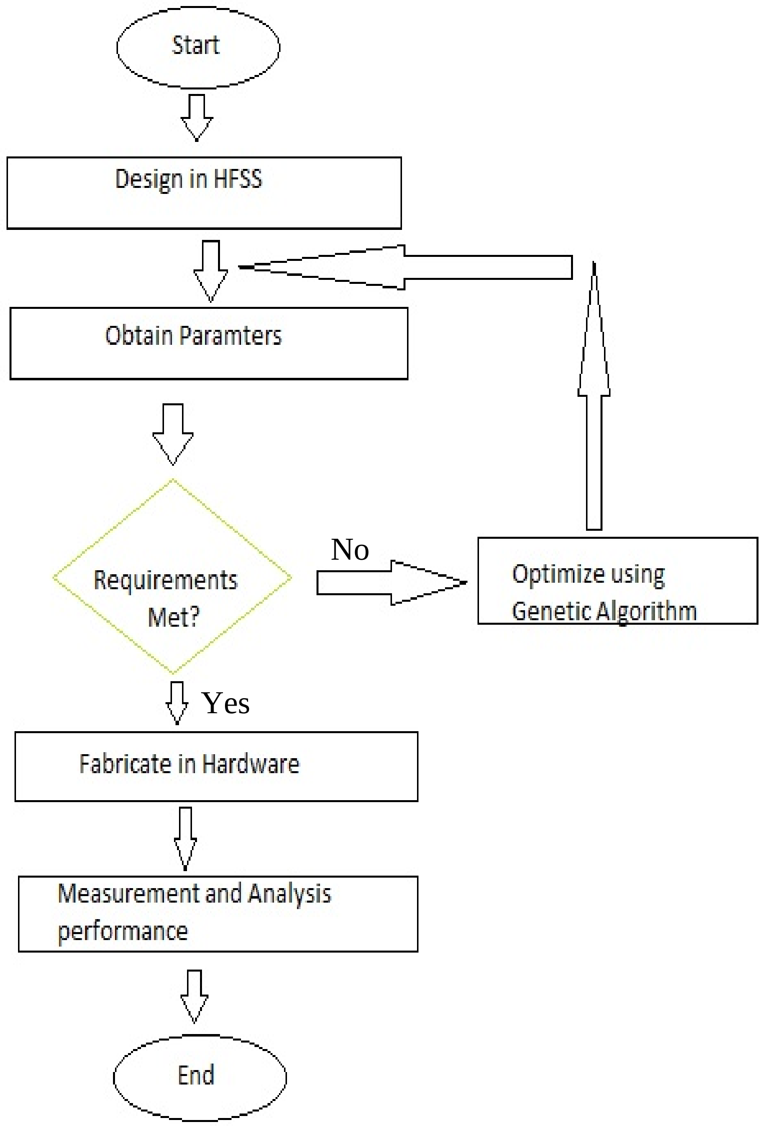
Figure 4.4 Different Parts of Swastika Shape

Let (H,K) be the center of swastika shape. L, W and T be the length, width and thickness of swastika shape resp. A, B, C, D, E and F be the different parts of swastika shape and with their proper combination we get swastika shape as a whole.

Table 4.1: Shape and size of Different Portion of Swastika Shape

Name of part	Size
A	position = [H-T/2, K-L/2] size = T*L
B	position = [H-L/2, K-W/2] size = L*T
C	position = [H-L/2, K-L/2] size = (L-T)/2*T
D	position = [H-L/2, K+T/2] size = T*(L-T)/2
E	position = [H-T/2, K-L/2] size = T*(L-T)/2
F	position = [H-T/2, K-L/2] size = (L-T)/2*T

Flowchart to design Antenna



4.5 Procedure to paste Carbon in CD

1. Take 50 gm of prepared activated carbon paste.
2. Mix it with 15 gm of H_2O.
3. Sonicate it for three hours.
4. Dry the sample in oven for 24 hours to thicken the paste.
5. Take the lightscribe CD and place it in DVD writer for coating.
6. Cover the center as :

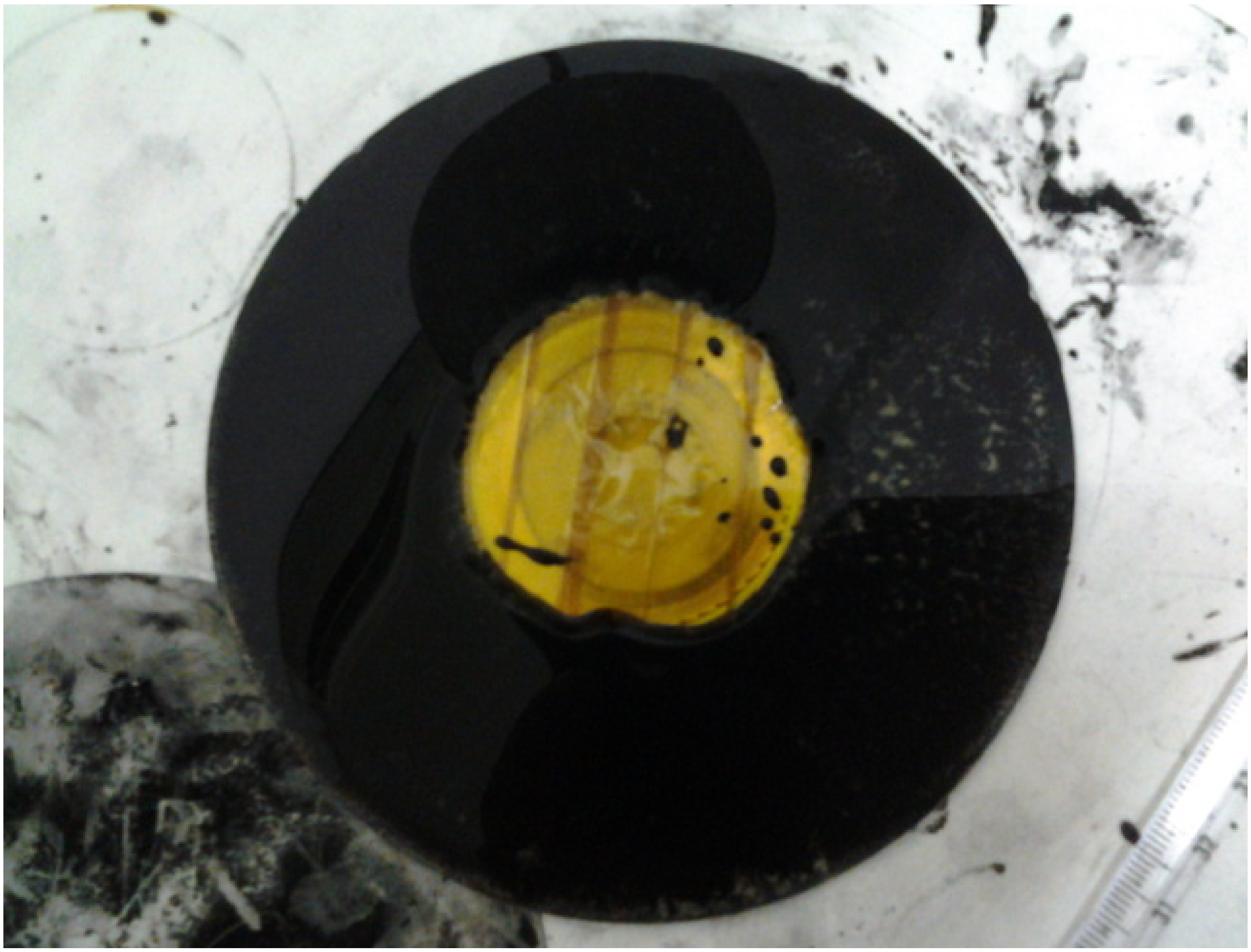


Figure 4.5: Covering and Coating of CD with activated Carbon

7. Apply the paste in Lightscribe disc.

8. Leave the CD overnight for dry.

9. Create different designs to make label in CD such as:

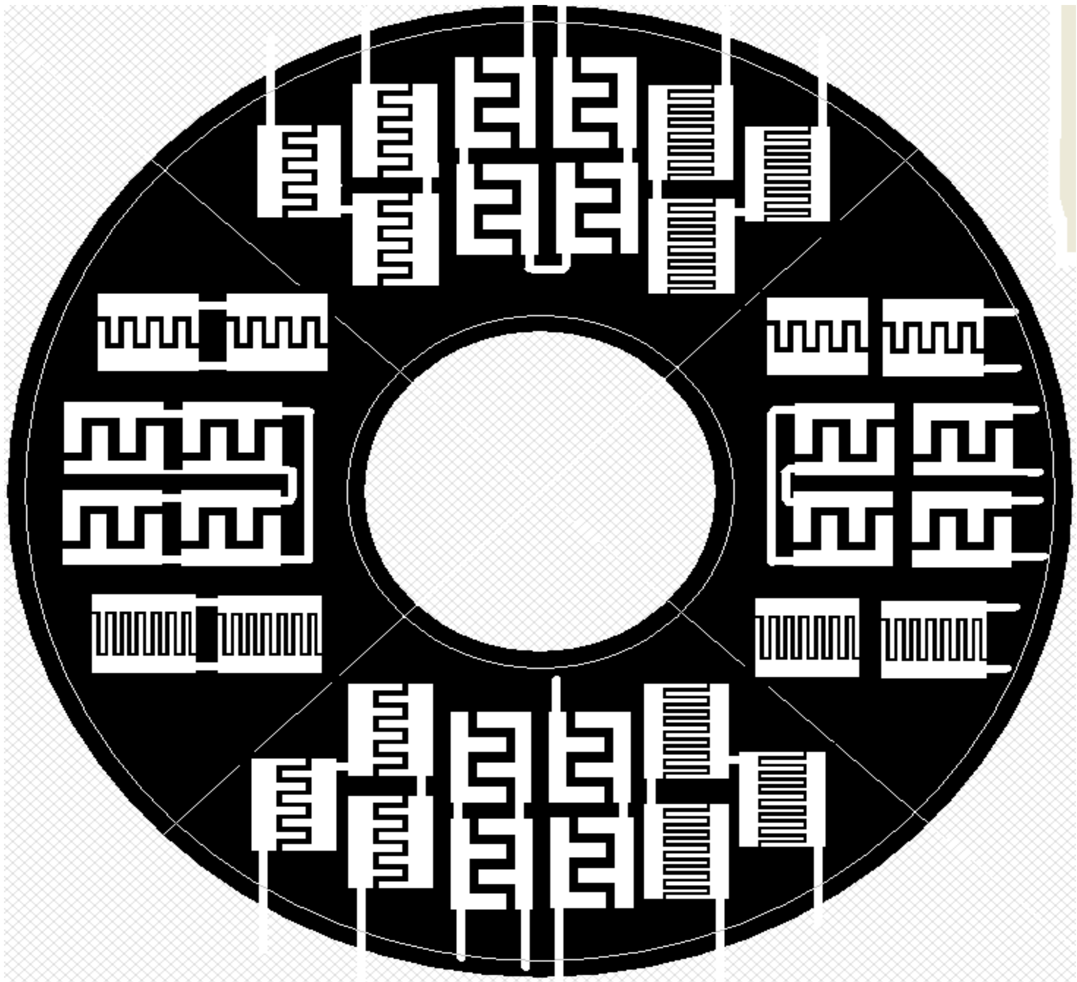


Figure 4.6 Different Designs to be imprinted on CD

10. Place the Cd upside down in the light scribe disc writer and run the program to label the CD.

CHAPTER 5

RESULTS AND DISCUSSIONS

5. Results and Discussions

Polycarbonate is an insulator. Carbon is an insulator too. So, they have extremely high resistance. But after the treatment of coated CD with laser in a light-scribe drive the resistance of carbon is highly reduced.

5.1 Experimental results:

a. **Before coating Activated carbon**

Figure 5.1 Before coating activated carbon in compact disc

Figure 5.2 Working of lightscribe drive without the coating of activated carbon

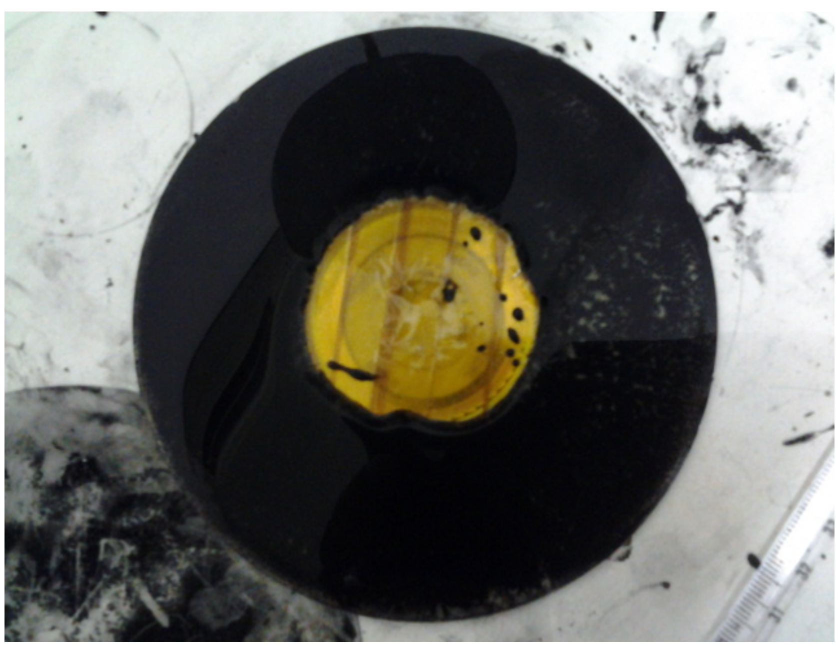


Figure 5.3 CD after coating Activated Carbon

b. After burning of disc / Acting of Laser

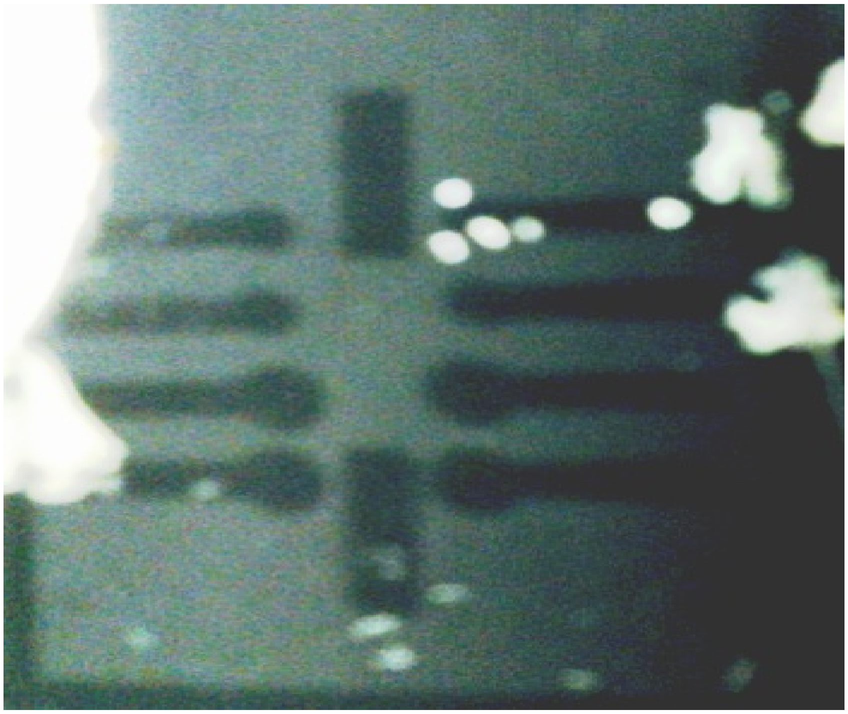


Figure 5.4 (a): Different structures imprinted in CD after laser treatment

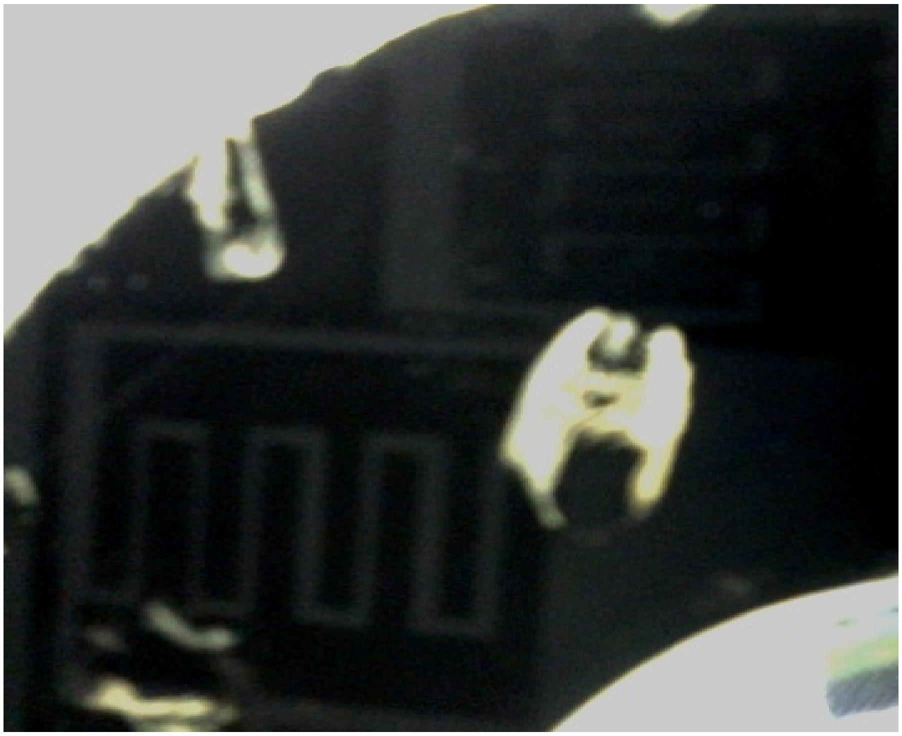


Figure 5.4 (b): Different structures imprinted on CD after laser treatment

Figure 5.4 (c): Different Structure imprinted on CD after laser treatment

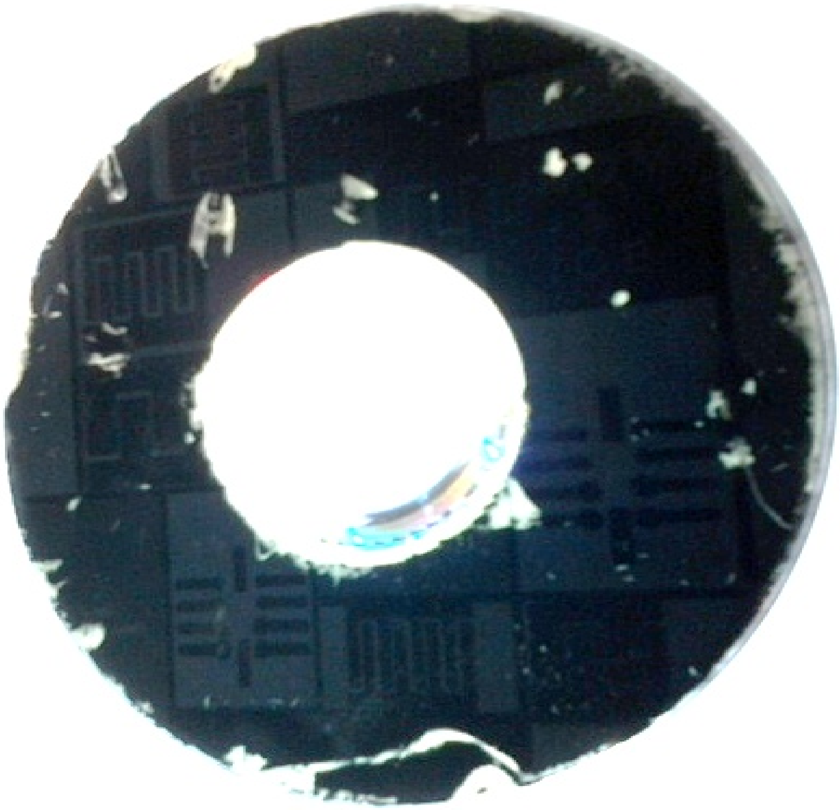


Figure 5.4 (d): Different structures imprinted on CD after laser treatment

5.2 Simulated Results

5.2.1 Results of reference antenna without any fractal slots

a. Copper as patch and copper as ground in polycarbonate substrate

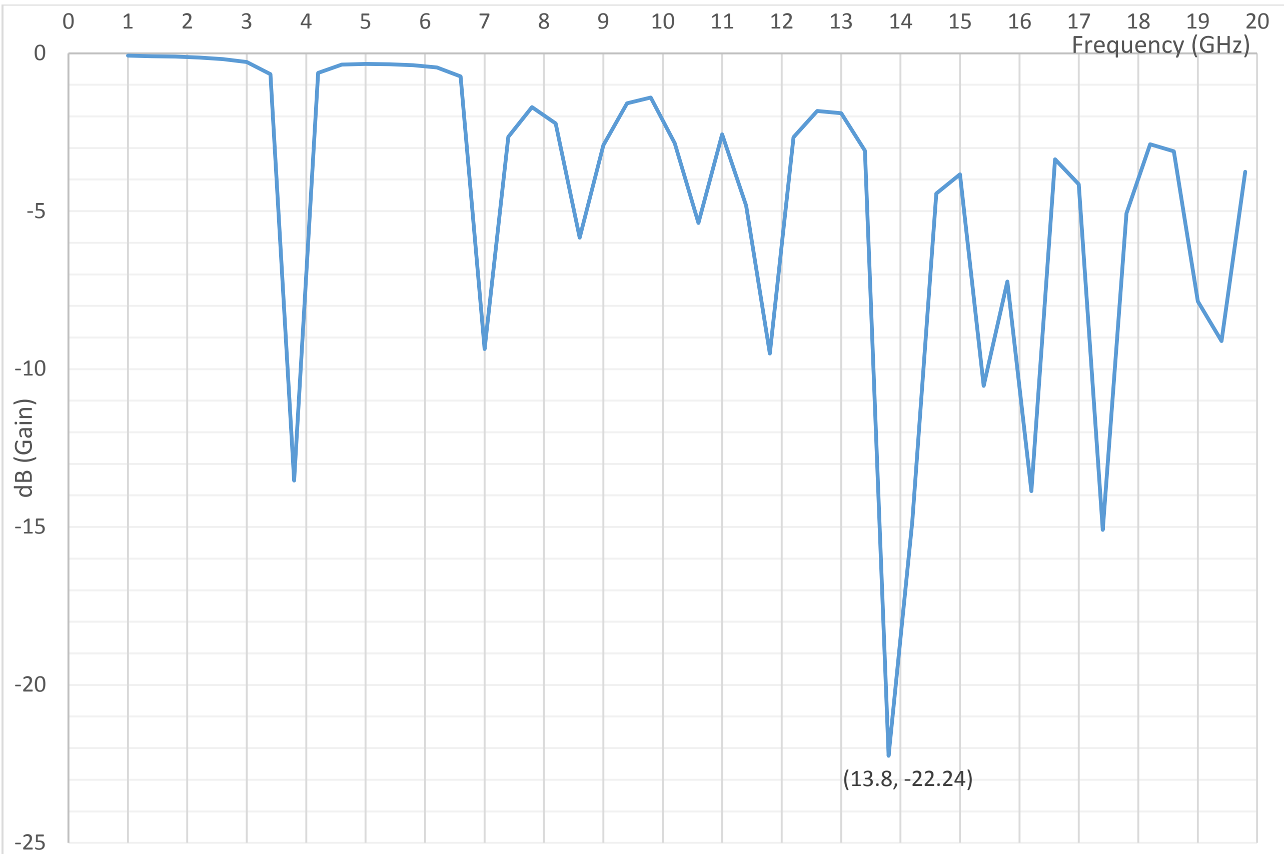


Figure 5.5: S11 of reference antenna of copper as patch and copper as ground in polycarbonate substrate

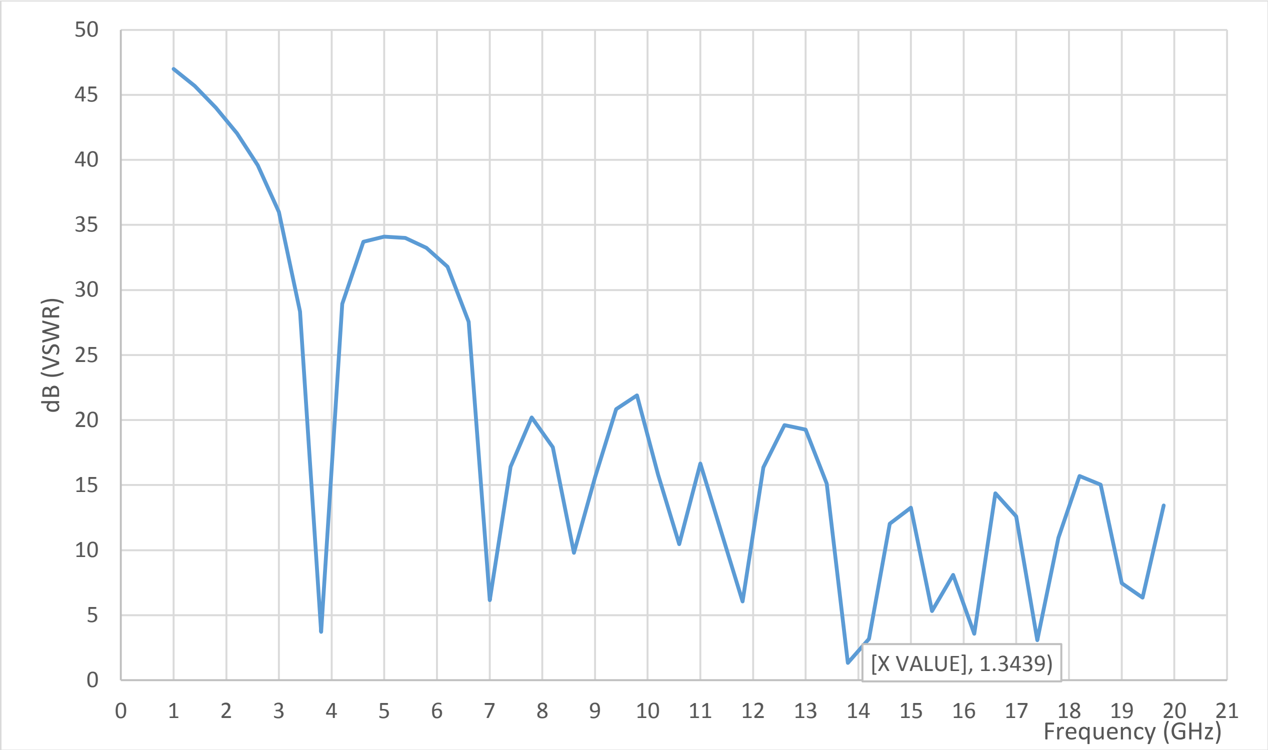


Figure 5.6: VSWR of reference antenna of copper as patch and copper as ground in polycarbonate substrate

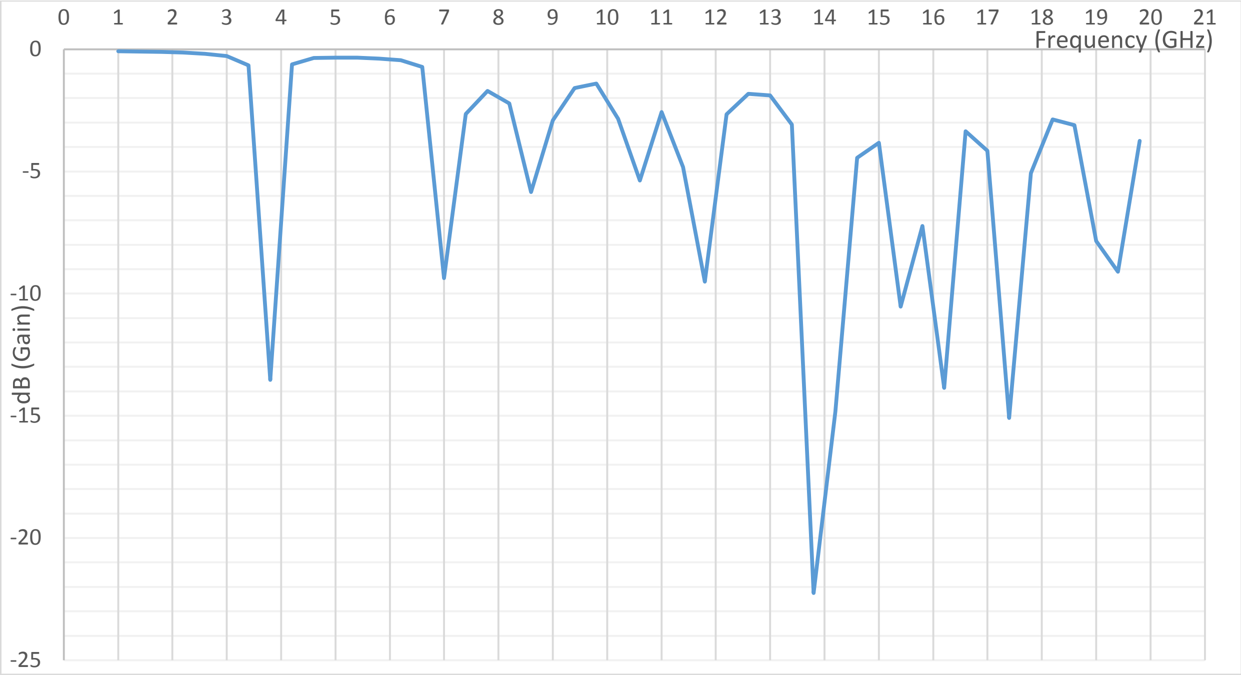


Figure 5.7 Bandwidth of reference antenna of copper as patch and copper as ground in polycarbonate substrate

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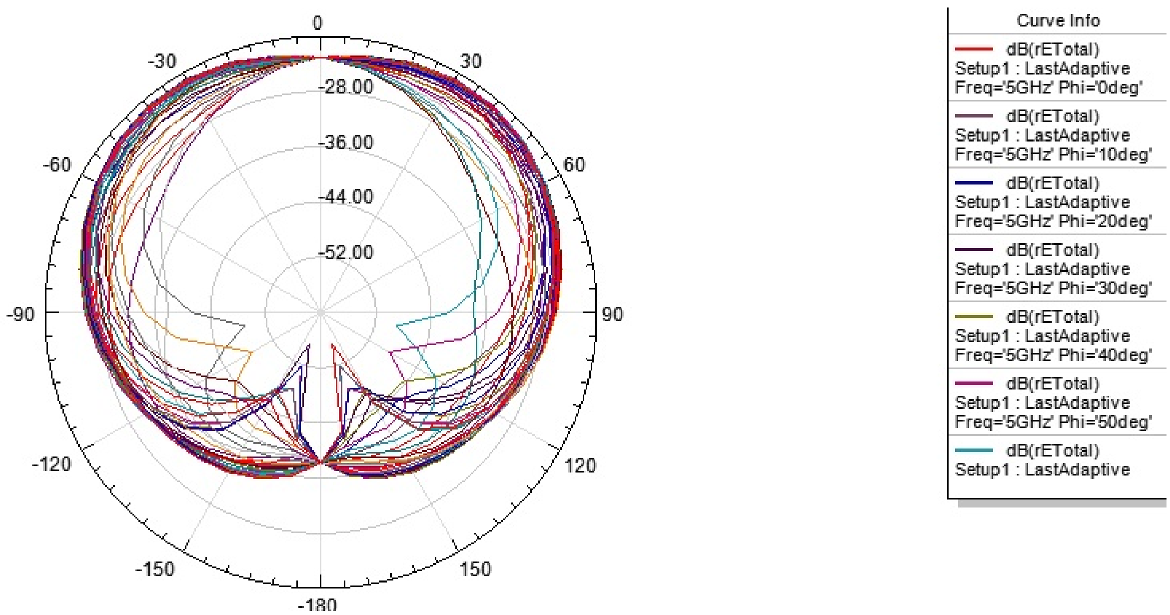

Figure 5.8: Radiation pattern of reference antenna of copper as patch and copper as ground in polycarbonate substrate

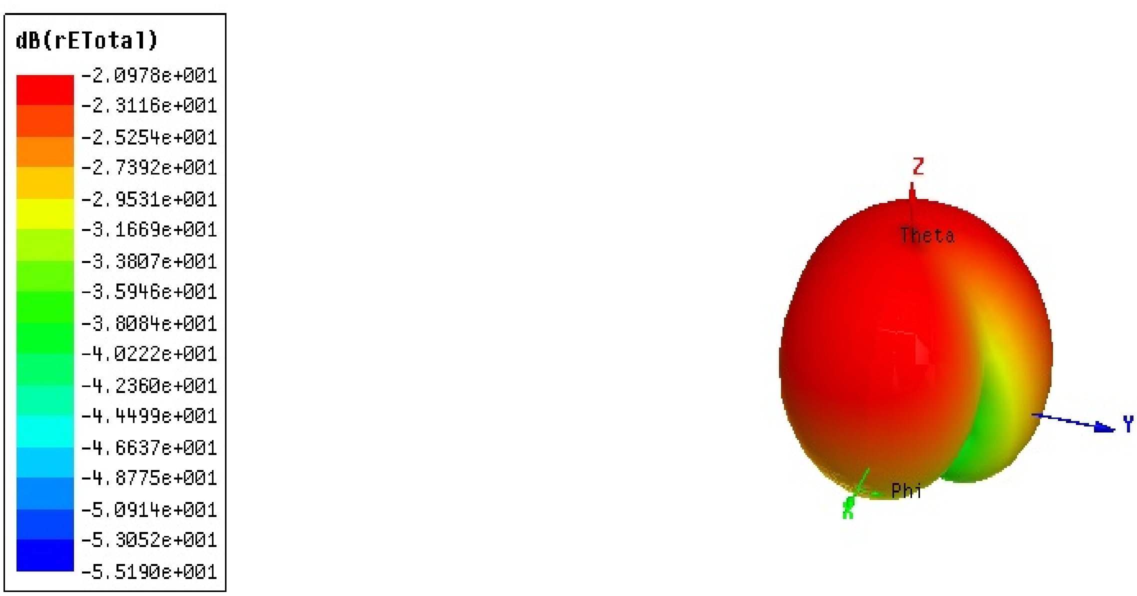

Figure 5.9: 3-D polar plot gain of reference antenna of copper as patch and copper as ground in polycarbonate substrate

c. **Graphite as patch and copper as ground in polycarbonate substrate**

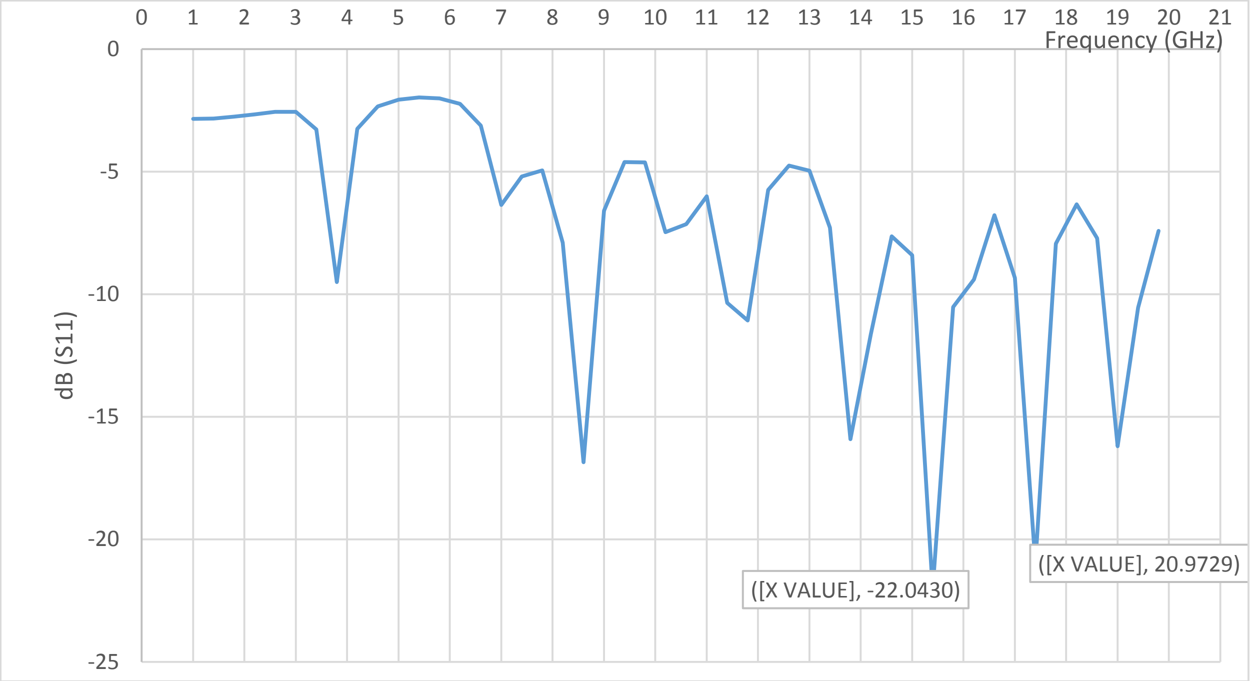

Figure 5.10: S11 of reference antenna of graphite as patch and copper as ground in polycarbonate substrate

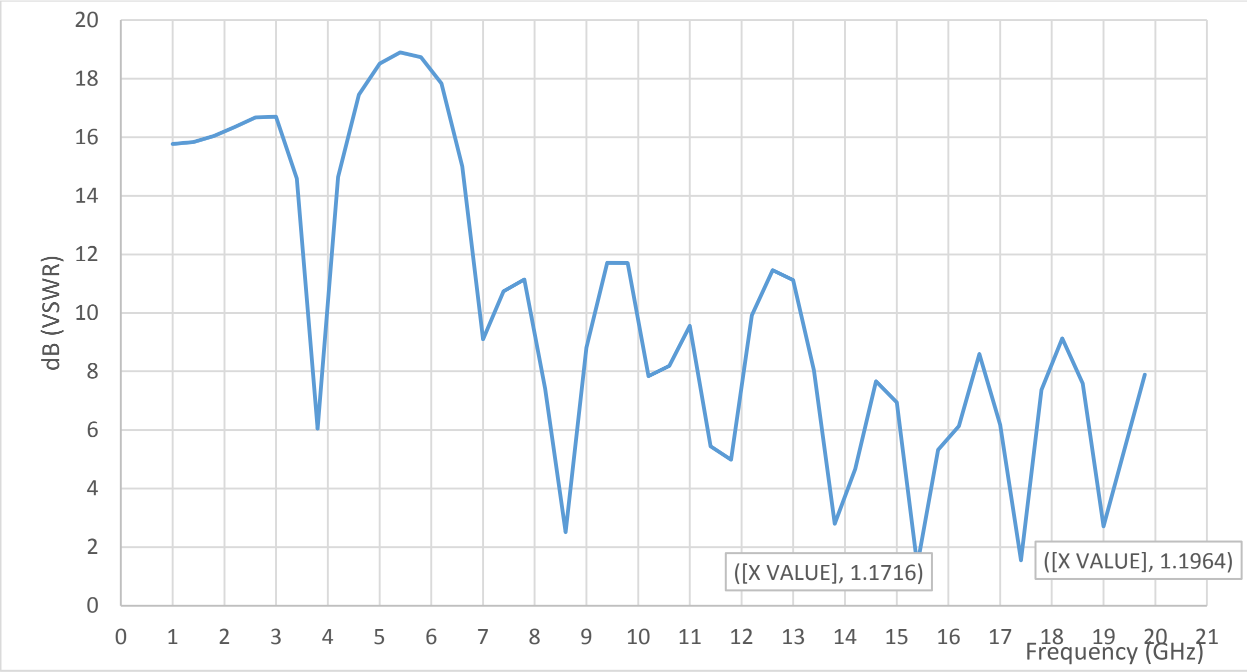

Figure 5.11: VSWR of reference antenna of graphite as patch and copper as ground in polycarbonate substrate

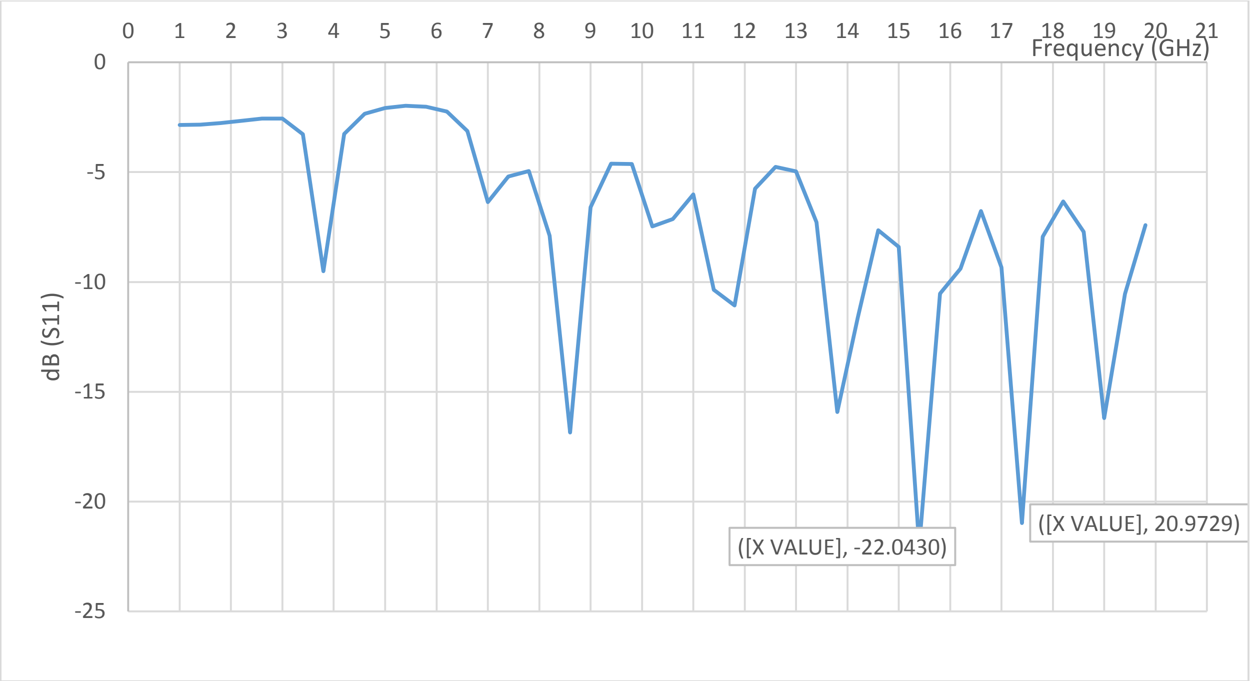

Figure 5.12: Bandwidth of reference antenna of graphite as patch and copper as ground in polycarbonate substrate

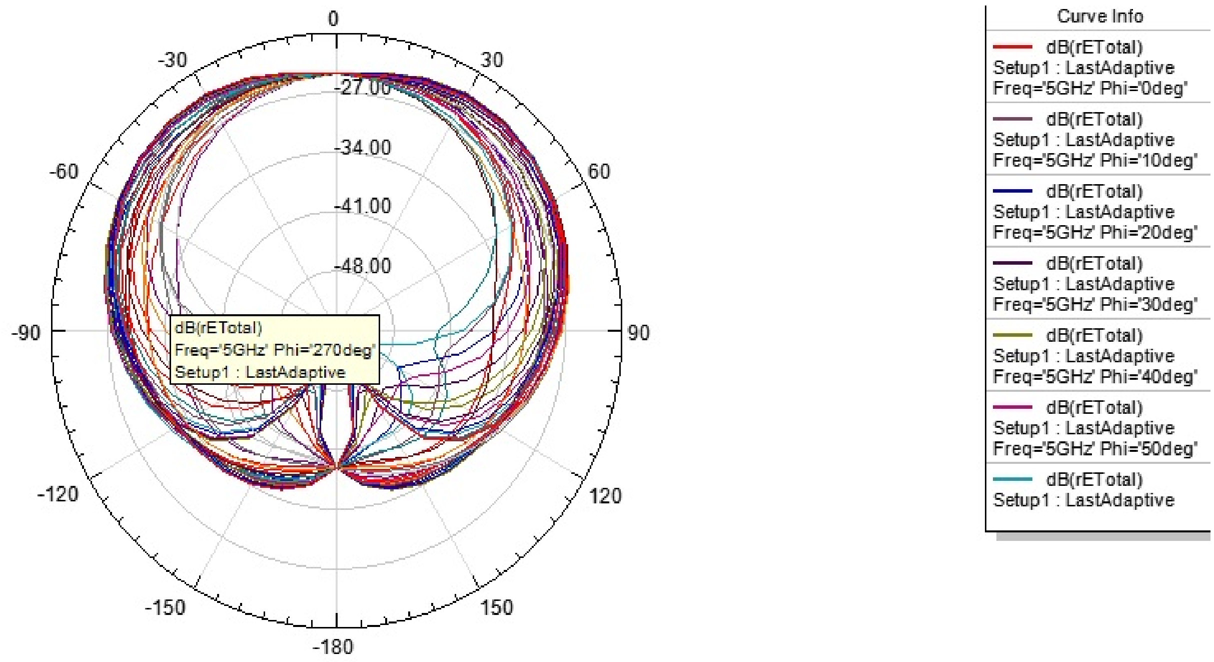

Figure 5.13 Radiation pattern of reference antenna of graphite as patch and copper as ground in polycarbonate substrate

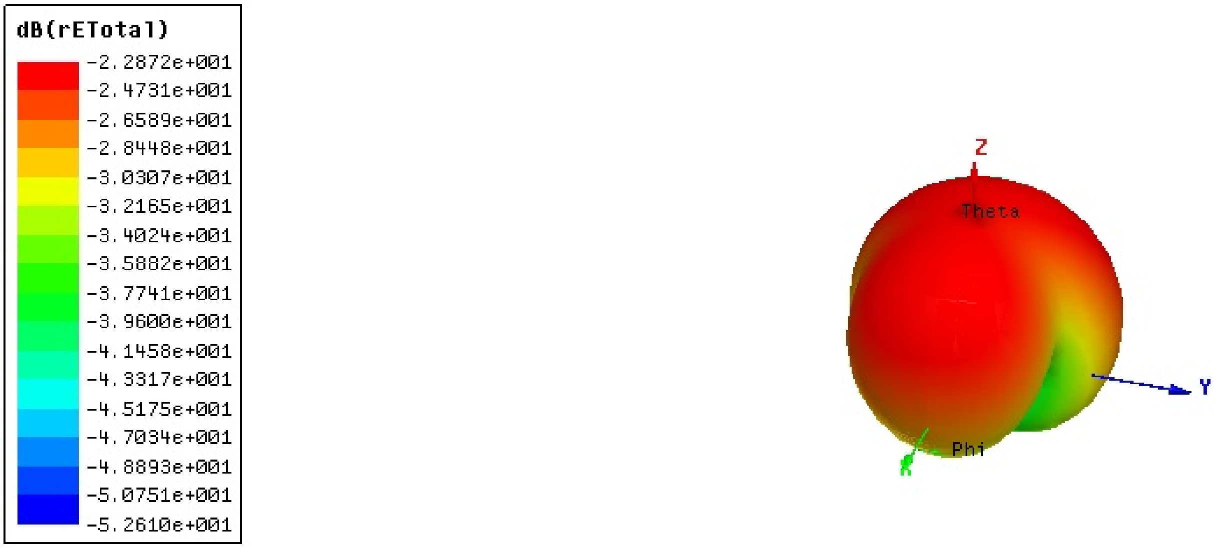

Figure 5.14: 3-D polar plot gain of reference antenna of graphite as patch and copper as ground in polycarbonate substrate

d. Copper as patch and copper as ground in corning-glass substrate

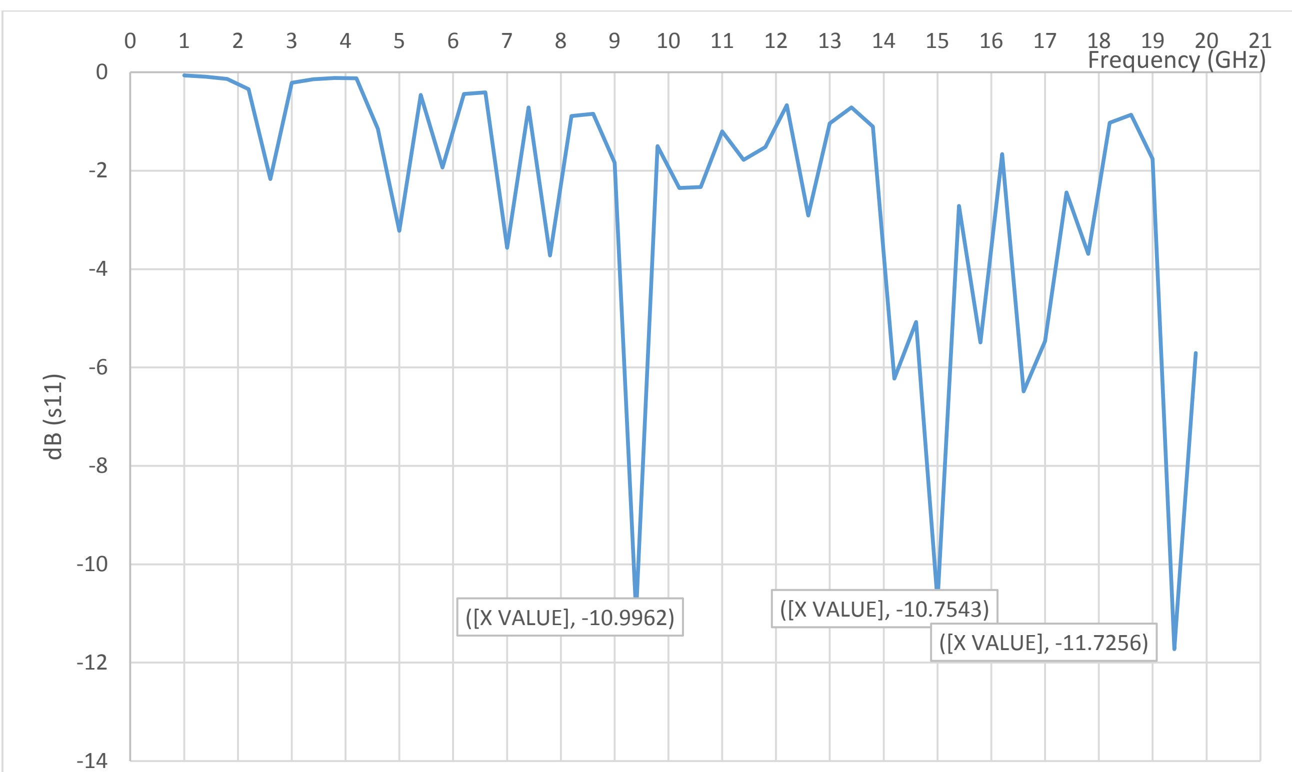

Figure 5.15: S11 of reference antenna of copper as patch and copper as ground in corning glass substrate

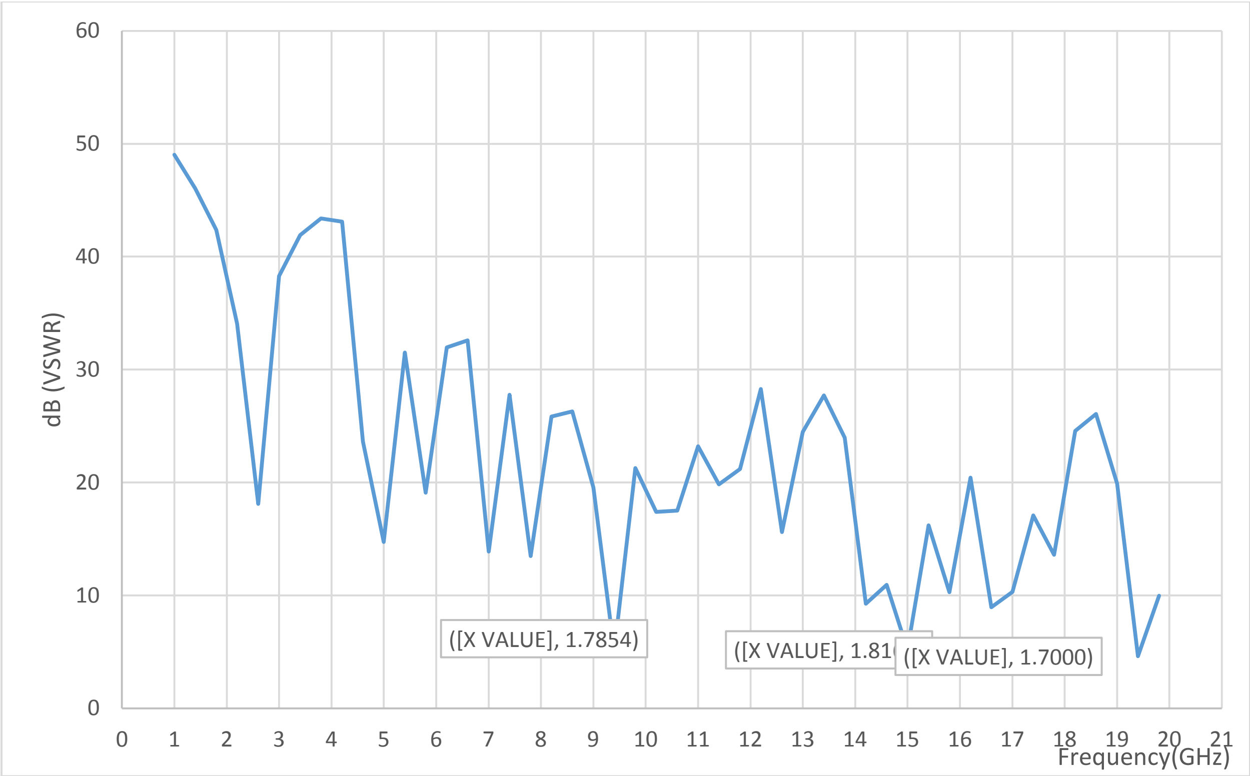

Figure 5.16: VSWR of reference antenna of copper as patch and copper as ground in corning glass substrate

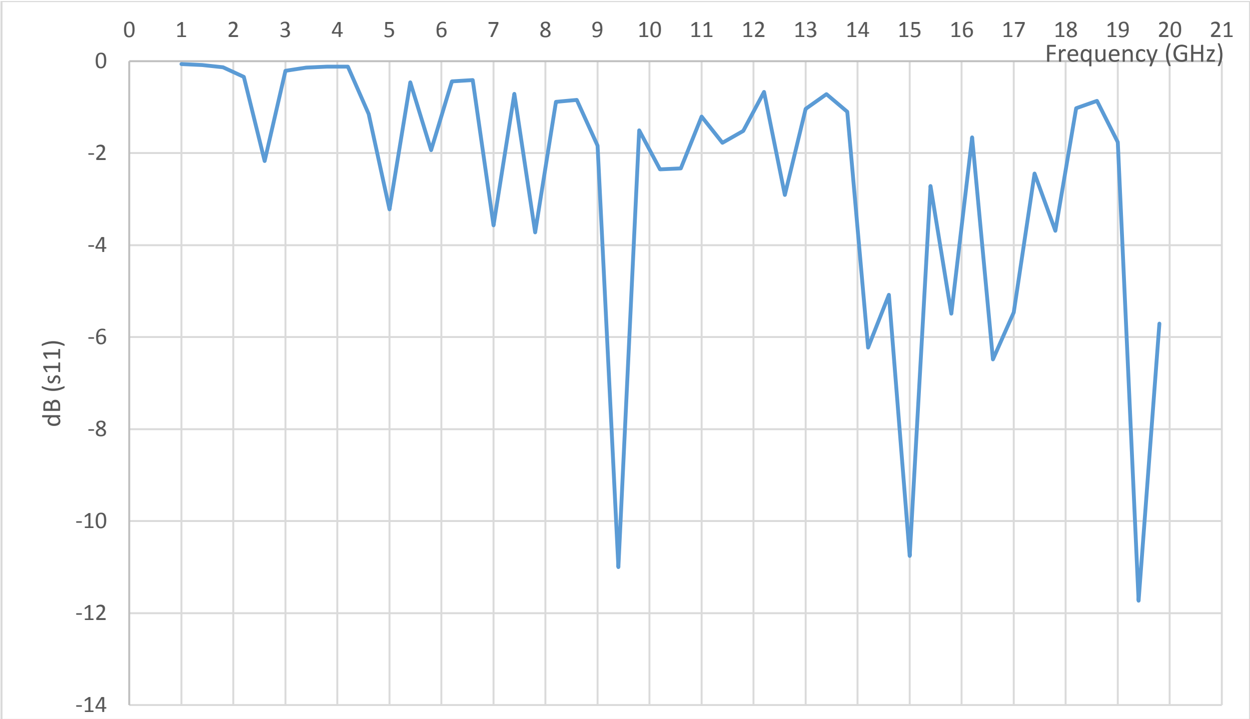

Figure 5.17: Bandwidth of reference antenna of copper as patch and copper as ground in corning glass substrate

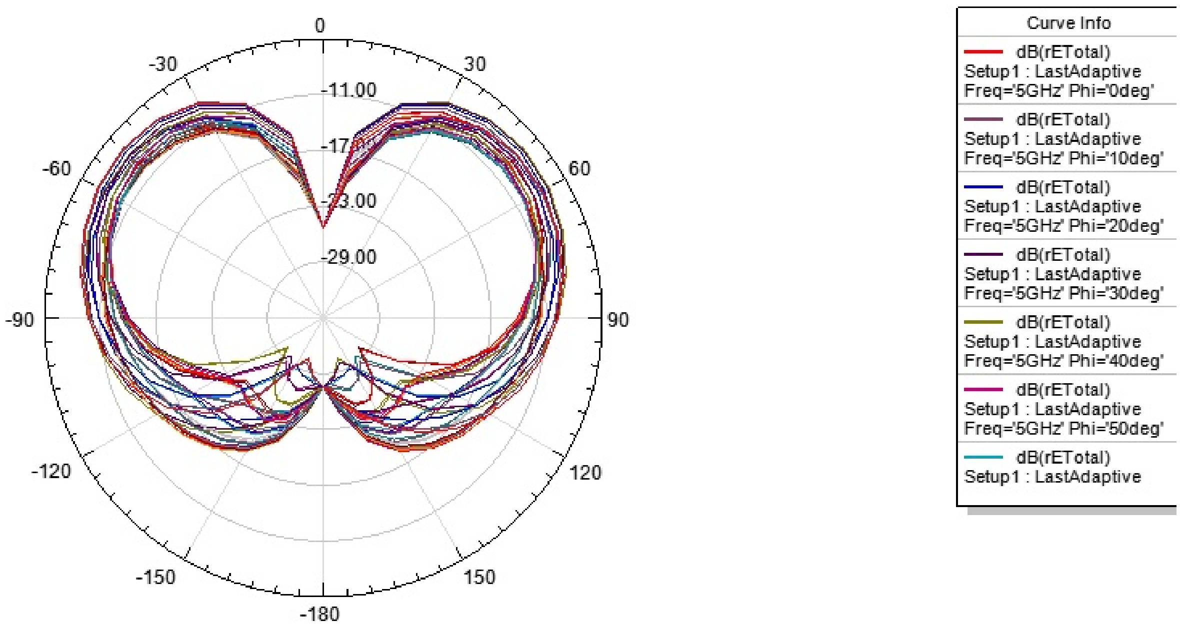

Figure 5.18: Radiation pattern of reference antenna of copper as patch and copper as ground in corning glass substrate

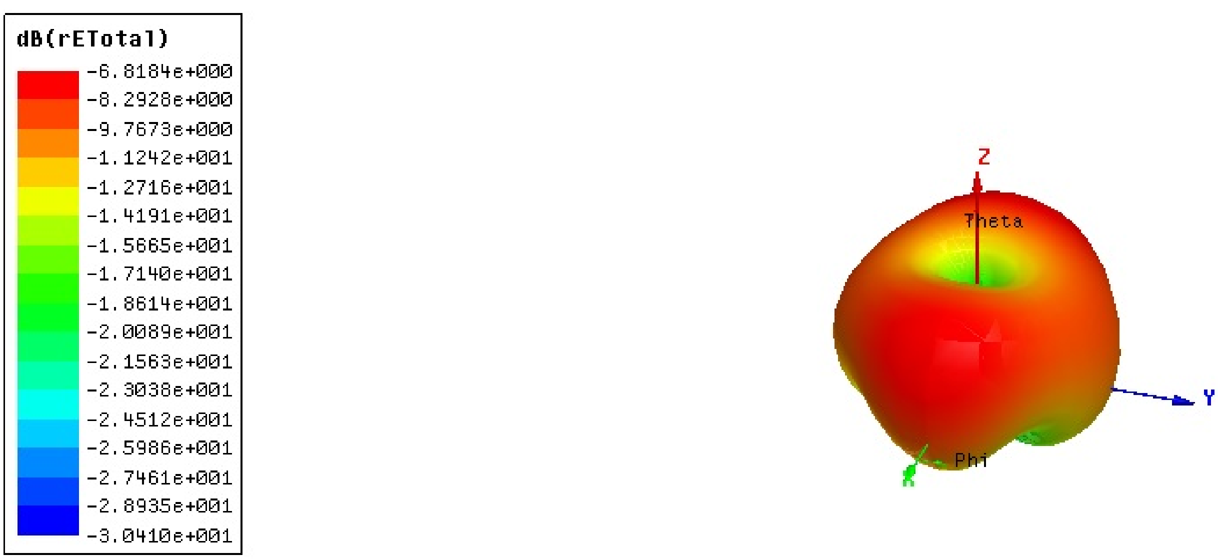

Figure 5.19: 3-D polar plot gain of reference antenna of copper as patch and copper as ground in corning glass substrate

d. Graphite as patch and copper as ground in corning-glass substrate

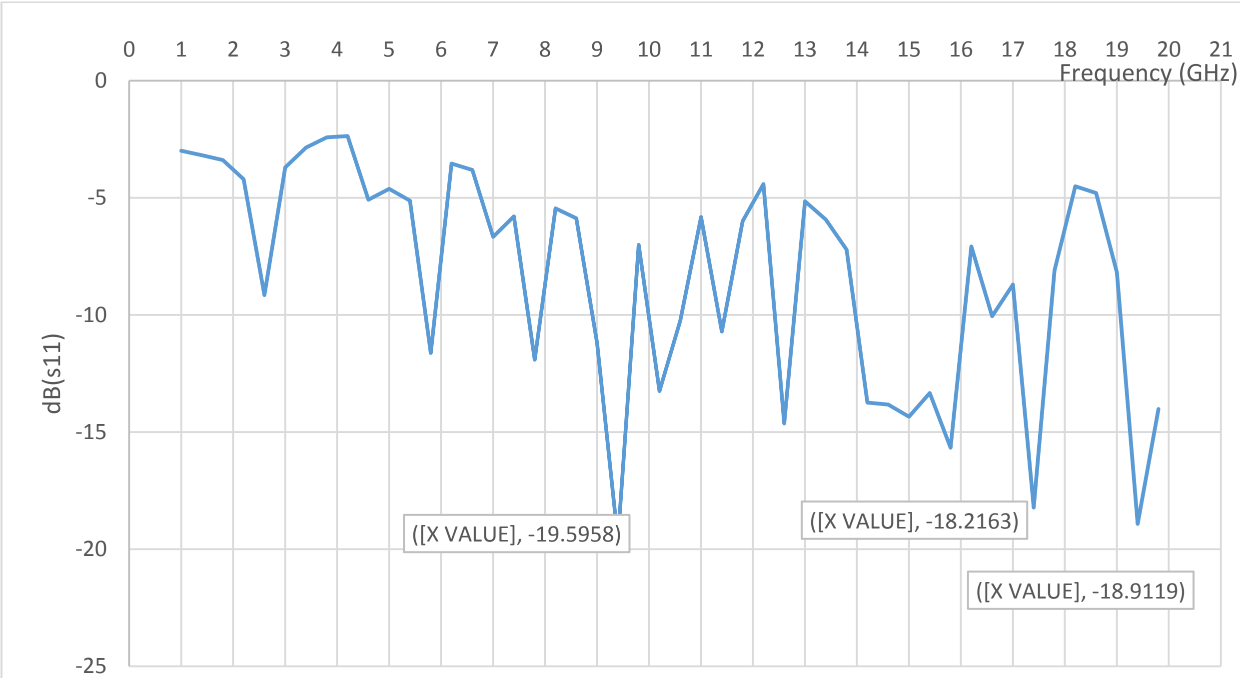

Figure 5.20: S11 of reference antenna of graphite as patch and copper as ground in corning glass substrate

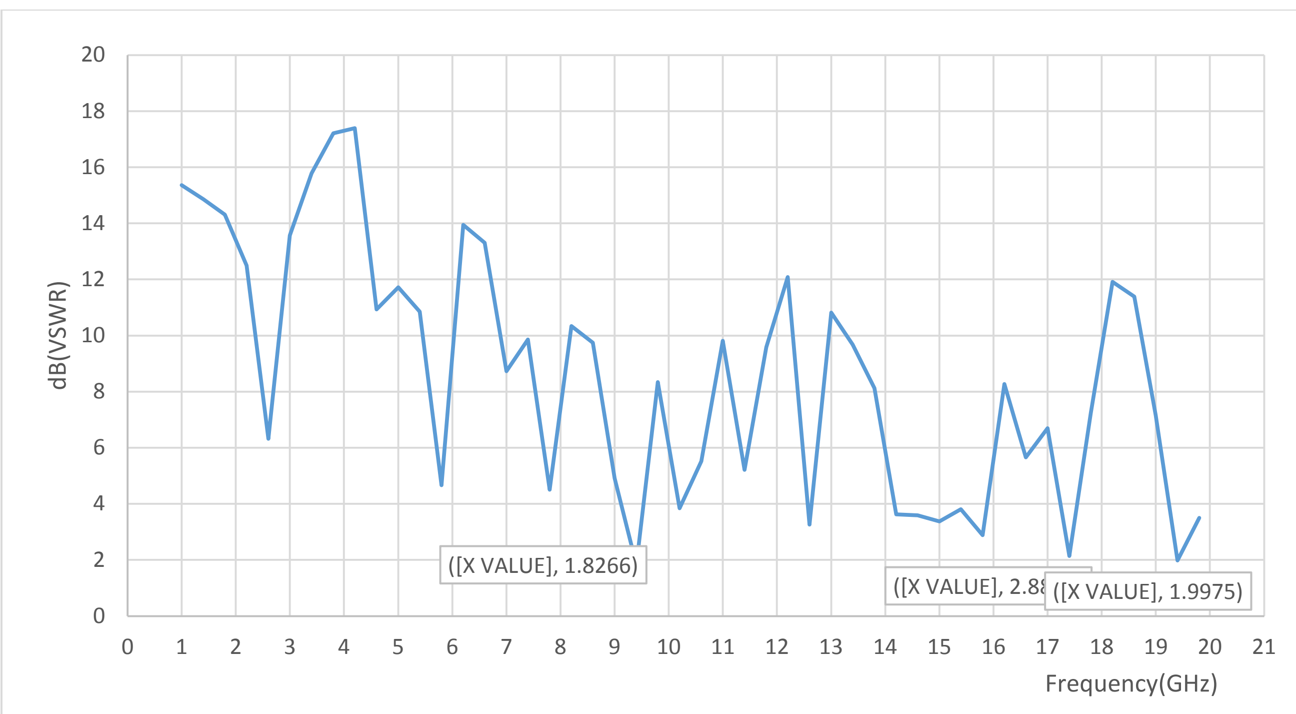

Figure 5.21: VSWR of reference antenna of graphite as patch and copper as ground in corning glass substrate

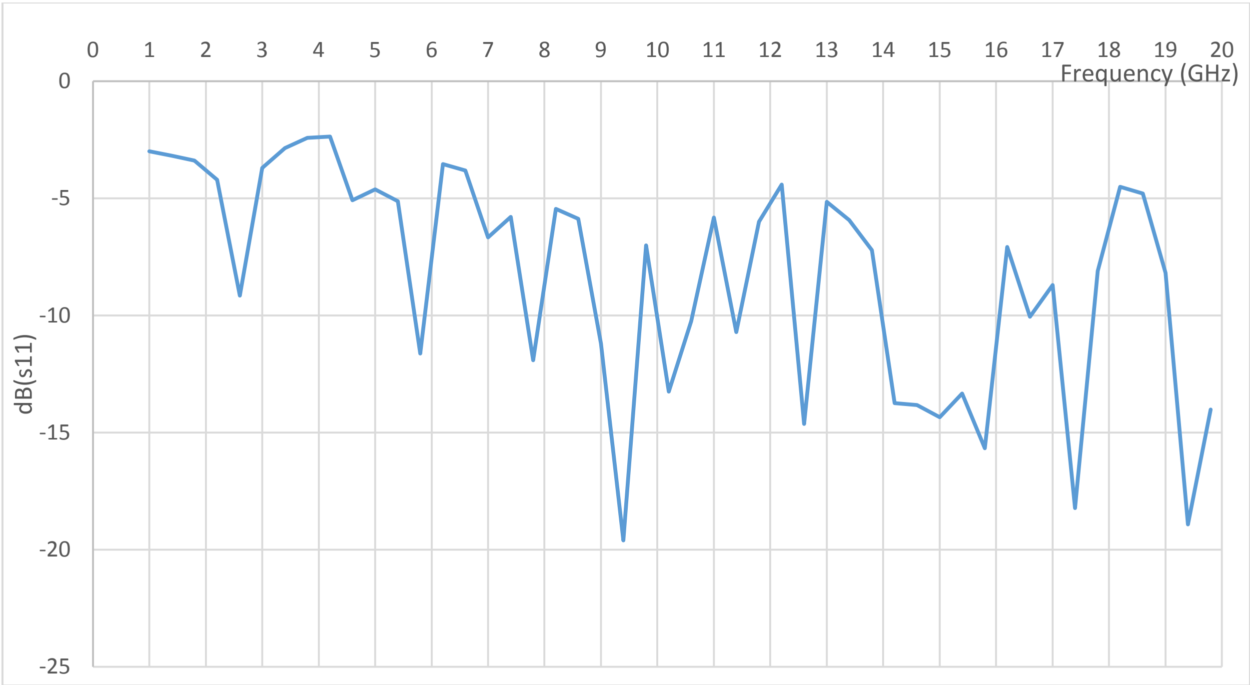

Figure 5.22: Bandwidth of reference antenna of graphite as patch and copper as ground in corning glass substrate

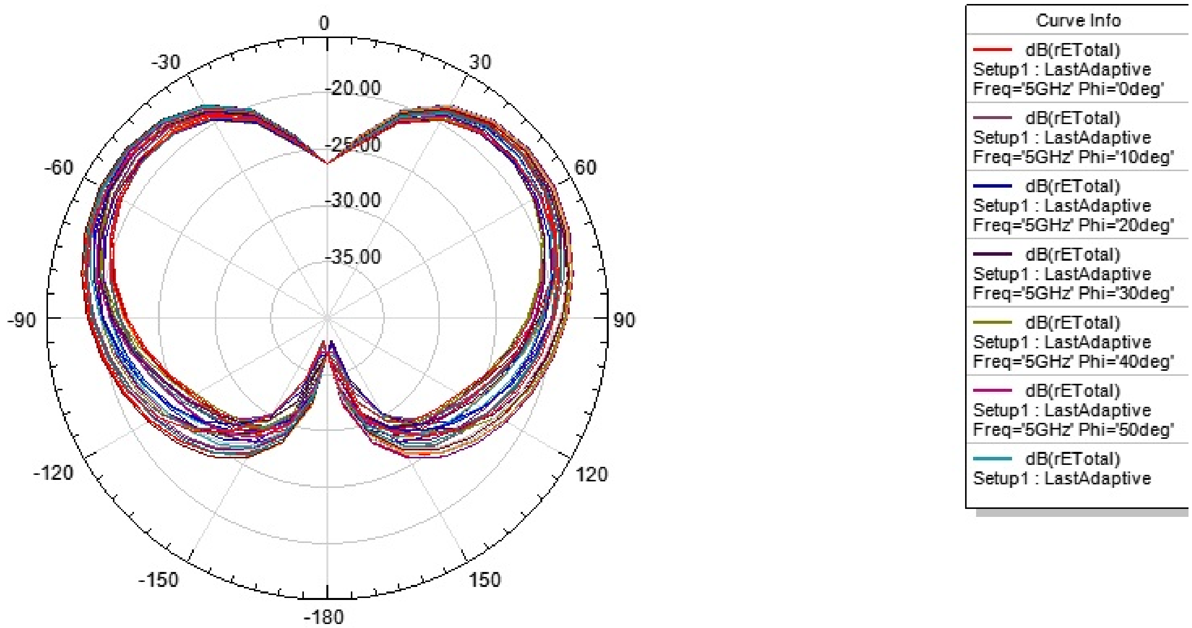

Figure 5.23: Radiation pattern of reference antenna of graphite as patch and copper as ground in corning glass substrate

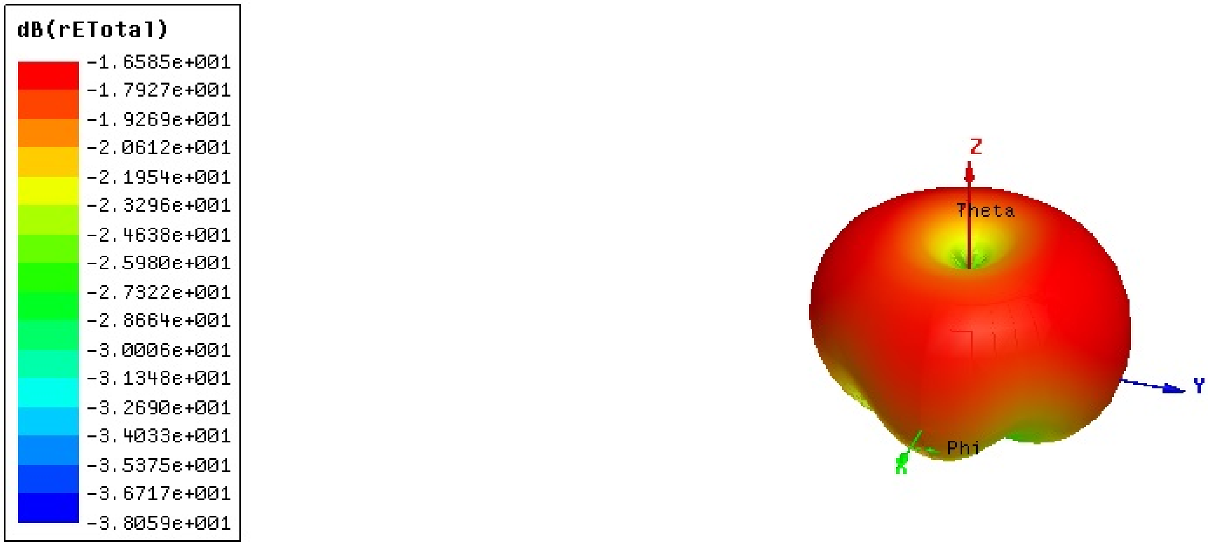

Figure 5.24: 3-D polar plot gain of reference antenna of graphite as patch and copper as ground in corning glass substrate

5.3 Results of antenna with swastika fractal slot

a. Copper as patch and copper as ground in polycarbonate substrate

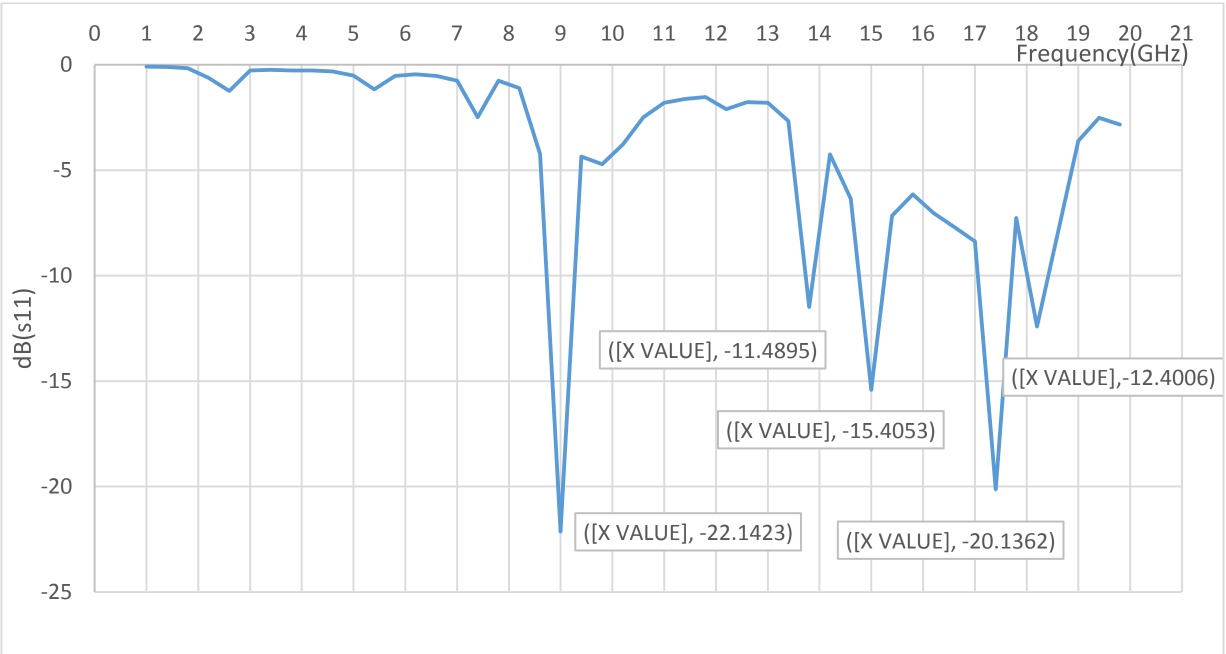

Figure 5.25: S11 of swastika slot antenna of copper as patch and copper as ground in polycarbonate substrate

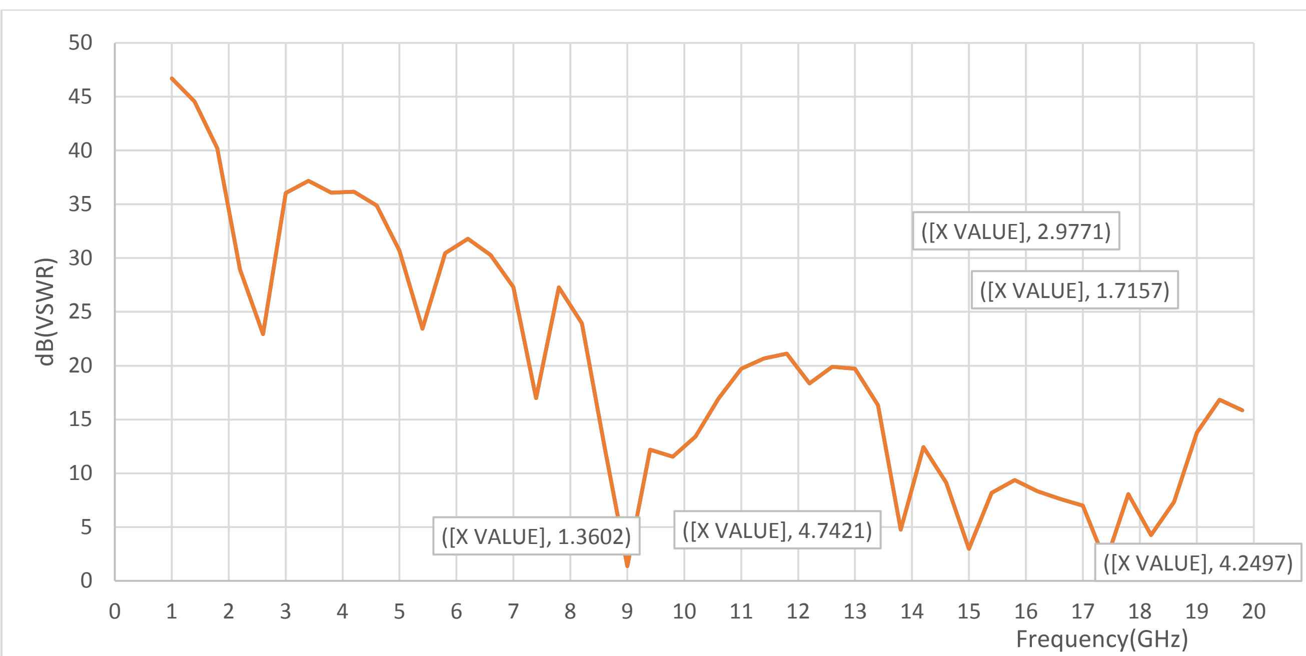

Figure 5.28: VSWR of swastika slot antenna of copper as patch and copper as ground in polycarbonate substrate

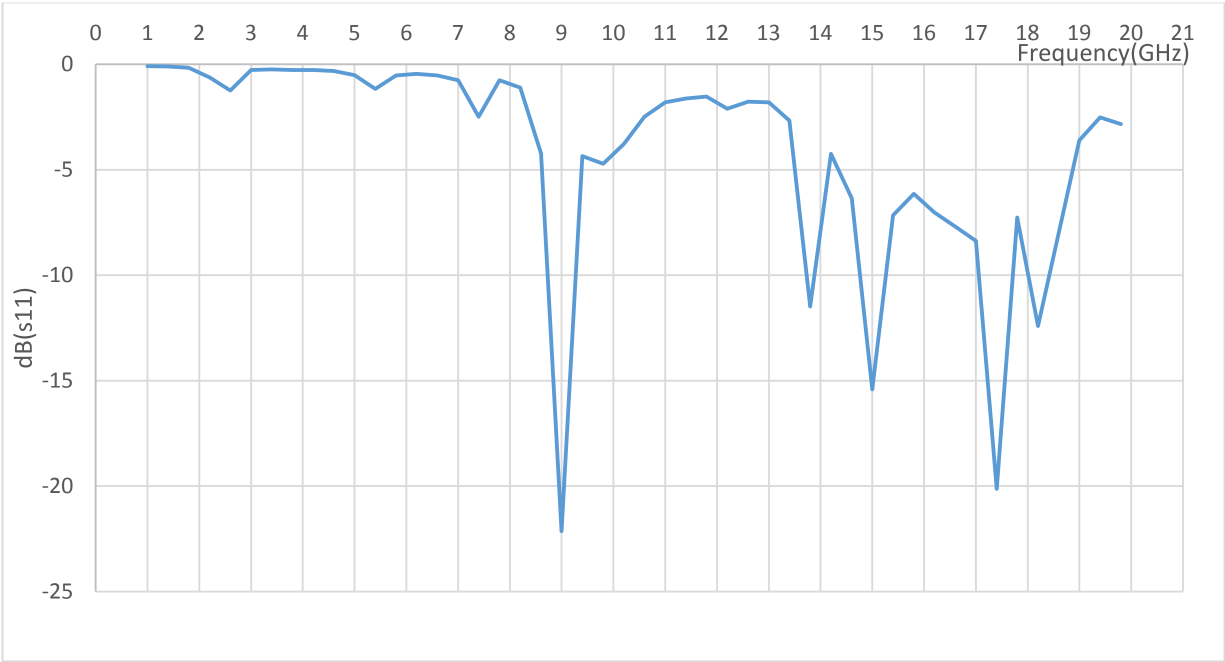

Figure 5.27: Bandwidth of swastika slot antenna of copper as patch and copper as ground in polycarbonate substrate

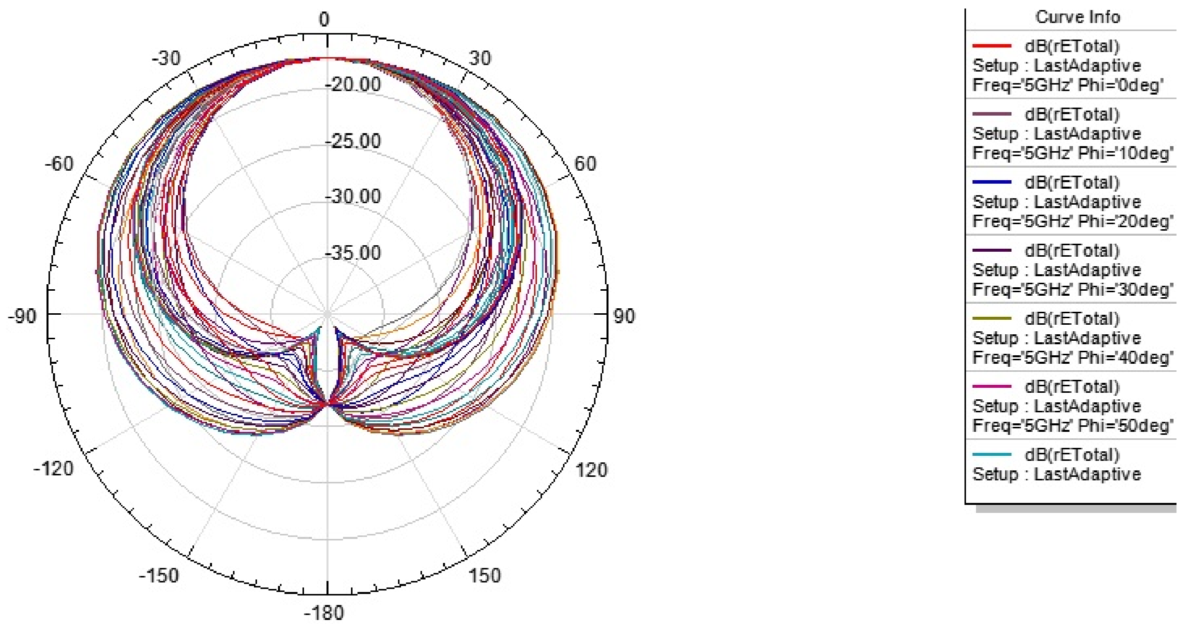

Figure 5.28: Radiation of swastika slot antenna of copper as patch and copper as ground in polycarbonate substrate

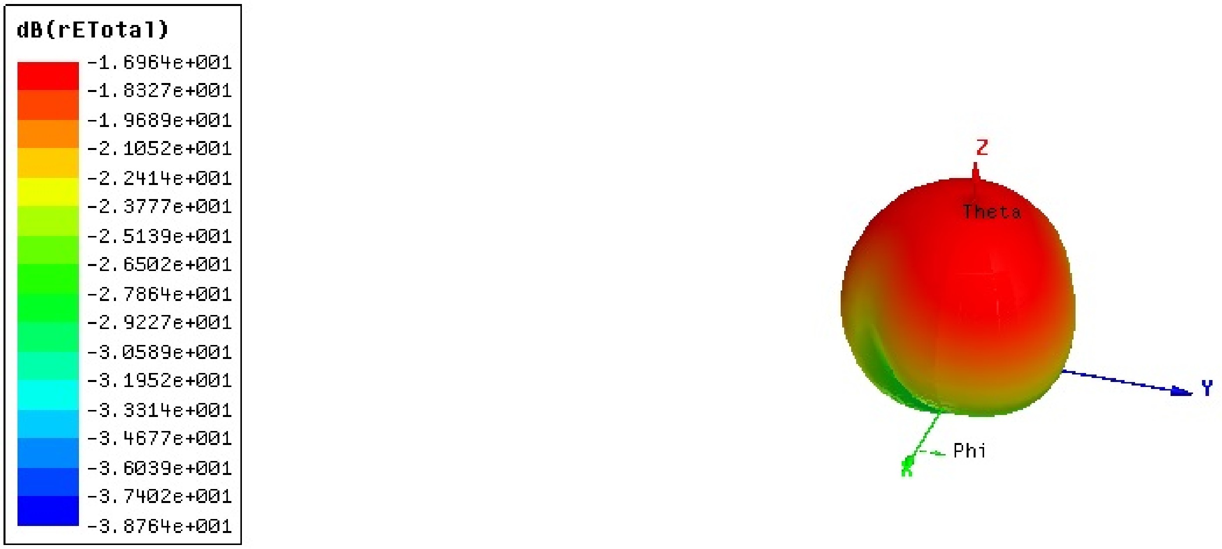

Figure 5.29: 3-D polar plot gain of swastika slot antenna of copper as patch and copper as ground in polycarbonate substrate

b. Graphite as patch and copper as ground in polycarbonate substrate

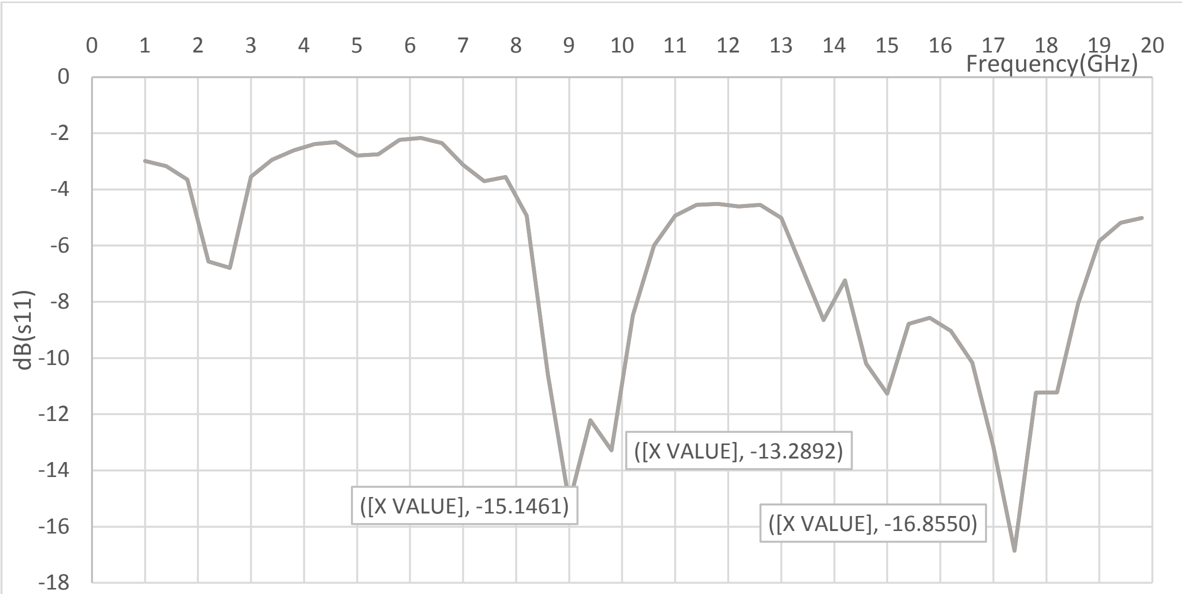

Figure 5.30: S11 of swastika slot antenna of graphite as patch and copper as ground in polycarbonate substrate

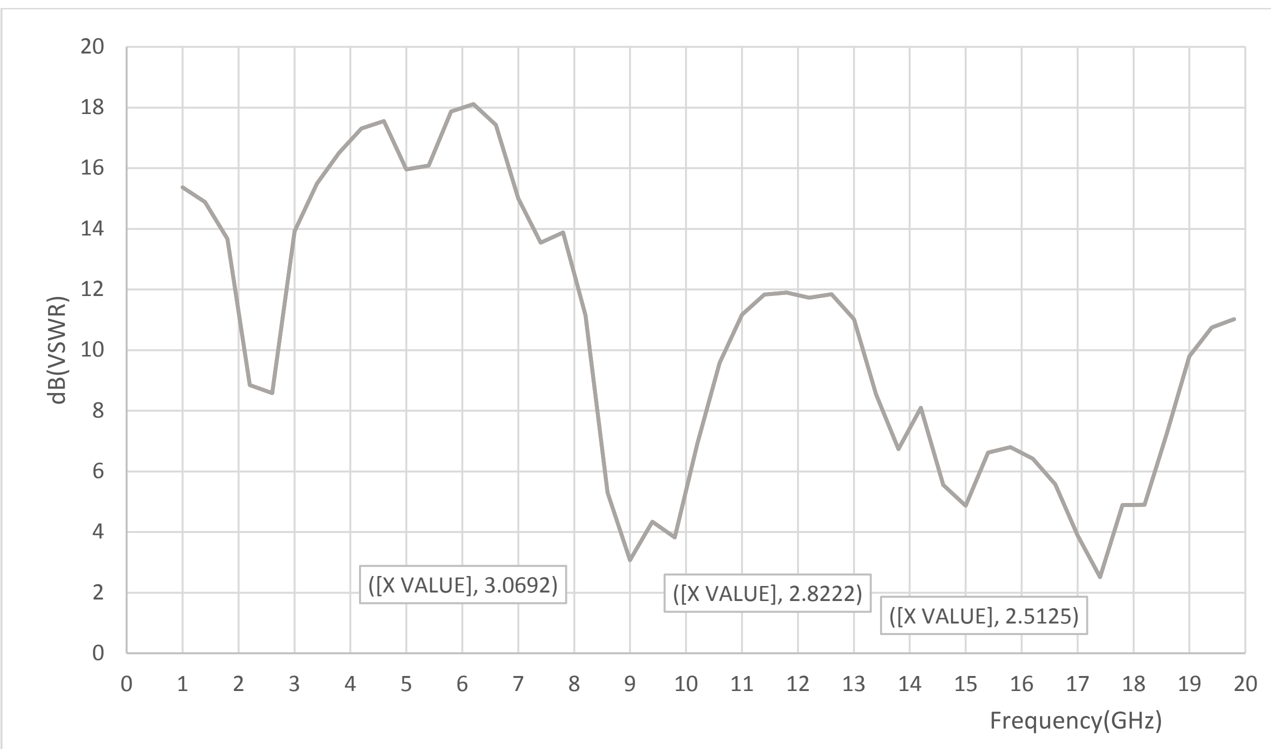

Figure 5.31: VSWR of swastika slot antenna of graphite as patch and copper as ground in polycarbonate substrate

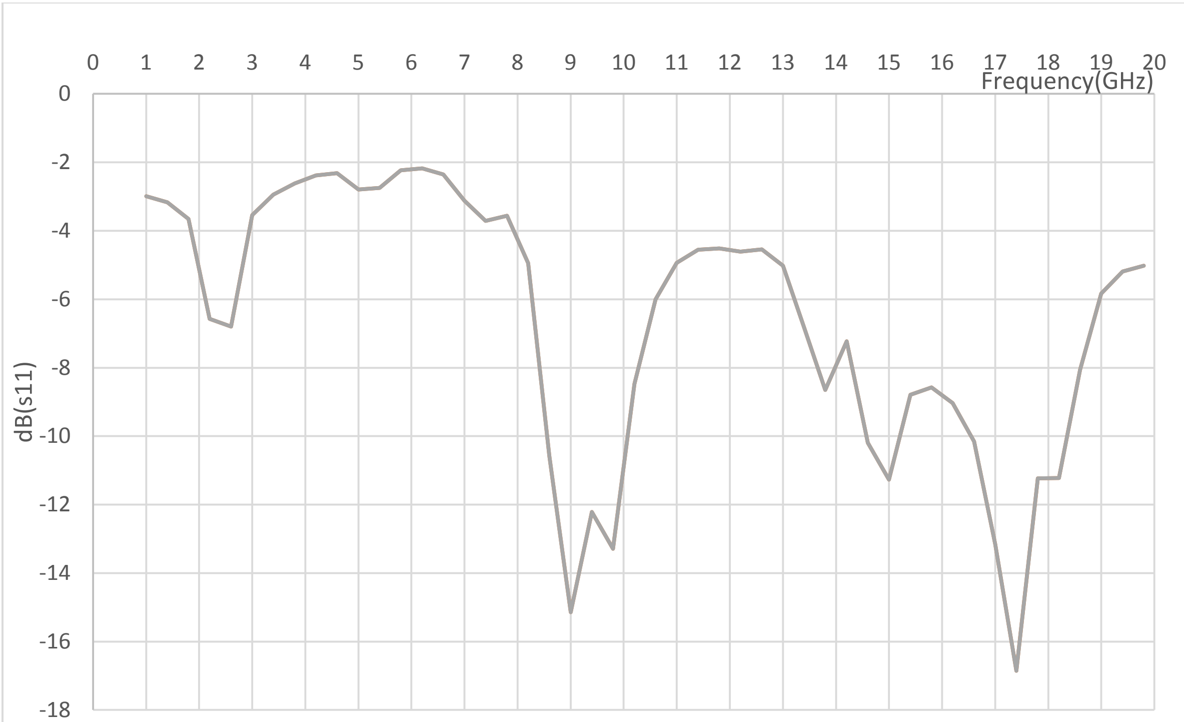

Figure 5.32: Bandwidth of swastika slot antenna of graphite as patch and copper as ground in polycarbonate substrate

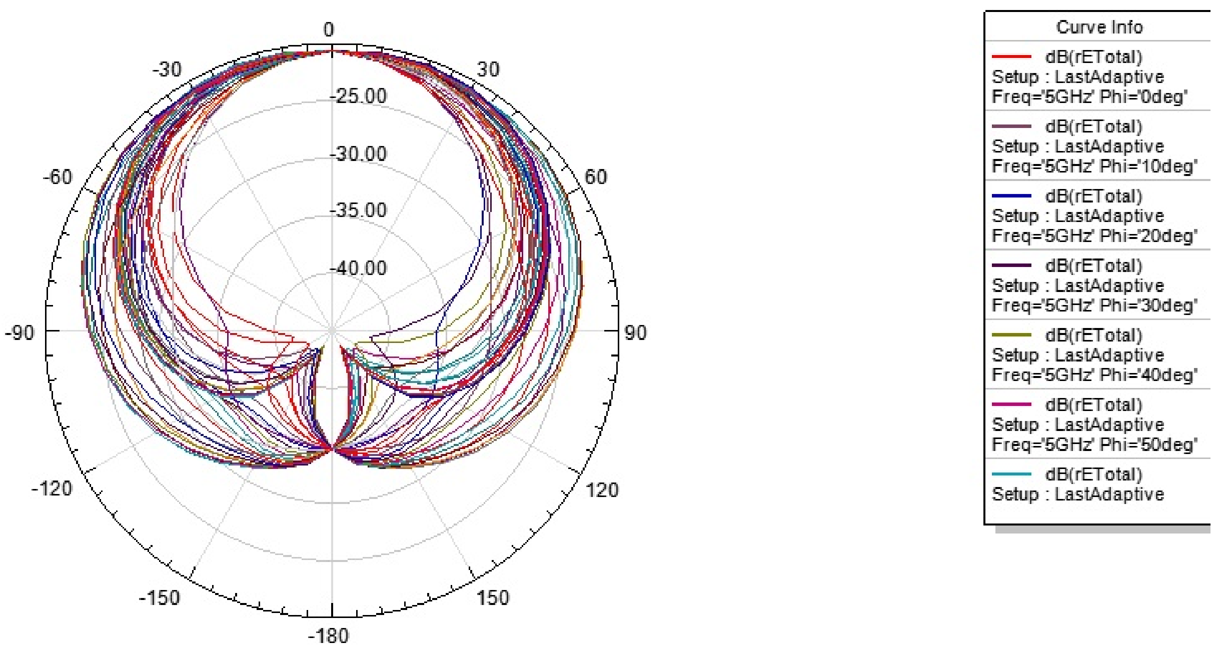

Figure 5.33: Radiation pattern of swastika slot antenna of graphite as patch and copper as ground in polycarbonate substrate

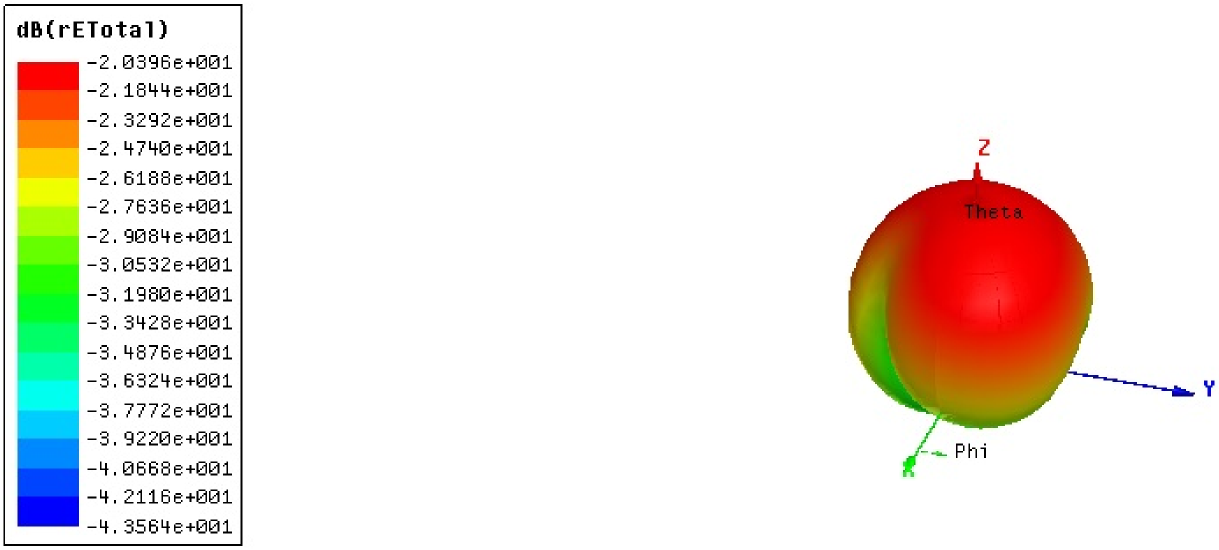

Figure 5.34: 3-D polar plot gain of swastika slot antenna of graphite as patch and copper as ground in polycarbonate substrate

c. Copper as patch and copper as ground in corning-glass substrate

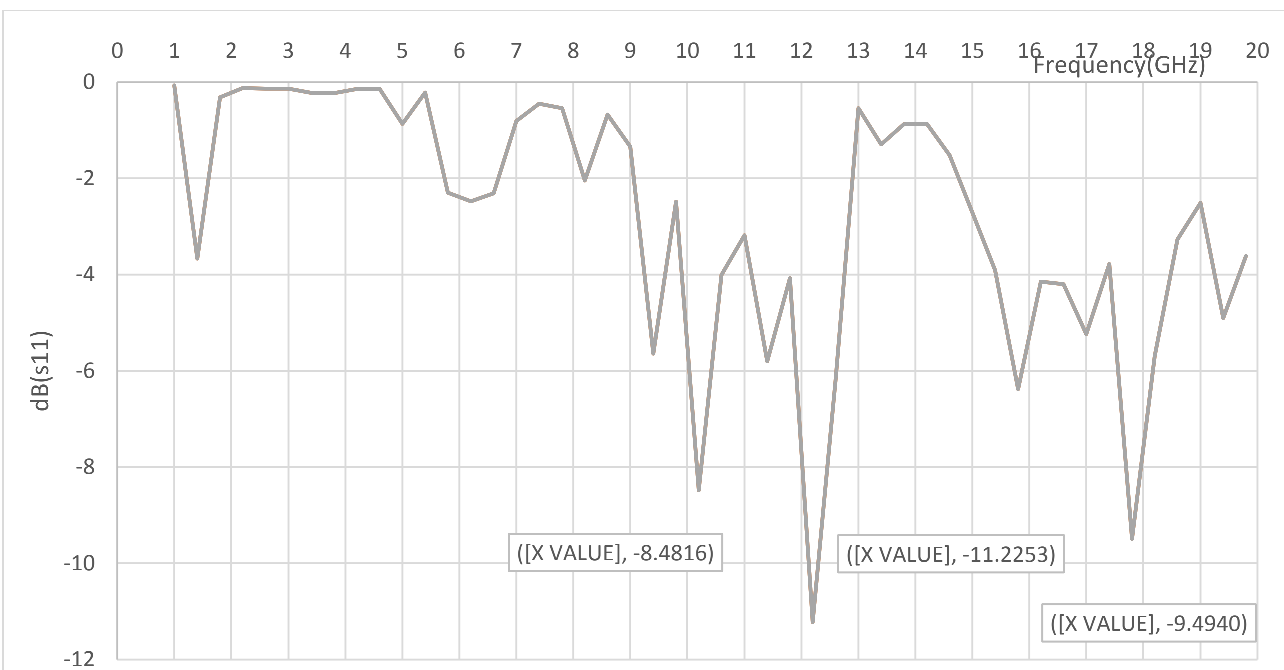

Figure 5.35: S11 of swastika slot antenna of copper as patch and copper as ground in corning glass substrate

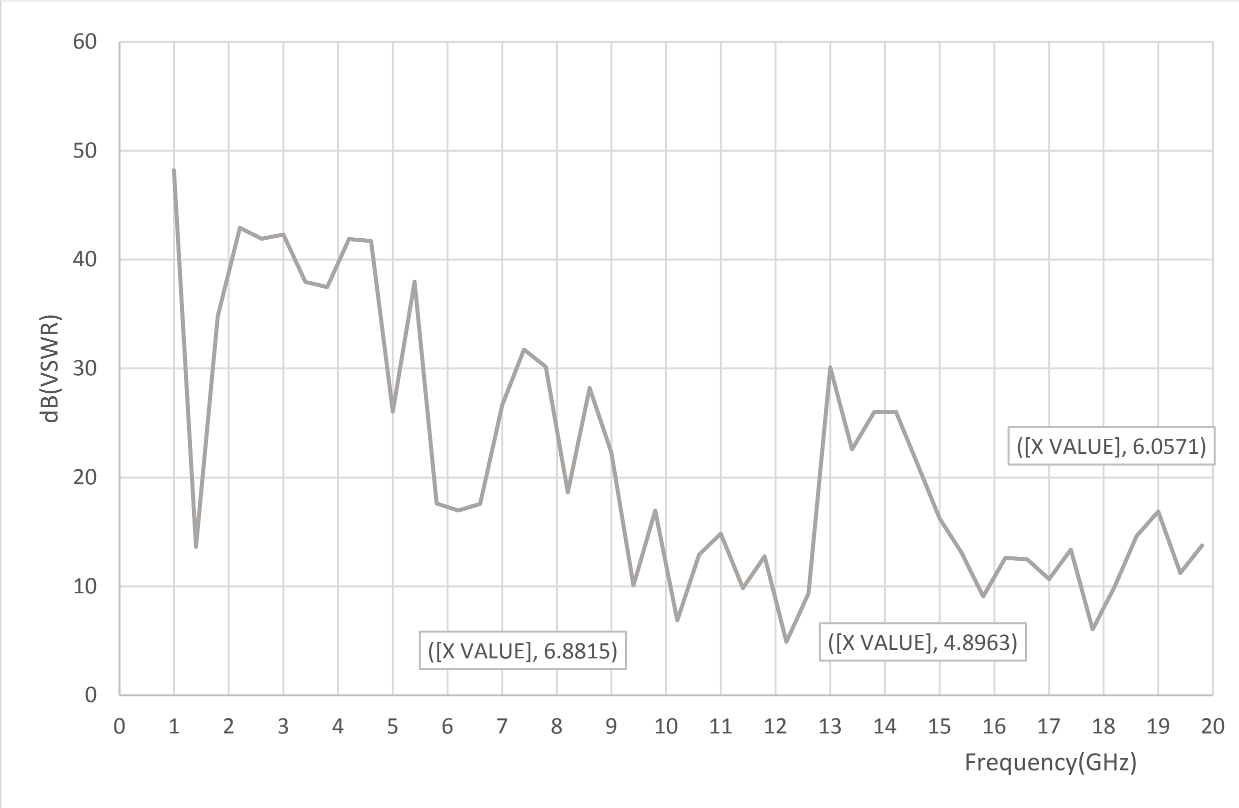

Figure 5.36: VSWR of swastika slot antenna of copper as patch and copper as ground in corning glass substrate

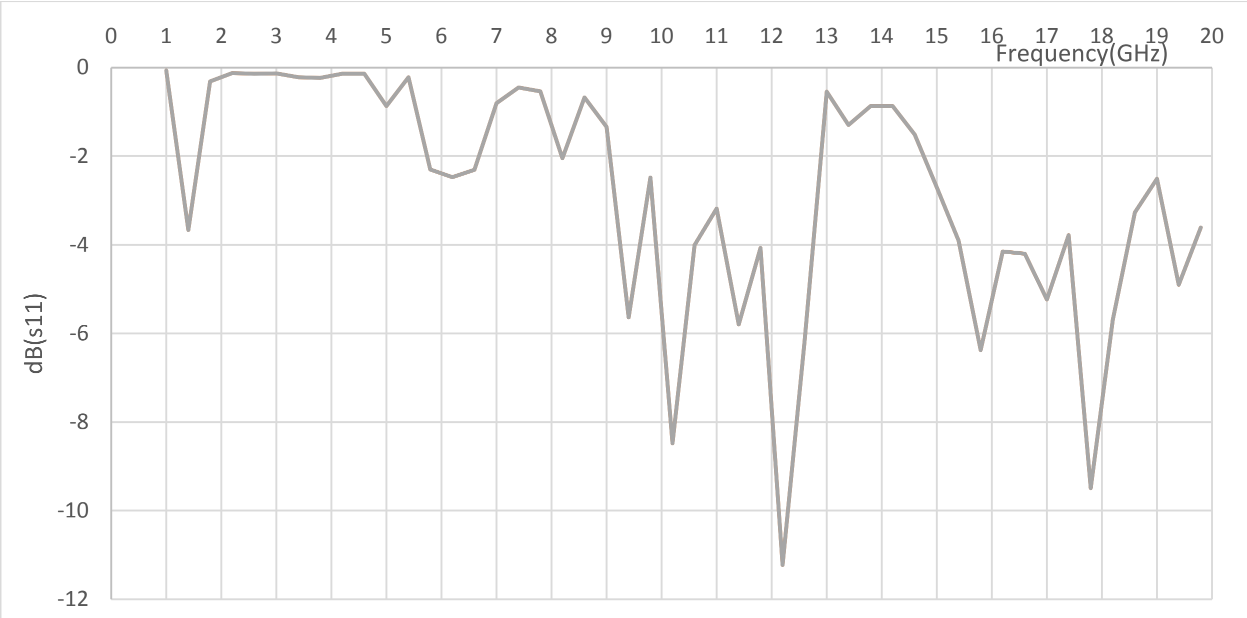

Figure 5.37: Bandwidth of swastika slot antenna of copper as patch and copper as ground in corning glass substrate

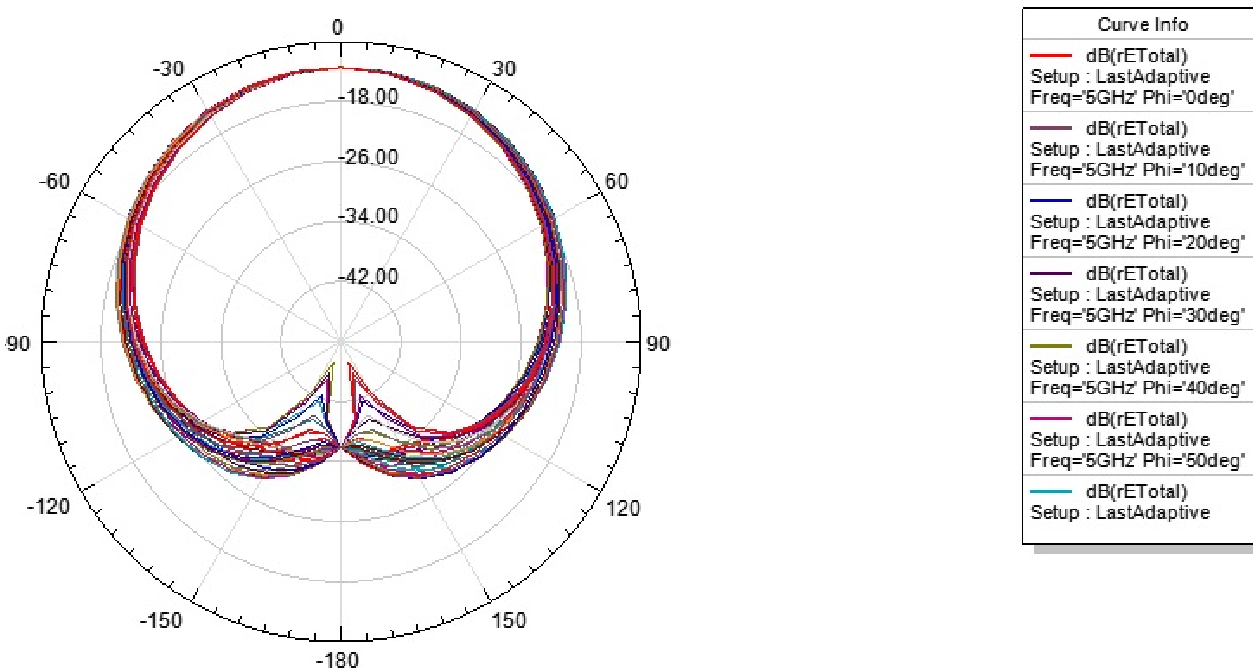

Figure 5.38: Radiation pattern of swastika slot antenna of copper as patch and copper as ground in corning glass substrate

Figure 5.39: 3-D polar plot gain of swastika slot antenna of copper as patch and copper as ground in corning glass substrate

d. Graphite as patch and copper as ground in corning-glass substrate

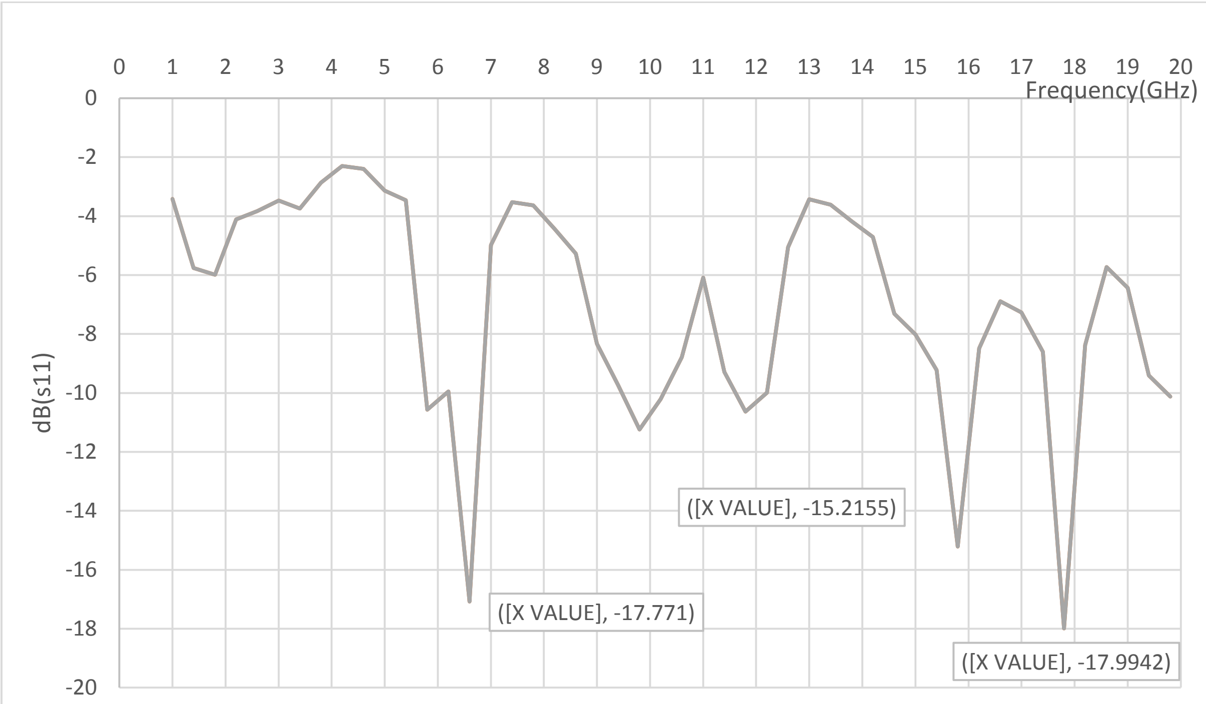

Figure 5.40: S11 of swastika slot antenna of graphite as patch and copper as ground in corning glass substrate

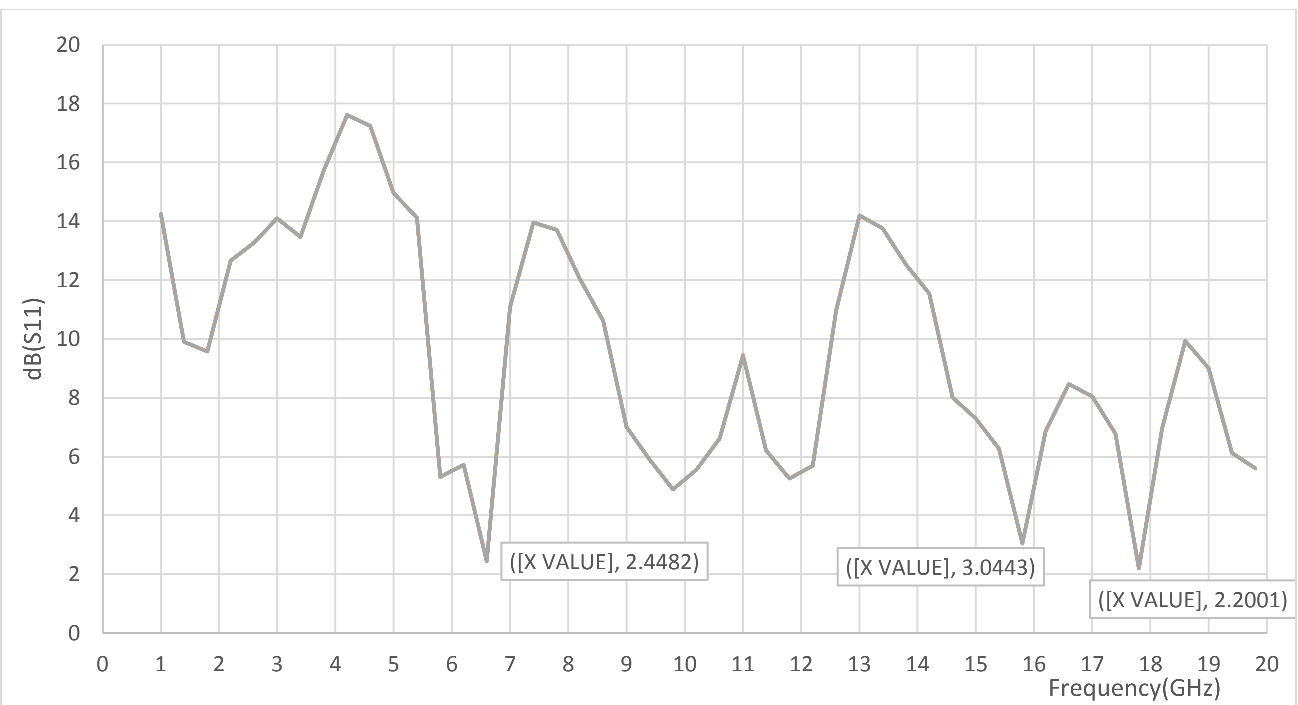

Figure 5.41: VSWR of swastika slot antenna of graphite as patch and copper as ground in corning glass substrate

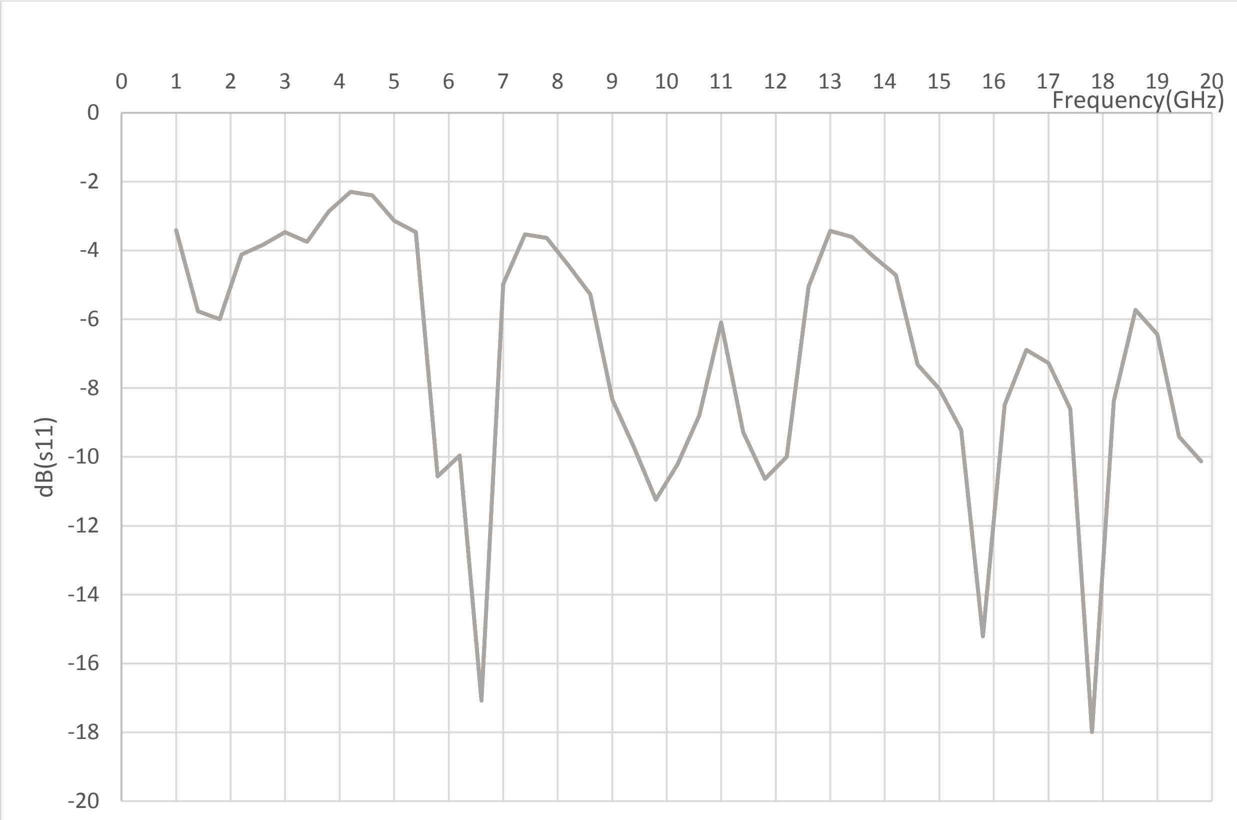

Figure 5.42: Bandwidth of swastika slot antenna of graphite as patch and copper as ground in corning glass substrate

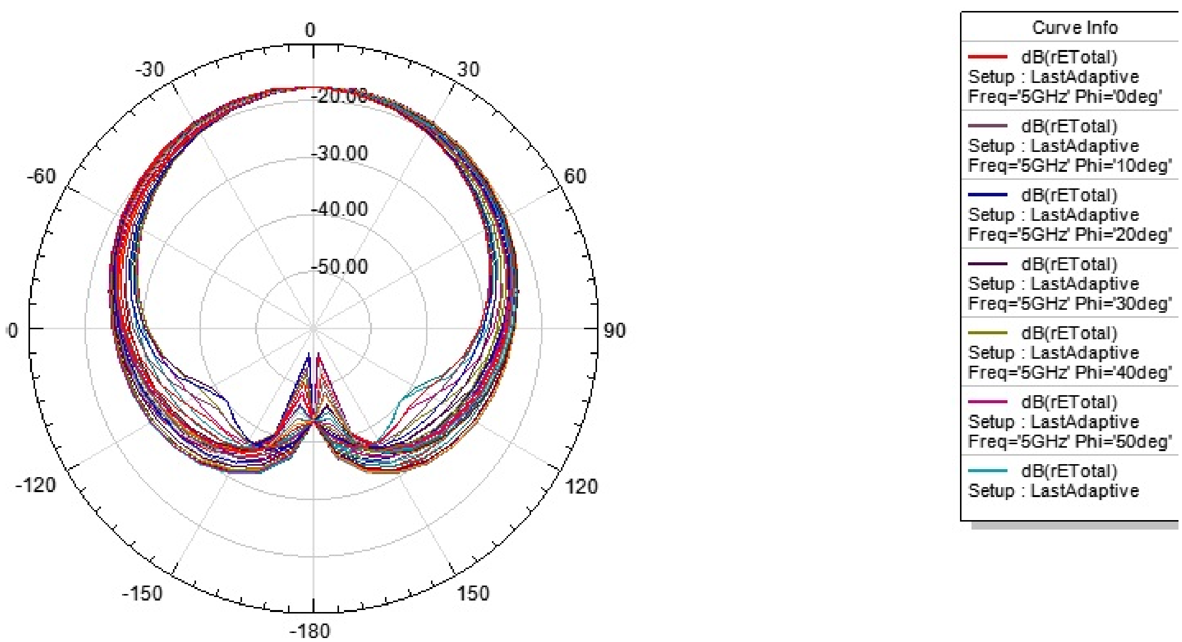

Figure 5.43: Radiation of swastika slot antenna of graphite as patch and copper as ground in corning glass substrate

Figure 5.44: 3-D polar plot gain of swastika slot antenna of graphite as patch and copper as ground in corning glass substrate

Discussions

Table 5.1: Comparison of resistance of activated carbon before and after laser treatment

S.No	Resistance of polycarbonate	Resistance of activated carbon	Resistance of imprinted images after laser activation
1.	10-12 Mega-ohm	10-12 Mega-ohm	12.3 kilo-ohm and 10.2 kilo-ohm within 5mm.

Table 5.2: Comparison of properties between copper and graphite patch in copper as a ground (polycarbonate substrate) of reference antenna (no slot)

S.No	In a polycarbonate with no slot					
	Patch	Ground	Resonating Frequency (GHz)	S11 (dB)	VSWR	Bandwidth (GHz)
1	Copper	Copper	13.8000	-22.2466	1.3439	0.9933
2	Graphite	Copper	15.4000 17.4000	-22.0430 –20.9729	1.1716 1.1964	0.5659 0.5545

In a polycarbonate substrate, copper used both as Ground as patch, resonating frequencies as found only at 13.80 GHz. But after using Graphite as patch and Carbon as Ground, dual resonating frequencies were observed at 15.40 GHz and 17.40 GHz. Both antenna designs have somehow similar loss, which is around 20-22 dB VSWR of both antenna designs are less than 2. VSWR of copper – copper as patch-ground is found to be 1.34. VSWR for Graphite- Copper as a patch-ground were found to be 1.17 and 1.19. Here, VSWR is also decreased for Graphite-Copper antenna than that of Copper- Copper as a patch- ground antenna. But the bandwidth of copper-copper is higher compared to that of graphite-copper antenna. Bandwidth of Copper-copper antenna is found to be 0.99 GHz whereas the bandwidth for graphite-copper antenna were found to be 0.56 GHz and 0.55 GHz respectively for 15.40 GHz and 17.40 GHz resonating frequencies.

Table 5.3: Comparison of properties between copper and graphite patch in copper as a ground (corning glass substrate) of reference antenna (no slot)

S.No	In a corning glass with no slot					
	Patch	Ground	Resonating Frequency (GHz)	S11 (dB)	VSWR	Bandwidth (GHz)
1	Copper	Copper	9.4000 15.0000 19.4000	-10.9962 -10.7543 -11.7256	1.7854 1.8166 1.7100	0.6012 0.4932 0.3269
2	Graphite	Copper	9.4000 17.4000 19.4000	-19.5958 -18.2163 -18.9191	1.8266 2.8890 1.9775	0.3366 0.485 0.3314

In a corning glass substrate, three resonating frequencies were observed. But for copper-copper antenna as a patch-ground there were no such appreciable loss. S11 for 9.40 GHz, 15.00 GHz and 19.40 GHz were found to be -10.99 dB, 10.75 dB and 11.72 dB. All the values were above -20.00 dB. VSWR for all these frequencies were found as 1.78, 1.81 and 1.71 respectively. Also, Bandwidth for these frequencies were found as 0.60 GHz, 0.49 GHz and 0.32 GHz respectively.

In case of Graphite-copper antenna as a patch-ground, here also three resonating frequencies were observed at 9.40 GHz, 17.40 GHz and 19.40 GHz. S11 parameters for these frequencies were -19.59 dB, -18.21 dB and -18.91 dB resp. which are near about - 20.00 dB. But VSWR for these were found quite higher compared to copper-copper antenna. VSWR were found as 1.82, 2.88 and 1.97. Bandwidths were found as 0.33 GHz, 0.48 GHz and 0.33 GHz respectively.

Table 5.4: Comparison of properties between copper and graphite patch in copper as a ground (polycarbonate substrate) of antenna with swastika slot

S.No	In a polycarbonate with a Swastika slot					
	Patch	Ground	Resonating Frequency (GHz)	S11 (dB)	VSWR	Bandwidth (GHz)
1	Copper	Copper	9.0000 13.8000 15.0000 17.4000 18.200	-22.1423 -11.4895 -15.4053 -20.1362 -12.4006	1.3617 4.7421 29771 1.7157 4.2427	0.3428 0.2546 0.1237 0.3569 0.2462
2	Graphite	Copper	9.0000 9.8000 17.4000	-15.1461 -13.2892 -168550	3.0692 2.8222 2.5125	0.6230 0.5448 0.5632

Here in a polycarbonate substrate with swastika slot for copper-copper antenna as patch- ground, resonating frequency were observed at 9.0000,13.8000,15.0000 and 17.4000 GHz with S11 parameter of -22.1423 dB, -11.4895 dB, -15.4053 dB, -20.1362 dB and -12.4006 dB resp. with their respective VSWR of 1.3617, 4.7421, 29771 , 1.7157 and 4.2427.

Table 5.5: Comparison of properties between copper and graphite patch in copper as a ground (corning glass substrate) of antenna with swastika slot

S.No	In a corning glass with swastika slot					
	Patch	Ground	Resonati0ng Frequency (GHz)	S11 (dB)	VSWR	Bandwidth (GHz)
1	Copper	Copper	10.2000 12.2000 17.8000	-8.4816 -11.2253 -9.4940	6.8815 4.8963 6.0571	0.5142 0.4982 0.2356
2	Graphite	Copper	6.6000 15.8000 17.8000	-17.0771 -15.2155 -17.9942	2.4482 3.0443 2.2001	0.2147 0.3019 0.3326

In a corning glass substrate of copper-copper antenna as patch-ground, resonating frequencies were found. But considering frequency to be 10.2000, 12.2000 and 17.8000 GHz. with S11 parameter of -17.0771, -15.2155 and -17.9942 dB resp with their respective VSWR of 6.8815, 4.8963 and 6.0571.

In a Graphite-copper antenna as Patch- ground, resonating frequency were found at 6.6000, 15.8000 and 17.8000 GHz with S11 parameters of -17.0771, -15.2155 and -17.9942 dB with their respective VSWR of 2.4482, 3.0443 and 2.2001.

CHAPTER 6

CONCLUSION

The prepared carbon sample from the waste part of Lapsi is an insulator. After the chemical processes, it formed as activated carbon which is still in the lab is also an insulator. However, after coating the carbon is a polycarbonate surface of a CD and acting it by laser in a lightscribe drive or blue ray drive, and different patterns are drawn on it, the places where patterns drawn were found to have very low resistance of about 10-12 KΏ. The resistance dropped hugely from mega ohm to kilo ohm which is very important property for antenna. For antenna design both ground and patch plane must be conducting and substrate in which patch and ground lies must be dielectric. The experiment concludes that after the action of laser in activated carbon there is huge decrease in resistance of the sample in a polycarbonate substrate. Due to the technical feasibility of connecting connector in polycarbonate substrate further experimental process were not possible as the connector needs metal surface for soldering. The simulation has been done in copper-copper and copper-graphite as a ground and patch in polycarbonate substrate and corning glass substrate. Polycarbonate has relative permittivity of and corning glass has relative permittivity of 4.2. Both of these materials are easily available in the market. Their lifespan is also quite durable and they are resistant to chemical, air and water. They can be made into any shapes and sizes. They are cheaper compared to other substrates also. So, these materials can be used as substrates for antennas for a frequency range of 1-20 GHz.

Introduction of swastika slot increased the band of resonating frequencies. It means that it can radiate and absorb multiple band of frequencies. On operating on multiple frequencies this antennas can be used as multi-functional and multi-purpose antennas.

As, compared to copper-copper antenna, the graphite-copper patch antenna as patch and ground has shown better performance in most of the aspects such as loss, VSWR, Bandwidth and radiation pattern. Graphite-copper patch antenna is recommended to make high performance antenna to absorb the radio and other electromagnetic signals very effectively.

CHAPTER 7

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