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DoubleElliptical Patch (DEP) Antenna with Inset Feed and Pyramidal Shaped Ground for C band Application

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ABSTRACT: ***The paper highlights the rapid evolution of wireless communication systems, prompting research to enhance performance by reducing the size of RF front-end systems. Micro-Strip Patch Antennas (MSPAs) play a pivotal role in various communication fields. The study proposes a novel Pyramidal Shaped Defect in Ground (DGS) Double Elliptical Micro-strip Patch Antenna (DEMPA) with inset feed for design flexibility. The Double-Elliptical Patch (DEP) is created by blending two half-elliptical patches, featuring the same major axis but different semi-minor axes. Inset feed is incorporated to enhance return loss (S11), and a pyramidal-shaped ground with inverted L slots improves antenna bandwidth. The proposed antenna spans the frequency range of 3 to 7 GHz, covering the C band and SUB6 band of the 5G spectrum. The novel shape achieves greater design flexibility and miniaturization, offering a remarkable return loss of -44dB at 4.3GHz and a far field total gain of 27dBm on its maximum side.***

KEYWORDS- Double elliptical patch, pyramidal Ground, returns loss, inset feed.

INTRODUCTION: In communication engineering, recent advancements prioritize smaller size and wider bandwidth for antenna design. The X band operates in the 7.0 to 11.2 GHz range, while the S band (2 to 4 GHz) is utilized in weather and surface ship radar. The C band (4 to 7 GHz) supports long-distance telecommunications, Wi-Fi, cordless phones, and weather radar. Coplanar Patch Antenna employs conductors on the same plane, while Coplanar Waveguide features a metallic strip with slits. CPWdimensions include central strip width (W) and slot width (s), with symmetrical structure. Microstrip Patch Antenna is created by etching the pattern on a metal trace bonded to an insulating substrate, forming ground plane substrates on the opposite side.

OBJECTIVE: The objective of this thesis is to do design and simulate of Double elliptical shaped Antenna with wide band characteristics using commercial tool HFSS.

METHODOLOGY

• An antennas are designed for the frequency range using design considerations and procedures.
• Model the antenna using HFSS.
• Simulating and optimizing design parameters.

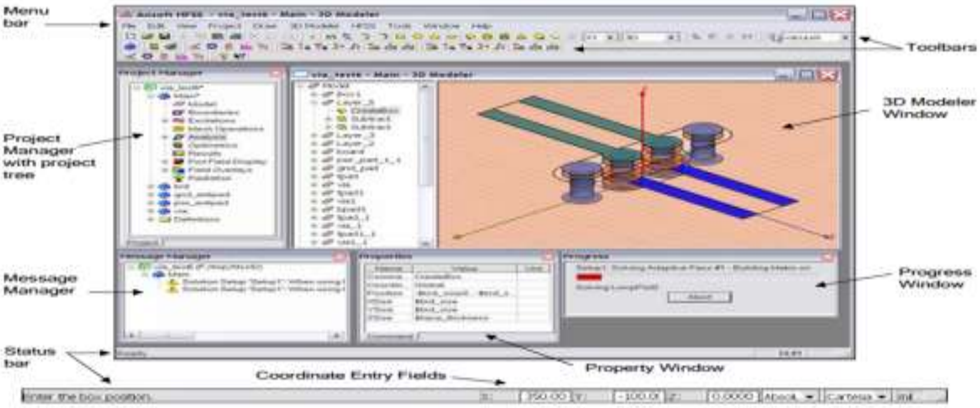
Literature:

- The section reviews technologies and designs of printed antennas for compact and multiband applications.
- The history of Ultrawideband (UWB) antennas dates back to the late 19th century with Oliver Lodge's development of the first wideband antenna in 1898
- Broadband antennas were initially limited to military applications, but the declassification of the 3.1–10.6 GHz frequency band in 2002 accelerated research and development for commercial UWB applications.
- The combination of a microstrip patch antenna at 900 MHz and a folded reflector antenna in the 60GHz frequency range has demonstrated excellent performance.

- Elliptical Micro-strip Patch Antennas (EMPA) with eccentricity variations offer advantages such as circular polarization and dual resonant frequencies.
- A modified form of ellipse, called 'double-ellipse,' is proposed, leading to the development of Double-Elliptical Micro-strip Patch Antennas (DEMPA) for miniaturization and improved design flexibility.

HFSS OVERVIEW: The name HFSS stands for High Frequency Structure Simulator.

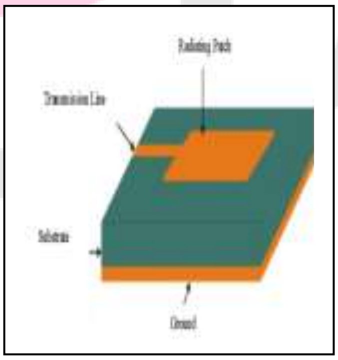
1. **High-Performance Full-Wave Electromagnetic Simulator:** HFSS stands for High-Frequency Structure Simulator, and it serves as a robust full-wave electromagnetic field simulator. It specializes in modeling arbitrary 3D volumetric passive devices, providing accurate solutions for complex electromagnetic problems.
2. **User-Friendly Graphical Interface:** HFSS takes advantage of the familiar Microsoft Windows graphical user interface, making it accessible and easy to use.
3. **Comprehensive Integration of Features:** The software integrates simulation, visualization, solid modeling, and automation into a cohesive environment. This integration streamlines the workflow, making it easy for users to perform tasks such as model creation, simulation, and result analysis within the same platform.
4. **Finite Element Method (FEM) and Adaptive Meshing:** HFSS employs the Finite Element Method (FEM) for electromagnetic field analysis, providing a powerful computational approach.
5. **Versatile Parameter Calculations:** Ansoft HFSS is capable of calculating essential parameters such as S-Parameters, Resonant Frequency, and Fields. This versatility makes it a valuable tool for engineers and researchers working on projects that require a detailed understanding of electromagnetic behavior and its impact on device performance.



MICROSTRIP PATCH ANTENNA :

A class of antennas that has gained considerable popularity in recent years is the microstrip antenna. There are many different types of microstrip antennas, but their common features are

- Very thin flat metallic region often called the patch
- Dielectric substrate
- Ground plane, which is usually much larger than the patch
- Feed, which supplies the element RF power.



Advantages :

- They are light in weight and take up little volume because of their low profile.
- They can be made conformal to the host surface.
- Low fabrication cost, hence can be manufactured in large quantities.
- They support both, linear as well as circular polarization.
- They can be made compact for use in personal mobile communication and hand held devices.

Disadvantages

- Narrow bandwidth.
- Lower power gain.
- Lower power handling capability.
- Polarization impurity.
- Surface wave excitation.

MICROSTRIP LINE FEED:

The microstrip patch can be fed with a microstrip line where the strip line connects the patch at the edge. So the impedance of the line should be matched to the edge impedance of the patch. There are several techniques to achieve the impedance patching which are inset feed, non-radiating edge feed and use of quarter wave transformers as shown in Fig 2.11(a) (b) (c) and (d) respectively.

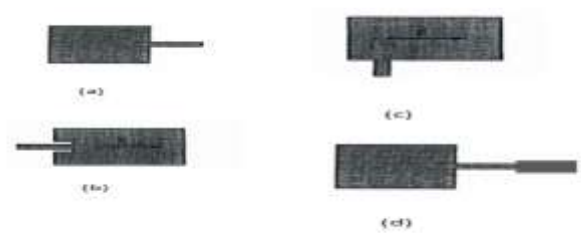


Fig 2.11: (a) Microstrip line feed (b) Inset Feed (c) Microstrip line feed at non-radiating edge (d) Microstrip line feed with quarter wave transformer.

ANTENNA PARAMETERS:

Returnloss: An essential characteristic to consider while evaluating an antenna is return loss. It has to do with maximum power transfer theory and impedance matching.The ratio of the antenna's incident power to the power reflected back from the source's antenna is known as the return loss (RL).

Radiationpattern: An antenna that radiates uniformly in all directions is called an isotropic antenna. An isotropic antenna is only good for comparison because it is not feasible to implement in real life. An ellipse-shaped microstrip or patch antenna is called an elliptical patch antenna.

Bandwidth: The elliptical shape can contribute to achieving a wider bandwidth compared to some other patch antenna shapes. This is crucial for applications that require communication over a range of frequencies.**Gain:** Patch antennas, including elliptical ones, typically offer moderate to high gain, making them suitable for point-to-point communication and satellite communication systems.

Substrate Material: The performance of the antenna is influenced by the substrate material on which it is constructed. Common substrate materials include dielectric materials like FR4.

Feed Mechanism: The feeding mechanism, such as microstrip line or coaxial feed, plays a crucial role in determining the impedance matching and overall performance of the antenna.

DESIGNING OF ELLIPTICAL PATCH ANTENNA:

Designing an elliptical patch antenna involves several steps and considerations to optimize its performance.

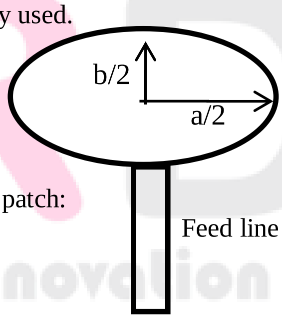
1. Determine Design Parameters:

Frequency: Define the operating frequency or frequency range of your antenna.

Dielectric Substrate: Choose a suitable dielectric substrate material. FR4 is commonly used.

Permittivity (ε_r): Select the permittivity of the substrate material.

Patch Dimensions: Determine the major and minor axes of the elliptical patch.



2. Calculate Patch Dimensions:

Use the following formulas as a starting point:Major axis (a) and minor axis (b) of the patch:

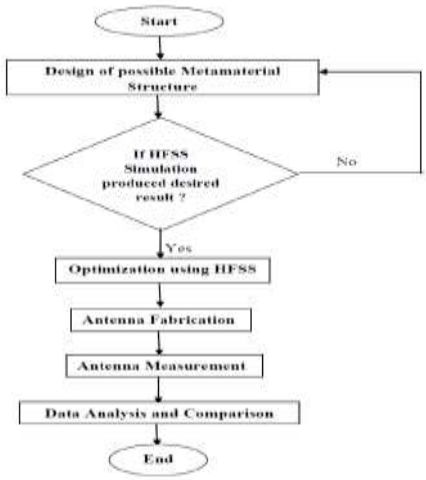
$$a = \frac{c}{f}\sqrt{\frac{\varepsilon_r+1}{2}}$$
$$b = \frac{c}{f}\sqrt{\frac{\varepsilon_r-1}{2}}$$

Where;

c is the speed of light (3×10^{-8} m/s),

f is the frequency of operation.

INTRODUCTION TO ANTENNA DESIGN:



DESIGN OF DOUBLE ELLIPTICAL PATCH ANTENNA:

Designing steps:

Step 1: For a r patch antenna practical values can be calculated by using standard formulas.

Step 1: Calculation of the width (W) $w = \frac{2c}{f_0\sqrt{\varepsilon_r+1}}$,

c = speed of light = c =3 x 10^{11} mm/s,εr = relative permittivity,W = width of patch

Step 2: Calculation of the Effective Dielectric Constant. This is based on height, dielectric constant of the dielectric and the calculated width of the patch antenna.

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

ε_{eff}=effective permittivity, ε_r= relative permittivity, h = substrate thickness,W = width of patch

Step 3: Calculation of the Effective length$L_{eff} = \frac{0.5c}{2f_0\sqrt{\varepsilon_{eff}}}$Where, L_{eff} = effective length

Step 4: Calculation of the length extension ΔL ,$\Delta L = 0.412h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.288)\left(\frac{w}{h}+0.8\right)}\right)$

Where, ΔL is the length extension because of fringing field.

Step 5: Calculation of actual length major axis and minor axis using the formulae ,$a = \frac{c}{f}\sqrt{\frac{\varepsilon_r \pm 1}{2}}$

Step 6: Calculation of the ground plane dimensions:

The ground plane dimensions are calculated as: L_g= 6h+L ,W_g= 6h+W

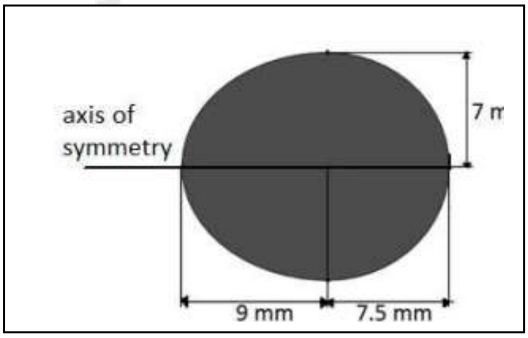
h = substrate thickness,L = length of patch, W = width of patch, L_g = length of ground,W_g=width of ground.

Step 7: Repeat the step 5 to calculate another ellipse of different minor axis values

Step 8: Combine a semi-ellipse from Step5and semi-ellipse from Step 7 to the Double elliptical shape

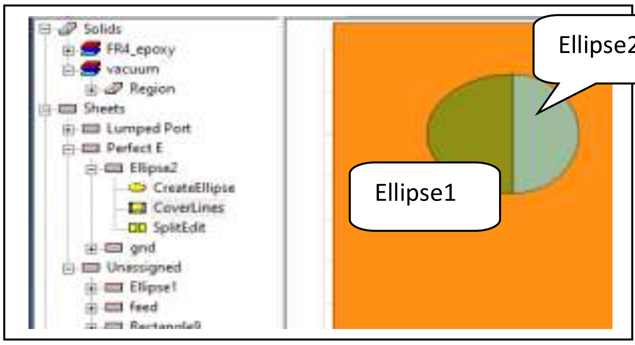
Step 9: Provide inset feed to improve the S11.

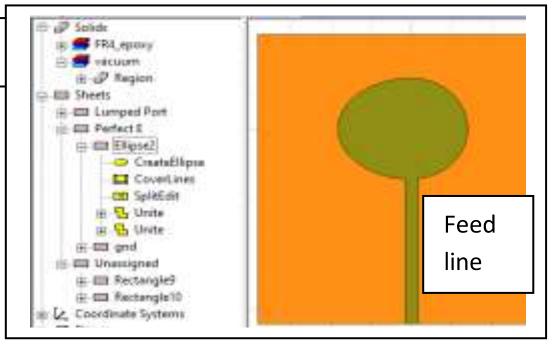
Step 10: Apply various DGS methods to improve the band width and radiation characteristics.



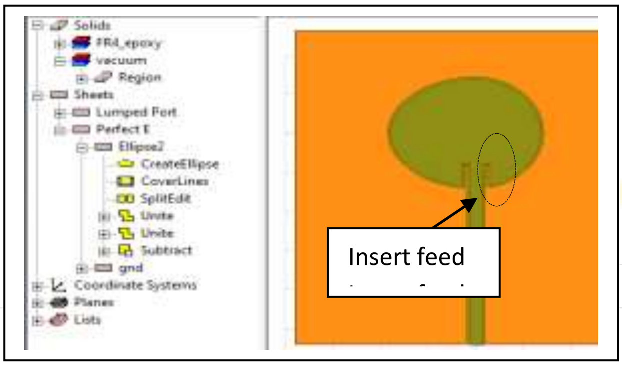
HFSS DESIGN:

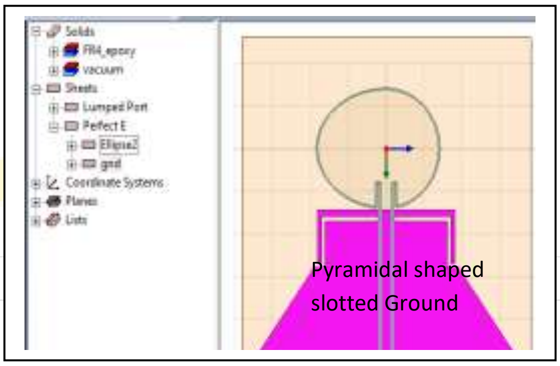
The design console of the HFSS environment is shown below. The design of DEP after the step7





Apply Feed line



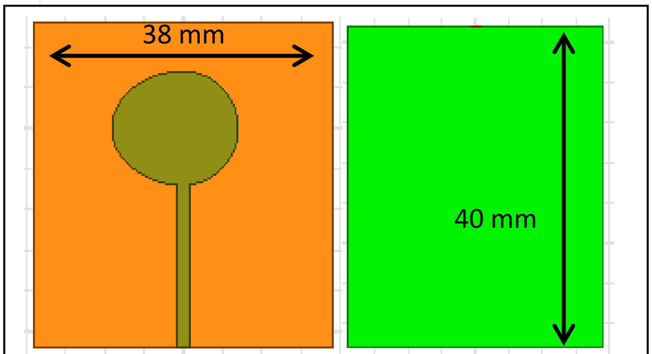


Apply Inset Feed to line

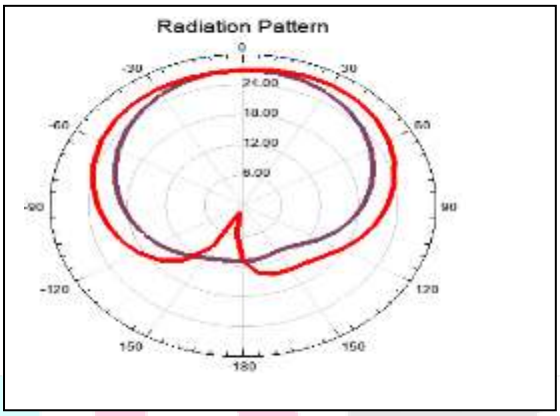
Applying GS

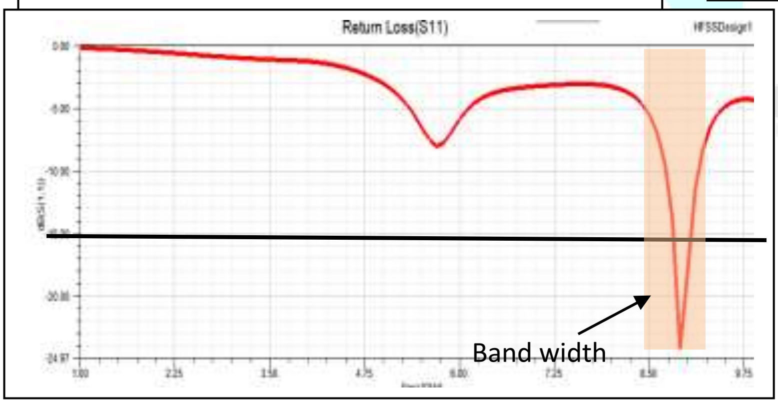
HFSS DESIGN ITERATIONS AND RESULTS:

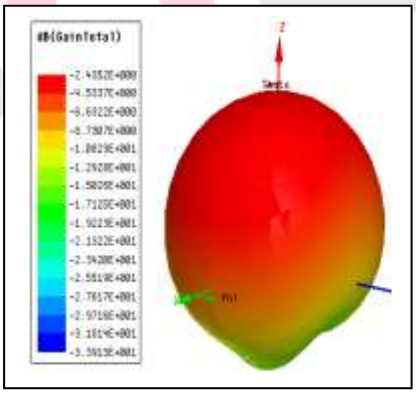
Iteration 1: DEP With Full Ground



Top View **Bottom view**

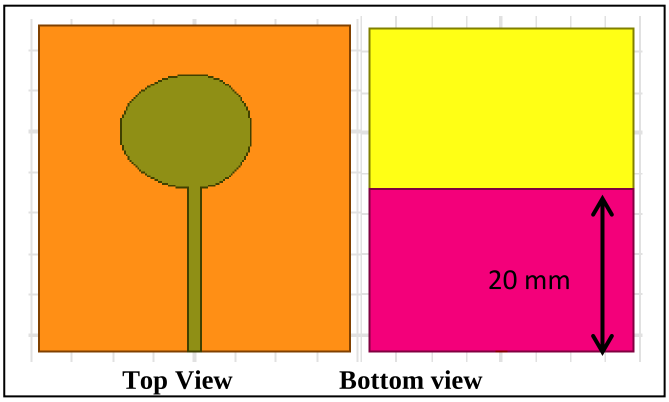


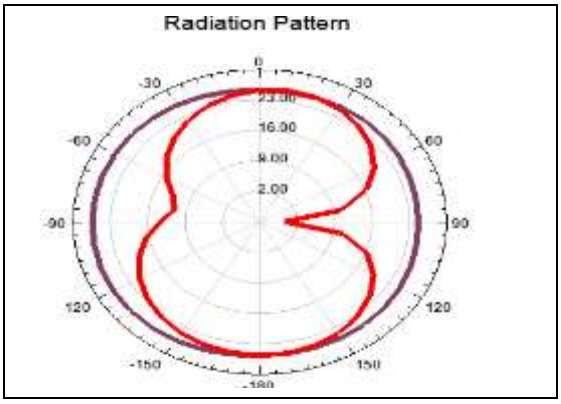


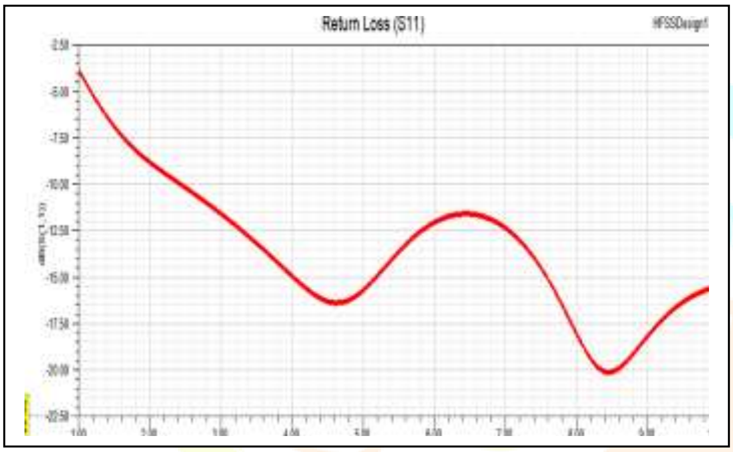


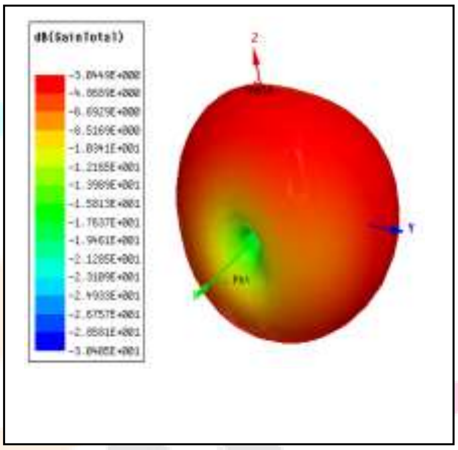
- In this iteration, the bandwidth is very narrow and the radiating band is centered at 9GHZ .Due to full ground the antenna radiated in monopole radiation pattern.

Iteration 2: DEP With Half Ground



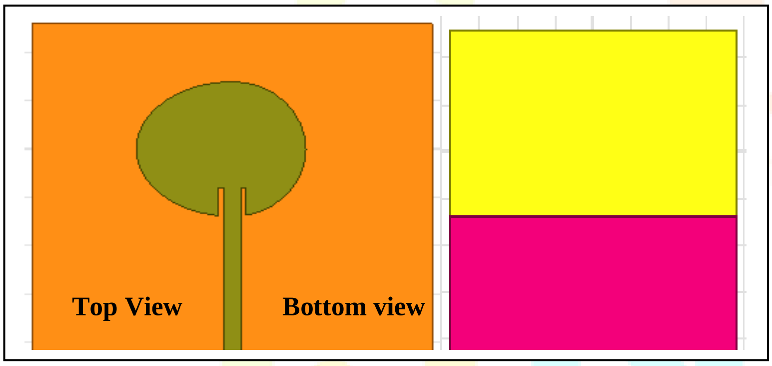


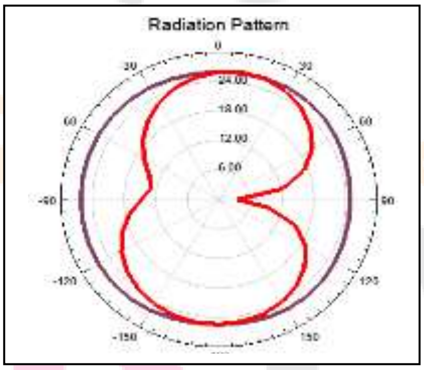


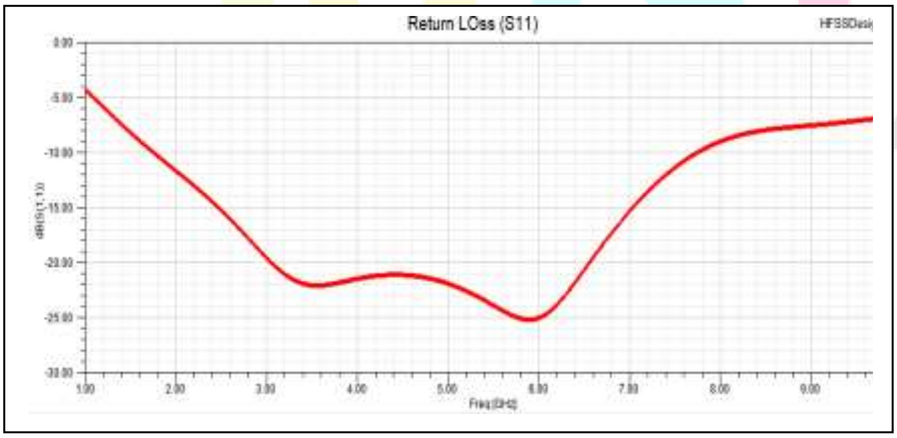


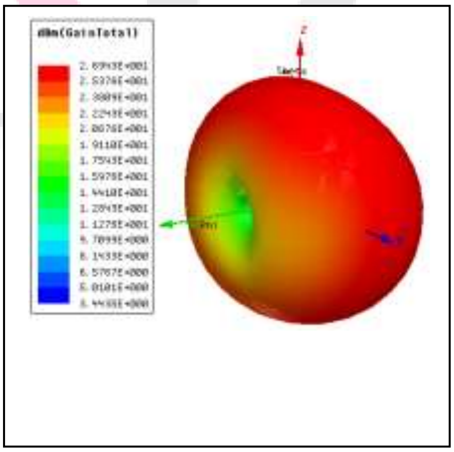
- In this iteration the ground under patch is removed, so that the band width is improved, but the return loss are poor. The radiation pattern is improved from monopole to dipole radiation.

Iteration 3: DEP With Half Ground And Inset Feed



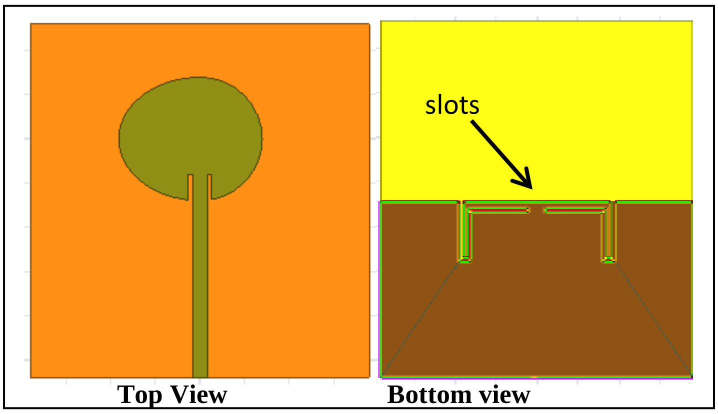


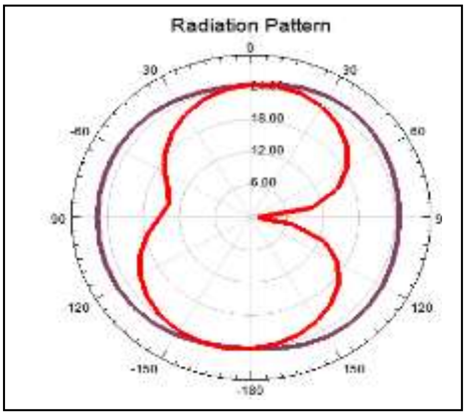


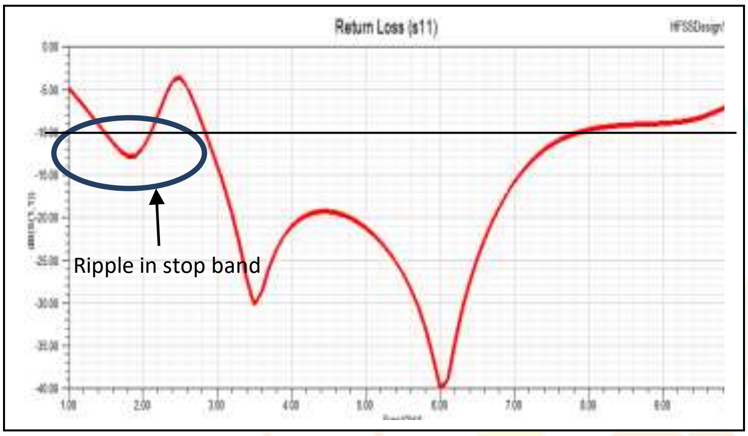


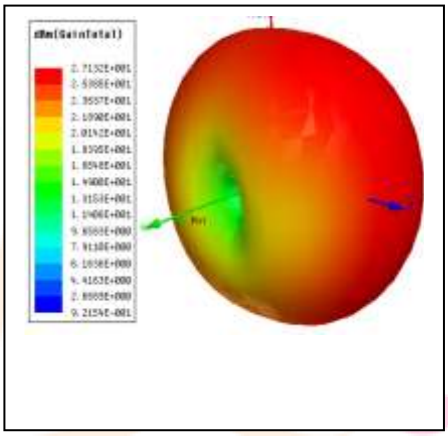
- In this iteration the ground under patch is removed, and feed method also changed. So that, the band width is improved, but the return loss are poor.

Iteration 4: DEP With Inset Feed And Slots In Ground



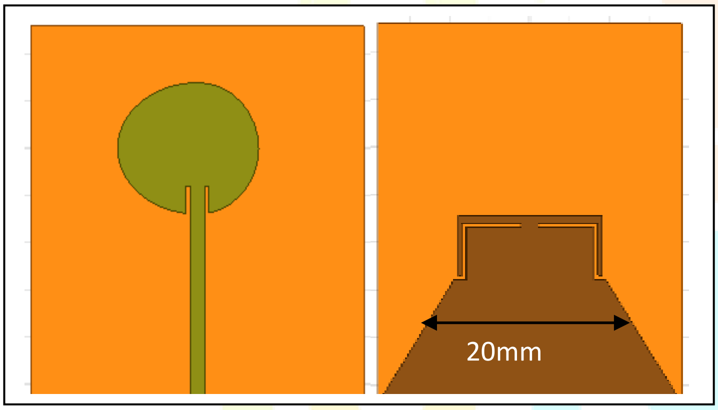


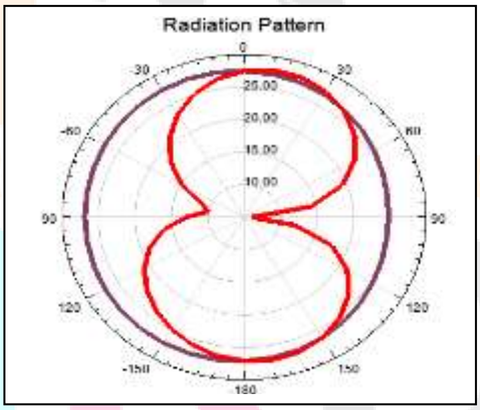


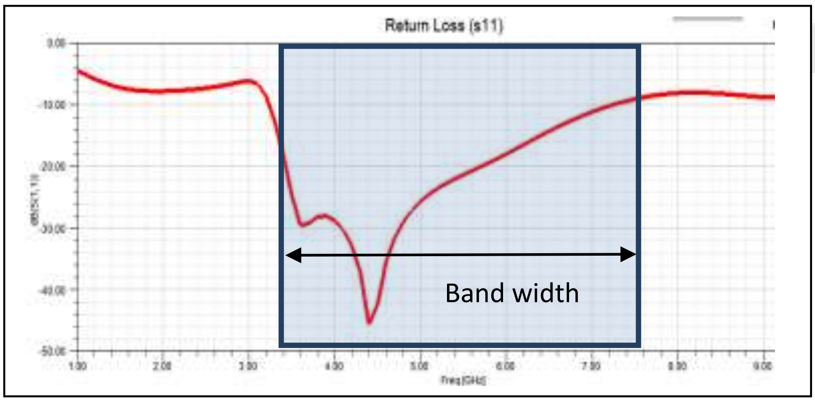


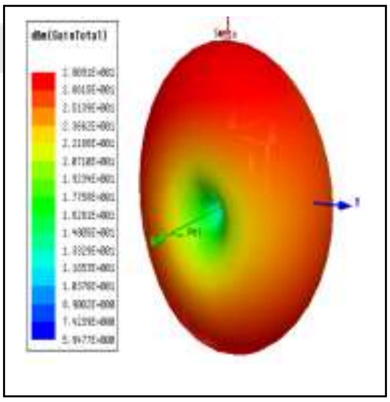
- ➢ In this iteration the ground under patch provided with slots, so that the band width is improved from -22dB to -40dB, but there is a ripple in out for the band that made the return loss are poor.

Iteration 5: DEP With Inset Feed, Pyramidal Shaped Ground And Slots In Ground







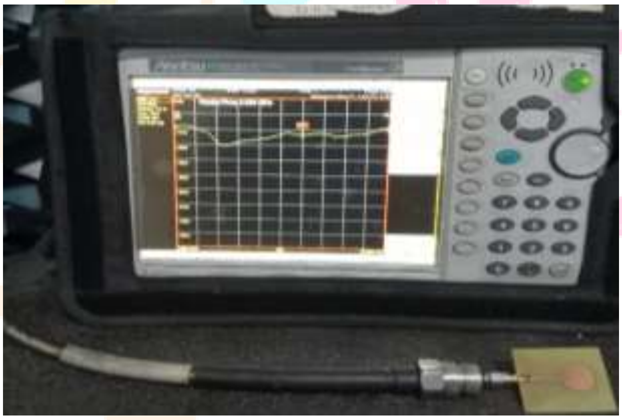


- ➢ Return loss is improved to -45dB. Further the ripple in stopband is removed. The radiation pattern also improved well.

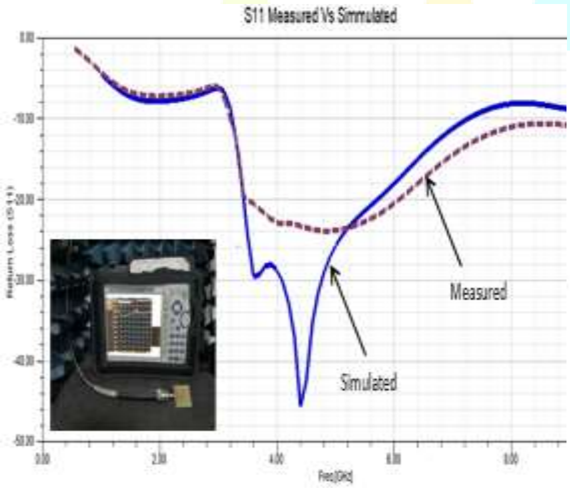
FABRICATED DESIGN:

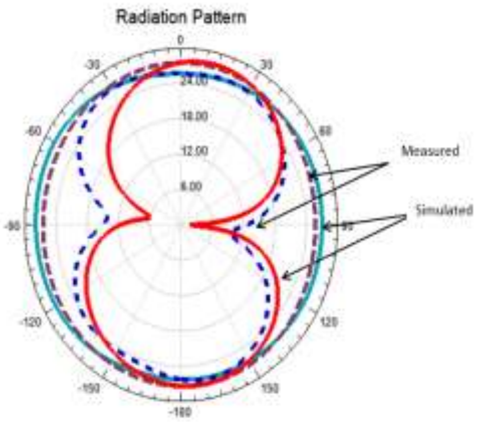
Top view   Bottom view

FABRICATION TESTING:
In this testing work the antenna is tested then the return loss & radiation pattern graphs are observedand then compared with the simulated results



Comparision between the measured and simulated results:





Here we observe the comparision between measured and simulated results of the double elliptical patch antenna.the measured return loss(s11) is -23.89643dB and the gain is 27dBm are noted ,also the antenna radiates in dipole radiation pattern

CONCLUSION: In this work the, the improvements of the work are inset feed and the GS. The shape of the patch is Double elliptical shaped with inset feed and the pyramidal shaped slotted GS is applied.

Iteration No.	Design description	S11 max(dB)	Band of operation & BW(GHz)	Gain (dBm)	Remarks
1	DEP with full ground	-24	8.8 - 9.3 & 0.5	27	Poor bandwidth& monopole radiation
2	DEP with half ground	-20	2.5 - 10 &7.5	25	Unbounded radiation band
3	DEP with half ground and inset feed	-25	1.8 - 7.8 & 6	25	Poor return loss
4	DEP with inset feed and slots in ground	-40	2.9 – 7.9 & 5	24	Ripple in stop band
5	DEP with inset feed, pyramidal shaped ground and slots in ground	-47	3.2 – 7.2 & 4	27	• Reduced ripple in stop band • Return loss improved

From abovetable it is concluded that the proposed model offers better results in 5th iteration. The return losses are improved with loss of minimum bandwidth. The gain also belter for the design proposed and the antenna radiates in the C band applications

FUTURE SCOPE OF THE PROPOSED WORK:

The proposed work can be further developed by changing the substrates of different constant material constants. The elliptical antenna can be replaced with different shapes. Other ground structures are can be used to improve the bandwidths. The reconfigurable antenna can be obtained by adding resonators with PIN diode. This can be used to design Rectenna (Rectifier-antenna) and other applications.

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