Antenna Design Project Report

Information and Communication Technology (ICT)

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A novel grating triangular patch antenna with transparent ground plane for C-band applications.

Abstract

In this paper, design and characterization of a novel grating equilateral triangular patch antenna for its use in C-band application is presented. At first, a simple equilateral triangular patch is designed and fabricated on glass substrate with transparent ground plane, which is followed by grating of the radiating patch in three different ways. Microstrip line feeding technique is used for excitation of the radiating patch. Return loss measurements are carried out for all the antenna samples so as to obtain the best grating line configuration. Co-polar and cross-polar radiation patterns of the simple triangular patch and the grating triangular patch antennas are measured. With the introduction of the grating lines the matching performance of the antenna increases. A shift in the resonant frequency towards the lower side of the frequency spectrum is observed with the change in the number of grating lines of the antenna, whereas changes in the radiation pattern remains insignificant.

Three different grating line configurations are investigated: (1) a single grating line, (2) two grating lines, and (3) three grating lines. The antenna with three grating lines exhibits the best matching performance, with a return loss of better than 17 dB over the entire C-band (5.6 GHz). The resonant frequency of the antenna is also shifted towards the lower side of the frequency spectrum with the introduction of grating lines.

The co-polar and cross-polar radiation patterns of the simple triangular patch antenna and the grating triangular patch antenna with three grating lines are measured and compared. The radiation patterns of the two antennas are similar, with the grating triangular patch antenna exhibiting a slightly higher gain.

Literature Survey

Triangular patch antennas are a type of microstrip patch antenna that is known for its simple design and ease of fabrication. However, triangular patch antennas typically have a narrow bandwidth and poor matching performance.

Grating lines can be introduced on the radiating patch of a triangular patch antenna to improve its matching performance and bandwidth. Grating lines are essentially narrow slots that are etched into the patch. The grating lines interact with the electromagnetic waves generated by the antenna to produce a wider bandwidth and better matching.

Transparent ground planes can be used in patch antennas to improve their optical transparency. Transparent ground planes are typically made of materials such as glass or sapphire.

A novel grating triangular patch antenna with a transparent ground plane for C-band applications was proposed in a paper by Borah et al. (2019). The antenna was fabricated on a glass substrate with a transparent ground plane. Grating lines were introduced on the radiating patch to improve the matching performance and bandwidth of the antenna.

The co-polar and cross-polar radiation patterns of the antenna were measured and compared to the radiation patterns of a simple triangular patch antenna. The radiation patterns of the two antennas were similar, with the grating triangular patch antenna exhibiting a slightly higher gain.

Brief theory and Calculations about the designed antenna

The basic front-end device of wireless communication system has been modified over the past few decades to meet the requirement of the recent technologies. Recent efforts are reported on designing antennas that can be mounted on the void transparent spaces without blocking or partially disturbing its optical transparency [1-3]. For designing such optically transparent antennas, use of various transparent conducting oxides (TCO), such as Indium Tin Oxide (ITO), Fluoride doped Tin Oxide (FTO) [4, 5], silver coated polyester (AgHT) [6], etc. are reported which inherently have some disadvantages like low gain, feeding complexities, high fabrication cost etc. [7]. These disadvantages can be overcome by designing meshed patch antenna which is an alternate way of achieving optical transparency.

A grating triangular patch antenna is a type of microstrip patch antenna that uses grating lines on the radiating patch to improve its matching performance and bandwidth. Grating lines are essentially narrow slots that are etched into the patch. The grating lines interact with the electromagnetic waves generated by the antenna to produce a wider bandwidth and better matching.

A transparent ground plane is a ground plane that is made of a material that is transparent to electromagnetic waves. Transparent ground planes are typically made of materials such as glass or sapphire.

The grating triangular patch antenna with a transparent ground plane for C-band applications operates in the following way:

1. The feed line excites the radiating patch, generating electromagnetic waves.
2. The grating lines interact with the electromagnetic waves, causing them to be scattered.
3. The scattered waves interfere with each other, resulting in a wider bandwidth and better matching.
4. The transparent ground plane allows the electromagnetic waves to radiate through the antenna.

Initially, an equilateral triangular patch is designed for its operation in the C-band (ISM) where the dimensions of the antenna are calculated from the resonance frequency equation of triangular patch

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}}$$

design for TM10 mode of operation given as
where, a is the side length dimension of the equilateral triangle and r is the effective dielectric constant of the substrate used. The antenna is fabricated on glass substrate of thickness 1 mm having a dielectric constant r = 6. Conducting copper tape is used to fabricate the antenna on the glass substrate where a mask of required dimension is used to ensure the consistency of the dimensions for different samples which are fabricated. Microstrip feedline technique is opted for exciting the patch which is also made up of conducting copper tape. Transparent silver coated polyester film (AgHT-8) is used as the ground plane whose standard conductivity is 1.25 × 105 S/m. A small portion of the conducting copper tape is fixed on the ground plane to incorporate the connector which is used for feeding the patch.

Table: Design Parameters

Parameters	Values
Designed frequency (*f*)	5.6 GHz
a	14.5 mm
s	34.0 mm
w	1.0 mm
δ	0.5 mm
d	2.4 mm
d_1	3.4 mm
d_2	5.3 mm

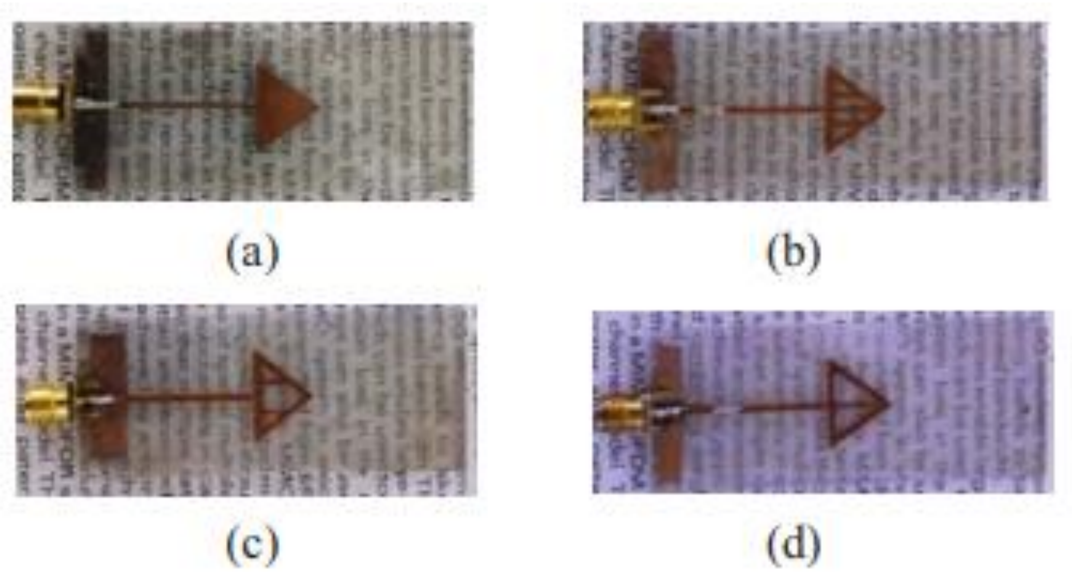


Figure: Fabricated antennas: (a) simple triangular patch (b) prototype 1 (c) prototype 2 (d) prototype 3

Explanation of the Proposed Antenna

A grating triangular patch antenna with transparent ground plane is a type of antenna that is designed to be optically transparent. This means that it can be used in applications where the antenna needs to be mounted on a transparent surface, such as a window or a solar panel. The antenna is made up of a triangular patch of metal that is etched with a series of grating lines. The grating lines help to improve the antenna's performance by increasing its bandwidth and gain.

The antenna is fabricated on a glass substrate, which is also optically transparent. The ground plane of the antenna is made of a transparent conductive oxide (TCO) material, such as indium tin oxide (ITO) or fluorine-doped tin oxide (FTO). TCO materials are highly conductive, but they are also transparent to light.

The antenna is fed using a microstrip line feed. The microstrip line feed is a narrow strip of metal that is printed on the glass substrate. The microstrip line feed is connected to the triangular patch at the center of the antenna.

The grating triangular patch antenna with transparent ground plane has a number of advantages over other types of transparent antennas. It has a high bandwidth, which means that it can be used to transmit a wide range of frequencies. It also has a high gain, which means that it can transmit and receive signals over long distances. Additionally, the antenna is relatively easy to fabricate and it is relatively inexpensive.

The grating triangular patch antenna with transparent ground plane has a number of potential applications in C-band frequencies. C-band frequencies are used for a variety of applications, including satellite communication, radar, and microwave relay. The antenna could be used to develop new types of transparent satellite communication terminals, radar systems, and microwave relay stations.

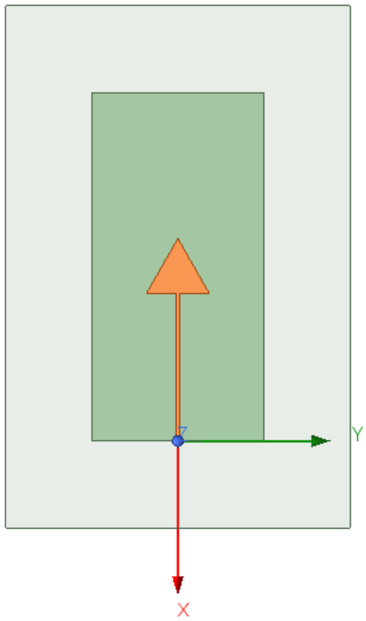
Here are some specific examples of potential applications for the grating triangular patch antenna with transparent ground plane in C-band frequencies:

Satellite communication terminals: The antenna could be used to develop new types of transparent satellite communication terminals that could be mounted on airplanes, ships, and buildings.
Radar systems: The antenna could be used to develop new types of transparent radar systems that could be used for weather forecasting, air traffic control, and military applications.
Microwave relay stations: The antenna could be used to develop new types of transparent microwave relay stations that could be used to transmit and receive data signals over long distances.
Overall, the grating triangular patch antenna with transparent ground plane is a promising new type of antenna that has a number of potential applications in C-band frequencies.

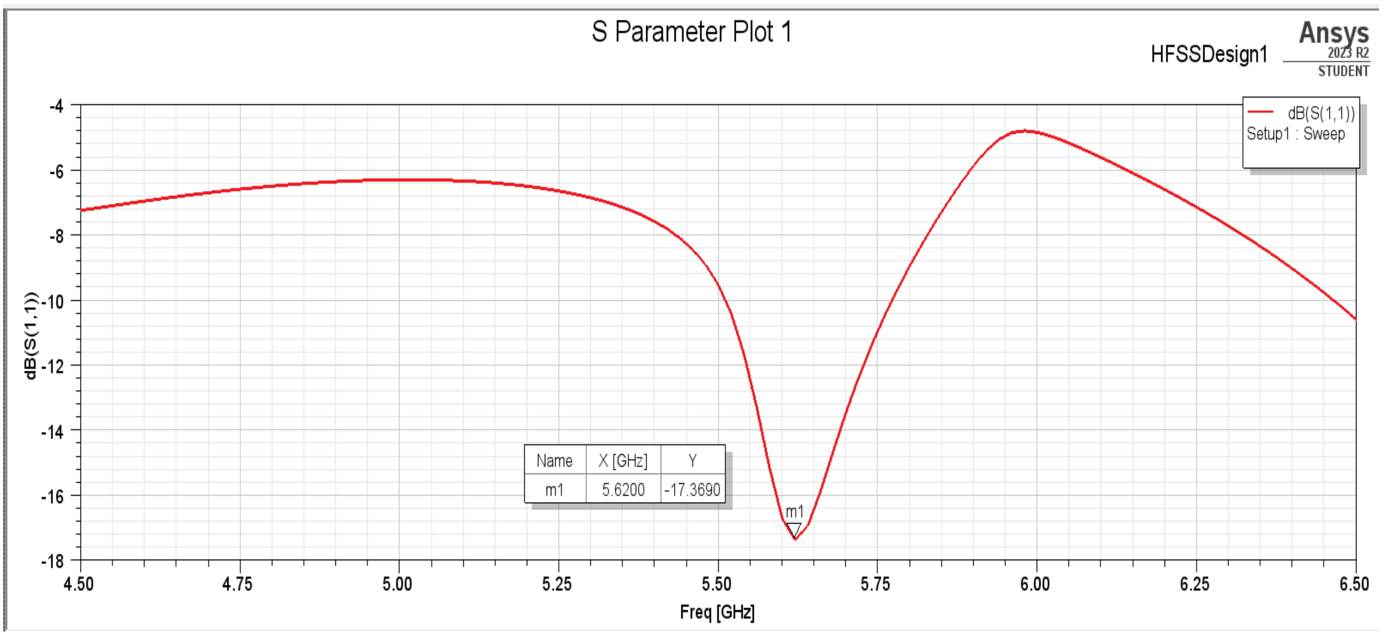
Simulation Results and Measurement Results

SIMPLE ANTENNA:

MODEL:

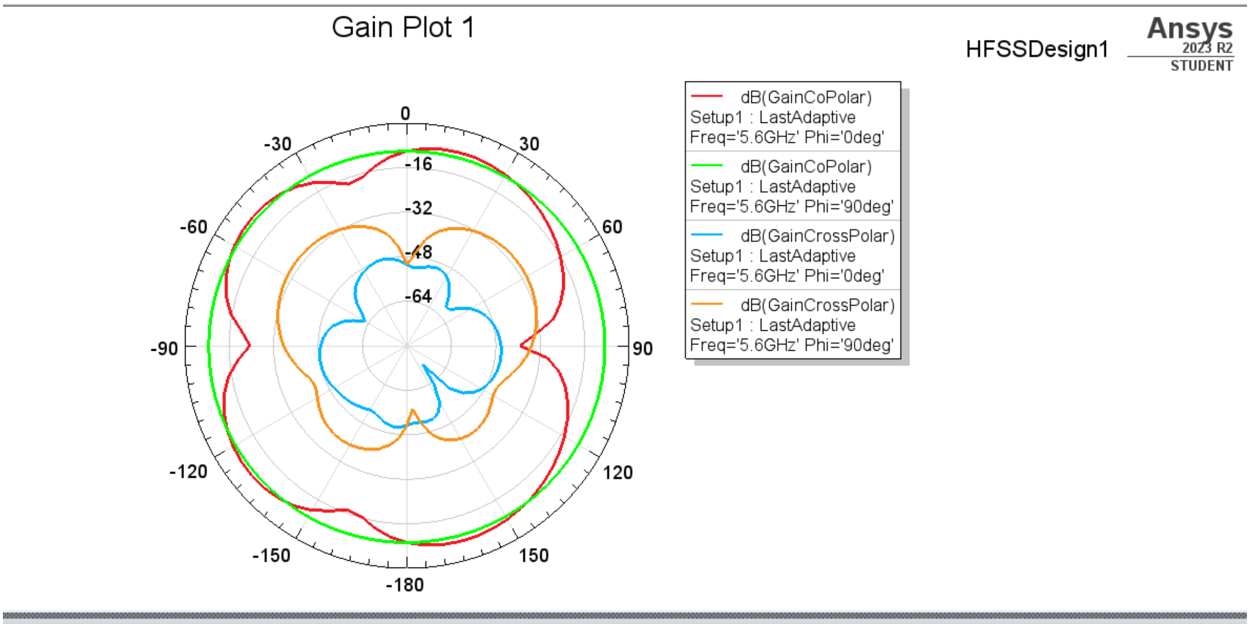


GRAPH:



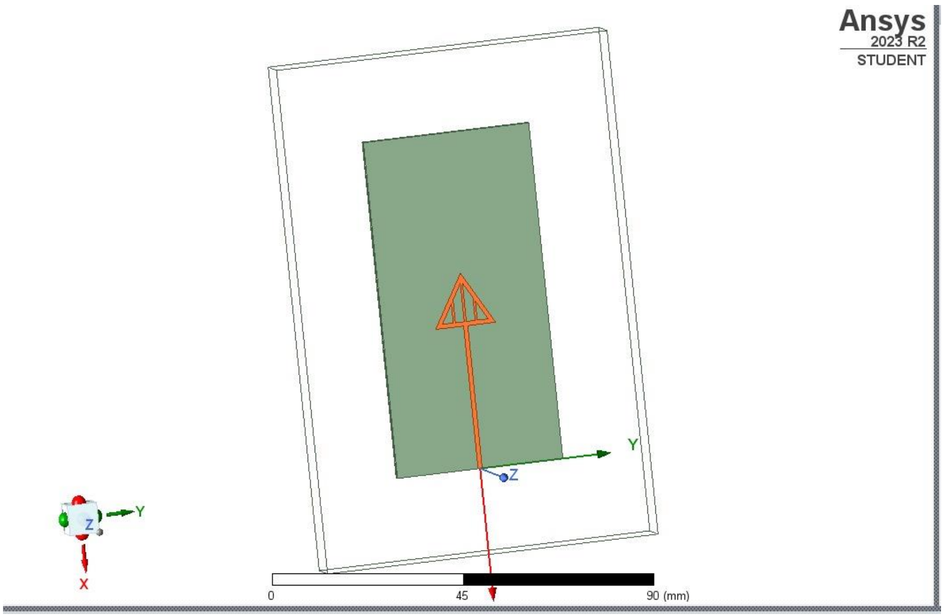
Simulated return loss plots for simple antenna with and without gratings

RADIATION PATTERN:

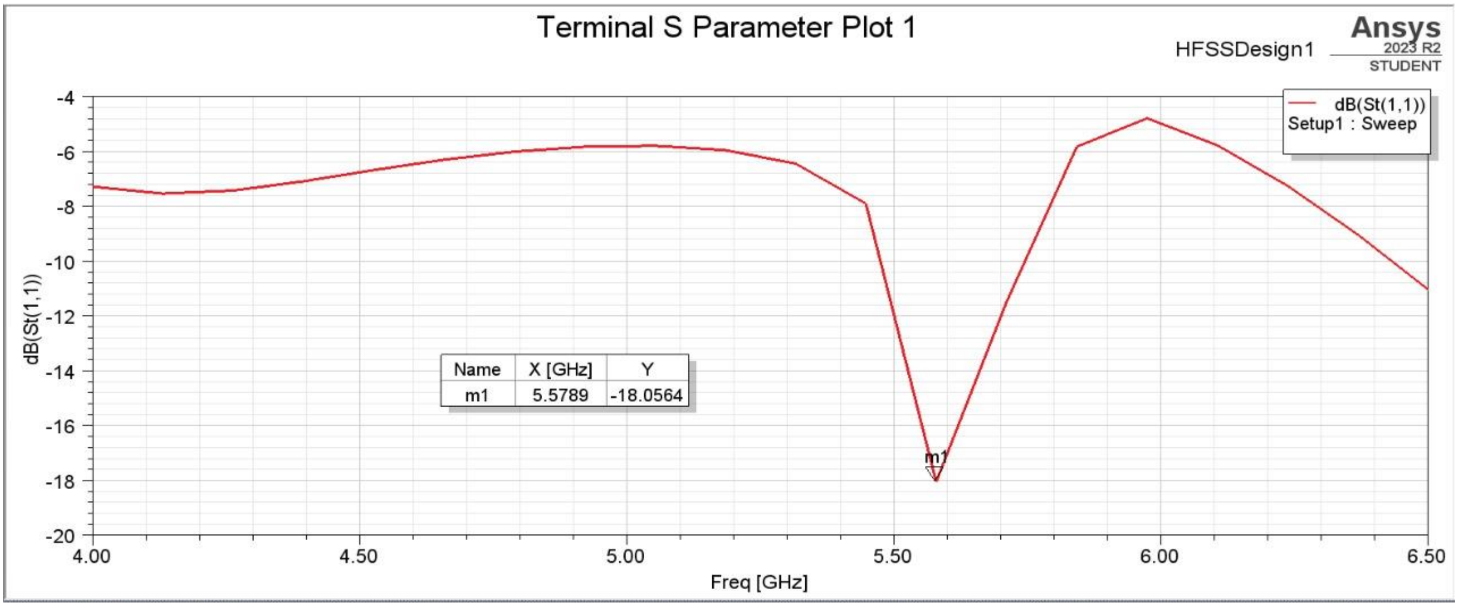


PROTOTYPE 1 ANTENNA:

MODEL:

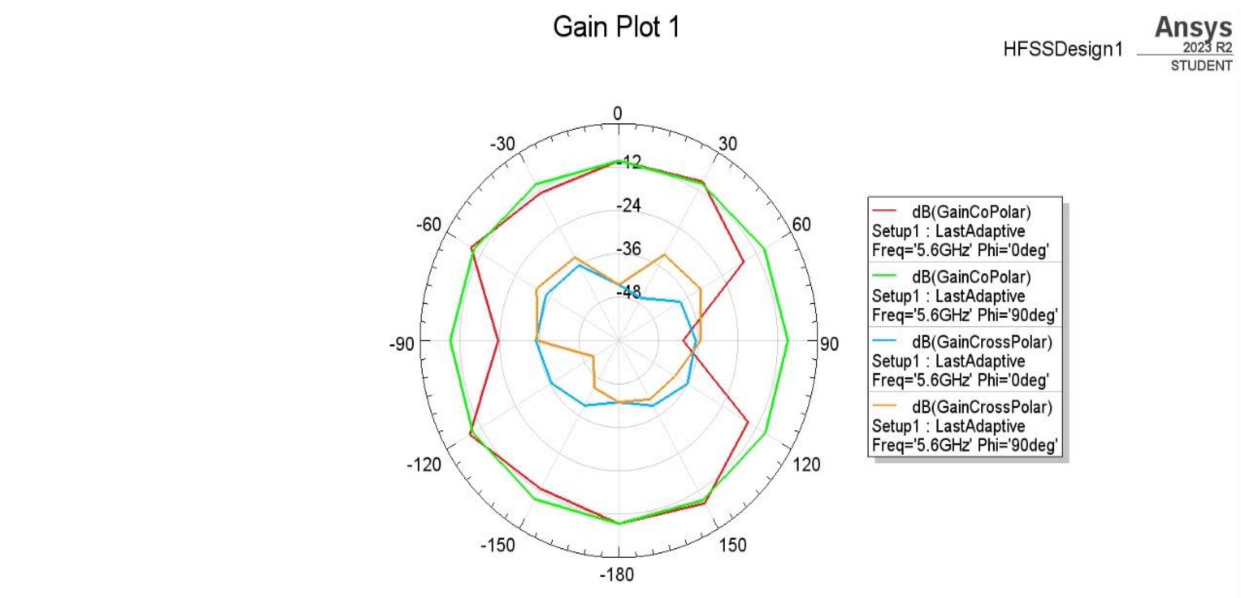


GRAPH:



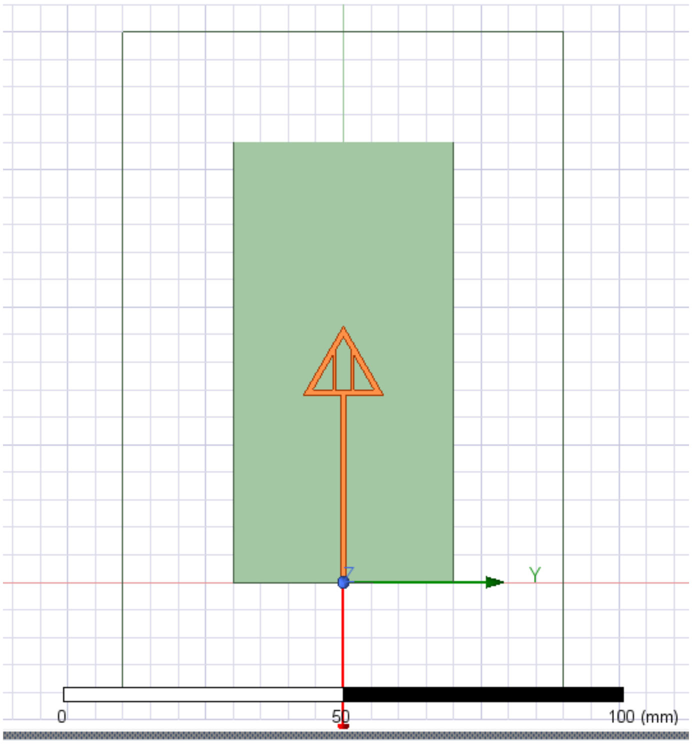
Simulated return loss plots for antenna prototype 1 with and without gratings.

RADIATION PATTERN:

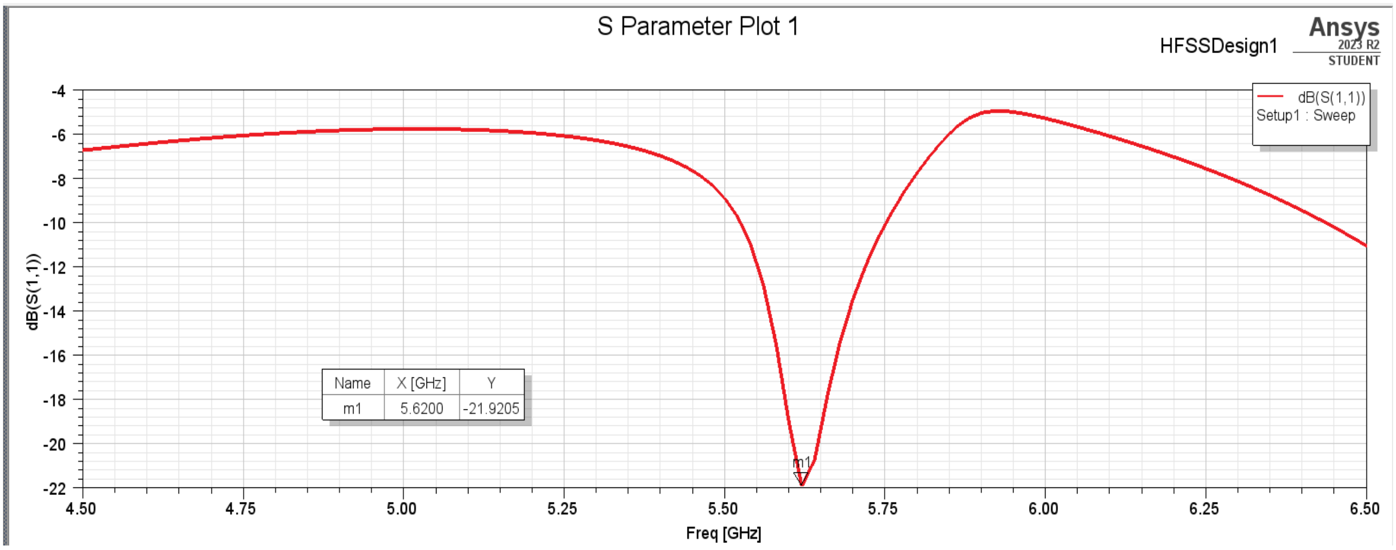


PROTOTYPE 2 ANTENNA:

MODEL:

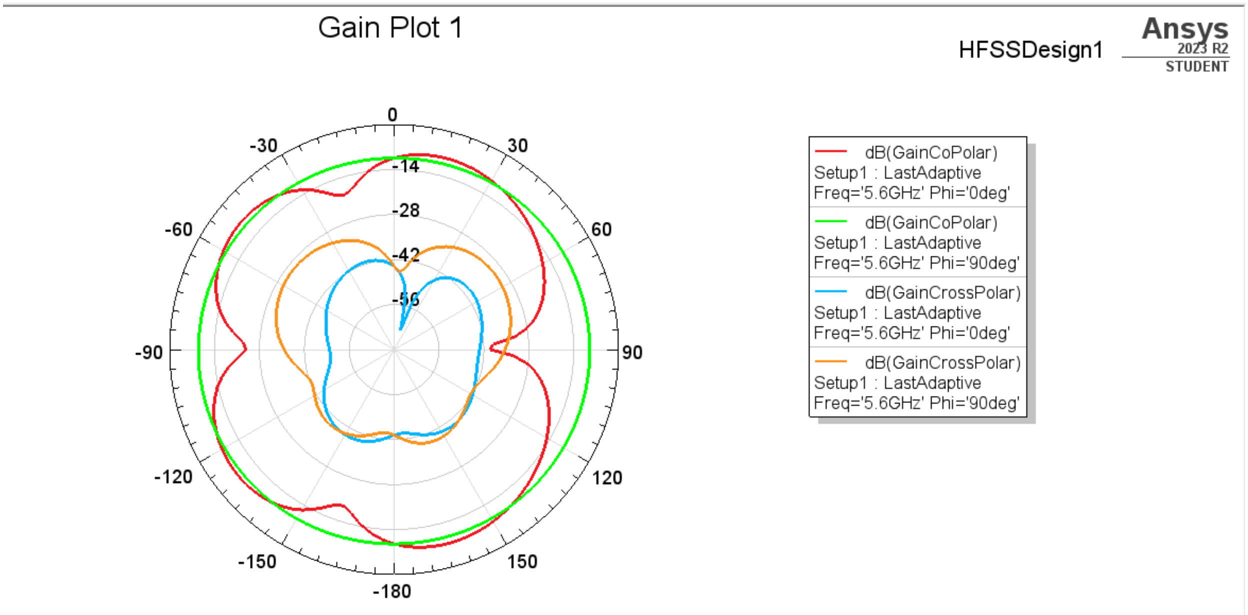


GRAPH:



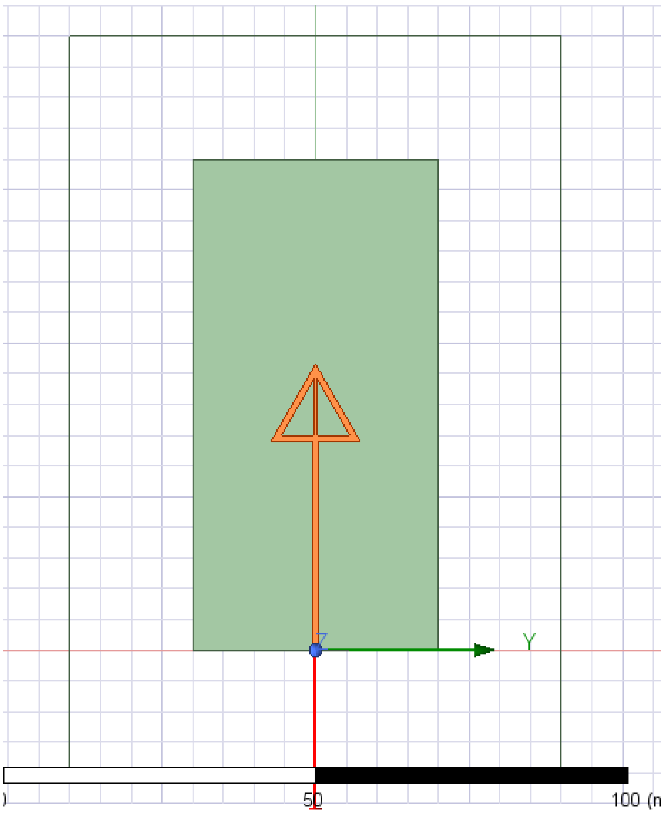
Simulated return loss plots for antenna prototype 2 with and without gratings.

RADIATION PATTERN:



PROTOTYPE 3 ANTENNA:

MODEL**:**



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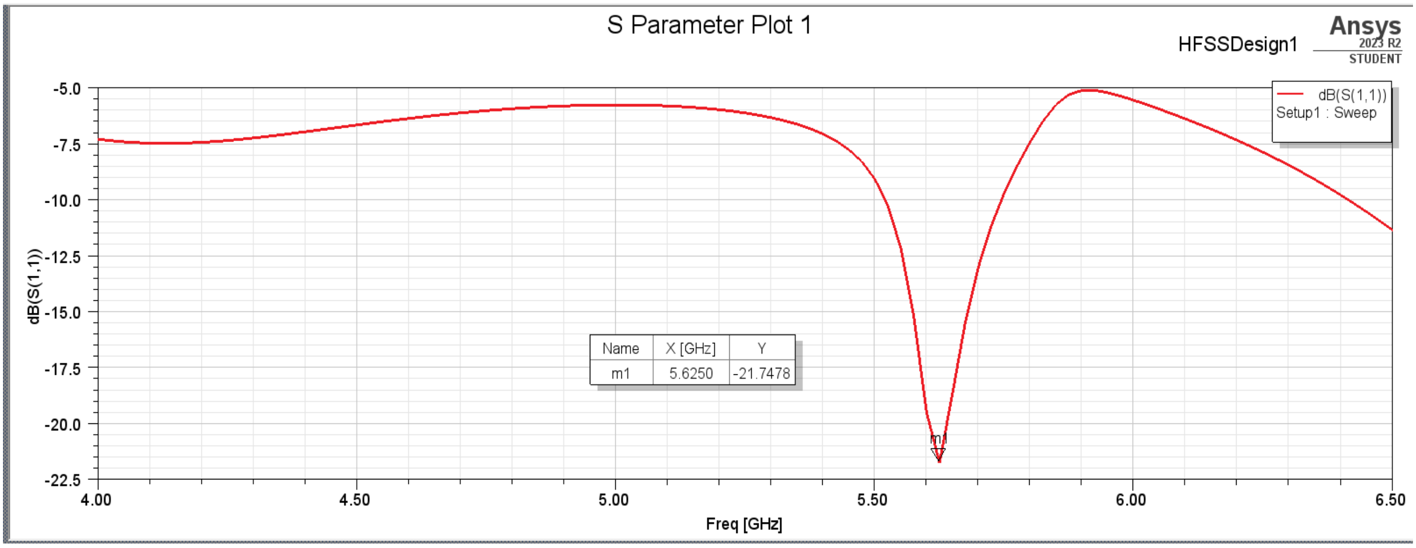

Simulated return loss plots for antenna prototype 3 with and without gratings.

RADIATION PATTERN:

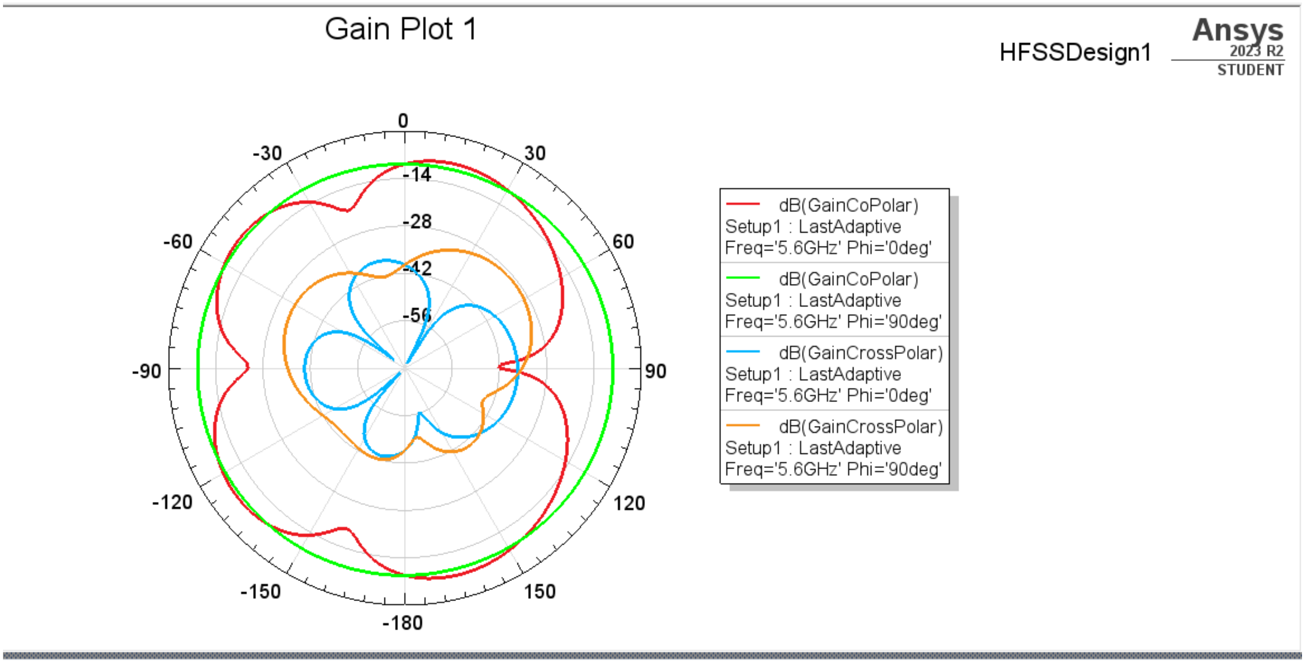

Table: Maximum return loss values at their corresponding resonant frequencies (5.6 GHz).

Antenna configuration	Results	Frequency (GHz)	S11(dB)
Simple	Simulated	5.62	-17.3690
Prototype 1	Simulated	5.5789	-18.0564
Prototype 2	**Simulated**	**5.62**	**-21.9205**
Prototype 3	Simulated	5.6250	-21.7478

Here Prototype 2 has maximum return loss compare to all 4 antennas and minimum loss occur in prototype 2 antenna.

Conclusions

In this work, a study on grating equilateral triangular patch antenna, designed and fabricated on glass substrate backed with transparent ground plane is presented. Triangular patch is opted for the design as it gives a better Q-value due to a high confinement of the field lines in it. From the measured and the simulated results, it is seen that the antenna prototype 2 shows a better matching performance with a return loss of -21.92 dB, resonating at 5.62 GHz. A shift in the resonant frequency to the lower side of the RF spectrum is observed with the change in grating line numbers, whereas the radiation pattern almost remains same as that of the simple triangular patch. Moreover, feeding complexities, high fabrication cost and other demerits that can be seen in the antennas designed with TCOs are absent in the proposed antenna design. Apart from this, the grating topology provides a better optical transparency (50.60 %) than the meshed patch antenna (45.55 %) having the same outer dimensions and line widths. The grating topology also provides a higher degree of freedom to the designers in terms of tunability due to shifting behavior of the resonant frequency.

References

1. A novel grating triangular patch antenna with transparent ground plane for C-band applications

   Pranjal Borah and Tulshi Bezboruah
   Department of Electronics and Communication Technology, Gauhati University, Assam, India