Compact Microstrip Antenna With Enhanced Bandwidth By Loading Magneto-Electro-Dielectric Planar Waveguide Metamaterial

A thesis submitted in partial fulfillment of the requirements for the award of the degree of

B.Tech
in Electronics and Communication Engineering

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BONAFIDE CERTIFICATE

This is to certify that the project titled **Compact Microstrip Antenna With Enhanced Bandwidth By Loading Magneto-Electro-Dielectric Planar Waveguide Metamaterial** is a bonafide record of the work done by

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in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Electronics and Communication Engineering** of the **NATIONAL INSTITUTE OF TECHNOLOGY, TIRUCHIRAPPALLI**, during the year 2017-21.

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Internal Examiner	**External Examiner**

ABSTRACT

Over the past decade, microstrip patch antennas have been widely used in wireless communication system for their low-profile, coplanar configuration, easy fabrication, and low cost. However, conventional patch antennas always suffer from narrow bandwidth (BW) and relatively large size. Moreover, the operation frequency of these antennas are exclusively dependent on the patch size. In recent years, electromagnetic (EM) metamaterials (MTMs) have become a field of intense research activities with remarkable achievements and have been widely applied to improve the performances of conventional devices and antennas.

A new concept of planar magneto-electro-dielectric waveguided metamaterials (MED-WG-MTM) is proposed to manipulate the effective permeability μeff and the effective permittivity εeff . The MEDWG-MTM cell consists of an electric complementary spiral ring resonator (CSR) in the upper metallic plane and a magnetic embedded Hilbert-line (EHL) in the ground plane. In our project we want to design a Compact Microstrip Antenna with Enhanced Bandwidth by Loading Magneto-Electro Dielectric Planar Waveguided Metamaterials.

We would be using the tool HFSS for the design purposes

Keywords : Increasing bandwidth (BW), magneto-electro-dielectric waveguided metamaterials (MED-WG-MTM), medium parameter manipulation, microstrip patch antenna, miniaturization.

ACKNOWLEDGEMENTS

We would like to express our deepest gratitude to the following people for guiding us through this course and without whom this project and the results achieved from it would not have reached completion.

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CHAPTER 1

INTRODUCTION

1.1 General

Metamaterial have a property that is not found naturally, it consists of artificial metallic structure which have negative permeability (Âµ) and permittivity . At the present day, substrates with low dielectric constant are preferred for getting maximum radiation. Thus metamaterial is used to improve the low gain and efficiency in wireless communication. In our project microstrip patch antenna is designed with frequency range 10 to 15 GHz. The performance of our fabricated antenna was analyzed and measured. CST Microwave Studio is used to design, simulation, and analyze the antenna.

Now a days, wireless communication system commonly use microstrip patch antenna for wireless devices as microstrip patch antenna has low weight, low cost, design and technology. Patch antenna requires low profile thus patch antenna consists of thin conducting sheet of about 1 by 1/2 mounted on surfaces. There is a narrow gap between the patch and the ground plane. The electric field is zero at the centre of patch. The impedance bandwidth and return loss are important parameters of antenna. The disadvantage of antenna is that the bandwidth is limited to few percent. But metamaterial based microstrip patch antenna gives significant improvement in bandwidth and return loss. The proposed square microstrip patch antenna has wide impedance bandwidth. The square geometry is smaller in size for a given frequency as compared to circular geometry. The performance of microstrip antenna depends on dimensions of antenna, substrate material, feeding technique. Generally conducting material like copper or gold is used for patch. Dielectric substrate with low dielectric constant gives better radiation, wide bandwidth and good efficiency.

The main motivation of this communication is to explore improved strategies to simultaneously address aforementioned issues. An electrically smaller MTM element is proposed by combining the electro dielectric and magneto-dielectric waveguided substrates , defined as the magneto-electro-dielectric waveguided MTM (MED-WGMTM).

1.2 Objectives

In our project we want to design a Compact Microstrip Antenna with Enhanced Bandwidth by loading Magneto-Electric Dielectric Planar Waveguided Metamaterials. The characterizations and working mechanisms are investigated in depth through electromagnetics (EM) simulation, circuit model calculation and effective material parameters analysis. Numerical results show that the MED-WG-MTM can be manipulated with a larger refractive index for miniaturization and a larger wave impedance for bandwidth (BW) enhancement. We had done simulation and designed Metamaterial patch Antenna with substrate FR4_epoxy at frequency=10GHZ. We had compared our previous patch antenna (substrate: Rogers RT/ duroid 5880(tm)) with metamaterial patch antenna.

CHAPTER 2

Literature review

2.1 Related Work

The main motivation of communication is to explore improved strategies to simultaneously address aforementioned issues. An electrically smaller MTM element is proposed by combining the electro-dielectric and magneto-dielectric waveguided substrates, defined as the magneto-electro-dielectric waveguided MTM (MED-WG-MTM). The rest of this communication is organized as follows. The working mechanism of the proposed MED-WG-MTM is investigated in depth by equivalent circuit model simulation and constitutive parameters analysis. For possible applications, a compact microstrip antenna with enhanced BW by loading the MED-WG-MTM is designed, fabricated, and measured based on the derived three-step frequency tuning method.

For a conventional microstrip antenna based on the pure dielectric material, the working frequency is in inverse proportion to the refractive index, so as the quality factor to the impedance BW [9]. For an antenna loaded with MED-WG-MTM elements, the basic working principle is almost the same. Consequently, the length and quality factor of the antennas at their resonances in both cases can be calculated as

$$\mathrm{Lref} \approx \frac{c}{2\mathrm{fo}\sqrt{\varepsilon \mathrm{ref}}} = \frac{c}{2\mathrm{fonref}}$$

$$\mathrm{LMTM} \approx \frac{c}{2\mathrm{fo}\sqrt{\varepsilon \mathrm{eff}\mu \mathrm{eff}}} = \frac{c}{2\mathrm{fonef}}$$

$$\mathrm{Qref} = \frac{\pi \mathrm{wp}}{4\mathrm{Grh}\eta \mathrm{ref}} = \pi \mathrm{wp}\frac{\sqrt{\varepsilon \mathrm{ref}}}{4\mathrm{Grh}\eta \mathrm{o}}$$

$$\mathrm{QMTM} = \frac{\pi \mathrm{wp}}{4\mathrm{Grh}\eta \mathrm{eff}} = \pi \mathrm{wp}\frac{\sqrt{\varepsilon \mathrm{eff}}}{4\mathrm{Grh}\eta \mathrm{o}\sqrt{\mu \mathrm{ef}}}$$

where εref is the effective permittivity of the pure dielectric material, Gr is the radiation conductance, εeff and μeff are the effective permittivity and permeability for the MED-WG-MTM, respectively. Then, the compact factor (CF) and BW improving factor (BIF) can be immediately obtained.

$$CF = \frac{n2ref}{n2eff} = \frac{\varepsilon ref}{\varepsilon eff \mu eff}$$

$$BIF = \frac{Qref}{QMTM} = \frac{\eta eff}{\eta ref} = \frac{\sqrt{\varepsilon ref \mu eff}}{\sqrt{\varepsilon eff}}$$

Based on the effective medium theory, it is able to achieve a smaller CF and a larger BIF to improve the antenna performance by manipulating the material parameters εeff or μeff . The reported magneto-dielectric MTM is just a special case for manipulating the parameter μeff ; however, the proposed MED-WG-MTM in this work can control both εeff and μeff , simultaneously.

2.1.1 Antenna Characteristics

- **Power gain:** In electromagnetics, an antenna's power gain or simply gain is a key performance number which combines the antenna 's directivity and electrical efficiency. In a transmitting antenna, the gain describes how well the antenna converts input power into radio waves headed in a specified direction.

- **Directivity:** An antenna's directivity is a **component of its gain;** the other component is its (electrical) **efficiency**. Directivity is an important measure because many antennas and optical systems are designed to radiate electromagnetic waves in a single direction or over a narrow angle.

- **Antenna radiation patterns:** In the field of antenna design the term radiation pattern (or antenna pattern or far-field pattern) refers to the **directional (angular) dependence of the strength of the radio waves from the antenna or other source**.

- **Polarization:** Antenna Polarization is the term used in **correspondence with the electromagnetic wave radiated through it**. It is defined as the orientation of the electric field vector of the radiated electromagnetic wave by the antenna with a negligible amount of losses.

2.1.2 Microstrip patch Antenna

Over the past decade, microstrip patch antennas have been widely used in wireless communication system for their low-profile, coplanar configuration, easy fabrication, and low cost.

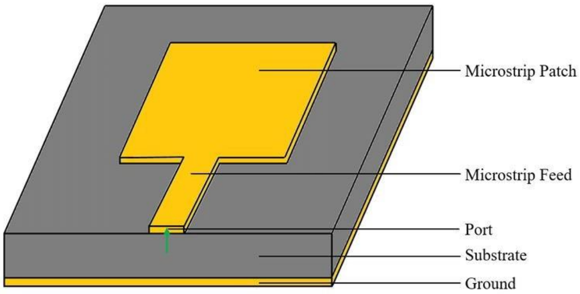

Fig 2.1.2.1 microstrip patch antenna

The most common type of microstrip antenna is commonly known as patch antenna. Antennas using patches as constitutive elements in an array are also possible. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and instead are made of a metal patch mounted above a ground plane using dielectric spacers; the resulting structure is less rugged but has a wider bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices.

2.2 Metamaterials and its properties

A **metamaterial** is any material engineered to have a property that is not found in naturally occurring materials. They are made from assemblies of multiple elements fashioned from composite materials such as metals and plastics. The materials are usually arranged in repeating patterns, at scales that are smaller than the wavelengths of the phenomena they influence. Metamaterials derive their properties not from the properties of the base materials, but from their newly designed structures. Their precise shape, geometry, size, orientation and arrangement gives them their smart properties capable of manipulating electromagnetics waves: by blocking, absorbing, enhancing, or bending waves, to achieve benefits that go beyond what is possible with conventional materials.

- Artificial compact structure
- Exhibit specific electromagnetic properties not observed in the constituent materials
- Small metallic resonators arranged in periodically manner

Properties:-

- Electric permittivity and magnetic permeability simultaneously negative in the same region.
- Backward propagation and negative refraction
- Ability to manipulate the electromagnetic signal

2.3 Metamaterial Antenna

Metamaterial antennas are a class of antennas which use metamaterials to increase performance of miniaturized (electrically small) antenna systems. Their purpose, as with any electromagnetic antenna, is to launch energy into free space. However, this class of antenna incorporates metamaterials, which are materials engineered with novel, often microscopic, structures to produce unusual physical properties. Antenna designs incorporating metamaterials can step-up the antenna's radiated power.

Antenna designs incorporating metamaterials can step-up the radiated power of an antenna. The newest metamaterial antennas radiate as much as 95 percent of an input radio signal. Standard antennas need to be at least half the size of the signal wavelength to operate efficiently. At 300 MHz, for instance, an antenna would need to be half a meter long. In contrast, experimental metamaterial antennas are as small as one-fiftieth of a wavelength, and could have further decreases in size.

Metamaterials are a basis for further miniaturization of microwave antennas, with efficient power and acceptable bandwidth. Antennas employing metamaterials offer the possibility of overcoming restrictive efficiency-bandwidth limitations for conventionally constructed, miniature antennas.

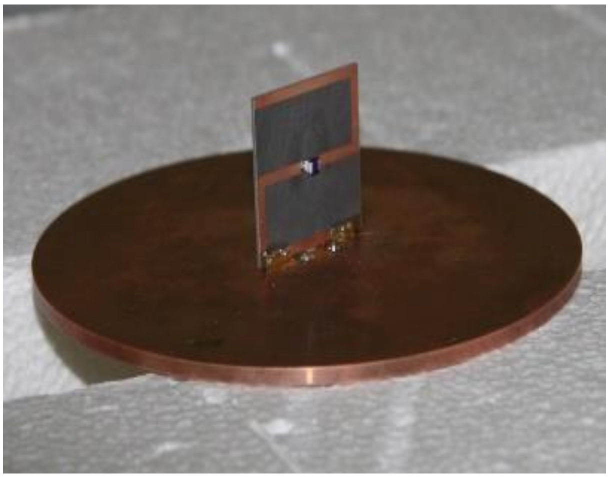

Fig. 2.3.1: Metamaterial Antenna

Advantages of Metamaterial antenna

- Metamaterial antenna design has size five times smaller with wider bandwidth.
- It does not require active phase shifters or amplifiers unlike traditional phased array antenna.
- It offers wide angle scanning and excellent beam performance.
- It offers electronically controlled pointing and polarization.
- It consumes very low power.
- Antennas are flat, light in weight and small in size.
- It uses software to steer instead of mechanical parts.
- It is compatible for planar integration with other components.

Disadvantages of Metamaterial antenna

- It is difficult to manufacture metamaterial based antennas in large quantities.
- It works for limited range of wavelengths.
- The shape of the antenna cannot be changed during operation.
- They are lossy.

CHAPTER 3
Methodology

3.1 Software Requirements

In our project we designed a Compact Microstrip Antenna with Enhanced Bandwidth by loading Magneto-Electric Dielectric Planar Waveguided Metamaterials. For project, which requires a design and simulation platform so we used HFSS Tools.

ANSYS HFSS is the premier EM tool for R&D and virtual design prototyping. It reduces design cycle time and boosts your products reliability and performance. Beat the competition and capture your market with ANSYS HFSS. HFSS, part of the ANSYS high-frequency electromagnetic design portfolio, is integrated with ANSYS Workbench for coupling EM effects into multiphysics analyses, such as temperature and deformation.

ANSYS HFSS software is the industry standard for simulating 3-D, full-wave, electromagnetic fields. Its gold-standard accuracy, advanced solvers and high-performance computing technologies make it an essential tool for engineers tasked with executing accurate and rapid design in high-frequency and high-speed electronic devices and platforms.

3.2 Design Analysis

Transmission line model represents the microstrip antenna by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially a nonhomogeneous line of two dielectrics, typically the substrate and air.

The value of (ε_{reff}) is slightly less then ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air.

$$W = \frac{C}{2f_0\sqrt{\left(\frac{\varepsilon_r + 1}{2}\right)}}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}}$$

$$L_{reff} = \frac{C}{2f_o\sqrt{\varepsilon_{reff}}}$$

$$\Delta L = 0.412h\ \frac{(\varepsilon_{reff}\ + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff}\ - 0.258)(\frac{W}{h} + 0.8)}$$

$$L = L_{eff} - 2\Delta L$$

$$L_g = 6h + L$$

$$W_g = 6h + W$$

where,

εreff = Effective dielectric constant

εr = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

Leff = effective length of the patch

3.2.1 Design Specification

The three essential parameters for the design of a rectangular Microstrip Patch Antenna are:

- Frequency of Operation: The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for my design is 10 and 15 GHz.
- Dielectric constant of the substrate (εr): The dielectric material selected for my design is Rogers RT/ duroid 5880(tm) which has a dielectric constant of 2.2 and FR4 epoxy which has a dielectric constant of 4.4 .
- Height of dielectric substrate (h): height of dielectric substrate is 1.6 mm.

3.2.2 Design Procedure: simple patch antenna

- Calculation the wavelength (λ)

  Because c = 3x10^8 and f0 = 15 GHz,

  So λ = c/f0

  By substituting c = 3x10^8 and f0 = 15 GHz,

  we get λ=20mm
- Calculation of the Width (W)

  εr= 2.2,

  we get W=4.5mm
- Calculation of the Effective length (Leff)

  εreff =1.023,

  we get Leff =61.79mm
- Calculation of the length extension (ΔL)

  Leff =61.79mm,

  we get ΔL=7.78mm

- Calculation of actual length of patch (L)

  Leff=61.79mm and ΔL=7.78mm,

  we get L=6.23mm
- Calculation of the ground plane dimensions (L(g) and W(g))

  L(g)=6h+L= 9.5 mm

  $W_{(g)}$=6h+W= 8 mm

3.2.3 Design Procedure: Metamaterial patch antenna

- Calculation the wavelength (λ)

  Because c = 3x10^8 and f0 = 10 GHz,

  So λ = c/f0

  By substituting c = 3x10^8 and f0 = 10 GHz,

  we get λ=16 mm
- Calculation of the Width (W)

  εr= 4.4, we get W= 2.2 mm
- Calculation of the Effective length (Leff)

εreff =1.023,

we get Leff =61.79mm

- Calculation of the length extension (ΔL)

  Leff =61.79mm,

  we get ΔL=7.78mm

- Calculation of actual length of patch (L)

  Leff=61.79mm and ΔL=7.78mm,

  we get L=2.2 mm

- Calculation of the ground plane dimensions (L(g) and W(g))

  L(g)=6h+L= 9 mm

  $W_{(g)}$=6h+W= 6 mm

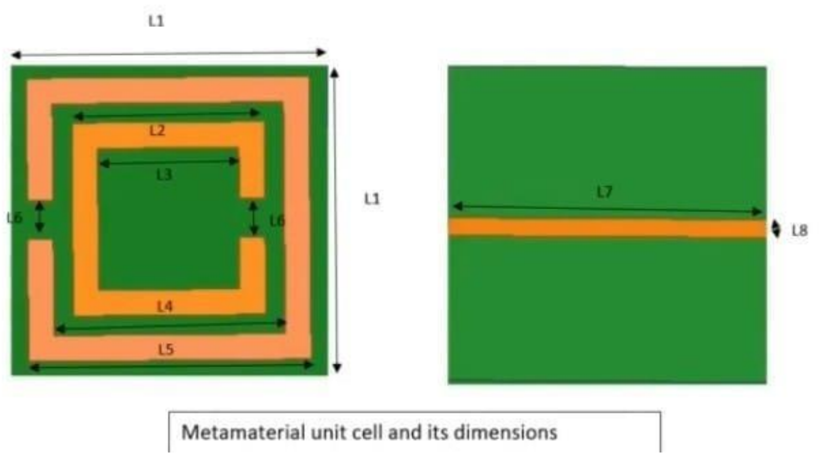

Fig 3.2.1 metamaterial patch antenna

Parameter: L1= 2.5 mm; L2= 1.5 mm; L3= 1.1 mm; L4= 1.8 mm;
L5= 2.2 mm; L6= 0.8 mm; L7= 2.5 mm; L8= 0.18mm;

3.3 Project Setup

The software used to design and simulate the microstrip patch antenna is HFSS. ANSYS HFSS software is the industry standard for simulating 3-D, full-wave, electromagnetic fields. Its gold-standard accuracy, advanced solvers and high-performance computing technologies make it an essential tool for engineers tasked with executing accurate and rapid design in high-frequency and high-speed electronic devices and platforms.

1. Radiation Pattern and Gain:

Radiation pattern and gain of microstrip patch antenna as shown in Result section. This figure represented by HFSS simulation and informs gain.

2. 3D Structure Microstrip Patch Antenna:

   Structure of microstrip patch antenna in 3D is shown in Result section. This figure represented by HFSS. The wires are on the top as patch, on the bottom as ground plane and between those wires as substrate. Feed point represented by rectangular slit.

3. Far-Field Radiation Pattern:

   The radiation pattern of microstrip antenna has a back lobe. In figure can be seen also the maximum value of signal strength captured by the antenna is 15.55 dB, which located at 15o. Points where the receiver is down by half from its maximum value (-3dB) is 5.55 dB, which located at position 335o and 45o. From the position where the receptivity decreased by -3dB antenna, we can determine the half power beamwidth of the microstrip antenna which is 70o.

4. Return loss:

   If minimum of return loss parameter is on left side of resonant frequency Keep Yo fixed and reduces the length of patch in step size then minima will shift towards resonant frequency and we can obtain the minimum of return loss parameter at specified resonant frequency and can be seen.

CHAPTER 4

Results and Discussion

4.1 Result for Compact Microstrip Antenna

A new concept of planar magneto-electro-dielectric waveguided metamaterials (MED-WG-MTM) is proposed to manipulate the effective permeability μeff and the effective permittivity εeff . The MEDWG-MTM cell consists of an electric complementary spiral ring resonator (CSR) in the upper metallic plane and a magnetic embedded Hilbert-line (EHL) in the ground plane.

We designed Microstrip patch Antenna with substrate Rogers RT/ duroid 5880(tm) and frequency = 15 GHz using HFSS and after simulating we got conclusion that These methods have disadvantages such as narrow bandwidth and low gain.

A new solution that is of great interest to designers is the use of electromagnetic metamaterials for antenna design. The use of metamaterials in antenna design not only dramatically reduces the size of the antenna but can also improve other antenna parameters such as enhancing bandwidth, increasing gain, or generating multiband frequencies of antennas operation.

MICROSTRIP ANTENNA CALCULATIONS

The rectangular microstrip antennas are made up of a rectangular patch with dimensions width (W) and length (L) over a ground plane with a substrate thickness (h) having dielectric constant (εr). There are numerous substrates that can be used for the design of microstrip antennas, having their dielectric constants usually in the range of $2.2 \leq \varepsilon r \leq 12$. The ones that are most desirable for antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency; larger bandwidth loosely bound fields for radiation into space, but at the expense of larger element size . The design of microstrip patch antenna assumes that the specified information includes dielectric constant of substrate (εr), height of substrate (h) and resonant frequency (fr) . After specifying εr, fr and h determine the values of Width (W) and Length (L). Different dimensions of rectangular microstrip antenna are calculated as follows:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Where v_0 is the free-space velocity of light.

The effective dielectric constant of microstrip antenna given as

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Expression of extension of length is given by

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

Then actual length of patch can be calculated

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L$$

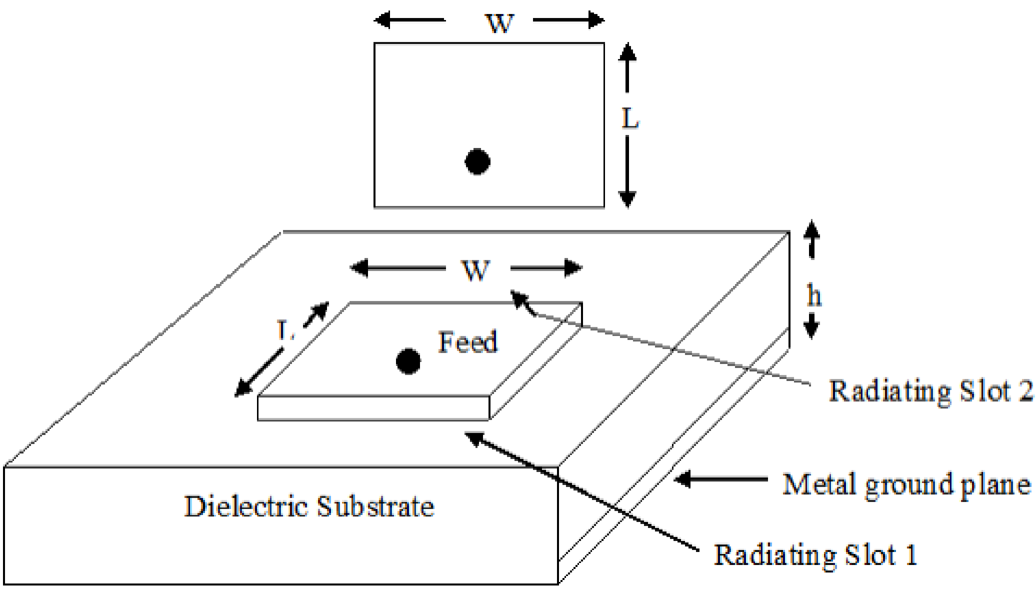

Figure 4.1: Simple patch antenna

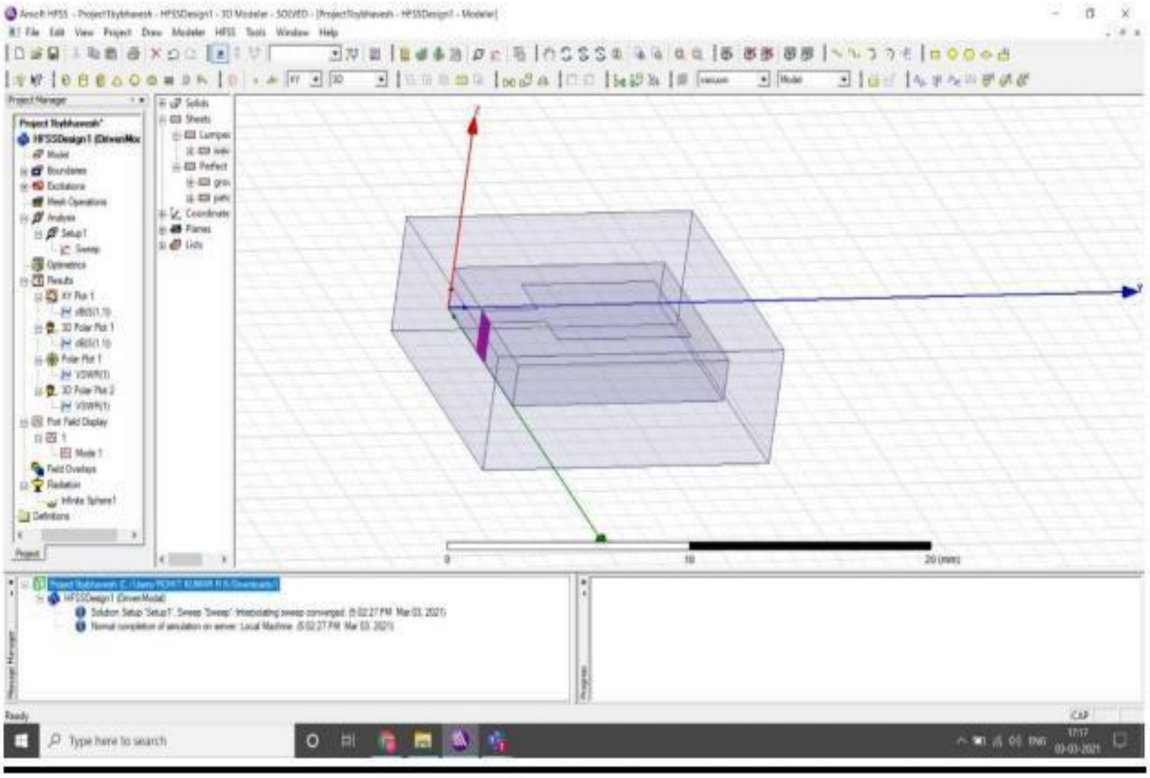

Figure 4.2: Simple micro-strip patch anteena

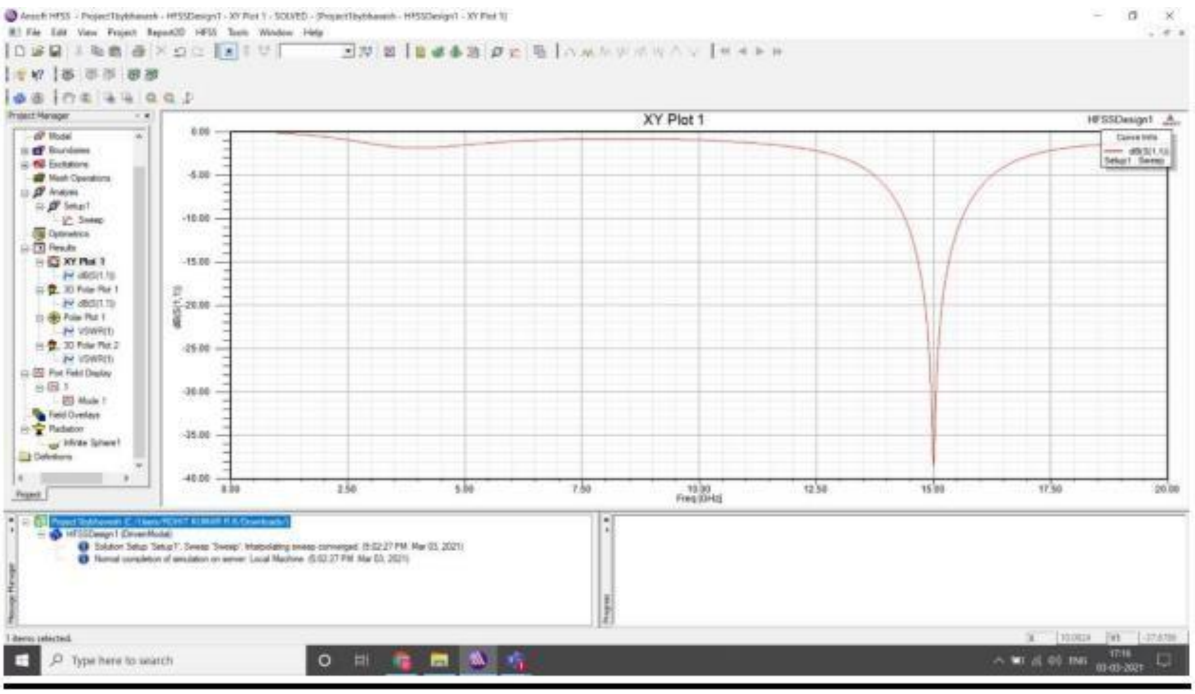

Figure 4.3: S-parameters vs frequency graph

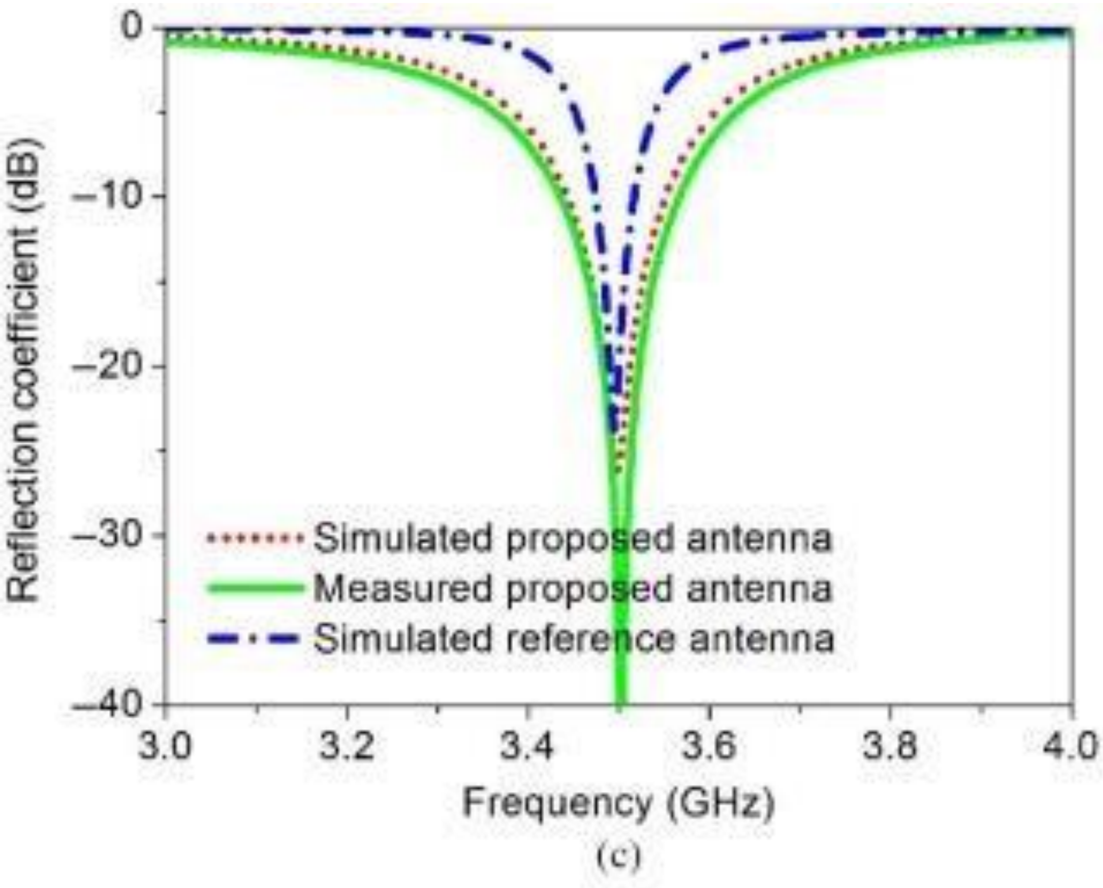

Figure 4.4: Final simulated and measured results for the reference and proposed antenna

4.2 Result for Compact microstrip patch antenna using Metamaterials

For a conventional microstrip antenna based on the pure dielectric material, the working frequency is in inverse proportion to the refractive index.

For an antenna loaded with MED-WG-MTM elements, the basic working principle is almost the same.

Compact factor (CF) = εref / εeff * μeff

BW improving factor (BIF) = (εref *μeff /εeff)^0.5

Based on the effective medium theory, it is able to achieve a smaller CF and a larger BIF to improve the antenna performance by manipulating the material parameters εeff or μeff . The reported magneto-dielectric MTM is just a special case for manipulating the parameter μeff ; however, the proposed MED-WG-MTM in this work can control both εeff and μeff , simultaneously.

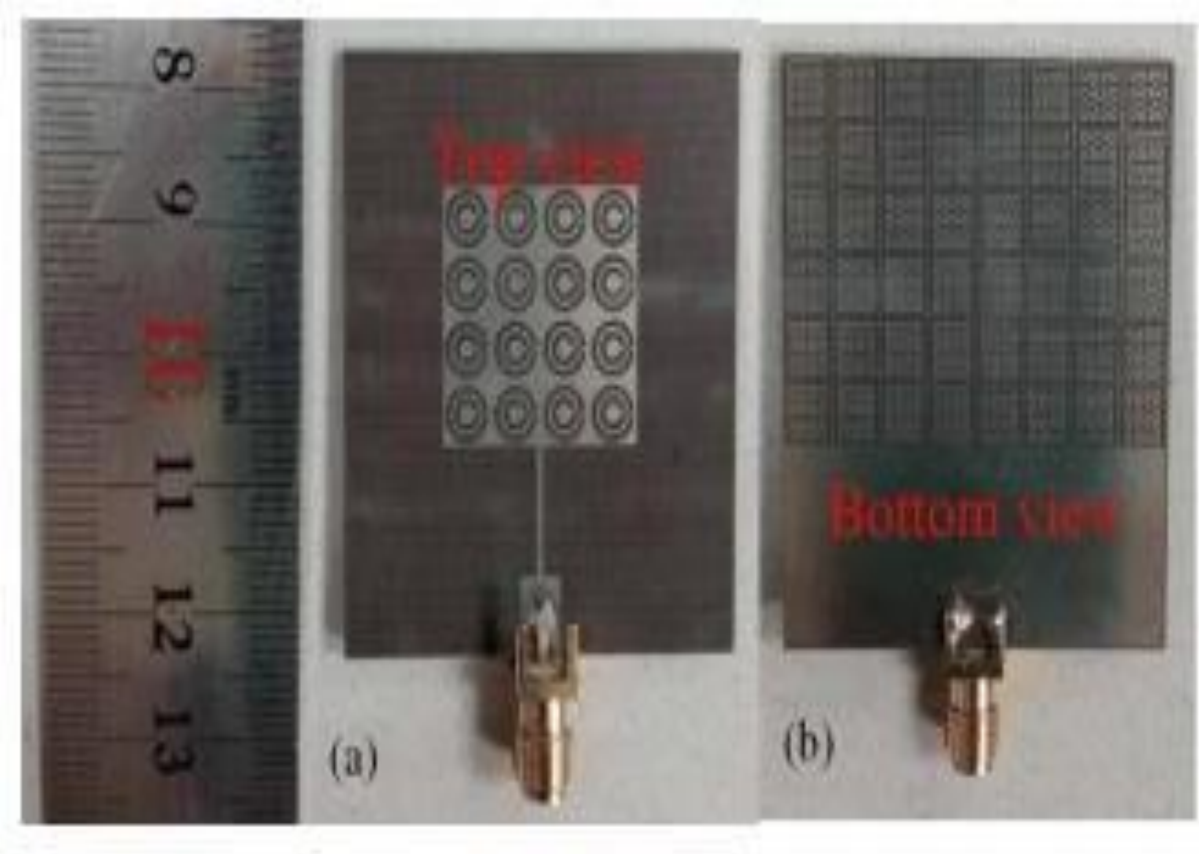

Figure 4.5: Photograph of the fabricated antenna. (a) Top view. (b) Bottom view.

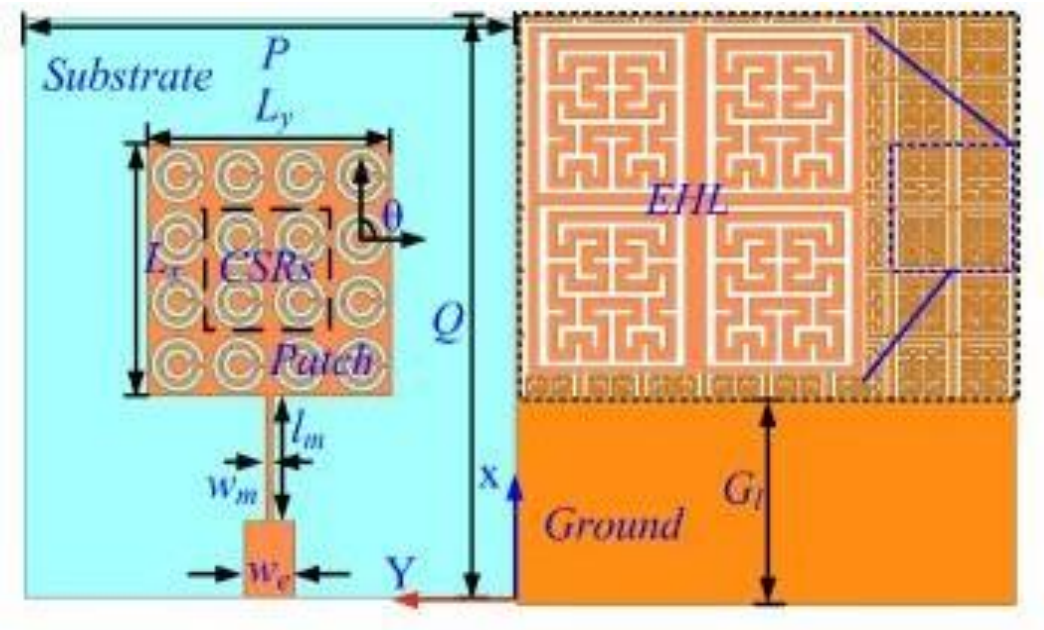

Figure 4.6: Schematic of the proposed antenna with MED-WG-MTM loading

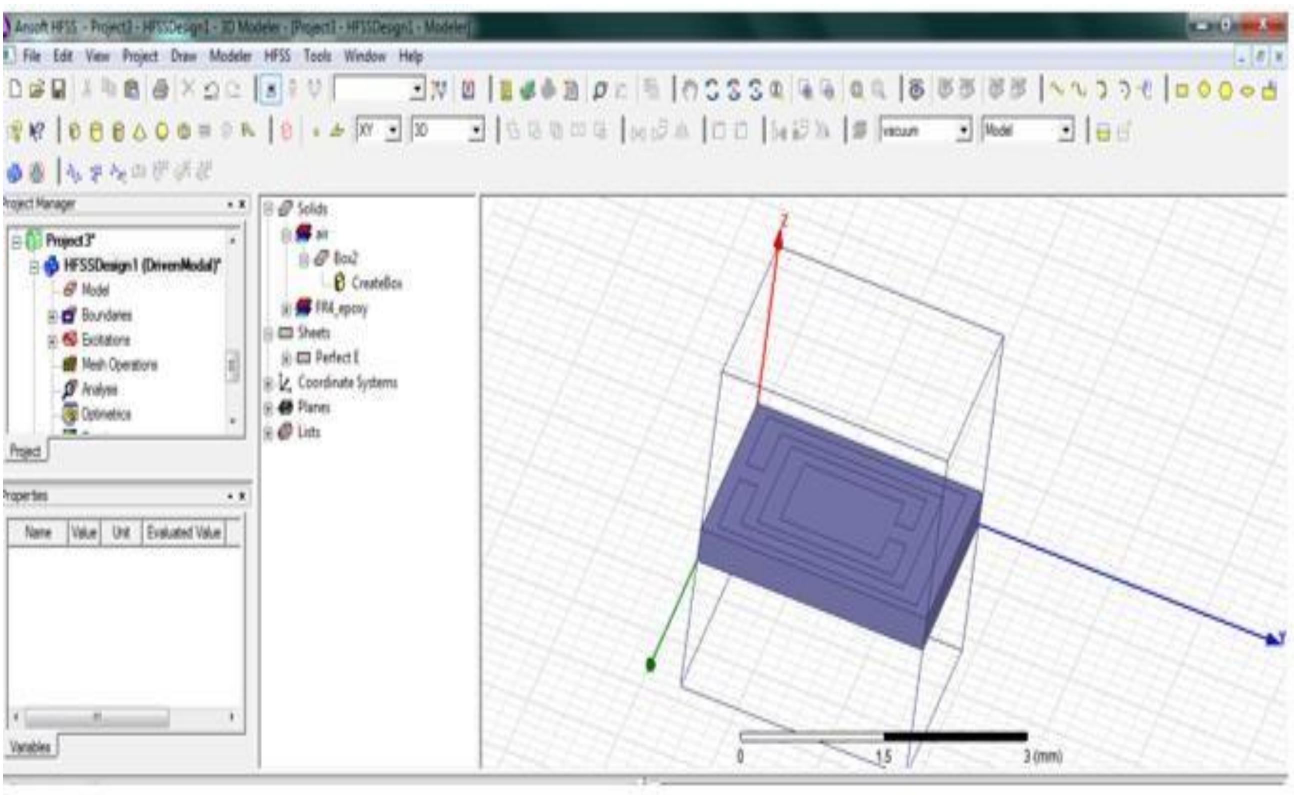

Figure 4.7: Model of metamaterial patch antenna

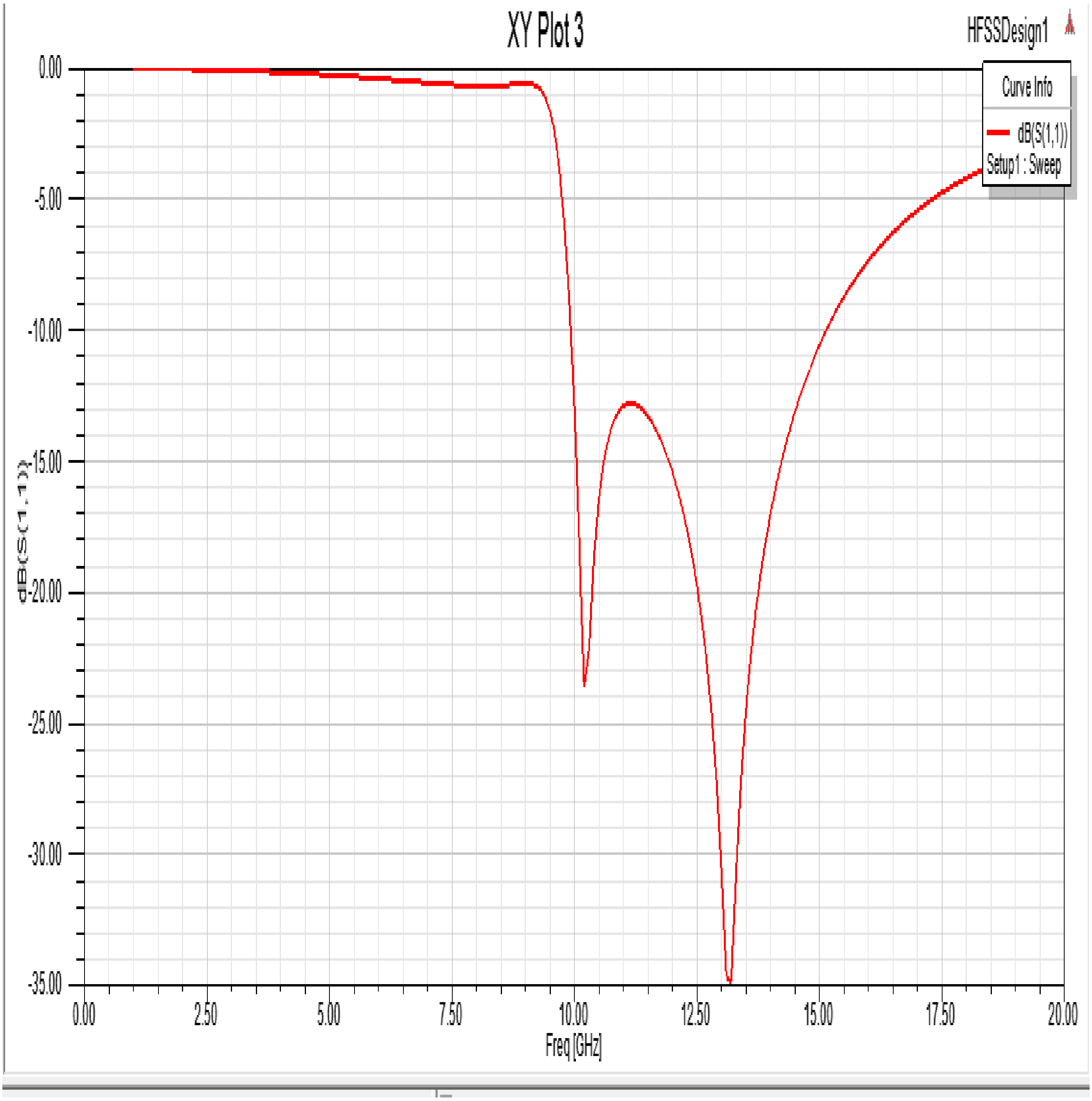

Figure 4.8: Return loss for microstrip patch antenna loaded with metamaterials

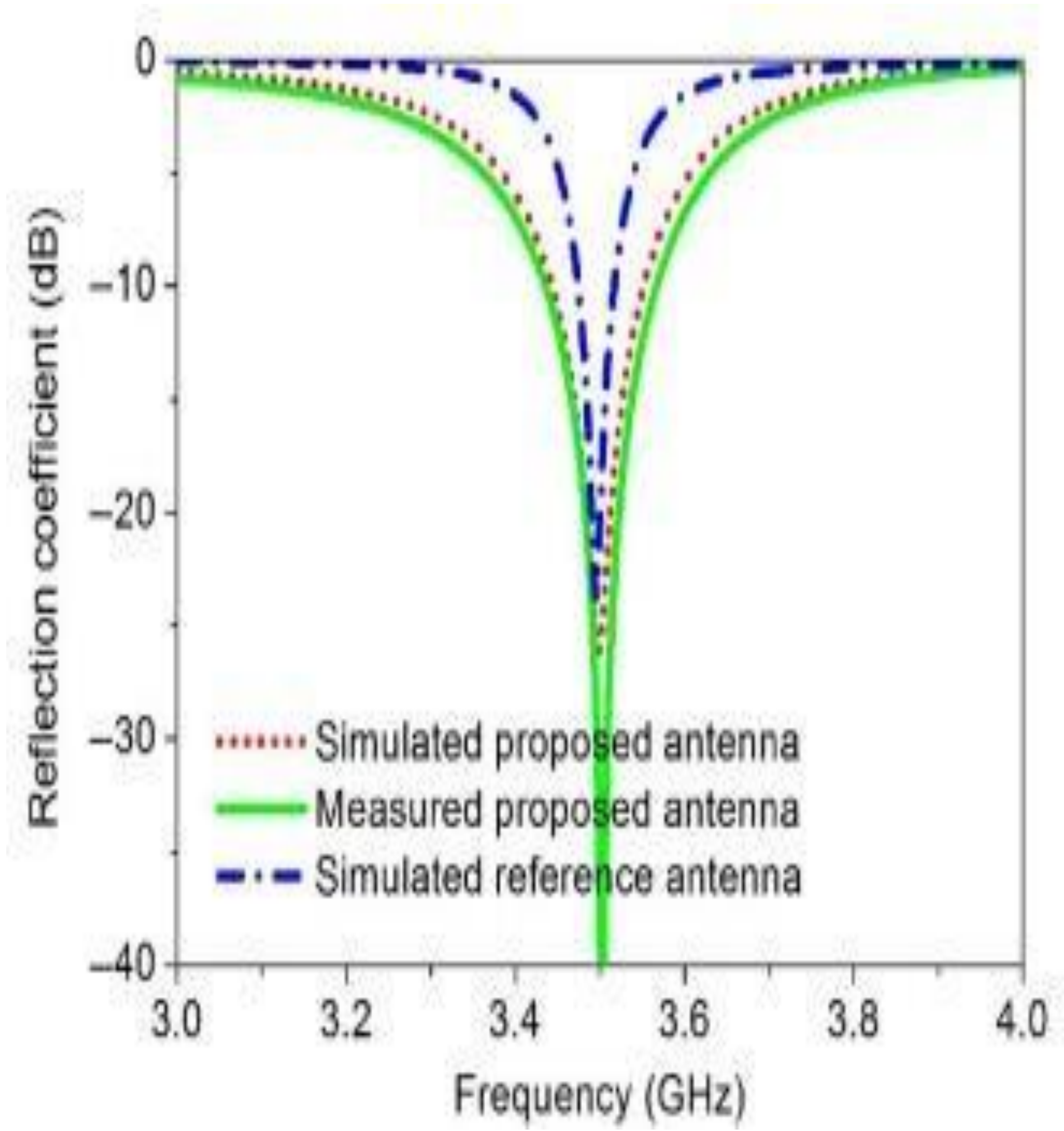

Figure 4.9: Simulated and measured S-parameters against frequency

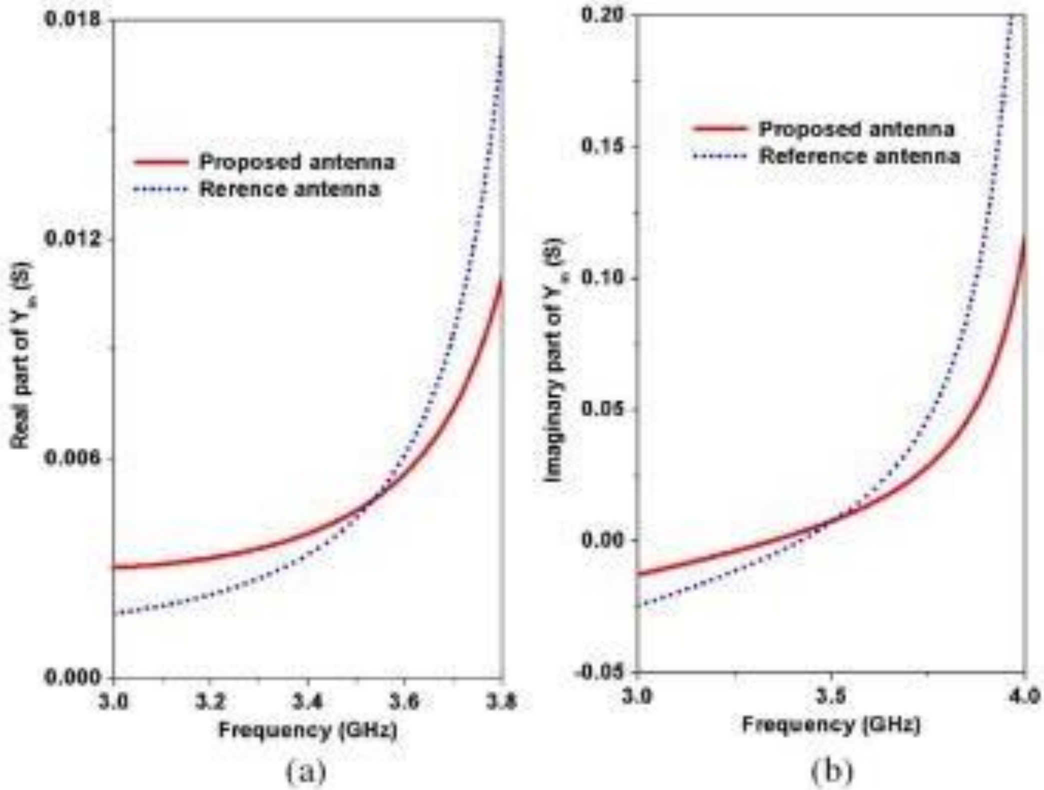

Figure 4.10: Simulated input admittance for both antennas. (a) Real part. (b) Imaginary part.

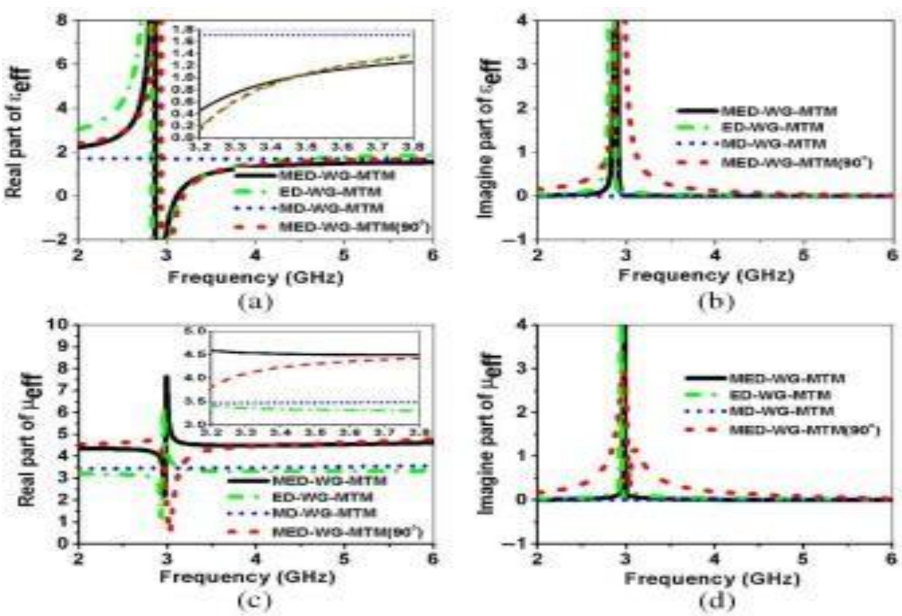

Figure 4.11: Effective material parameters for four different MTM cells. (a) Real part and (b) imaginary part of the permittivity εeff ; (c) Real part and (d) imaginary part of the permeability μeff .

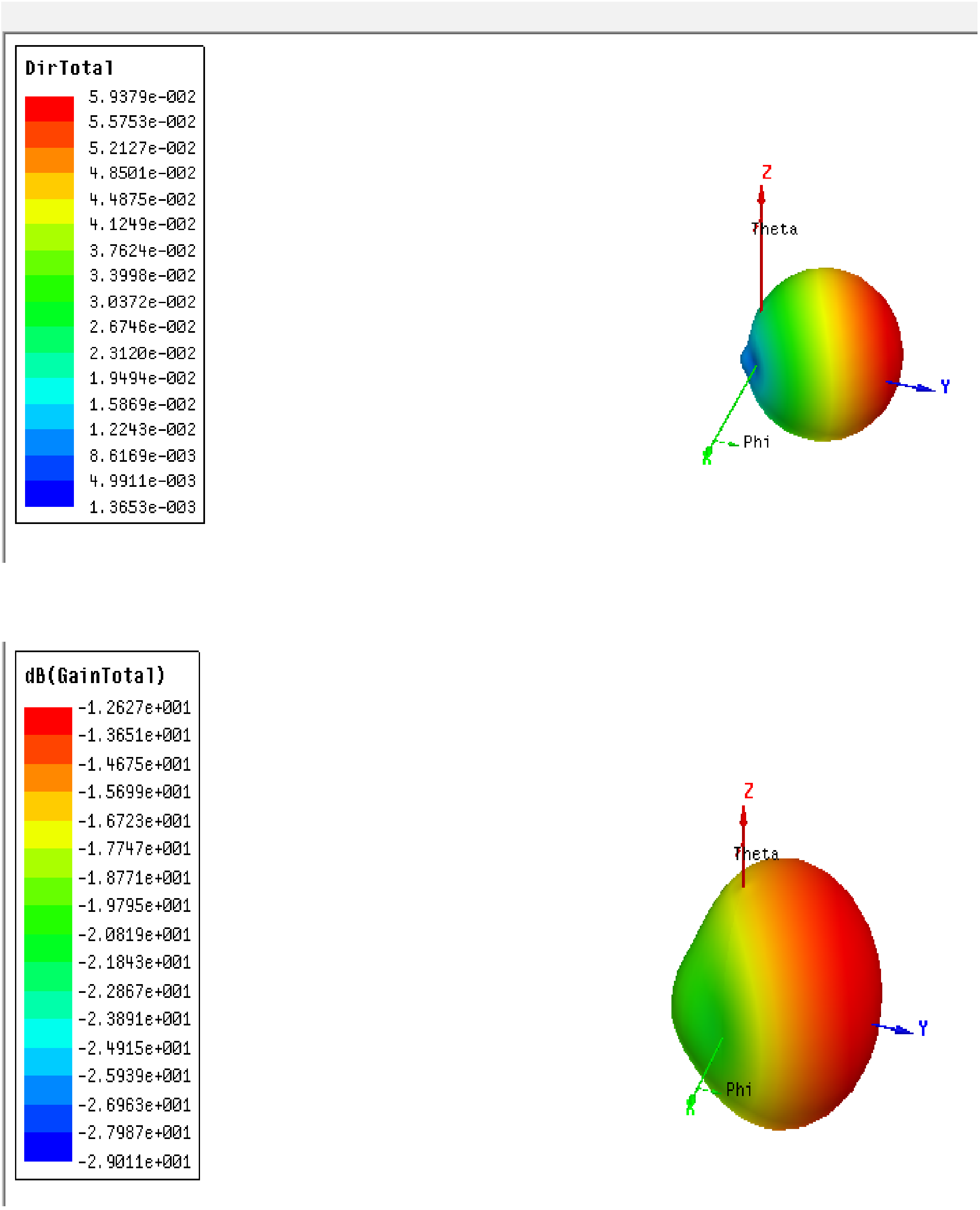

Figure 4.12: Directivity and gain

4.3 Comparison between patch antenna and metamaterial antenna

Parameters	Microstrip patch Antenna	Metamaterial patch Antenna
Resonant frequency	15 GHz	10GHz
Return loss (S11)	-11.3 dB	-23.1 dB and -34.2 dB
bandwidth	45.5 MHz	82 MHz and 32 MHz

CHAPTER 5

Conclusion and Future work

5.1 Conclusion

Microstrip antennas is one of the most innovative topics in antenna theory and design,and have application in modern microwave systems. In this world till now, microstrip patch antennas also have some advantages. Some research are going on to improve the gain and bandwidth of patch antenna. Existing solutions leads to the problems of spurious radiation and high complexity. This new approach come up with a new solution called metamaterial. Metamaterials play important role in the antenna design due to its interesting and unusual properties. By this review, Metamaterials can be used for the performance enhancement of microstrip patch antennas. A metamaterial antenna is made by loading the metamaterial structure over the substrate. There are different Kind of metamaterial substrates. If change the metamaterial substrate will change in the parameters of antenna. Gain of a patch antenna increases by a value of 1.5dB to 7dB with the addition of metamaterial structures. Miniaturization is the primary function of metamaterial. In all the works mentioned here shows that use of metamaterials results in about 50% reduction in the size of a patch antenna. Narrow bandwidth and lower gain are the two main drawbacks of microstrip patch antenna. By using metamaterial we can overcome these problem.

By observing the simulated results it is very clear that the compact DNG Metamaterial antenna gives better gain and efficiency compared to an ordinary patch antenna which is very useful for point to point wireless propagation. This is possible only because of the unusual properties of Metamaterials. Also due to the miniaturization it is very convenient to use in wireless networks. This is possible only because of the unusual properties of Metamaterials.

Due to the unusual properties of the Metamaterials by using a single unit cell the antenna gives of 3.768 dB, overall efficiency of 53.76 and a VSWR of 3.5 at 10 GHz frequency which is very good for point to point wireless communication and wireless LANs.

This antenna has better VSWR, gain and radiation efficiency compared to an ordinary patch antenna. And another Metamaterial antenna using three unit cells gives a better gain of 5.197

dB, overall efficiency of 92.5% and a VSWR of 3.5 at 10 GHz frequency. And the gain, efficiency and return loss are 4.183 dB, 60.78%, -23.1db respectively for 10 GHz

5.2 Future scope of work

The explosive growth in the demand for wireless communication and information transfer using handsets and personal communications (PCS) devices has created the need for major advancements of antenna designs as a fundamental part of any wireless system. One type of antennas that fulfills most of the wireless systems requirements is the metamaterial microstrip antennas. These antennas are widely used on base stations as well as handheld devices. Metamaterial microstrip antennas have a variety of configurations and are currently the most active field in antenna research and development. The metamaterial microstrip antennas, due to their great advantages, have increasingly wide range of applications in wireless communication systems as handheld mobile devices, satellite communication systems, and biomedical applications. In most personal communications, the handheld antenna is placed on a small plastic/shielding box that is in close proximity to biological tissue of user body hence its radiation may cause health hazardous effects. Added to the operational requirements, the users and service providers usually demand wireless units with antennas that are small and compact, cost effective for manufacturability, low profile, and easy to integrate with other wireless communication system components. The antenna designer must consider all these issues besides the electrical characteristics of the antenna performance which include antenna tuning (operating frequency), VSWR and return loss (input impedance), bandwidth, gain and directivity, radiation pattern, diversity, and size of the chassis (expressed as a function of wavelengths) and specific absorption rate (SAR) of the antenna. These design considerations have led antenna designers to consider a wide variety of structures to meet the often conflicting needs for different applications.

In summary, metamaterials have come a long way in the last 15 years. Researchers today have gained a better understanding of the technology. With companies moving towards production of metamaterial-based devices, metamaterials offer the possibility of being used in a wide range of applications.