

**RF & MICROWAVE COMPONENT DESIGN LAB/CIRCUIT
SIMULATIONLAB
List of Experiments**

S.No.	Name of Experiment
1.	To Design and Simulate Rectangular Waveguide
2.	Design and simulate Quarter Wave transformer at $f = 1$ GHz.
3.	Design and Simulate Power Divider
4.	To study the Microstrip and Coaxial feeding technique
5.	To Design and Simulate planar Band pass filter at a frequency of $f = 2$ GHz.
6.	Design and simulate the Band reject filter at a frequency $f = 2$ GHz.
7.	To design and simulate cylindrical dielectric resonator antenna at resonating frequency 3.5 GHz
8.	To Design and Simulate Micro strip patch antenna at resonating frequency = 2 GHz.

Experiment No. - 1

Aim -

To Design and Simulate Rectangular Waveguide

Software Required –

CST studio

Theory-

Electromagnetic waves propagating in open space travel out in all directions. The power intensity of these waves decreases as the distance increases - it is proportional to the power of the source divided by the square of the distance. The waveguide operates by confining the electromagnetic wave inside a metallic structure so that it does not spread out, and losses resulting from this effect are eliminated. In electromagnetic , the term waveguide may refer to any linear structure that guides electromagnetic waves between two endpoints. Typically a waveguide is thought of as a transmission line comprising a hollow conducting tube, which may be rectangular or circular within which electromagnetic waves are propagated. Unlike coaxial cable, there is no centre conductor within the waveguide. Signals propagate within the confines of the metallic walls that act as boundaries. The signal is confined by total internal reflection from the walls of the waveguide. Waveguides are used principally at frequencies in the microwave range. Waveguides will only carry or propagate signals above a certain frequency, known as the cut-off frequency. Below this the waveguide is not able to carry the signals. The cut-off frequency of the waveguide depends upon its dimensions.

Rectangular Waveguide: - A rectangular waveguide is a hollow metallic tube with a rectangular cross section. The conducting walls of the waveguide confine the electromagnetic fields and thereby guide the electromagnetic wave. The rectangular waveguide is basically characterized by its dimensions i.e., length a and breadth b .

$$f_{c_{mn}} = \frac{1}{2\sqrt{\mu\epsilon}} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

Modes:-Waveguide propagation modes depend on the operating wavelength and polarization and the shape and size of the guide. The modes of the waveguide are typically classified into following types:

- TE modes (Transverse Electric) have no electric field component in the direction of propagation.
- TM modes (Transverse Magnetic) have no magnetic field component in the direction of propagation.
- TEM modes (Transverse Electromagnetic) have neither electric nor magnetic field component in the direction of propagation.

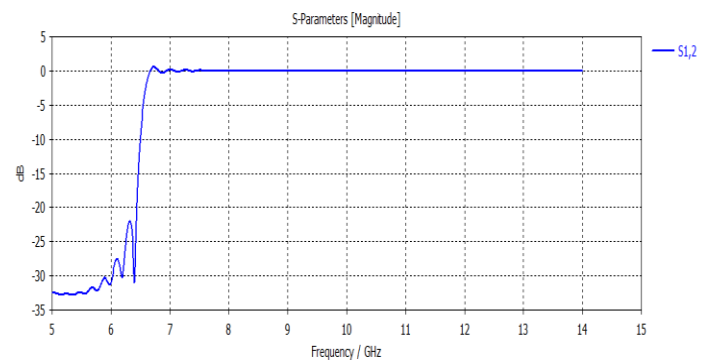
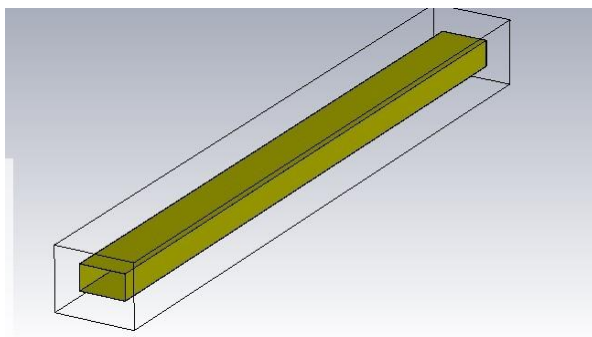
Parameters Values (in mm)

Inner substrate	Length	7.112
	Width	3.556
	Height	100
Outer substrate	Length	7.2
	Width	3.6
	Height	100

Table 6.1 Proposed Antenna Dimensions

Parameters	Values
Width (a)	22.89 mm
Height (b)	10.16 mm
Cutoff Frequency (fc)	6.56 GHz

Design and Result:



Cconclusion-

As Shown in Graph S_{11} and S_{21} is near Zero means Complete Signal is transmitted from Port 1 to Port 2 and the S_{11} is having below -60 dB signal is 10^6 times Weaker than the transmitted Signal so the All the Signal is Transmitted not Reflect the Input Port .

Experiment No. - 2

Aim

Design and simulate Quarter Wave transformer at $f = 1$ GHz.

Software Required

CST studio

Theory

A quarter-wave impedance transformer, often written as $\lambda/4$ impedance transformer, is a transmission line or waveguide used in electrical engineering of length one quarter wavelength (λ), terminated with some known impedance. It presents at its input the dual of the impedance with which it is terminated.

The relationship between the characteristic impedance, Z_0 , input impedance, Z_{in} and load impedance, Z_L is:

Alternatives to the quarter-wave impedance transformer include lumped circuits that can produce the impedance inverter function, and stubs for impedance matching.

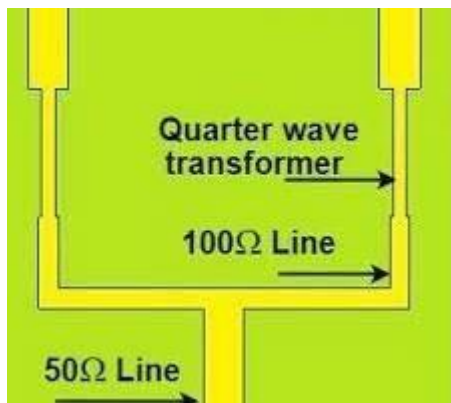
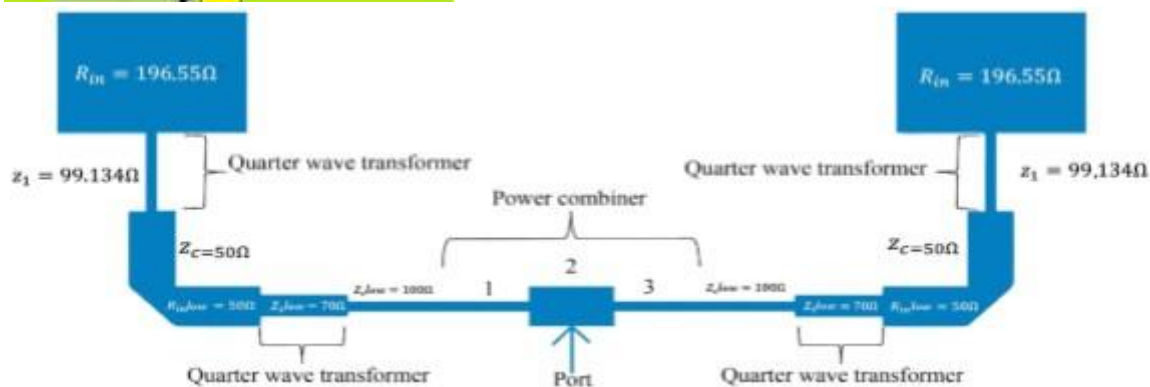


Fig- quarter wave transformer



Formula

A quarter-wave transformer is a transmission line segment that transforms the impedance at one end to a different impedance at the other end. The characteristic impedance (Z_0) of the quarter-wave transformer and the input and output impedances (Z_{in}) and (Z_{out}) are related by the following formula:

$$Z_0 = \sqrt{Z_{\text{in}} \cdot Z_{\text{out}}}$$

Where:

Z_0 is the characteristic impedance of the quarter-wave transformer,

Z_{in} is the input impedance,

Z_{out} is the output impedance.

This formula assumes that the quarter-wave transformer is an ideal transmission line and that there are no losses in the line.

Procedure

Designing a Quarter Wave Transform using CST Microwave Studio (CST MWS) involves several steps. Below is a general procedure for designing Quarter Wave Transform, along with measurements you can perform in CST:

Step 1: Define Specifications

- Determine the operating frequency (f_0) is 2 GHz of the Quarter Wave Transform.
- Design Substrate taking material, Rogger 5870(Lossy).
- Design Ground with Copper(annealed) Material.
- Choose the size and shape of the Quarter Wave Transform.

Step 2: Initial Design

- Create a new project in CST MWS.
 - Choose the Time Domain solver and set up the simulation environment.
 - Start with an initial design of the Quarter Wave Transform based on given specifications.
- ### Step 3: Simulation and Optimization

- Simulate the initial design to obtain the radiation pattern, impedance matching, and other relevant characteristics.
- Use the optimization tools in CST to fine-tune the Quarter Wave Transform (e.g., size, shape) to meet your specifications.
- Iterate the optimization process until the desired antenna performance is achieved.

DESGIN:

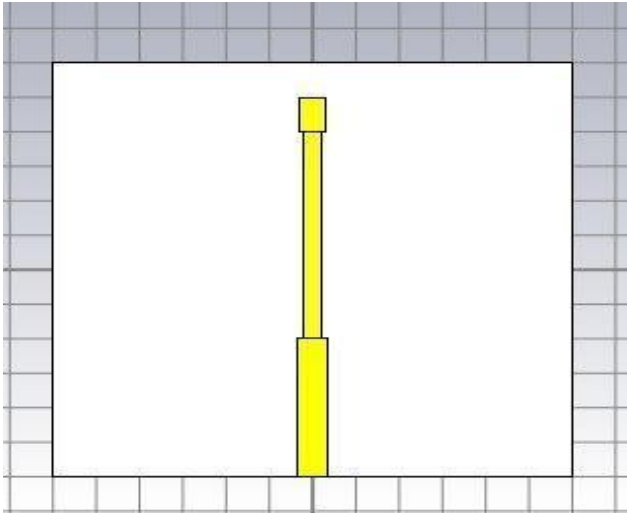


Fig- design of quarter wave transformer (front view)

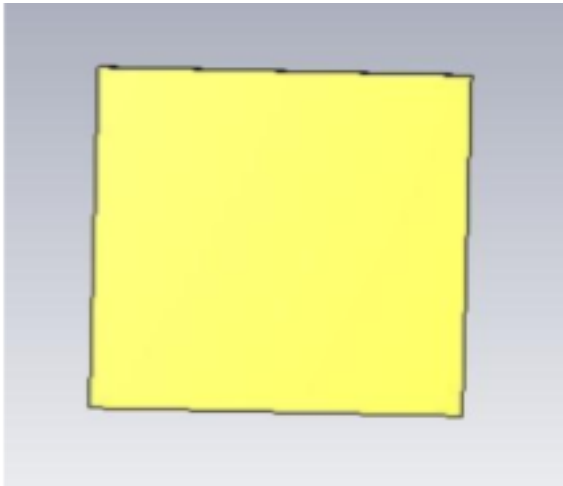
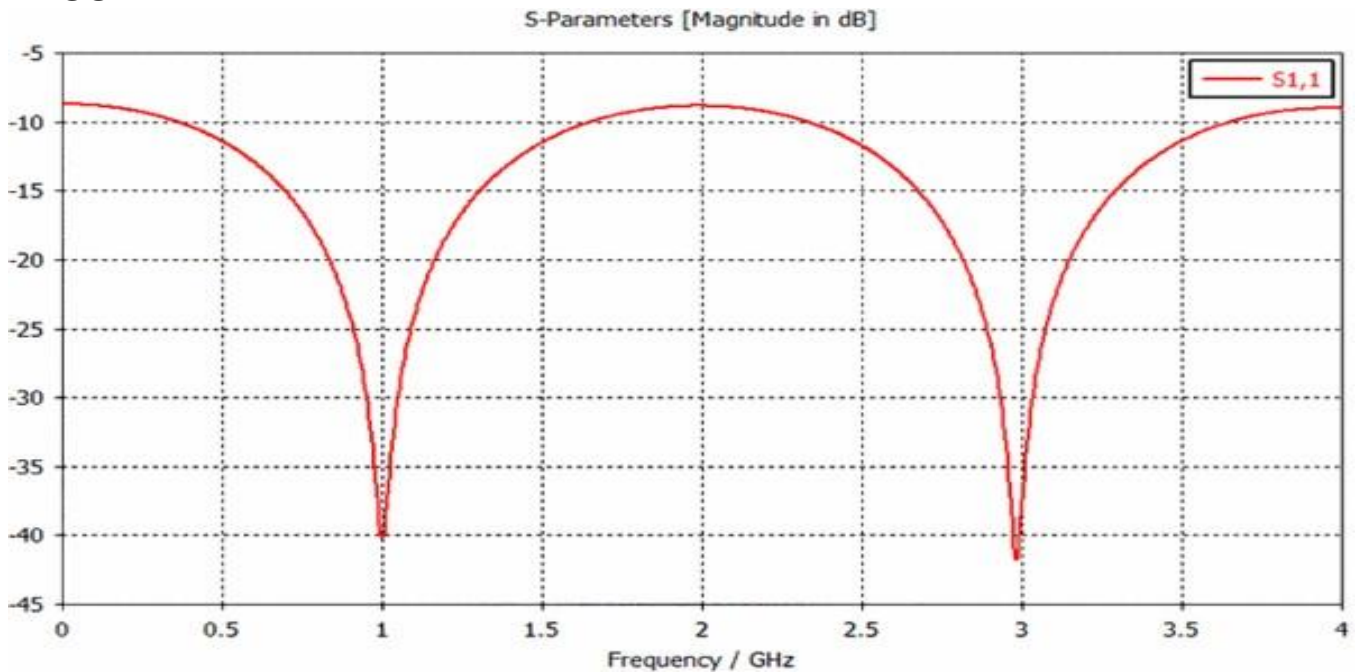


Fig - design of quarter wave transformer (back view)

Parameters table:

Parameter	Value	Description
h	0.787 mm	Substrate thickness
t	0.035 mm	Metallization thickness
eps_r	4.3	Substrate permittivity
Z0	50 Ω	System characteristic impedance
RL	100 Ω	Load impedance
W50	2.35 mm	50 Ω line width
W70	1.23 mm	70.71 Ω line width
l70	24.5 mm	Transformer length

RESULT:



Conclusion

A quarter-wave transformer is a simple impedance transformer which is commonly used in impedance matching in order to minimize the energy which is reflected when a transmission line is connected to a load. The quarter-wave transformer uses a transmission line with different characteristic impedance and with a length of one-quarter of the guided-wavelength to match a line to a load and we simulate and get the result.

Experiment No. - 3

Aim

Design and Simulate Power Divider

Software Required

CST Studio

Theory

A power divider in milli-meterwave (mm-Wave) technology is a passive microwave component used to split an input signal into multiple output signals with equal or predetermined power ratios. These devices are commonly used in mm-Wave and high-frequency applications, such as radar systems, wireless communication, and various types of sensors. The key characteristics and considerations for power dividers in mm-Wave technology are as follows:

1. Frequency Range: Power dividers designed for mm-Wave applications typically operate in frequency ranges above 30 GHz, with some applications extending into the terahertz (THz) range. They are designed to handle the high-frequency signals used in these systems.
2. Miniaturization: Due to the high operating frequencies, mm-Wave power dividers are often compact and must be designed with tight tolerances to ensure proper signal splitting and minimal loss. Miniaturization techniques, such as planar transmissionline structures and microstrip technology, are commonly employed.

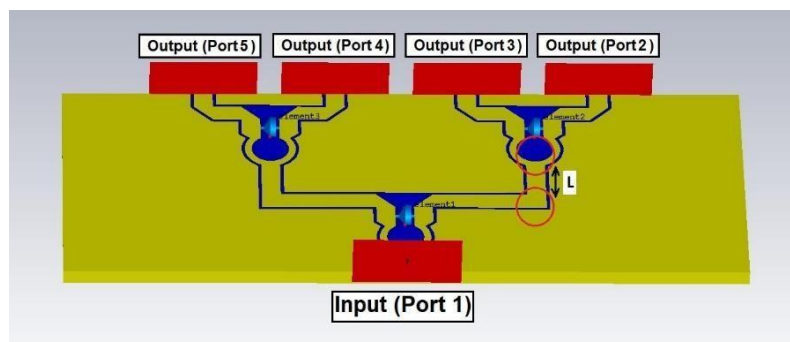
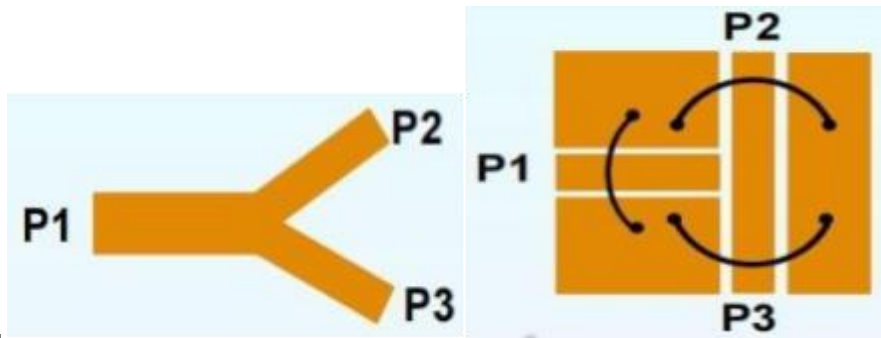


Fig No. 1 Block Diagram of Power Divider

Types of Dividers

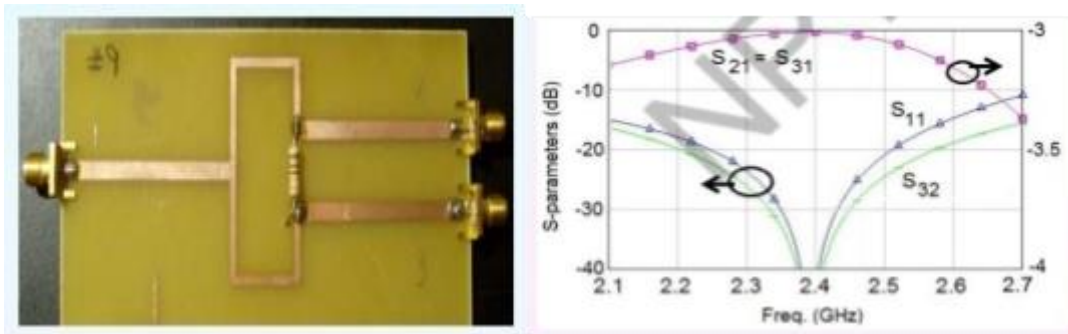
- a. Wilkinson Power Divider: This is a commonly used power divider design that provides equal power splitting and isolation between output ports. It consists of resistors and quarter-wave transmission lines
- b. T-Junction Power Divider: This type of divider uses a T-shaped junction to split the signal into two equal parts. It is relatively simple and cost effective



Micro-strip Line

CPW

T-junction power dividers.



Wilkinson Power divider frequency response.

Procedure

Designing a Power Divider using CST Microwave Studio (CST MWS) involves several steps. Below is a general procedure for designing Power Divider, along with measurements you can perform in CST:

Step 1: Define Specifications

- Determine the operating frequency (f_0) is 2 GHz of the Power Divider .
- Design Substrate taking material, Rogger 5870(Lossy).
- Design Ground with Copper(annealed) Material.
- Choose the size and shape of the cylindrical DRA.
- Calculate Z_0 for Feeding
- Design Feed by calculate Line Impedance.
- Design four bricks (Q1, Q2, Q3, Q4, Q5 & Q6).
- Add All (Q1,Q2, Q3, Q4, Q5 & Q6) by Boolean Algebra.

Step 2: Initial Design

- Create a new project in CST MWS.
- Choose the Time Domain solver and set up the simulation environment.
- Start with an initial design of the Power Divider based on given specifications.
- After Completion of Design.
- Pick face - Select macros solver, where we use port.
- For Selection of Port, First calculate port Extension Coefficient.

Step 3: Simulation and Optimization

- Simulate the initial design to obtain the antenna's radiation pattern, impedance matching, and other relevant characteristics.
- Use the optimization tools in CST to fine-tune the Power Divider parameters (e.g., size, shape) to meet your specifications.
- Iterate the optimization process until the desired performance is achieved.

Measurements

parameters	values
substrate	Width : 60mm Length : 60mm Height : 0.787mm
Ground	Width : 60mm Length : 60mm Height : 0.035mm
Feed	Width : 2.35mm Length : 60mm Height : 0.035mm

Design & Dimensions

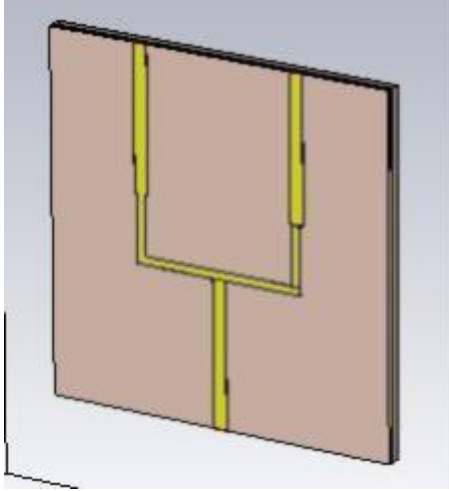


Fig - power-divider

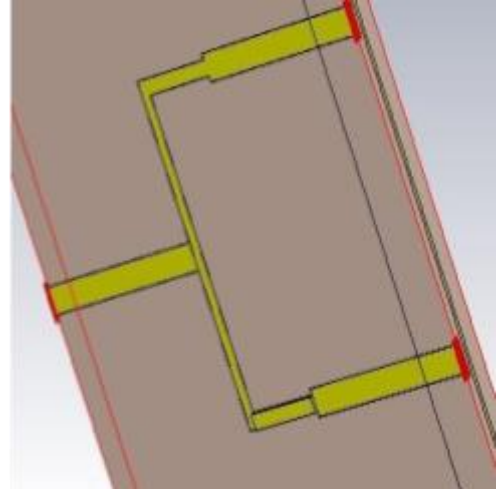
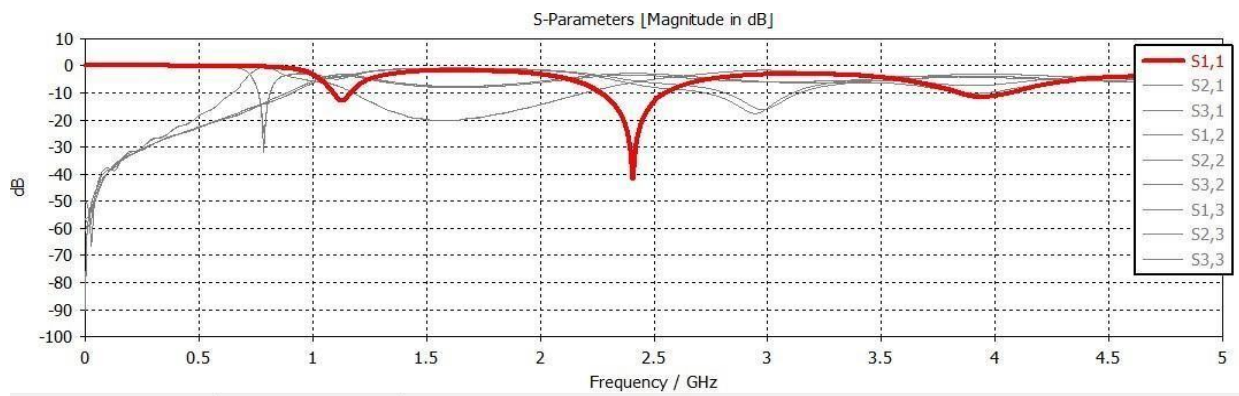
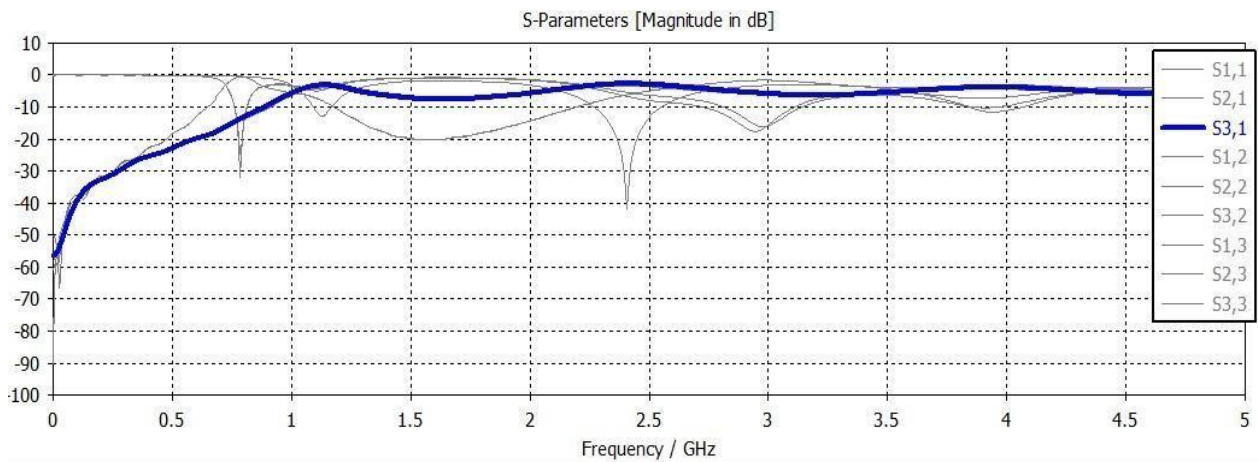
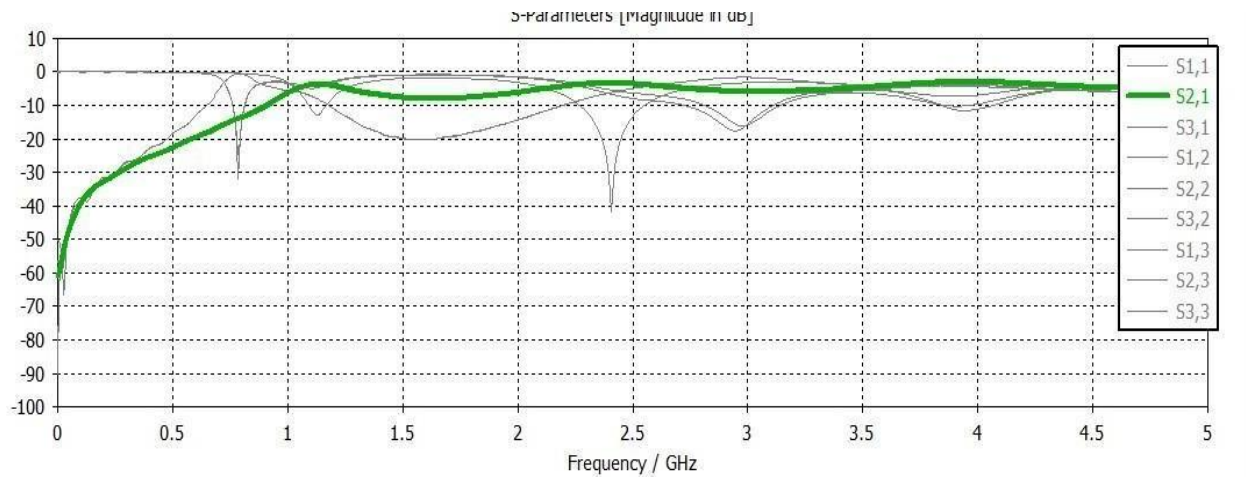


Fig- ports (1,2,3)





Conclusion

This Power Divider is Design and Simulate and Graph Shown that the poweris equally transmitted to both Port as shown in S parameter S₁₂ and S₁₃ having Same Pattern that means Port 2 and port 3 receive the same signal

Experiment No. - 4

Aim-

To study the Microstrip and Coaxial feeding technique

Materials Required -

CST Software

Theory-

Microstrip Feeding Technique -

Microstrip feed is a widely used technique in microwave and RF (radio frequency) engineering for feeding signals to antennas and other passive devices like filters and couplers. It involves a transmission line constructed on a dielectric substrate, typically with a conductive strip on one side and a ground plane on the other.

In summary, microstrip feeds are a fundamental building block in microwave and RF engineering, providing a means to efficiently transport and couple RF signals in various applications, especially those requiring planar and compact designs. Proper design and optimization of microstrip feeds are essential for achieving desired performance characteristics in these systems.

Coaxial Feeding Technique -

Coaxial feeding is a widely employed technique in the field of electronics and telecommunications. It relies on a specially designed coaxial cable, comprising an inner conductor enveloped by an insulating material and shielded by an outer conductor. This construction serves a fundamental purpose: transmitting electrical signals and power while minimizing interference. The inner conductor carries the signal, while the outer conductor acts as a protective shield, guarding against external electromagnetic disturbances. This technology finds extensive application, from delivering cable TV signals to homes to facilitating high-speed internet connections. Coaxial feeding offers the advantages of low signal loss over long distances and reliable protection from interference, making it a staple in many communication systems. However, it is important to note that coaxial cables do have bandwidth limitations compared to other technologies like optical fiber, and they can be bulkier and less flexible in certain applications.

Formula -

Microstrip Feeding:

1. Microstrip Line Characteristic Impedance (Z):

$$Z = \frac{87}{\sqrt{\epsilon_{\text{eff}}}} \ln \left(\frac{5.98h}{w+1.7t} \right)$$

Where:

Z is the characteristic impedance of the microstrip line.

ϵ_{eff} is the effective dielectric constant of the microstrip line.

h is the substrate thickness.

w is the width of the microstrip line.

t is the thickness of the microstrip conductor.

2. Microstrip Patch Resonant Frequency (f):

$$f = \frac{c}{2\sqrt{\epsilon_{\text{eff}}}} \sqrt{\frac{1}{(l+0.6w)}}$$

Where:

f is the resonant frequency of the microstrip patch antenna.

c is the speed of light.

ϵ_{eff} is the effective dielectric constant of the microstrip patch.

l is the effective electrical length of the microstrip patch.

w is the width of the microstrip patch.

Coaxial Feeding:

1. Coaxial Line Characteristic Impedance (Z):

$$Z = \frac{60}{\sqrt{\epsilon_r}} \ln \left(\frac{D}{d} \right)$$

Where:

Z is the characteristic impedance of the coaxial line.

ϵ_r is the relative permittivity of the dielectric material between the inner and outer conductors.

D is the outer diameter of the coaxial line.

d is the inner diameter of the coaxial line.

2. Velocity of Propagation (v):

$$v = \frac{c}{\sqrt{\epsilon_r}}$$

Where:

v is the velocity of propagation.

c is the speed of light.

ϵ_r is the relative permittivity of the dielectric material between the inner and outer conductors.

Procedure -

Microstrip Feeding -

Designing a microstrip-fed antenna using CST Microwave Studio (CST MWS) or similar electromagnetic simulation software involves several steps. Below is a general procedure for designing a microstrip-fed antenna, along with measurements you can perform in CST:

Step 1: Define Specifications

- Determine the operating frequency (f_0) of the antenna.
- Specify the desired radiation pattern characteristics (e.g., gain, beamwidth).
- Decide on the antenna type (e.g., patch antenna, microstrip dipole, microstrip slot antenna).
- Choose the substrate material properties (permittivity and loss tangent).
- Determine the feed type (e.g., microstrip line feed, coaxial feed, aperture-coupled feed).

Step 2: Initial Design

- Create a new project in CST MWS.
- Choose the appropriate solver and set up the simulation environment (e.g., 3D, frequency domain).
- Start with an initial antenna design based on your specifications.

Step 3: Simulation and Optimization

- Simulate the initial design to obtain the antenna's radiation pattern, impedance matching, and other relevant characteristics.
- Use the optimization tools in CST to fine-tune the antenna parameters (e.g., patch dimensions, microstrip line width, feed position) to meet your specifications.
- Iterate the optimization process until the desired antenna performance is achieved.

Step 4: Manufacturing and Fabrication

- Once you have a finalized design, export the layout or design specifications for fabrication. This may include generating Gerber files for PCB fabrication or detailed drawings for other manufacturing methods.

- Select the appropriate substrate material and thickness for constructing the microstrip-fed antenna.

Step 5: Simulation Validation

- Import the fabricated antenna structure into CST MWS for validation.
- Simulate the fabricated antenna to compare the actual performance with the simulated results.
- Adjust any discrepancies between simulation and measurement by fine-tuning the physical design if necessary.

Coaxial Feeding -

Designing an antenna with coaxial feeding using CST Microwave Studio (CST MWS) or similar electromagnetic simulation software involves several steps. Below is a general procedure for designing an antenna with coaxial feeding, along with measurements you can perform in CST:

Step 1: Define Specifications

- Determine the operating frequency (f_0) of the antenna.
- Specify the desired radiation pattern characteristics (e.g., gain, beamwidth).
- Decide on the antenna type (e.g., dipole, patch, horn, or any other type).
- Choose the substrate material properties (permittivity and loss tangent, if applicable).
- Define the coaxial feed characteristics (e.g., connector type, feed position).

Step 2: Initial Design

- Create a new project in CST MWS.
- Choose the appropriate solver and set up the simulation environment (e.g., 3D, frequency domain).
- Start with an initial antenna design based on your specifications, including the geometry and position of the coaxial feed.

Step 3: Simulation and Optimization

- Simulate the initial design to obtain the antenna's radiation pattern, impedance matching, and other relevant characteristics.

- Use the optimization tools in CST to fine-tune the antenna parameters (e.g., dimensions, feed position) to meet your specifications.
- Iterate the optimization process until the desired antenna performance is achieved.

Step 4: Manufacturing and Fabrication

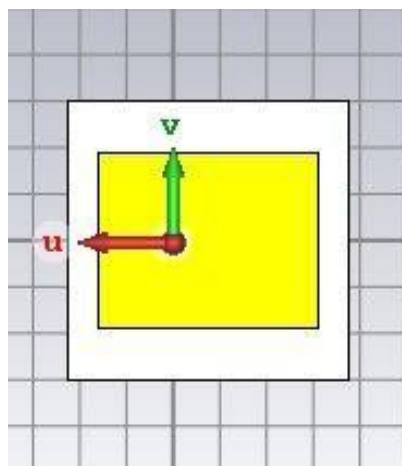
- Once you have a finalized design, export the layout or design specifications for fabrication. This may include generating manufacturing drawings or specifying material properties.
- Select the appropriate materials and fabrication methods for constructing the antenna and the coaxial feed.

Step 5: Simulation Validation

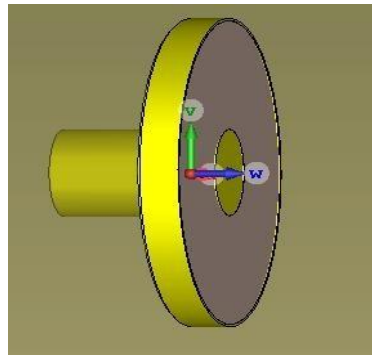
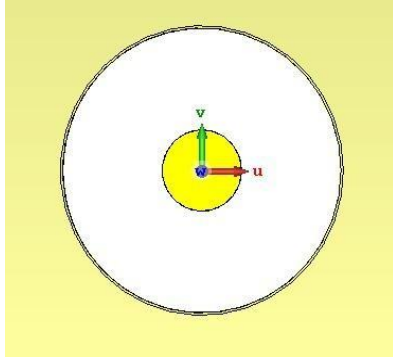
- Import the fabricated antenna structure (including the coaxial feed) into CST MWS for validation.
- Simulate the fabricated antenna to compare the actual performance with the simulated results.
- Adjust any discrepancies between simulation and measurement by fine-tuning the physical design if necessary.

Design -

Microstrip Feeding Technique -



Coaxial Feeding Technique -



Conclusion -

In conclusion, both microstrip and coaxial feeding techniques are essential and widely used methods for transmitting electrical signals and power in various electronic and telecommunication applications. Each technique has its own set of advantages and disadvantages, making them suitable for different scenarios.

Experiment No. - 5

Aim -

To Design and Simulate planar Band pass filter at a frequency of $f = 2$ GHz.

Software Required -

CST Software

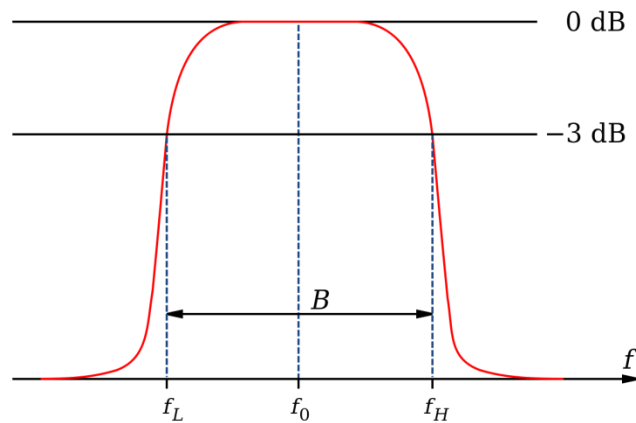


Fig. Band pass Filter

Theory -

A band pass filter is an electronic circuit or device that allows a specific range of frequencies, called the "passband," to pass through while attenuating or blocking frequencies outside of this range. Here's a brief overview of the theory behind a band pass filter:

1. **Frequency Range** - A band pass filter is designed to pass a particular range of frequencies, typically defined by a lower and upper cutoff frequency.
2. **Filter Response** - It exhibits a characteristic frequency response curve, with maximum signal transmission (gain) within the passband and reduced gain or attenuation outside of it.
3. **Components** – Band pass filters can be constructed using various electronic components like capacitors, inductors, and resistors. Different filter designs, such as LC (inductor-capacitor) filters or active filters with operational amplifiers, are used depending on the application.
4. **Formula** - The bandwidth is given by:

$$BW = f_H - f_L$$

The center frequency (f_c) of the bandpass filter is the midpoint between the lower and upper cutoff frequencies:

$$f_c = \frac{f_L + f_H}{2}$$

5. **Types** - There are different types of band pass filters, including passive and active filters.

- (i) Passive filters use passive components (capacitors, inductors, resistors) and are generally simple but may have limited performance.
- (ii) Active filters incorporate active components like operational amplifiers to achieve better control and performance.

6. **Applications** – Band pass filters are used in a wide range of applications, including radio receivers, audio processing, communication systems, and instrumentation, where isolating a specific frequency range or rejecting unwanted frequencies is essential.

Constructing a Band pass Filter

Figure 1(a) shows how a band-pass filter can be constructed by simply cascading high-pass and low-pass filter stages. The typical gain/frequency response for this arrangement is shown in Figure 1(b). The cutoff frequency of the high-pass circuit becomes the low cutoff frequency for the band pass filter, and the cutoff frequency for the low-pass circuit becomes the high cutoff frequency (f_2), as illustrated.

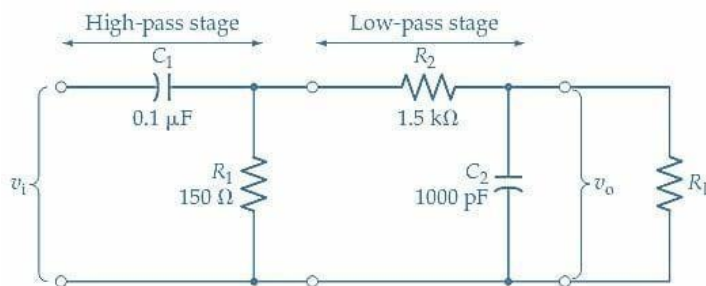


Figure -1 (a) Band pass filter constructed of high-pass and low-pass stages

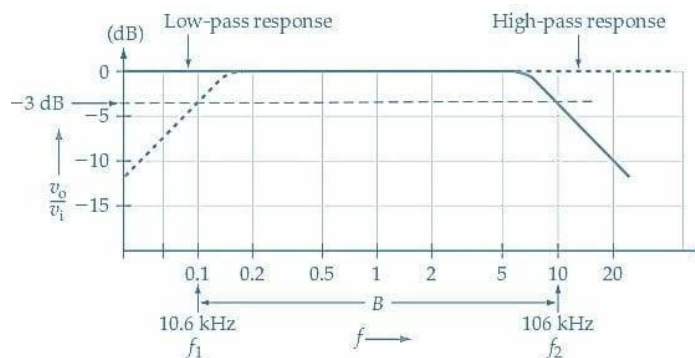


Figure -1 (b) Band pass frequency response of combined stages

Band pass filter consisting of cascade high pass and low pass stages. The high pass stages blocks signal frequency up to f_1 and the low pass stages blocks frequencies above f_2 , thus passing the band of frequency between f_1 and f_2 .

Filter

Definition - A filter is a device, mechanism, or method used to selectively allow certain elements, substances, or signals to pass through while blocking or attenuating others. Filters are employed in various fields and applications to refine, separate, or modify what can pass and what should be excluded. Filters can be physical objects, electronic circuits, software algorithms, or natural phenomena, depending on their application.

Types of Filter

- (i) **Butterworth filter**
- (ii) **Chebyshev filters**
- (iii) **Elliptic filter**

(i) Butterworth filter

A Butterworth filter, named after the British engineer and physicist Stephen Butterworth, is a type of electronic filter that has a smooth and maximally flat frequency response within its passband. In other words, it is designed to have a uniform gain or attenuation for frequencies within a certain range, with no ripples in the passband.

(ii) Chebyshev filters

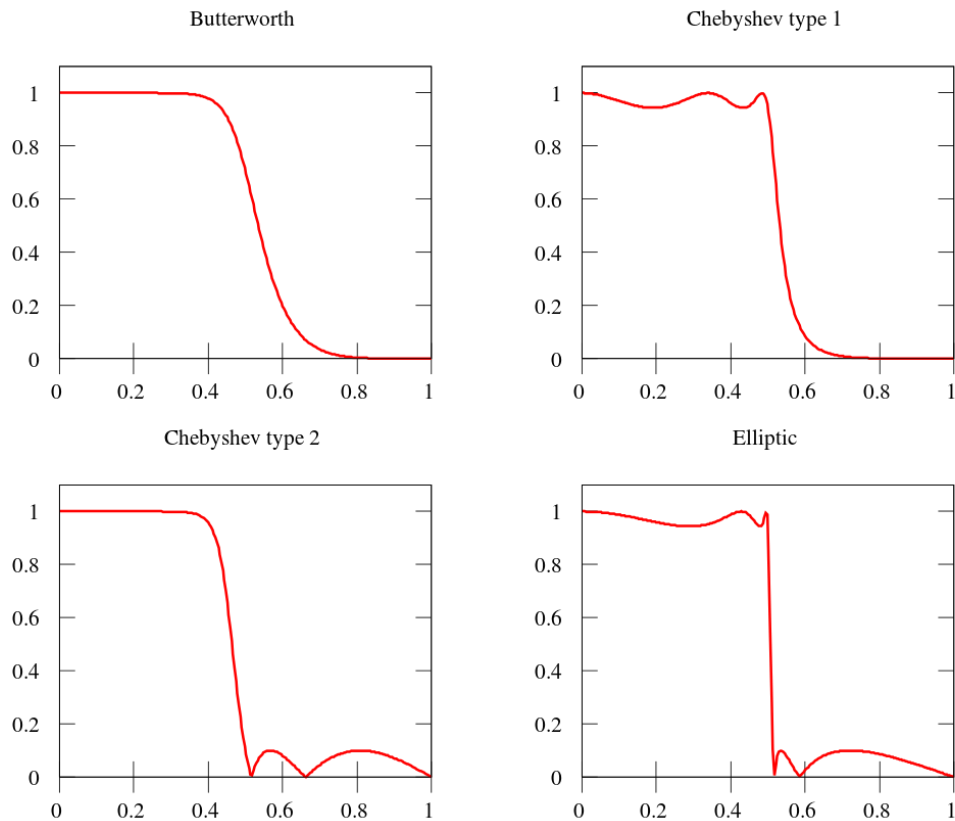
The Chebyshev filter is a type of electronic filter designed to have a specific frequency response in the passband and stopband. It is characterized by its ability to achieve a steeper roll-off rate (i.e., a more abrupt transition between passband and stopband) compared to other filter types like Butterworth filters. There are two common variations of Chebyshev filters:

Chebyshev Type I: This filter is designed to have a ripple in the passband. In other words, the filter allows for some variation in gain or attenuation within the passband to achieve a steeper roll-off in the stopband. Chebyshev Type I filters are used when it is acceptable for the signal to have some variation in amplitude within the passband.

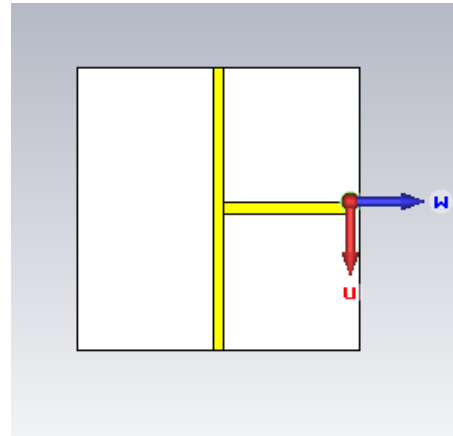
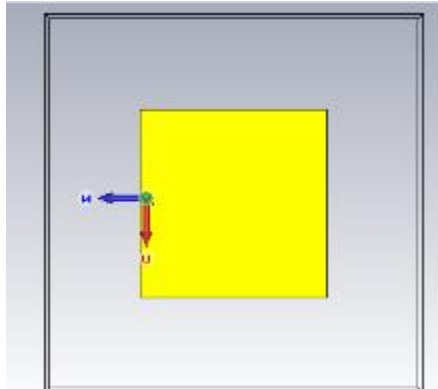
Chebyshev Type II: This filter, on the other hand, has no ripple in the passband. It is used when a flat frequency response is required within the passband. This type of Chebyshev filter achieves a steeper roll-off than the Butterworth filter at the expense of a less flat response in the passband.

(iii) Elliptic filter

An elliptic filter, also known as a Cauer filter or Zolotarev filter, is a type of electronic filter designed to have a very sharp transition between its passband and stopband while allowing for a specified level of ripple in both regions. This characteristic makes elliptic filters suitable for applications where a high degree of selectivity is required, and some variation in amplitude response is acceptable.

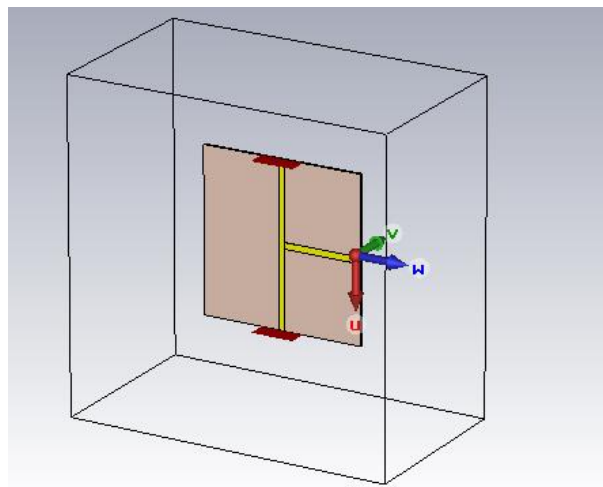


Design Band pass Filter



Design Measurement

Name	Values
(1) Substrate	30 X 30
(2) Substrate thickness	0.787 (mm)
(3) Substrate material	Rogers RT 5870 (lossy)
(4) Ground	30 X 30
(5) Ground thickness	0.035
(6) Ground material	Copper
(7) Feed	1.175 X 30
(8) Feed thickness	0.822
(9) Feed material	Copper
(10) Stub	1.175 X 1.175
(11) Stub thickness	0.787 0.787 + 0.035
(12) Stub material	Copper



Procedure – Band pass filter

Designing a band pass filter using CST Microwave Studio (CST MWS) or any other electromagnetic simulation software involves several steps. Below is a general procedure for designing a band pass filter, along with measurements you can perform in CST:

Step 1: Define Specifications

- Determine the center frequency (f_0) of your band pass filter.
- Specify the desired bandwidth (BW) of the filter.
- Define the filter's insertion loss (IL) and return loss (R_L) requirements.
- Decide on the filter topology (e.g., coupled resonator, waveguide, micro strip, etc.).

Step 2: Initial Design

- Create a new project in CST MWS.
- Choose the appropriate solver and set up the simulation environment (e.g., 3D, 2D, frequency domain, or time domain).
- Start with an initial filter design based on your specifications.

Step 3: Simulation and Optimization

- Simulate the initial design to obtain S-parameters (S_{11} , S_{21} , etc.) and analyze the performance.
- Use the optimization tools in CST to fine-tune the filter parameters (e.g., dimensions, coupling coefficients, resonator positions, etc.) to meet your specifications.
- Iterate the optimization process until the desired filter response is achieved.

Step 4: Manufacturing and Fabrication

- Once you have a finalized design, export the layout or design specifications for fabrication.
- This may include generating Gerber files for PCB fabrication or detailed drawings for other manufacturing methods.

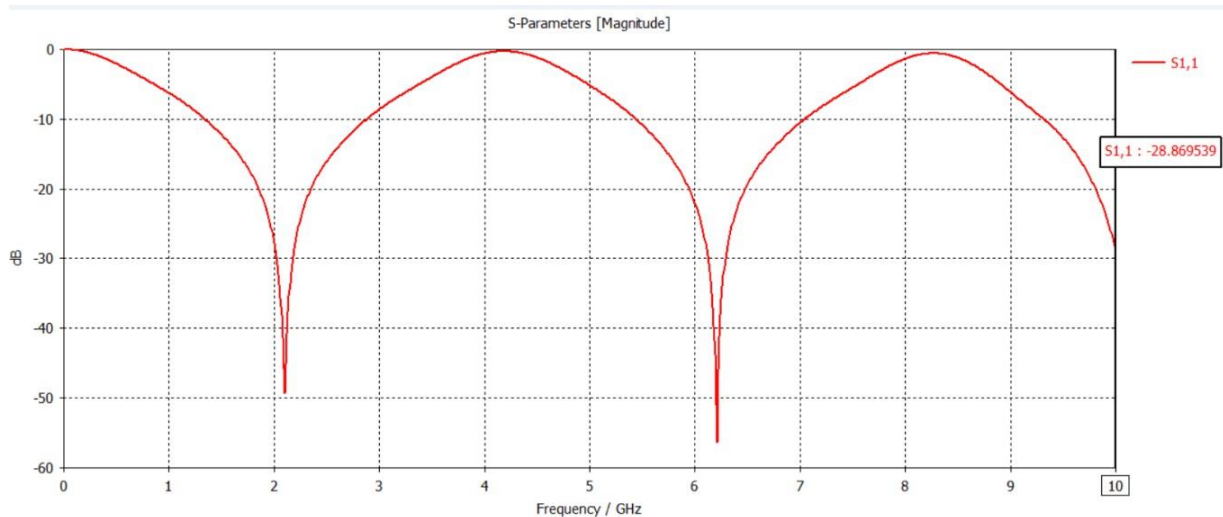
- Select the appropriate materials and manufacturing processes for your filter design.

Step 5: Simulation Validation

- Import the fabricated filter structure into CST MWS for validation.
- Simulate the fabricated filter to compare the actual performance with the simulated results.
- Adjust any discrepancies between simulation and measurement by fine-tuning the physical design if necessary

Result

S – Parameter



Experiment No. - 6

Aim -

Design and simulate the Band reject filter at a frequency 2 GHz.

Apparatus Required -

CST Software.

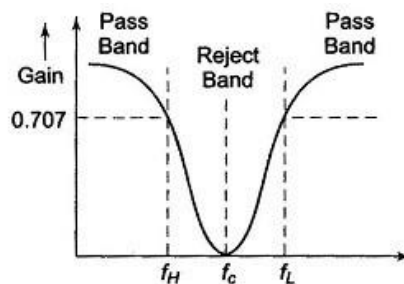


Fig. 15.20 (b) Frequency Response of a Wide Band Reject Filter

Theory

A band-reject filter, also known as a notch filter, is an electronic circuit or device designed to attenuate or reject a specific range of frequencies while allowing frequencies outside of that range to pass through. Here's a brief overview of the theory behind a band-reject filter:

- 1. Frequency Rejection:** A band-reject filter is designed to reject a certain frequency range, often referred to as the "notch" or "stopband." This means it attenuates or blocks signals within this range while letting frequencies outside the notch pass with minimal attenuation.
- 2. Filter Response:** It exhibits a characteristic frequency response curve with a deep notch in the attenuation at the center frequency of the notch. Frequencies within the notch experience high attenuation, while those outside the notch experience little attenuation.
- 3. Components:** Band-reject filters can be constructed using various electronic components, including capacitors, inductors, and resistors, in different configurations. Passive filters and active filters with operational amplifiers are common designs.
- 4. Formula -** The bandwidth is given by:

$$BW = f_H - f_L$$

The center frequency (f_c) of the bandreject filter is the midpoint between the lower and upper cutoff frequencies:

$$f_c = \frac{f_L + f_H}{2}$$

5. **Types:** There are various types of band-reject filters, including passive notch filters, active notch filters, and digital notch filters. The choice depends on the specific application and requirements.

6. **Applications:** Band-reject filters are used in applications where you need to eliminate or reduce interference or noise at specific frequencies while preserving the rest of the signal. Common applications include audio equalization, noise reduction in audio signals, and removing power line interference from sensitive measurements.

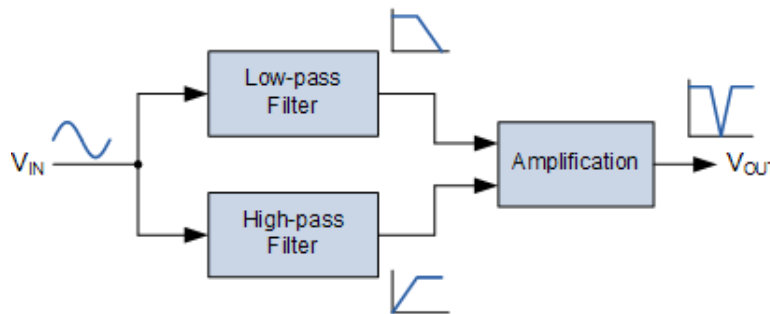


Fig. - Band Stop Filter Configuration

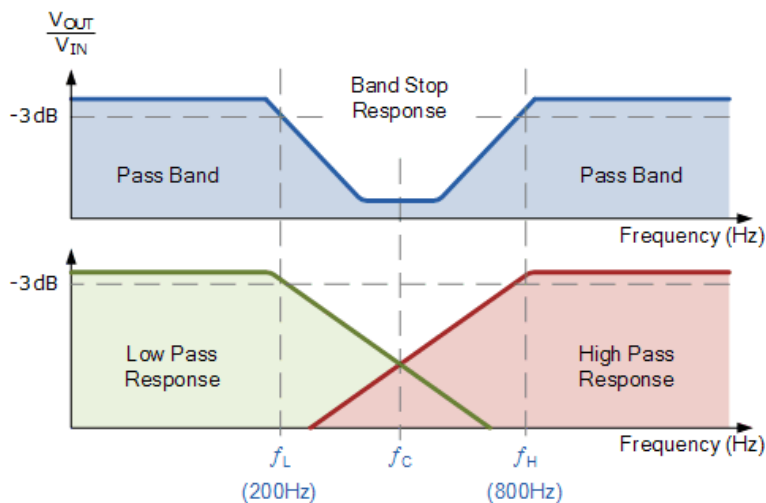


Fig. - Band Stop Filter Characteristics

A band reject filter, also known as a band stop filter or notch filter, is a filter that passes most frequencies unaltered, but attenuates those in a specific range to very low levels. It is the opposite of a band-pass filter.

Band reject filters can be implemented using a variety of different circuit topologies. One common approach is to use a combination of a low-pass filter and a high-pass filter in parallel. The low-pass filter is designed to pass frequencies below the stopband, while the high-pass filter is designed to pass frequencies above the stopband. The two filters are then connected in parallel, and the output of the parallel combination is the band reject filter output.

Another common approach to implementing band reject filters is to use a resonator. A resonator is a circuit that has a natural frequency at which it oscillates. When a signal is applied to a resonator at its natural frequency, the resonator will oscillate strongly. However, when a signal is applied to a resonator at a frequency other than its natural frequency, the resonator will oscillate weakly.

Band reject filters can be designed to have a wide or narrow stopband. A widebandband reject filter has a stopband that is many times wider than its passbands. A narrowband band reject filter, also known as a notch filter, has a stopband that is very narrow, typically only a few hertz wide.

The performance of a band reject filter is characterized by its stopband attenuation and its passband ripple. The stopband attenuation is the amount of attenuation that the filter provides to signals within the stopband. The passband ripple is the amount of variation in the filter's gain across the pass bands.

Band reject filters are an important tool in signal processing and electronics. They are used in a wide variety of applications to improve the performance of electronic systems.

Here is a simple example of how to design a band reject filter:

Determine the lower and upper cut-off frequencies of the filter. These are the frequencies that you want to reject.

Choose a type of band reject filter to design. There are many different types of band reject filters, each with its own advantages and disadvantages. Some common types of band reject filters include:

- (i) RC band reject filters
- (ii) RLC band reject filters
- (iii) Active band reject filters

Procedure – Band reject

Designing a band-reject filter (also known as a notch filter) using CST Microwave Studio (CST MWS) or similar electromagnetic simulation software involves several steps. Below is a general procedure for designing a band-reject filter, along with measurements you can perform in CST:

Step 1: Define Specifications

- Determine the center frequency (f_0) of the stopband (the frequency you want to reject).
- Specify the desired bandwidth (BW) of the notch.
- Define the filter's insertion loss (IL) and return loss (RL) requirements.
- Decide on the filter topology (e.g., coupled resonator, waveguide, microstrip, etc.).

Step 2: Initial Design

- Create a new project in CST MWS.
- Choose the appropriate solver and set up the simulation environment (e.g., 3D, 2D, frequency domain, or time domain).
- Start with an initial filter design based on your specifications.

Step 3: Simulation and Optimization

- Simulate the initial design to obtain S-parameters (S_{11} , S_{21} , etc.) and analyze the performance.
- Use the optimization tools in CST to fine-tune the filter parameters (e.g., dimensions, coupling coefficients, resonator positions, etc.) to meet your specifications.
- Iterate the optimization process until the desired filter response is achieved.

Step 4: Manufacturing and Fabrication

- Once you have a finalized design, export the layout or design specifications for fabrication.
- This may include generating Gerber files for PCB fabrication or detailed drawings for other

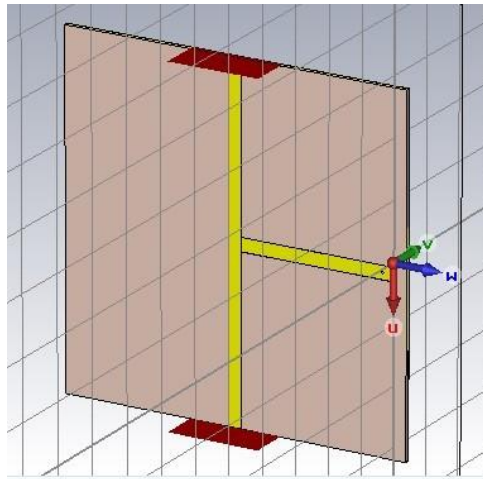
- manufacturing methods.
- Select the appropriate materials and manufacturing processes for your filter design.

Step 5: Simulation Validation

- Import the fabricated filter structure into CST MWS for validation.
- Simulate the fabricated filter to compare the actual performance with the simulated results.
- Adjust any discrepancies between simulation and measurement by fine-tuning the physical design if necessary

Design and Design measurement

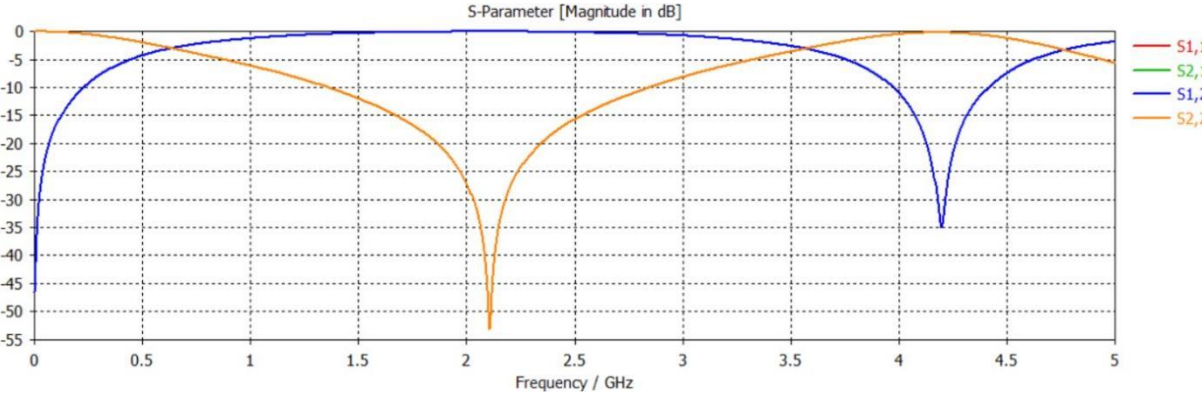
Planar Band reject filter



Name	Values
(1) Substrate	30 X 30
(2) Substrate thickness	0.787 (mm)
(3) Substrate material	Rogers RT 5870 (lossy)
(4) Ground	30 X 30
(5) Ground thickness	0.035
(6) Ground material	Copper
(7) Feed	1.175 X 30
(8) Feed thickness	0.822
(9) Feed material	Copper
(10) Stub	1.175 X 1.175
(11) Stub thickness	0.787 0.787 + 0.035

(12) Stub material	Copper
--------------------	--------

Result
S – Parameter



Experiment No. 7

Aim -

To design and simulate cylindrical dielectric resonator antenna at resonating frequency 3.5 GHz

Materials Required -

CST Software

Theory -

A cylindrical dielectric resonator antenna (DRA) is an innovative and efficient type of antenna that leverages the properties of dielectric materials to achieve desirable radiation characteristics. This antenna consists of a cylindrical-shaped dielectric material, often ceramic, which is excited by an external feed or a probe. The cylindrical DRA exploits the resonant properties of the dielectric material to efficiently radiate electromagnetic waves. When the dimensions of the cylindrical DRA are carefully chosen to match the wavelength of the desired frequency, resonance occurs, leading to enhanced radiation efficiency and bandwidth.

One of the significant advantages of cylindrical DRA is its compact size compared to traditional antennas. Its cylindrical shape allows for a reduced footprint, making it suitable for applications with limited space constraints. Additionally, cylindrical DRAs exhibit low-profile designs, making them suitable for integration into various wireless communication devices and systems.

Furthermore, the dielectric material within the antenna helps focus the electromagnetic energy, enhancing radiation efficiency and reducing the antenna's sensitivity to nearby objects and ground planes. This feature is particularly valuable in applications where isolation from environmental factors or interference is crucial.

In summary, cylindrical dielectric resonator antennas offer an innovative solution for achieving compact, efficient, and low-profile antennas in modern wireless communication systems. Their reliance on dielectric resonant properties allows for improved radiation efficiency and reduced sensitivity to surrounding objects, making them a valuable choice for a range of communication applications.

Formula -

The design of a cylindrical dielectric resonator antenna (DRA) involves several parameters, and specific formulas may vary based on the exact geometry and configuration of the antenna. However, I can provide you with some general information and formulas commonly associated with cylindrical dielectric resonator antennas:

The resonant frequency of the cylindrical DRA can be estimated using the following formula:

$$f = \frac{c}{2\pi} \sqrt{\frac{\epsilon_r}{V}}$$

where:

f is the resonant frequency,

c is the speed of light,

ϵ_r is the relative permittivity of the dielectric material,

V is the volume of the cylindrical DRA.

Procedure -

Designing a Cylindrical Dielectric Resonator Antenna (DRA) using CST Microwave Studio (CST MWS) or similar electromagnetic simulation software involves several steps. Below is a general procedure for designing a cylindrical DRA, along with measurements you can perform in CST:

Step 1: Define Specifications

- Determine the operating frequency (f_0) of the cylindrical DRA.
- Specify the desired radiation pattern characteristics (e.g., gain, beamwidth).
- Decide on the material properties of the dielectric resonator (permittivity and loss tangent).
- Choose the size and shape of the cylindrical DRA.

Step 2: Initial Design

- Create a new project in CST MWS.
- Choose the appropriate solver and set up the simulation environment (e.g., 3D, frequency domain).
- Start with an initial design of the cylindrical DRA based on your specifications.

Step 3: Simulation and Optimization

- Simulate the initial design to obtain the antenna's radiation pattern, impedance matching, and other relevant characteristics.

- Use the optimization tools in CST to fine-tune the DRA parameters (e.g., size, shape) to meet your specifications.
- Iterate the optimization process until the desired antenna performance is achieved.

Step 4: Manufacturing and Fabrication

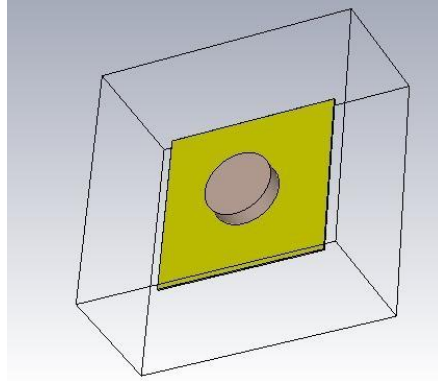
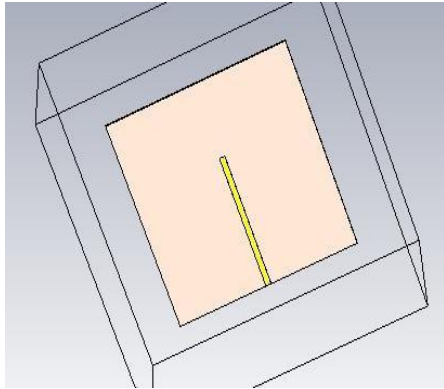
- Once you have a finalized design, export the layout or design specifications for fabrication. This may include generating manufacturing drawings or specifications for the dielectric resonator.
- Select the appropriate materials for constructing the cylindrical DRA, considering the dielectric properties specified in your design.

Step 5: Simulation Validation

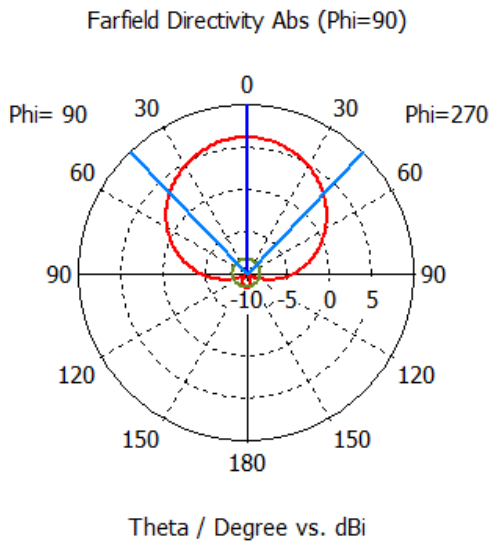
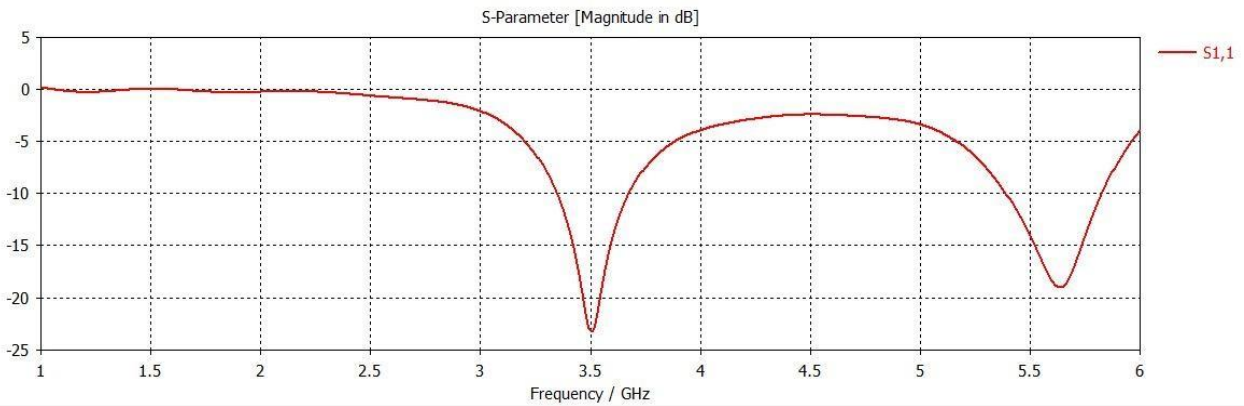
- Import the fabricated cylindrical DRA structure into CST MWS for validation.
- Simulate the fabricated DRA to compare the actual performance with the simulated results.
- Adjust any discrepancies between simulation and measurement by fine-tuning the physical design if necessary.

Design and Measurement -

Name	Values
Substrate	40 X 40 mm
Substrate thickness	0.787 mm
Substrate material	Roggers RT5870 (lossy)
Ground	40 X 40 mm
Ground thickness	0.787 mm
Ground material	Copper (annealed)
Feed	40 X 1.175 mm
Feed thickness	0.035 mm
Feed material	Copper (annealed)
DRA Radius	16
DRA Material	Alumina (lossy)

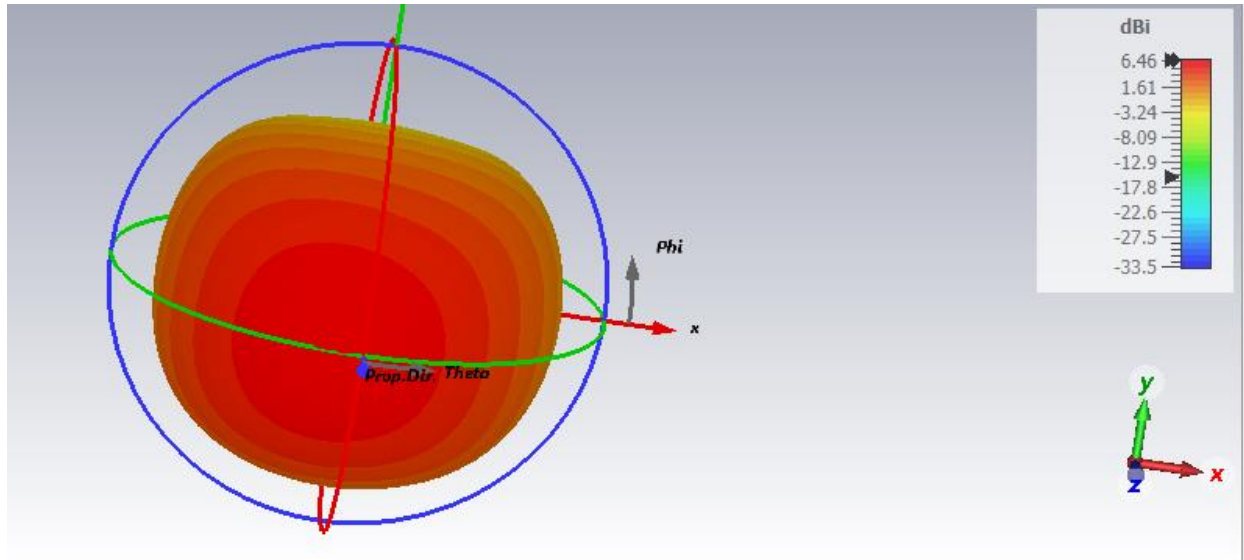


Result -



— farfield (f=3.5) [1]

Frequency = 3.5 GHz
 Main lobe magnitude = 6.13 dBi
 Main lobe direction = 0.0 deg.
 Angular width (3 dB) = 88.3 deg.
 Side lobe level = -14.3 dB



Conclusion -

In conclusion, the cylindrical dielectric resonator antenna (DRA) represents a significant advancement in antenna technology, offering a compact, efficient, and low-profile solution for various wireless communication applications. By exploiting the resonant properties of dielectric materials, cylindrical DRAs achieve enhanced radiation efficiency and bandwidth, making them well-suited for modern communication systems.

Experiment No. - 8

Aim

To Design and Simulate Micro strip patch antenna at resonating frequency = 2 GHz.

Software Required

CST studio

Theory

The Micro strip Patch Antenna is a streamlined design comprising four essential elements: the patch, ground plane, substrate, and feeding part. Classified as a single-element resonant antenna, its characteristics are fixed once the frequency is determined. The patch, a slender metal strip or array, sits on one side of a non-conductive substrate, with the ground plane mirroring it on the other side. Typically crafted from thin copper foil coated with corrosion-resistant metals like gold or nickel, the patch can take various shapes, with rectangular and circular being the most prevalent. The substrate, crucial for spacing and support, is thin, with a thickness ranging from 0.01 to 0.05 of the free-space wavelength. High dielectric-constant materials are sometimes used to both support and reduce patch size. For employed.

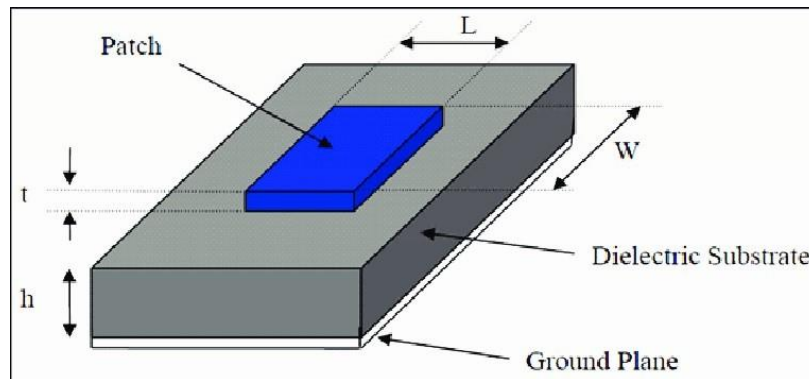


Fig5.1: Micro strip patch antenna

The frequency of operation of the patch antenna 1 is determined by the length L. The center frequency will be approximately given:

$$f_c \approx \frac{c}{2L\sqrt{\epsilon_r}} = \frac{1}{2L\sqrt{\epsilon_0\epsilon_r\mu_0}}$$

$$\epsilon_{eff} = \frac{\epsilon_R + 1}{2} + \frac{\epsilon_R - 1}{2} \left[\frac{1}{\sqrt{1 + 12 \left(\frac{h}{W} \right)}} \right]$$

$$W = \frac{c}{2f_0 \sqrt{\frac{\epsilon_R + 1}{2}}}$$

$$L = \frac{c}{2f_0 \sqrt{\epsilon_{eff}}} - 0.824h \left(\frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8 \right)} \right)$$

Substrate materials fall into three categories based on dielectric constants:

1. Those with a dielectric constant between 1.0 and 2.0, including air, polystyrene foam, or dielectric honeycomb.
2. Materials with ϵ_r in the range of 2.0–4.0, often composed mostly of fiberglass-reinforced Teflon.
3. Materials with a dielectric constant between 4 and 10, such as ceramic, quartz, or alumina.

Microstrip antennas offer advantages like compact size, low profile, and light weight, making them adaptable to planar and non-planar surfaces. They occupy minimal volume when mounted and are cost-effective to manufacture using contemporary printed-circuit technology. However, they come with drawbacks, notably low efficiency, a narrow bandwidth of less than 5%, and low RF power due to the limited separation between the radiation patch and the ground plane, making them unsuitable for high-power applied.

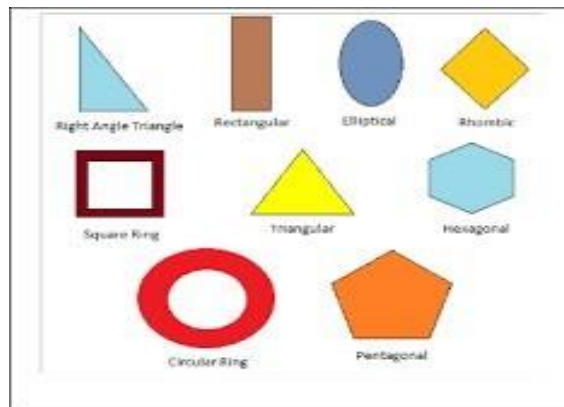


Fig5.2: Most frequently encountered forms of patch antennas

Feeding Methods:

Various methods exist for feeding a micro strip antenna, with the most popular ones being:

1. Micro strip Line.
2. Coaxial Probe (coplanar feed).
3. Proximity Coupling.
4. Aperture Coupling.

Given that the antenna radiates from one side of the substrate, feeding can occur from the other side (ground plane) or from the side of the element. The paramount consideration is achieving maximum power transfer—ensuring the feed line matches the antenna's input impedance.

Advantages of Microstrip Antennas:

- Low profile (can even be “conformal,” i.e. flexible to conform to a surface).
- Easy to fabricate (use etching and photolithography).
- Easy to feed (coaxial cable, microstrip line, etc.).
- Easy to incorporate with other microstrip circuit elements and integrate into systems.
- Patterns are somewhat hemispherical, with a moderate directivity (about 6-8 dB is typical).
- Easy to use in an array to increase the directivity.

Disadvantages of Microstrip Antennas :

- Low bandwidth (but can be improved by a variety of techniques). Bandwidths of a few percent are typical. Bandwidth is roughly proportional to the substrate thickness and inversely proportional to the substrate permittivity.
- Efficiency may be lower than with other antennas. Efficiency is limited by conductor and dielectric losses*, and by surface-wave loss**.
- Only used at microwave frequencies and above (the substrate becomes too large at lower frequencies).
- Cannot handle extremely large amounts of power (dielectric breakdown).

Antenna Design and its Dimensions:

The proposed antenna geometry containing of a dielectric substrate, patch along with microstrip feed line, is shown in Fig 1. The rectangular patch is separated from the ground plane with FR-4 Epoxy Dielectric substrate with the above-shown dimensions.

Parameters Values (in mm)

substrate	length		60	
	width		60	
	height		1.6	
patch	length		47	
	width		38	
	height		0.035	
ground	length		60	
	width		60	
	height		0.035	
ϵ_r			2.33	
ϵ_{eff}			2.13	
L			38	
h			1.6	
w			48	
feeding	Inner conduct or	radius	Outer	0.6
			inner	0
		width	Wmin	-2*.035-1.6
			Wmax	Add=0.5
	Outer conducto r	radiu s	Outer	2.1+.035
			inner	2.1
		width	Wmin	0
			Wmax	Add=0.5
	teflon	Radius	outer	2.1
			inner	0.6
		width	Wmin	-0.035
			Wmax	Add=0.5

Table5.1Proposed Antenna Dimensions

All the dimension of designed parameters of MPA is shown above in Table 1(All coordinates are drawn from center origin). The figure beneath shows a structure of a rectangular microstrip patch antenna. It consists of a dielectric substrate (R-5870), patch, and ground plane.

In this experiment we have designed microstrip patch antenna at 2.4 GHz from above formula for which Width will be 49.25mm and effective permittivity 2.22 and length effective will be 41.94mm.

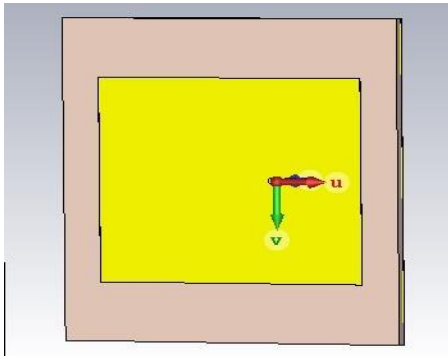


Fig- 5.3 front view

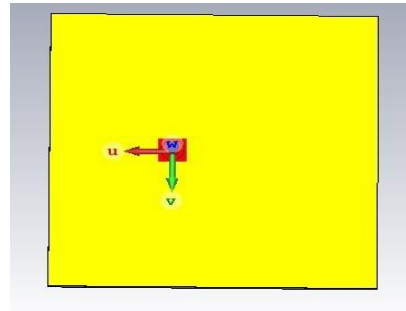


Fig-5.4 back view

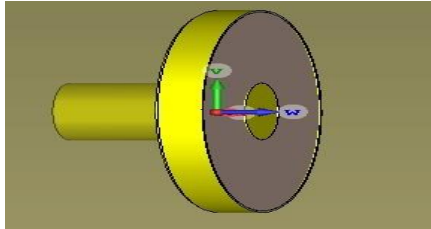


fig- 5.5 claxial feeing(side view)

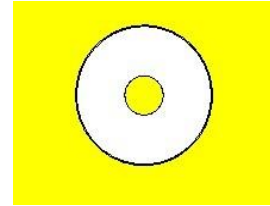
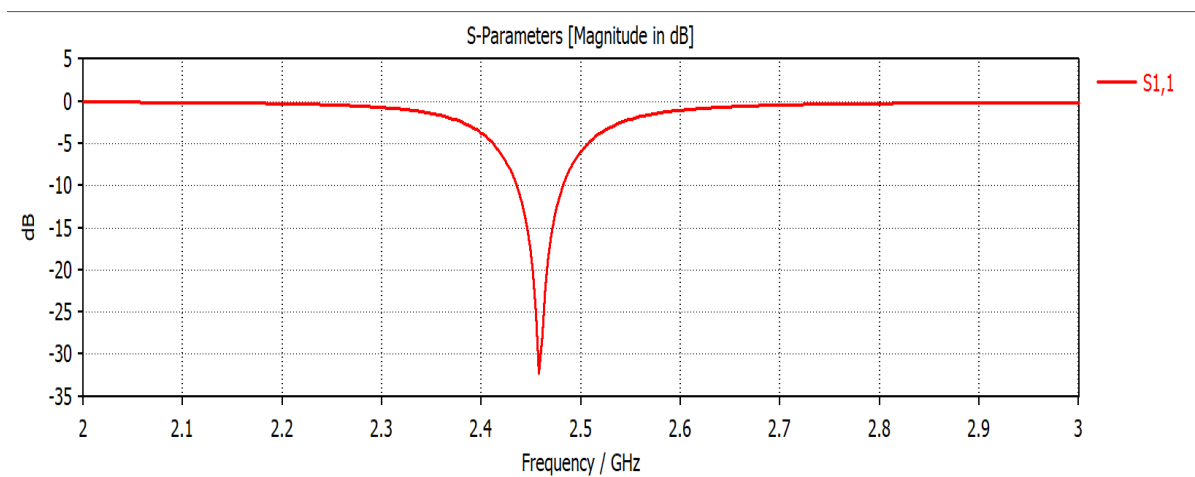
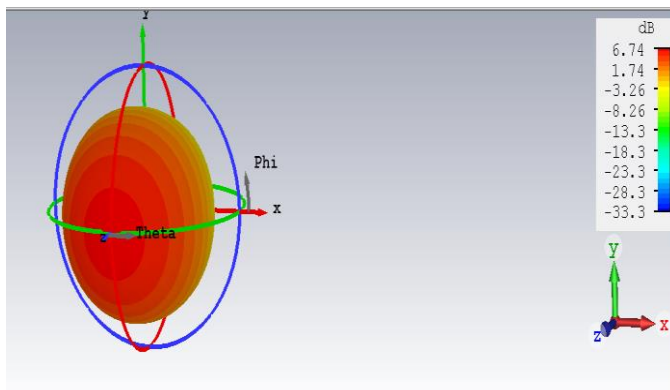
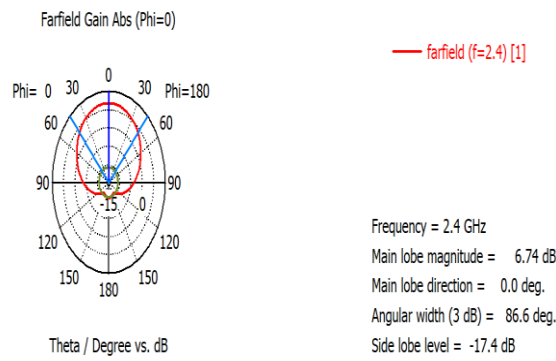


fig 5.6 coaxial feeding(front view)

RESULT:





Conclusion-

The **micro strip patch antennas** are most preferable **antennas** due to its inherent advantages like small size and weight, low cost, printed directly on the circuit board, low profile and easy to fabrication.