20EC61 – MICROWAVE ENGINEERING LAB

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Approved by AICTE,New Delhi and Permanently Affiliated to JNTUK,Kakinada
Accredited by NAAC with "A" Grade and NBA(ECE,CSE,IT,EEE & ME) Under Tier-I

COURSE OBJECTIVE:

This Lab deals with the measurements of the EM signals at microwave frequency range. It involves measurement of frequency, wave length, VSWR, Impedance and scattering parameters of various micro wave devices like Circulator, Directional Coupler, and Magic-Tee. Even the latest trend of software tool i.e. HFSS is also introduced and microwave devices will be verified by evaluating the related parameters.

COURSE OUTCOMES:

At the end of the course, student will be able to

- **CO1** Demonstrate the functions of microwave bench setup (Understand – L2)
- **CO2** Examine the properties of microwave passive devices using HFSS (Apply – L3)
- **CO3** Estimate the frequency, wave length, VSWR, impedance and scattering parameters of microwave devices (Apply – L3)
- **CO4** Adapt effective communication, presentation and report writing skills (Apply – L3)

List of Experiments

1. Reflex Klystron Characteristics
2. Gunn diode Characteristics
3. Attenuation measurement
4. VSWR measurement
5. Directional coupler characteristics
6. Impedance and frequency measurement
7. Scattering parameters of circulator
8. Scattering parameters of Magic tee

Using HFSS Simulation software:

9. Scattering parameters of branch line coupler
10. Scattering parameters of rat-race coupler
11. Design and S-parameter measurement of microwave band stop filter
12. Design and S-parameter measurement of microwave balun

REFLEX KLYSTRON CHARACTERISTICS	EXPT. NO : 1
	DATE :

1. AIM:

To verify the mode characteristics of the reflex klystron tube and determine its electronic tuning range.

2. COMPONENTS & TOOLS REQUIRED:

1. Klystron power supply SKPS-610
2. Klystron tube 2K25
3. Klystron Mount XM -251
4. Isolator XI -621
5. Frequency meter XF -710
6. Variable Attenuator XA -520
7. Slotted line XS -651
8. Tunable probe XP -655
9. Detector mount XD -451
10. VSWR Meter SW-155
11. Cooling Fan

3. THEORY:

The Reflex Klystron makes the use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated & passed through the positive resonator towards negative reflector, which retards and finally reflects the electrons and the electrons turn back through the resonator. Suppose an RF-field exists between the resonator, the electrons traveling forward will be accelerated or retarded, as the voltage at the resonator changes in amplitude. The accelerated electrons leave the resonator at an increased velocity and the retarded electrons leave at the reduced a result, returning electrons leaving the resonator will need different time to return, due to change in velocities. As a result, returning electrons group together in benches. As the electron bunches pass through resonator, they interact with voltage at resonator grids. If the bench passes the grid at such a time that the electrons are showed down by the voltage then energy will be delivered to the resonator; and klystron will oscillate.

The dimensions of resonant cavity primarily determine the frequency. Hence by changing the volume of resonator, mechanical tuning of klystron is possible. Also, a small frequency change can be obtained by adjusting the reflector voltage. This is called Electronic Tuning.

4. BLOCK DIAGRAM:

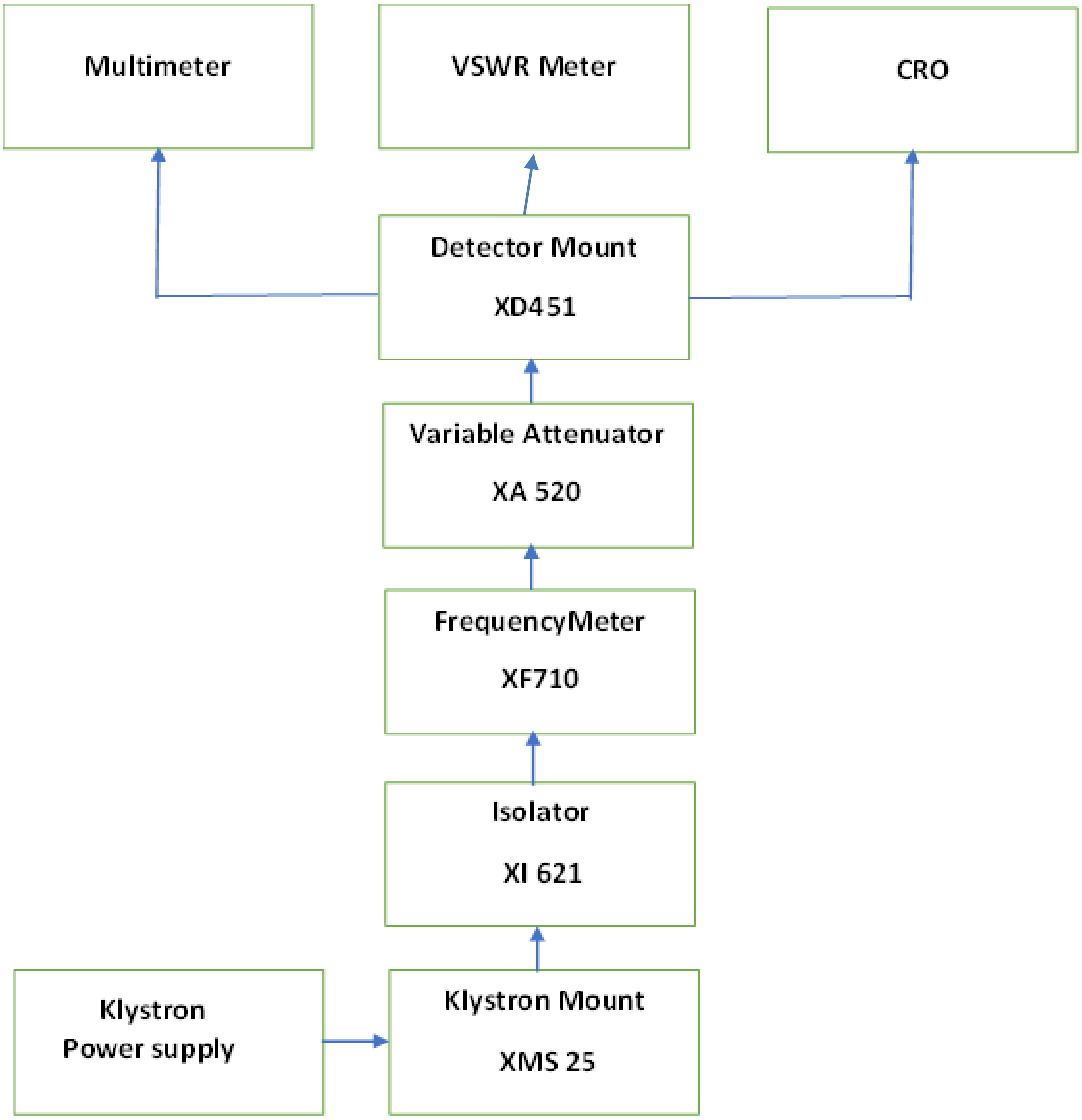

Figure.1: Set up for the study of reflex Klystron Characteristics

A microwave test bench is an assembly of various microwave components, held together by Nuts & Bolts. It consists of a microwave source (Oscillator) at one end. The waves generated are led down by a wave guide through various components, so that the student can observe the propagation of waves, and their interaction and/or processing by various components.

4.1. Klystron Power Supply:

Klystron Power supply is a regulated power supply for operating low power klystron. Klystron power supply generates voltage required for driving the reflex klystron tubes like 2k25, 2k56, 2k22. It is absolutely stable, regulated and short circuit protected power supply. It has the facility to vary the Beam Voltage continuously and built in facility of square wave and saw tooth generators, for amplitude and frequency modulation.

A waveguide of suitable length having octal base on the broad wall of the waveguide for mounting the klystron tube. It consists of movable short at one end of the waveguide to direct the microwave energy generated by the klystron tube. A small hole located exactly at the center of the broad wall of the waveguide is used to put the coupling pin of the tube as the electric field vector of EM energy is maximum at the center only. The maximum power transfer can be achieved by tuning of the movable plunger.

4.2. Reflex Klystron

The reflex klystron, employs a somewhat different strategy to extract energy from an electron beam in the form of microwave oscillation. The anode of the klystron is a resonant cavity that contains perforated grids to permit accelerated electrons to pass through and continue their journey. Such electrons are not, however, subsequently collected by a positive electrode. Rather, they are deflected by a negatively polarized 'reflector' and are thereby caused to fall back into the cavity grids. The operational objective of the tube is to have such electrons return to the cavity grids at just the fight time to reinforce the electric oscillatory field appearing across these grids. When this situation exists, oscillations are excited and sustained in the cavity. Microwave power is coupled out of the cavity by means of a loop if coaxial cable is used, or simply through an appropriate aperture if a waveguide is used for delivering the power to the load. After the kinetic energy of the electrons has been given up to the oscillatory field of the cavity, the spent electrons fall back to the positive biased control grid where they are collected, thereby adding to control grid current.

If the tube is not oscillating, a relatively high number of electrons are deflected by the retarding field of the reflector with sufficient energy to pass through the cavity grids, thence to be collected by the control grid. However, when oscillations are sustained in the cavity, the falling electrons yield most of their energy to the oscillating electric field appearing across the cavity grids. Such electrons are subsequently collected by the cavity grids, which in this function behave as the plate of an ordinary diode. Inasmuch as the spent electrons do not fall into the positive field of the control grid, a profound dip in control-grid current accompanies the onset of oscillation within the cavity.

4.3.Isolator:

The microwave test bench includes an attenuator, and an isolator. Both of these help to stop the reflected power from reaching the oscillator and pulling the frequency of the cavity and Gunn diode off tune when the load impedance is varied. An isolator is a two port device that transmits microwave or radio frequency power in one direction only. It is used to shield equipment on its input side, from the effects of conditions on its output side; for example, to prevent a microwave source being detuned by a mismatched load. An ideal isolator transmits all the power entering port 1 to port 2, while absorbing all the power entering port 2.

$$S = \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix}$$

An isolator in a non-reciprocal device, with a non-symmetric matrix.

To achieve non-reciprocity, an isolator must necessarily incorporate a non-reciprocal material. At microwave frequencies this material is invariably a ferrite which is biased by a static magnetic field. The ferrite is positioned within the isolator such that the microwave signal presents it with a rotating magnetic field, with the rotation axis aligned with the direction of the static bias field. The behavior of the ferrite depends on the sense of rotation with respect to the bias field, and hence is different for microwave signals travelling in opposite directions. Depending on the exact operating conditions, the signal travelling in one direction may either be phase-shifted, displaced from the ferrite or absorbed.

4.4. Attenuator:

Attenuators are required to adjust the power flowing in a waveguide. Attenuators are of fixed, variable and rotary vane type, i.e.

(i) Fixed: Any amount of fixed attenuation can be supplied between 3 to 40 dB. These attenuators are calibrated frequency band.

(ii) Variable: Variable attenuators provide a convenient means of adjusting power level very accurately.

4.5. Direct reading frequency meter:

This Frequency Meter has convenient readout with high resolution is provided by long spiral dials. These dials have all frequency calibrations visible so you can tell at a glance the specific portion of each band you are measuring. Overall accuracy of these frequency meters is 0.17% and includes such variables as dial calibration. It is constructed from a cylindrical cavity resonator with a variable short circuit termination. The shorting plunger is used to change the resonance frequency of the cavity by changing the cavity length. DRF measures the frequency directly. It is particularly useful when measuring frequency differences of small changes. The cylindrical cavity forms a resonator that produces a suck-out in the frequency response of the unit. This you would turn the knob until a dip in the response is observed.

4.6. Slotted section:

The slotted line is the basic instrument of microwave measurements. With its help it is possible to determine the VSWR, attenuation, phase and impedances. The position of carriage (probe) can be read from a scale with its vernier. The total travel of probe carriage is more than three time of half of guide wavelength. This system consists of a transmission line (waveguide), a traveling probe carriage and facility for attaching/detecting instruments. The slot made in the center of the broad face do not radiate for any power of dominant mode. The precision-built probe carriage having centimeters scale with a vernier reading of 0.1 mm least count is used to note the position of the probe. Additionally slotted section can be used to measure reflection coefficient and the return loss.

4.7. Crystal Detector:

The crystal detector (Detector mount) can be used for the detection of microwave signal. RF choke is built into the crystal mounting to reduce leakage from BNC connector. Square law characteristics may be used with a high gain selective amplifier having a square law meter calibration. At low level of microwave power, the response of each detector approximates to square law characteristics and may be used with a high gain selective amplifier having a square law meter calibration.

Figure.2 Microwave bench set up

Klystron Mount

Isolator

Frequency Meter

Variable attenuator

Slotted Section

Detector Mount

Figure.3: Microwave Components

6. EXPERIMENTALPROCEDURE:

Carrier wave operation

1. Connect the components and equipment as shown in the figure.
2. Set the variable Attenuator at the minimum position.
3. Set the mod-switch of klystron power supply at CW position, beam voltage control knob to fully anti clock wise and Repeller voltage control knob to fully clock wise and the meter switch to "off" position.
4. Rotate the knob of frequency meter at one side fully.
5. Connect the DC microampere meter with detector.
6. Switch ON the klystron power supply, VSWR meter and cooling fan for the klystron tube.
7. Put on beam voltage switch and rotate the beam voltage knob clock wise slowly up to 300 V meter reading and observe beam current position. The beam current should not increase more than 30mA.
8. Change the Repeller voltage slowly and watch current meter set the voltage for maximum deflection in the meter.
9. Turn the plunger of klystron mount for the maximum output.
10. Rotate the knob of frequency meter slowly and stop at that position, where there is lowest output current on multi meter. Read directly the frequency meter between two horizontal line and vertical marker. If micrometer type frequency meter is used, read the micrometer reading and use the frequency chart.
11. Change the Repeller voltage and read the current and frequency for each Repeller voltage.

Square wave operation

1. Connect the equipment and components
2. Set micrometer of veritable attenuator around some position.
3. Set the range switch of VSWR meter at 40dB position, input selector switch to crystal impedance position, meter switch to narrow position.
4. Set mod-selector switch to AM_MOD position beam voltage control knob to fully anti clockwise position.
5. Switch ON the klystron power supply, VSWR meter and cooling fan.

6. Keep the AM-Mod amplitude knob and AM- FREQ, knob at the mid-position.
7. Rotate the reflector voltage knob to get deflection in VSWR meter.
8. Rotate the AM-MOD amplitude knob to get maximum output in VSWR meter
9. Maximize the deflection with frequency knob to get the maximum output in VSWR meter.
10. If necessary, change the range switch of VSWR meter 30dB to 50dB if the deflection in VSWR meter is out of scale or less than normal scale respectively. Further the output can be also reduced by variableattenuator for setting the output for any particular position.

Mode study on oscilloscope

1. Set the components and equipment.
2. Keep position of variable attenuator at minimum attenuation position.
3. Set mode selector switch to FM-MOD position, FM frequency knob at mid position, keep beam voltage knob fully anti clock wise and reflector voltage knob to fully clockwise and beam switch to "OFF”
4. Keep the time/division scale of oscilloscope around 100 Hz frequency measurement and volt/div. to lower scale.
5. Switch “ON” the klystron power supply.
6. Switch ON beam voltage switch and set beam voltage to 300V by beam voltage control knob.
7. Keep amplitude knob of FM modulator to maximum position and rotate the reflector voltage anti clock wise to get modes as shown in the figure. The horizontal axis represents reflector voltage axis and vertical represents output power.
8. By changing the reflector voltage and amplitude of FM modulation, any mode of klystron tube can be seen on CRO.

7. OBSERVATIONS:

Table.1: Mode characteristics of Amplitude modulation

S. No	Repeller Voltage V_R (V)	Output voltage (V)

Table.2: Mode characteristics of Frequency modulation

S. No	Repeller Voltage V_R (V)	**F_{MAX} (GHz)**	**F_{MIN} (GHz)**

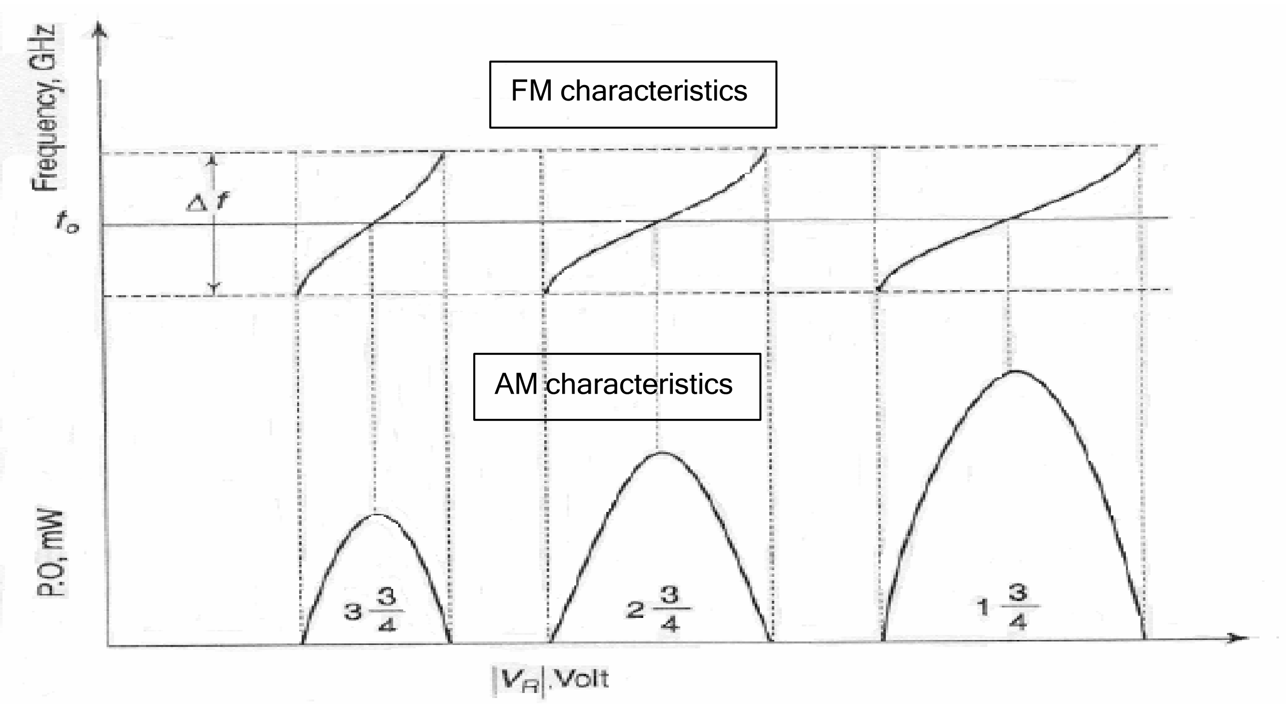

Figure.4: Mode Characteristics of Reflex Klystron

8. PRECAUTIONS:

1. Turn off the microwave power sources when assembling or disassembling the components.
2. Never look in to the open end of a wave-guide that is connected to the other equipment.

9. CONCLUSION:

The characteristics of the reflex klystron tube are studied under amplitude modulation and frequency modulation and the electronic tuning range is determined.

10. VIVA -VOCE QUESTIONS:

1. Explain the operation Reflex Klystron.
2. What is the need of resonant cavity?
3. What is meant by Velocity Modulation?
4. What is the advantage of multi cavity Klystron?

GUNN DIODE CHARACTERISTICS	EXPT. NO : 2
	DATE :

1. AIM:

To study the V-I characteristics of Gunn Diode.

2. COMPONENTS & TOOLSREQUIRED:

1.	Gunn power supply	XS -610
2.	Gunn Oscillator	XG -11
3.	Isolator	XI -621
4.	Frequency meter	XF -710
5.	Matched termination	XL -400

3. THEORY:

The Gunn Oscillator is based on negative differential conductivity effect in bulk semiconductors, which has two conduction bands, separated by an energy gap. A disturbance at the cathode gives rise to high field region, which travels towards the anode. When this field domain reaches the anode, it disperse and another domain is formed at the cathode and starts moving towards anode and so on. The time required for domain to travel from cathode to anode gives oscillation frequency.

In a Gunn Oscillator the Gunn diode is placed in a resonant cavity. Cavity dimensions determine the Oscillation frequency. Gunn Oscillator can be amplitude modulated with the bias voltage. We have used a PIN modulator for square wave modulation of the signal coming from Gunn Oscillators

4. BLOCKDIAGRAM:

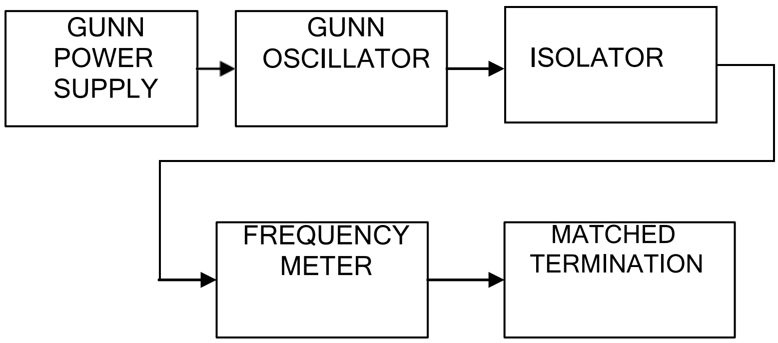

Figure.1: Set up for the study of Gunn diode V-I Characteristics

4.1. Gunn Power Supply:

The Gunn power supply delivers the DC and control voltages required for the operation of the Gunn oscillator and PIN modulator and. enables the demodulated microwave signal to be quantitatively evaluated.

4.2. PIN modulator:

PIN Diode modulators offer an ideal way for amplitude and pulse modulation of microwave signals through a wide range of frequencies. These modulators utilize PIN Diode which is mounted across the waveguide line R.F. isolated DC bias lead passing to an external TNC (F) Connectors.

5. MODEL GRAPHS:

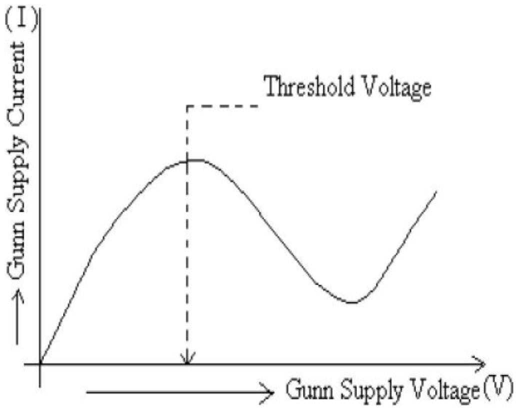

Figure 2(a) : Gunn diode Characteristics (b): Gunn Diode (c) Gunn Oscillator

6. EXPERIMENTAL PROCEDURE:

- Set the components as shown in the figure.
- Keep the control knobs of Gunn power supply as below

  Meter switch - OFF

  Gunn bias knob - Fully anti clockwise

  Pin bias knob - Fully anti clockwise

  Pin Mode frequency - Any position.
- Set the micrometer of Gunn Oscillator for required Frequency of operation.
- Switch ON the Gunn Power supply.
- Measure the Gunn diode current corresponding to the various Gunn bias voltages Through the digital panel meter and meter switch. Do not exceed the bias voltage above 10 volts.
- Plot the voltage and current readings on the graph as shown in the figure
- Measure the threshold voltage which corresponds to maximum current.

7. OBSERVATIONS:

Frequency of Operation=_______G Hz

Micro-meter Reading =_______mm

Maximum Threshold Voltage= __________V

Table.1: V I Characteristics of Gunn Diode

S. No	Voltage (V)	Current (A)

8. PRECAUTIONS:

- Turn off the microwave power sources when assembling or disassembling the components.
- Never look in to the open end of a wave-guide that is connected to the other equipment.
- Do not keep Gun bias knob position at threshold position for more than 10 – 15 seconds; readings must be obtained as fast as possible.

9. CONCLUSION:

The characteristics of Gunn Diode are studied and calculated the maximum threshold voltage.

10. VIVA -VOCE QUESTIONS:

- What is Gun effect?
- What happens to the Gunn diode at the threshold level?
- What is the range of X – band frequency?
- What are the applications of Gunn Diode?

ATTENUATION MEASUREMENT	EXPT. NO : 3
	DATE :

1. AIM: To measure the attenuation of fixed attenuators.

2. COMPONENTS & TOOLS REQUIRED:

1.	Gunn power supply	XS -610
2.	Gunn Oscillator	XG -11
3.	Pin Modulator	XM – 55
4.	Isolator	XI -621
5.	Frequency meter	XF -710
6.	Variable Attenuator	XA -520
7.	Slotted line	XS -651
8.	Tunable probe	XP -655
9.	Detector mount	XD -451
10.	Attenuator(fixed)	XC – 621
11.	Matched termination	XL -400

3. THEORY:

The attenuator is a two port bi-directional device which attenuates some power when inserted into the transmission line.

Attenuation A (db) = 10 log P_1/ P_2 Where P1 = power detected by the load without the attenuator in the line. P2 = Power detected by the load with the attenuator in the line.

Insertion loss of attenuator =P1-P2.

The attenuators consist of a resistive vane inside the wave-guide to absorb microwave power according to its position with respect to sidewall of the wave guide. As electric field is maximum at center in TE_{10} mode, the attenuation will be maximum if the vane is placed at center of the wave-guide. Moving from center towards the sidewall attenuation decrease. In the fixed attenuator the vane position is fixed where as in variable attenuator, the help of micrometer of can change its position by other methods.

Following characteristics of attenuators can be studied

1. Attenuation A (dB)
2. Frequency sensitivity i.e. variation of attenuation with change in frequency at any fixed position of vane.

4. BLOCK DIAGRAM:

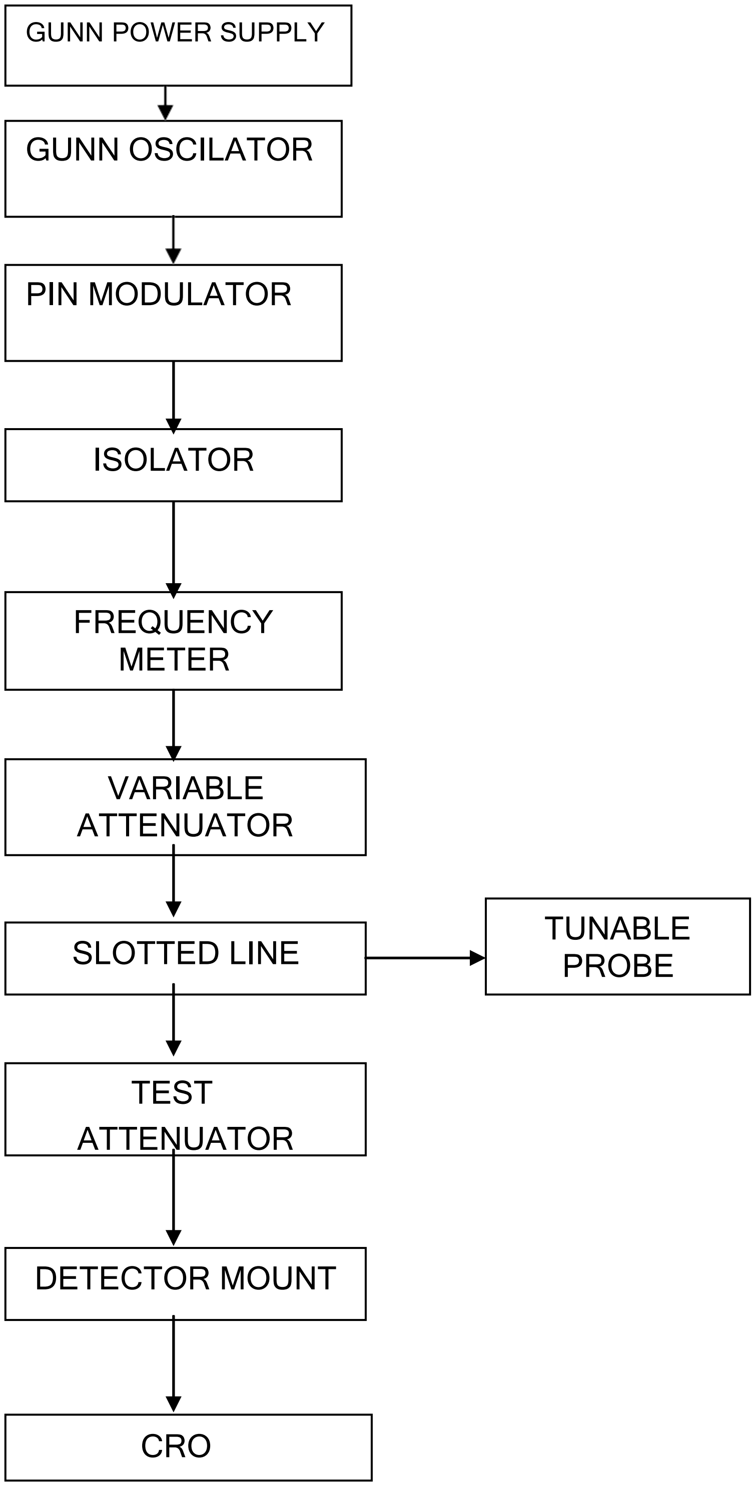

Figure.1: Set up for the measurement of Attenuation

Figure 2: (a)Variable attenuator (b)Fixed attenuator

5. EXPERIMENTAL PROCEDURE:

1. Connect the equipment as shown.
2. Energize the microwave source for maximum power at any position.
3. Set any reference level on the CRO with the help of Variable attenuator.
4. Without connecting test attenuator. Let it be P1 or V1.
5. Carefully disconnect the detector mount from the slotted line without disturbing Any position on the set up place the test attenuator (3dB) to the slotted line and Detector mounts to other part of test attenuator
6. Let it be P2 then the insertion loss of test attenuator will be (P1-P2) dB.
7. Carefully disconnect the detector mount from the slotted line without disturbing any position on the set up place the test attenuator(10dB) to the slotted line and detector mount to other part of test attenuator
8. Let it be P3 then the insertion loss of test attenuator will be (P1-P3) dB.
9. Repeat the above step7,step 8 to test attenuation for 13 dB attenuator and calculate the Attenuation A by using the attenuation formula.

6. PRECAUTIONS:

1. Turn off the microwave power sources when assembling or disassembling the components.
2. Never look in to the open end of a wave-guide that is connected to the other equipment.

7. OBSERVATIONS:

1. Power(Voltage) detected by the load without the attenuator in the line (P_1) or (V_1) = _
2. Power(Voltage) detected by the load with the test attenuatorin the line (P_2) or (V_2) =___

Attenuation = 10 log (P_1 /P_2) =_______dB.

Attenuation = 20 log (V_1 /V_2) =_____dB

8. RESULT:

The attenuation of various fixed attenuators is measured.

9. VIVA -VOCE QUESTIONS:

1. What is attenuation?
2. How many types of attenuators are there?
3. What is insertion loss?
4. What is the function of PIN Modulator?

DIRECTIONAL COUPLER CHARACTERSTICS	EXPT. NO : 4
	DATE :

1. AIM:

To estimate the Directivity, Coupling factor, Insertion loss of a given directional coupler

2. COMPONENTS & TOOLSREQUIRED:

1.	Gunn power supply	XS -610
2.	Gunn Oscillator	XG -11
3.	Pin Modulator	XM – 55
4.	Isolator	XI -621
5.	Frequency meter	XF -710
6.	Variable Attenuator	XA -520
7.	Slotted line	XS -651
8.	Tunable probe	XP -655
9.	Detector mount	XD -451
10.	Matched termination	XL -400

3. THEORY:

A directional coupler is a device with which it is possible to measure the incident and reflected wave separately. It consists of two transmission lines the main arm and auxiliary arm, electro magnetically coupled to each other. The power entering in the main arm gets divided between port 2 and 3, and almost no power comes out in port 4, power entering at port 2 is divided between port 1 and port 4. With built in termination and power entering at port 1 the directivity of the coupler is measure of separation between incident wave and the reflected wave.

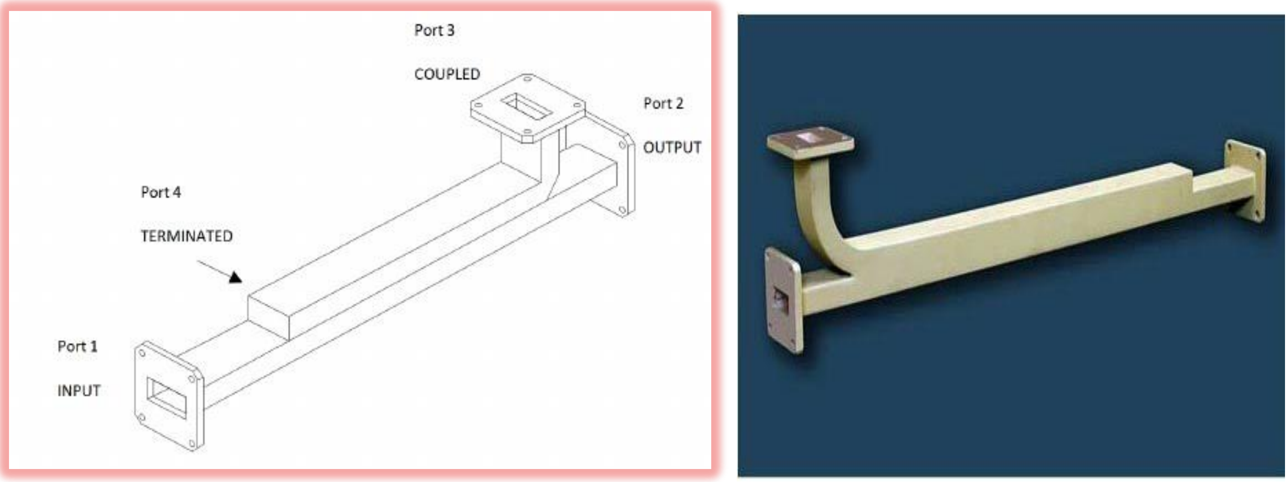

Figure 1: A Schematic of Directional coupler

Coupling (db) = 10 log $_{10}$ (P1 / P3)   or   20 log $_{10}$ (V1 / V3) where port 2 is matched.

Isolation (db) = 10 log $_{10}$ (P2 / P3)   or   20 log $_{10}$ (V2 / V3) where port 1 is matched.

Directivity D (db) = 10 log $_{10}$ (P2 / P1) or   20 log $_{10}$ (V2 / V1)

Insertion loss (dB) = 10 log $_{10}$ (P1/ P2) or 20 log $_{10}$ (V1 / V2)

4. BLOCK DIAGRAM:

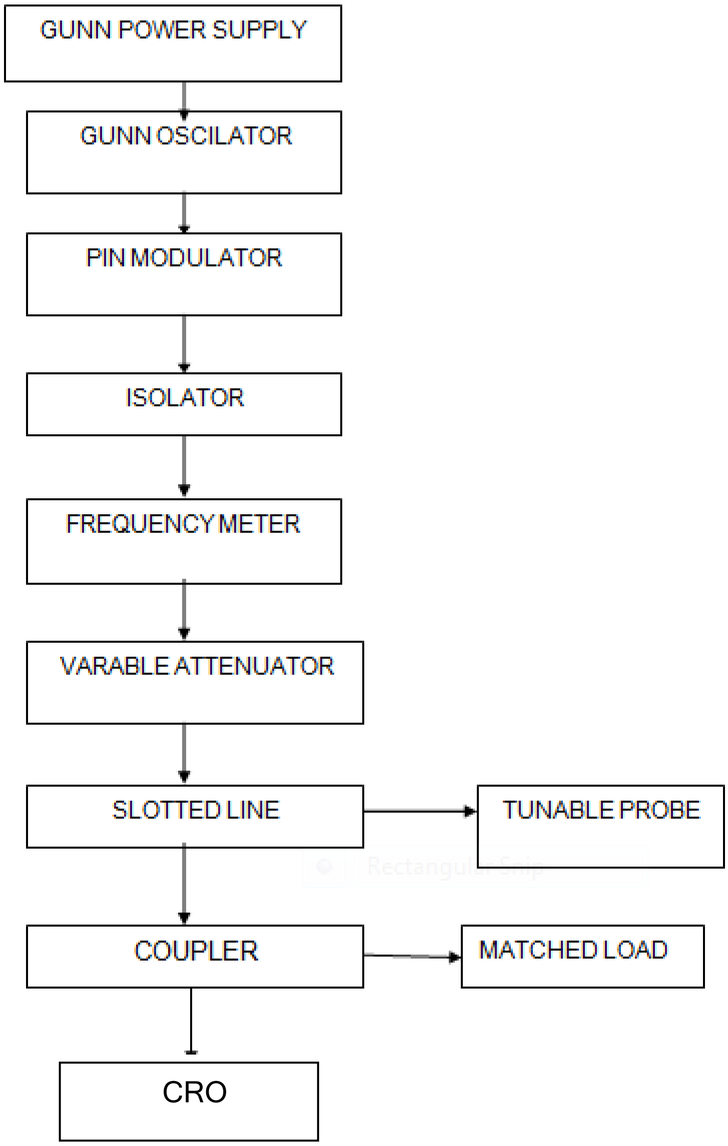

Figure.2: Set up for the measurement of Coupler Parameters

5. EXPERIMENTALPROCEDURE:

Measurement of Coupling Factor, insertion loss, isolation & Directivity:

1. Set up the equipment as shown in the block diagram.
2. Energize the microwave source for particular frequency operation.
3. Without connecting the multi hole directional coupler connect the detector mount to the slotted line in one side and CRO on other side. Tunethe detector for maximum output. Let it be P1

4. Carefully disconnect the detector mount from the slotted line without disturbing any position on the set up place the directional coupler to the slotted line to por1 and detector mount to port 2 of coupler note down the voltage on CRO. Let it be p2and port 3 should be connected to matched termination
5. Similarly connect detector mount to port 3 noted down the voltage on CRO.Let it be p3 and port 2 should be connected to matched termination.
6. Repeat the steps from 3 to 7. For other frequency
7. Calculate directivity, Coupling factor, Insertion loss for a given directional coupler

6. OBSERVATIONS:

1. Coupling (db) = 10 log $_{10}$ (P_1 /P_3)(or) 20 log $_{10}$ (v_1 /v_3) =_____
2. Isolation (db) =10 log $_{10}$ (P_2 /P_3))(or) 20 log $_{10}$ (v_2 /v_3) =_____
3. Directivity D (db) = 10 log $_{10}$ (P_3 /P_4))(or) 20 log $_{10}$ (v_3 /v_4) =___
4. Insertion Loss (db) =10 log $_{10}$ (P_1 / P_2))(or) 20 log $_{10}$ (v_1 /v_2) = _____

7. PRECAUTIONS:

1. Turn off the microwave power sources when assembling or disassembling the components.
2. Never look in to the open end of a wave-guide that is connected to the other equipment.

8. CONCLUSION:

The parameters of directional coupler are measured.

9. VIVA -VOCEQUESTIONS:

1. What is Directivity?
2. What is Coupling Factor?
3. What is the relation between directivity, coupling factor and insertion loss?
4. How many ports in a directional coupler?

VSWR MEASUREMENT	EXPT. NO : 5
	DATE :

1. AIM:

To determine the VSWR of a X-band rectangular wave-guide in TE_{10} mode.

2. COMPONENTS & TOOLS REQUIRED:

1. Gunn power supply XS -610
2. Gunn Oscillator XG –11
3. Pin Modulator XM –55
4. Isolator XI -621
5. Frequency meter XF -710
6. Variable Attenuator XA -520
7. Slotted line XS -651
8. Tunable probe XP -655
9. Detector mount XD -451
10. Matched termination XL -400

3. THEORY:

The electromagnetic field at any point of transmission line may be considered as the sum of two travelling waves, the incident wave, which propagates from the source to the load and the reflected wave which propagates towards the generator. The reflected wave is set up by reflection of incident wave from a discontinuity in the line or from the load impedance. The superposition of the two travelling waves, gives rise to a standing wave along the line. The maximum field strength is found where the waves are in phase and minimum where the two waves add in opposite phase. The distance between two successive minimum (maximum) is half the guide wavelength on the line. The ratio of electrical field strength and incident wave is called reflection coefficient. The voltage standing wave ratio (VSWR) is defined as ratio between maximum and minimum field strength along the line. Hence VSWR denoted by s is as follows

VSWR = E max / E min = (V max) + (V min) / (V max) - (V min)

4. BLOCKDIAGRAM:

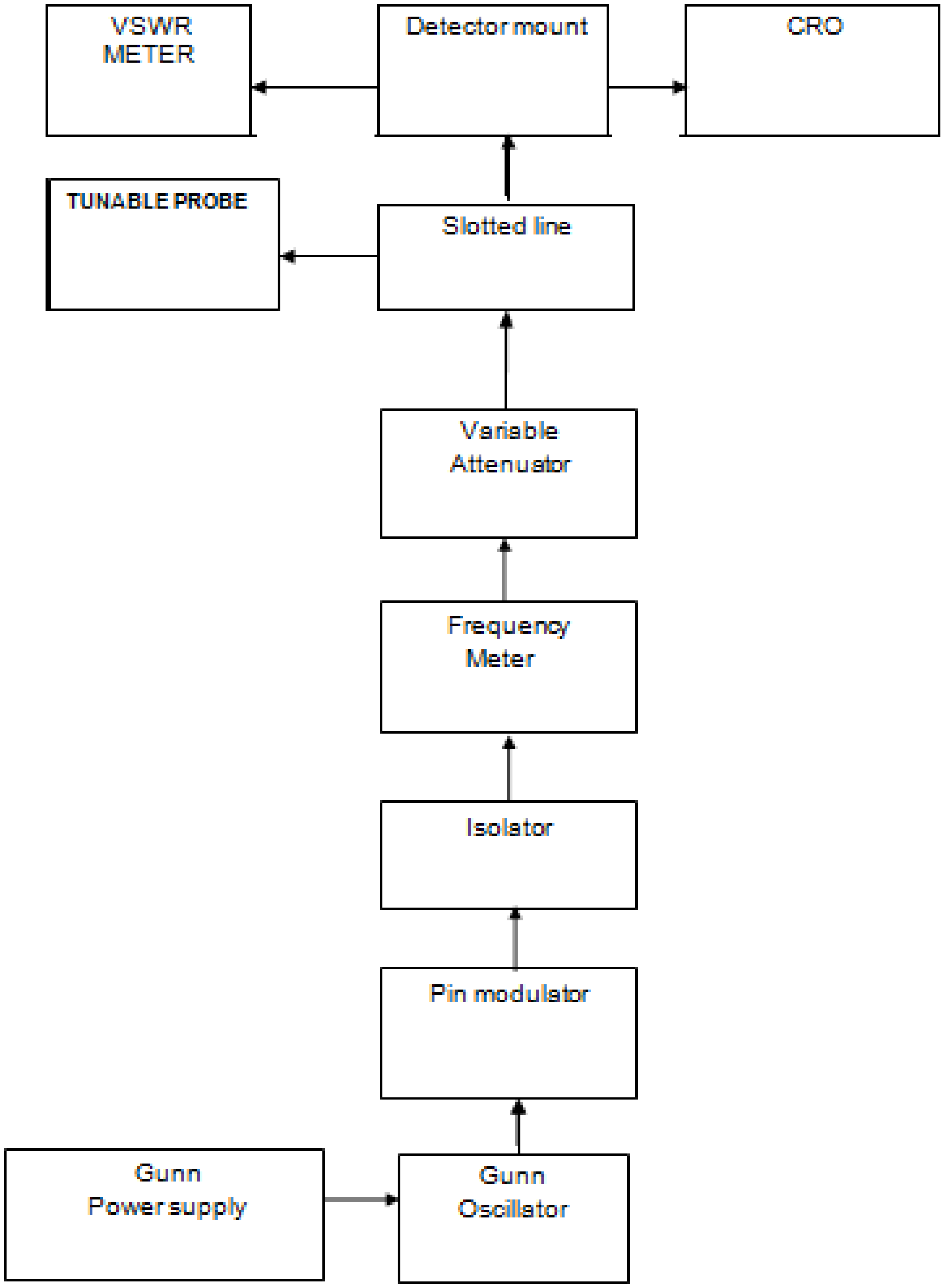

Figure.1: Set up for the measurement of VSWR

5. EXPERIMENTALPROCEDURE:

1. Set the components as shown in the figure.
2. Set the variable attenuate at minimum position.
3. Keep the control knob VSWR meter
   as Range - 50 db position
   Input switch - crystal low impedance
   Meter switch – normal position
   Gain - Mid position
4. Keep the knob control of Gunn power supply as
   below Meter switch - off
   Gunn bias knob - Fully anti clockwise
   Pin bias knob - Fully anti clock wise
   Pin mode frequency - any position
5. Switch ON the Gunn power supply, VSWR meter and cooling fan.
6. By adjusting of the frequency meter value. Variable attenuate, tunable probe and note the maximum voltage form the oscilloscope note it as V max.
7. Again by adjusting the above equipment note the min voltage which is observed as a square wave from the oscilloscope note it as V min.

   Then calculate the VSWR by the formula

   VSWR = Vmax + Vmin / Vmax – Vmin
8. Measurement of low VSWR:
9. Move the probe along the slotted line to get maximum deflection in VSWR meter.
10. Adjust the VSWR meter gain control knob until the meter indicates 1.0 on normal VSWR scale.
11. Keep the entire control knob as it is, move the probe to next minimum position. Directly read the VSWR on scale.

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6. OBSERVATIONS:

Using CRO

VSWR = Vmax + Vmin / Vmax -Vmin

Using VSWR meter

VSWR=

7. PRECAUTIONS:

1. Turn off the microwave power sources when assembling ordisassembling the components.
2. Never look in to the open end of a wave-guide that is connected tothe other equipment.

8. CONCLUSION:

The VSWR of the given rectangular wave guide in TE_{10} mode is measured.

9. VIVA -VOCE QUESTIONS:

1. Define VSWR?
2. What is the impedance at the open end of a wave-guide?
3. What is meant by Guided wavelength?
4. What is the function of the slotted line section?

1. AIM: To calculate the signal frequency and impedance of a given load.

2. COMPONENTS & TOOLSREQUIRED:

1. Gunn power supply XS -610
2. Gunn Oscillator XG -11
3. Pin Modulator XM – 55
4. Isolator XI -621
5. Frequency meter XF -710
6. Variable Attenuator XA -520
7. Slotted line XS -651
8. Tunable probe XP -655
9. Detector mount XD -451
10. Matched termination XL -400

3. THEORY:

Where Z0 is the characteristic impedance of the waveguide at the operating frequency. Z is the load impedance. The measurement is performed as the unknown device is connected to the slotted section and the position of one minimum is determined. The unknown device is replaced by Movable short to the slotted section. Two successive minima positions are noted. Twice the difference between the minima positions will be guide wavelength λg.

. Z=d/λg where λg is the guide wavelength

The electromagnetic field at any point .of transmission line may be considered as the sum of two traveling waves the "Incident wave " which propagates the form the source to load and reflector wave which propagates towards the generator. The super position of the two traveling wave, give rise to a standing wave along the line the maximum field strength is found when the waves are in phase and minimum when the waves are out of phase. To determine the wave length in TE_{10} mode rectangular wave guide λo, λg and λc are related as below

$$1/\lambda o^2 = 1/\lambda g^2 + 1/\lambda c^2$$

$\lambda o$is the free space wave length

λg is the guide wave length

λc is the cut off wave length

For TE_{10} mode $\lambda c = 2a$ where " a " is the broad dimension of wave guide a = 22.86mm . F=c/λo

4. BLOCK DIAGRAM

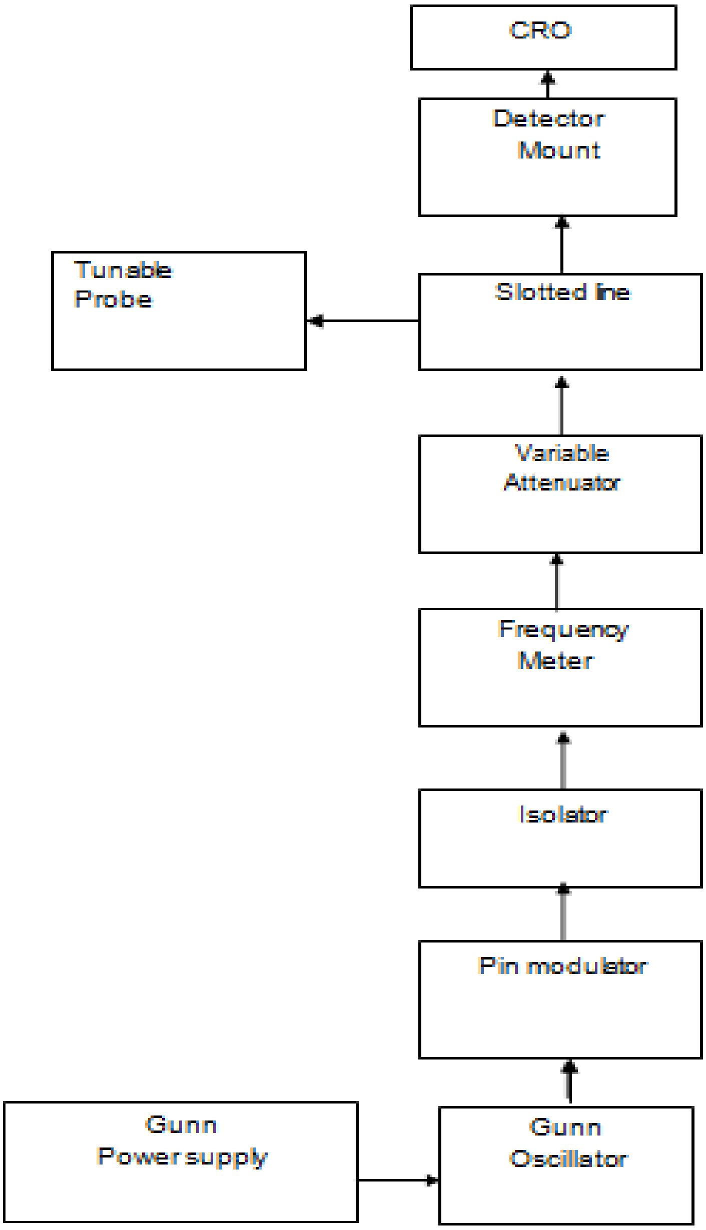


Figure.1: Set up for the measurement of Frequency and Impedance

5. EXPERIMENTAL PROCEDURE:

1. Set the components as shown in the figure.
2. Set the variable attenuate at minimum position.
3. Keep the control knob VSWR meter as

   Range - 50 dB position

   Input switch - crystal low

   impedance Meter switch – normal position

   Gain - Mid position

4. Keep the knob control of Gunn power supply as

   below Meter switch - off

   Gunn bias knob - Fully anti clockwise

   Pin bias knob - Fully anti clock

   wise Pin mode frequency - any position

5. Switch ON the Gunn power supply, VSWR meter and cooling fan.
6. By adjusting of the frequency meter value. Variable attenuate, tunable probe and note the maximum voltage madding form the oscilloscope note it as V max.
7. The unknown device is connected to the slotted line position. In this case we take a wooden piece. The position of one minimum is noted down.
8. The unknown device is replaced short to the slotted line the next minimum position is noted.
9. The difference of these two minimum position note it as ‘ d ’.
10. Then the impedance Z of the un know load is measured

    as $Z = d / \lambda g$

    Where λg is the guided wave length

11. The experiment is repeated for different values.
12. Calculate the guide wavelength as device the distance below two successive minimum position
13. Measure the wave guide inner board dimension “a“ which is around 22.86mm for X – band
14. Calculate the frequency by following equation

$$F = c/\lambda_o = \sqrt{1/\lambda_g^2 + 1/\lambda_c^2}$$

Where c = 3×10^8 m/second that is velocity of light

15. Verify with frequency obtained by frequency meter
16. Above experiment can be verified at different frequencies.

6. OBSERVATIONS:

1. First Minimum (d_1) = _____________
2. Second Minimum (d_2) = __________
3. Third Minimum (with wood piece) (d_3) = ______
4. Guide wave length $\lambda g = 2(d_1 - d_2)$ = _______
5. $d = d_2 - d_3$ =______
6. Impedance $Z = d/\lambda g$= ______________
7. $\lambda c = 2 \times a$ = -------
8. . $1/\lambda o^2 = 1/\lambda g^2 + 1/\lambda c^2$=_________________
9. $F = c/\lambda o$ **= -------**

7. PRECAUTIONS:

1. Turn off the microwave power sources when assembling or disassembling the components.
2. Never look in to the open end of a wave-guide that is connected to the other equipment.

8. CONCLUSION:

The signal frequency and impedance of the given load in TE_{10} mode is measured.

9. VIVA -VOCE QUESTIONS:

1. What is the impedance at the open end of a wave-guide?
2. What is meant by Guided wavelength?
3. Define Cut – off wave length.
4. What type of frequency meter used in microwave test bench?

SCATTERING PARAMETERS OF CIRCULATOR	EXPT. NO : 7
	DATE :

1. AIM: To measure the Scattering parameters of Circulator.

2. COMPONENTS & TOOLS REQUIRED:

1. Gunn power supply XS -610
2. Gunn Oscillator XG -11
3. Pin modulator XM – 55
4. Isolator XI -621
5. Frequency meter XF -710
6. Variable Attenuator XA -520
7. Slotted line XS -651
8. Tunable probe XP -655
9. Detector mount XD -451
10. Matched termination XL -400

3. THEORY:

Circulator is defined as a device with ports arranged such that energy entering a port is coupled to an adjacent port but not coupled to other ports. This is depicted in fig. below. Circulator can have any number of ports.

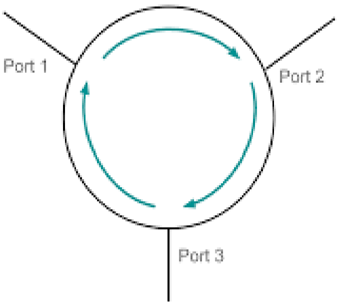


Figure.1: circulator

Insertion loss

Insertion loss is the ratio of power detected at the output port to the power supplied by source to the input port measured with other ports terminated in the matched load. It is expressed in dB.

Isolation

It is the ratio of power applied to the output that measured at input. This ratio is expressed in dB. The isolation of circulator is measured with the third port terminated in a matched load.

3. BLOCK DIAGRAM

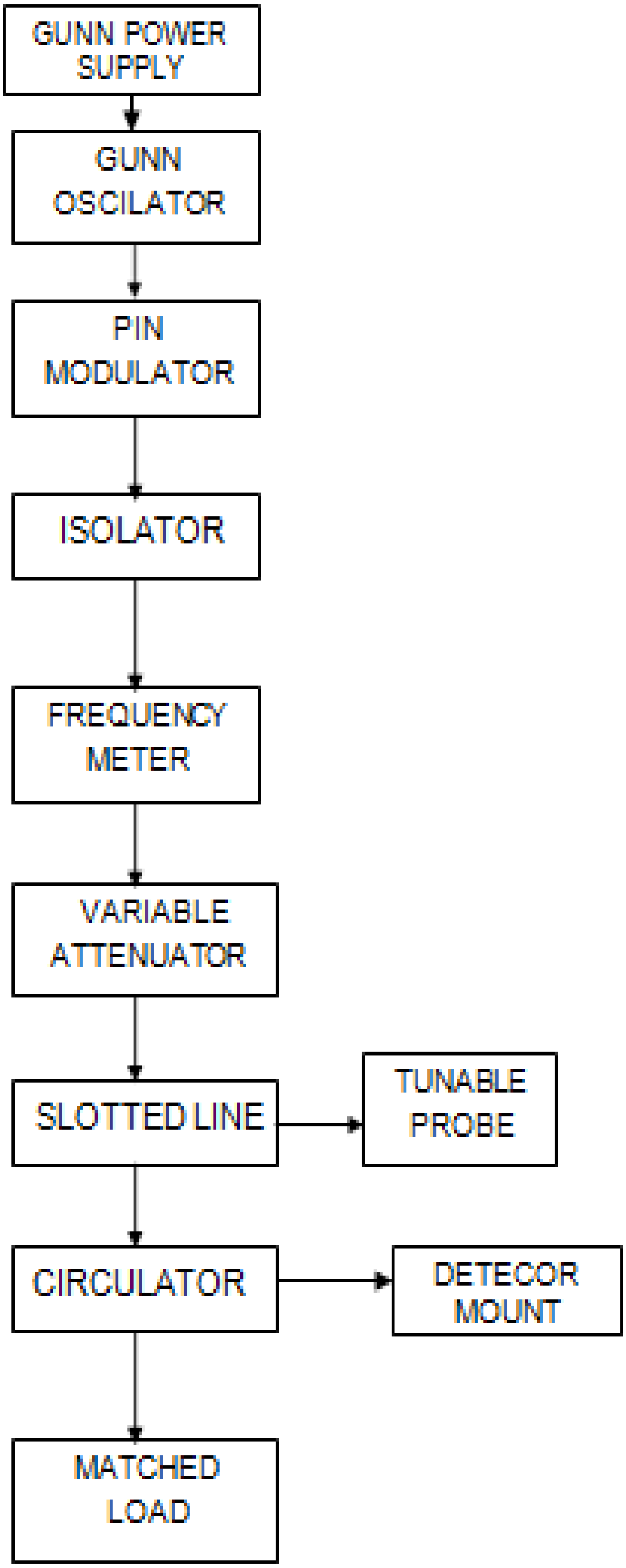


Figure.1: Set up for the measurement of Circulator parameters

5. EXPERIMENTAL PROCEDURE:

1. Set up components as shown in block diagram.
2. Energize the microwave source for particular frequency of operation
3. Tune the detector mount for maximum output in the CRO. Let it be P1
4. Carefully remove the detector mount from slotted line without disturbing the position of the set up.
5. Insert the circulator between slotted line and detector mount.
6. Keep input port of circulator to slotted line and detector its output port.
7. A matched termination should be placed at third port in case of circulator.
8. Record the reading in the CRO. Let it be P_2
9. Compute insertion loss given as $P_1 - P_2$ in dB.
10. For measurement of isolation, the circulator has to be connected in reverse That is output port to slotted line and detector to input port with other port terminated by matched termination for circulator
11. Record the reading of CRO and let it be P_3
12. Compute isolation as P1- P3 in Db
13. The same experiment can be done for other ports of circulator.

6. OBSERVATIONS:

1. Gunn power supply voltage: _________
2. Microwave reading: _________________
3. Frequency meter reading: ____________
4. Input voltage at port1: _______________
5. Output voltage at port2: _____________
6. Output voltage at port3: _____________
7. Isolation(dB) = 20 log10 (V1 / V3) =_________
8. Insertion loss (dB) = 20 log10 (V1 / V2) =_________

7. PRECAUTIONS:

1. Turn off the microwave power sources when assembling or dis assembling the components.
2. Never look in to the open end of a wave-guide that is connected to the other equipment.

8. CONCLUSION:

The Scattering parameters of Circulator and various losses are measured.

9. VIVA -VOCEQUESTIONS:

1. What are the applications of Circulator?
2. What is meant by Velocity Modulation?
3. Explain at what port the sum signal and difference signal is obtained.
4. Explain the operation Circulator.

SCATTERING PARAMETERS OF MAGIC TEE	EXPT. NO : 8
	DATE :

1. **AIM:** To measure the Scattering parameters of Magic Tee.

2. COMPONENTS & TOOLS REQUIRED:

1. Gunn power supply XS -610
2. Gunn Oscillator XG -11
3. Pin Modulator XM – 55
4. Isolator XI -621
5. Frequency meter XF -710
6. Variable Attenuator XA -520
7. Slotted line XS -651
8. Tunable probe XP -655
9. Detector mount XD -451
10. Attenuator(fixed) XC -621
11. Matched termination XL -400

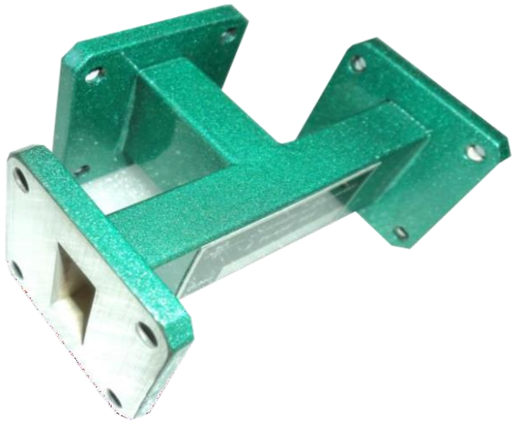
3. THEORY:

A Tee – Junction is an intersection of three wave guides in the form of English alphabet 'T'. There are several types of Tee – junctions such as H – plane Tee, E – plane Tee, Magic Tee junction and Rat race junction.

Magic Tee is a E – H Plane Tee. The port 1 and port 2 are collinear arms, port 3 is the H – arm and port 4 is the E – arm. Such a device became necessary because of the difficulty of obtaining a completely matched 3-port junction. This four port Tee combines the power or dividing the power depending on the power applied to either E-plane or H-plane Tee.

Isolation:

Isolation is the ratio of power applied to the output to that measured at the input. This ratio is expressed in dB. The isolation of a circulator is measured with the third port terminated in a matched load.



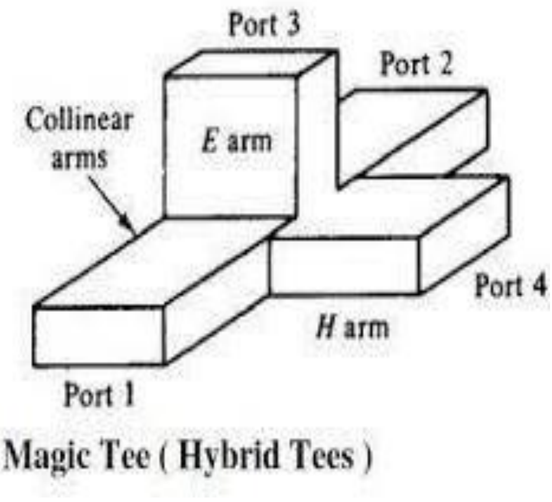


Figure.1: Magic Tee

4. BLOCK DIAGRAM

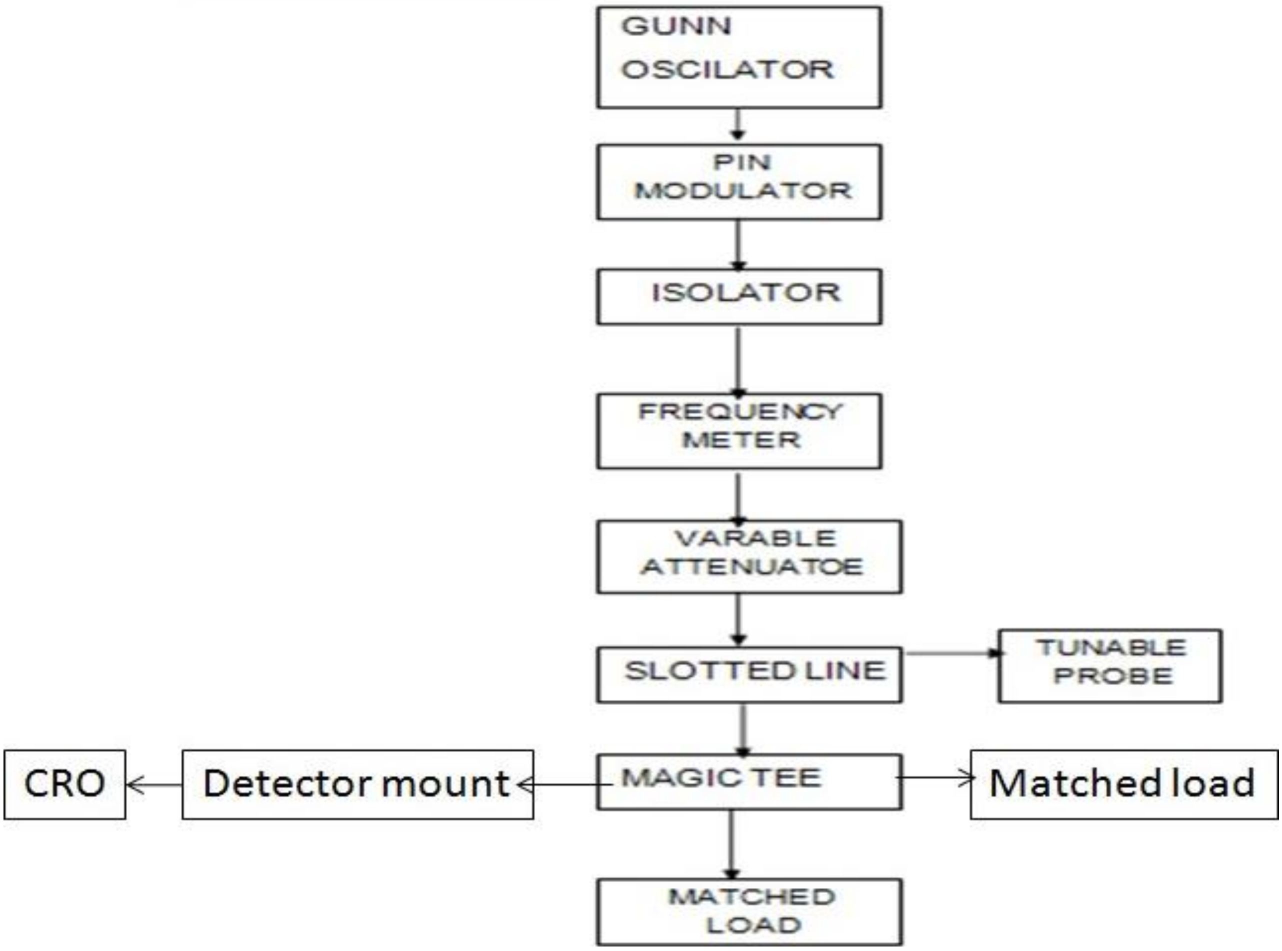


Figure.1: Set up for the measurement of Magic Tee parameters

5. EXPERIMENTAL PROCEDURE

1. Set up components as shown in block diagram.
2. Energize the microwave source for particular frequency of operation
3. Tune the detector mount for maximum output in the CRO. Let it be P1
4. Carefully remove the detector mount from slotted line without disturbing the position of the set up.
5. Insert the Magic Tee between slotted line and detector mount.
6. carefully place the magic Tee after slotted section keeping H arm input port 4 and detector to E arm (Port3) and matched termination to arm 1 and 2 noted down the reading of CRO let it be p3
7. A matched termination should be placed at port1, 2 in case of Magic-Tee.
8. carefully place the magic Tee after slotted section keeping E arm input port 3 connected to slotted section and detector to H arm (Port4) and matched termination to arm 1 and 2 noted down the reading of CRO let it be p4
9. Determine the isolation between port 3 and 4 as P3-P4 in dB.
10. carefully place the magic Tee after slotted section keeping E arm input port 3 connected to slotted section and detector to arm 1, matched termination to port2 & H arm noted down the reading of CRO let it be p1
11. carefully place the magic Tee after slotted section keeping E arm input port 3 connected to slotted section and detector to arm 2, matched termination to port1 & H arm noted down the reading of CRO let it be p2
12. Repeat the step10& 11 for other ports

6. Observations:

P1=output at port1=

P2= output at port2=

P3= Input at port3 =

P4 =Input at port4=

Coupling factor=20log(V1/V3) =

Isolation=20log(V3/V4) =

E arm P3=P1 -P2

H arm P4= P1+P2

7. PRECAUTIONS:

1. Turn off the microwave power sources when assembling or disassembling the components.
2. Never look in to the open end of a wave-guide that is connected to the other equipment.
3. Turn off the microwave power sources when assembling or disassembling thecomponents.
4. Never look in to the open end of a wave-guide that is connected to the other equipment.

8. CONCLUSION:

The Scattering parameters of Magic Tee are measured.

9. VIVA -VOCEQUESTIONS:

1. What are the applications of Magic Tee?
2. What is the other name for Magic Tee?
3. Explain the construction of Magic Tee
4. Explain the operation of Magic Tee

9. Scattering parameters of branch line coupler

EXPT. NO : 9

DATE :

1. Aim: To design a branch line quadrature hybrid junction and, plot the S-parameter magnitudes from $0.5f_0$ to $1.5f_0$, where f_0 is the operating frequency.

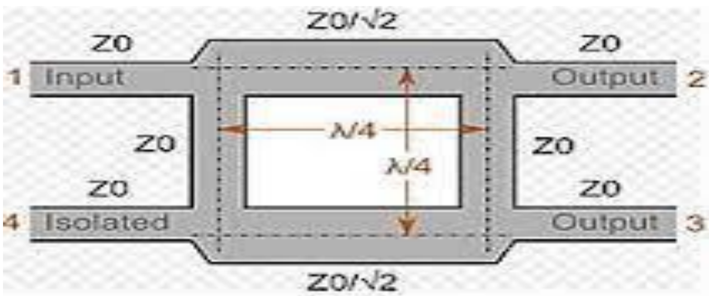
2. COMPONENTS & TOOLSREQUIRED:

(i)ANSYS circuit simulator

(ii) Personal computer

3. THEORY:

Quadrature hybrid couplers are basic building blocks for many RF and microwave systems The Hybrid Coupler is a 4-port device, known as the quadrature coupler or branch- line coupler. The input splits into two output signals, of equal magnitude, with a 90 degree phase difference. Quadrature hybrid couplers provide improved input match for un balanced loads. Its scattering matrix (ideally) has the symmetric solution for a matched, lossless, reciprocal 4-port device:



$$S = \frac{-1}{\sqrt{2}} \begin{pmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{pmatrix}$$

Figure 9.1. Schematic diagram of branch line coupler with S-matrix

4. Design Specifications:

(i) Transmission line impedances=35.5Ω, 50Ω

(ii)Transmission line length=90^0

(iii)Operating frequency f_0=1GHz

5.Design and simulation flow:

1. Open project editor and add insert circuit design
2. Select microstrip lines from components
3. Connect the all microstrip line according to diagram
4. Assign line length, impedances, operating frequency according to specifications
5. Connect 4 ports with impedance 50Ω to structure
6. Assign analysis setup i.e from 0.5GHz to 1.5GHz
7. Plot the S-Parameters (S_{11}, S_{21},S_{31}, S_{41}), where S_{11} is the reflection coefficient, S_{21},S_{31} are transmission coefficients and S_{41} is the isolation

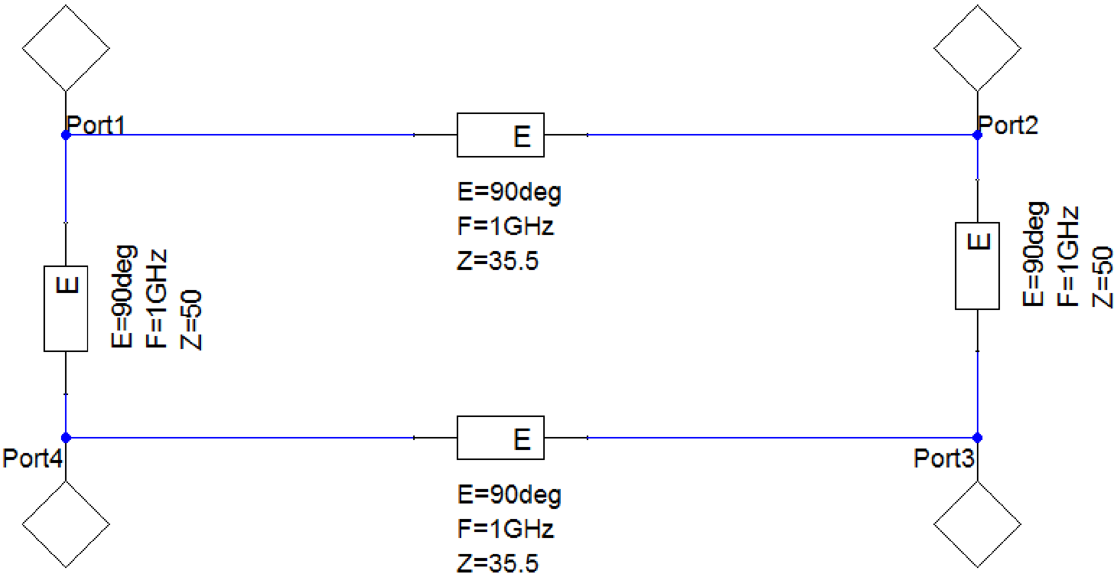


Figure 9.2. Branch line coupler using ANSYS circuit simulator

6.Results:

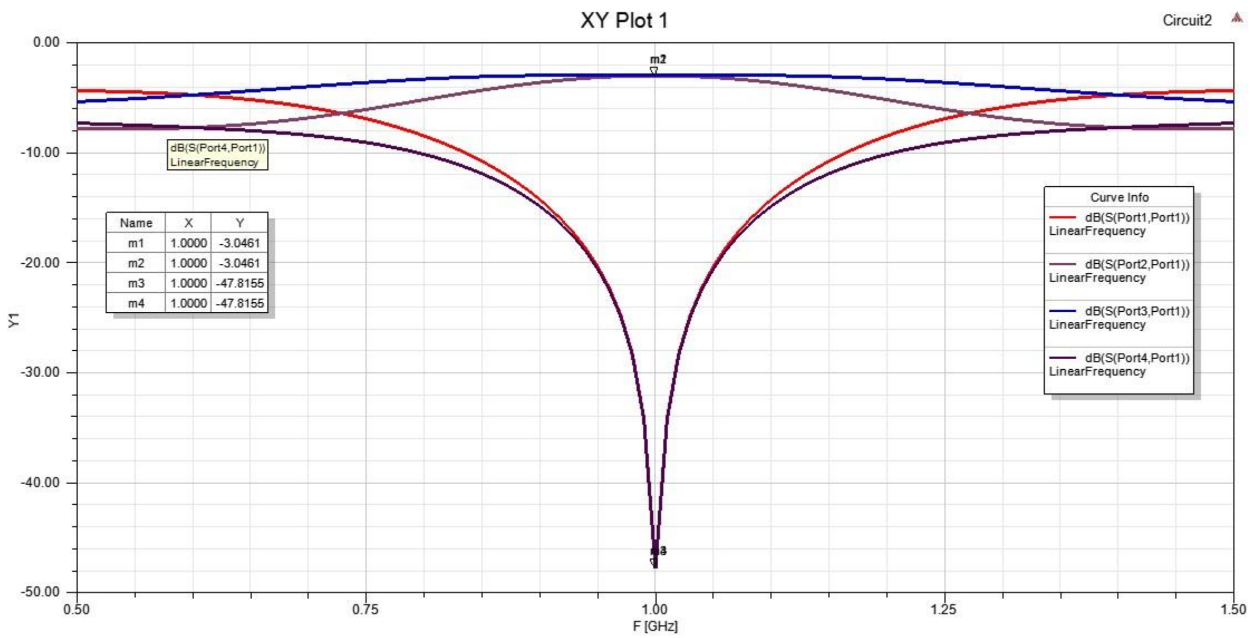


Figure. 9.3. S-Parameters (S_{11}, S_{21}, S_{31}, S_{41}) vs Frequency (GHz)

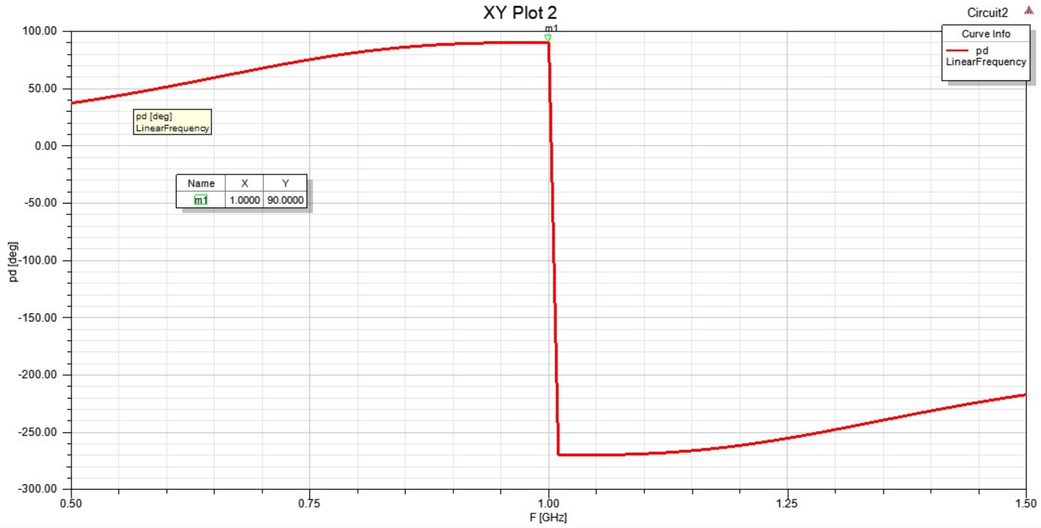


Figure. 9.4. Phase difference vs Frequency (GHz)

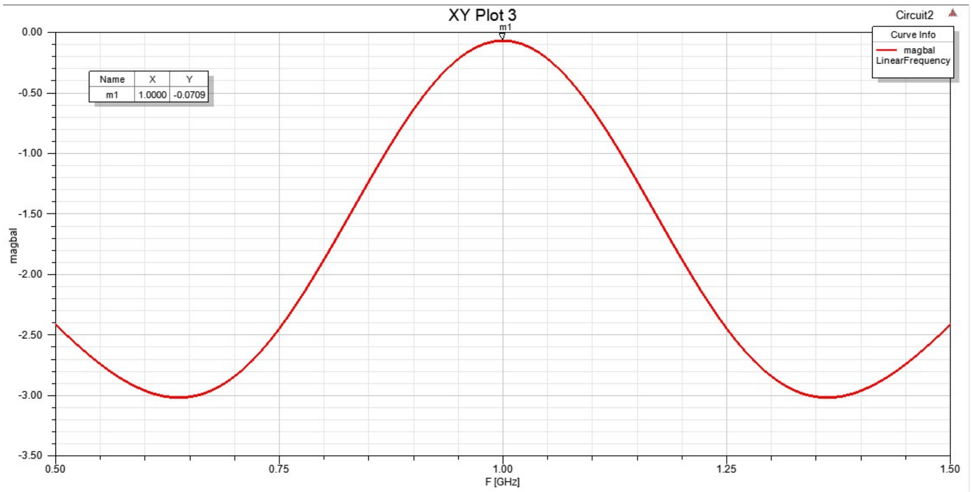


Figure. 9.5. Magnitude difference vs Frequency (GHz)

7.Precautions:

1. Save the setup due to power correction.
2. Don't open unnecessary files.
3. Shut down the system before leaving the job.

8.Result:

Branch line coupler is designed, simulated and plot the S-parameters

9.Viva Questions

1. Describe the properties of BLC
2. Mention other name of BLC?
3. What are the applications of BLC?
4. What is the phase difference between output ports in BLC?

10. Scattering parameters of rat-race coupler

EXPT. NO : 10
DATE :

1.Aim: To design a rat race coupler and, plot the S-parameter magnitudes from $0.5f_0$ to $1.5f_0$, where f_0 is the operating frequency.

2.Apparatus & Tools:

1. ANSYS HFSS circuit simulator
2. Personal computer

3.Theory:

Rat-race coupler is also called as hybrid ring coupler .It is 180° hybrid having 4 ports as Shown in the figure.

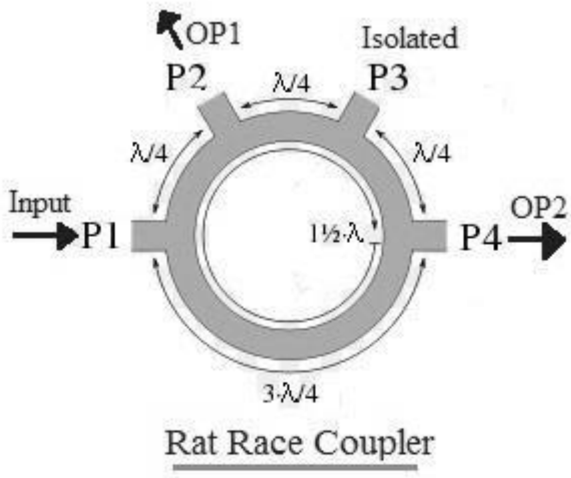


Figure. 10.1 Rat race coupler (RRC)

It has four ports which are λ/4 away from the other in the top half of the hybrid ring (i.e. between P1 and P2, P2 and P3, P3 and P4). In the bottom half of the hybrid ring P1 and P4 ports are 3*λ/4 Wavelengths away from each other. The power fed at the port-1 is splitted across port-2 and port-4 Where as port-3 is completely isolated. It is used in wide variety of applications such as balanced Mixers, balanced amplifiers, antenna feeding networks, power multipliers or power dividers.

4.Design Specifications:

(i)Transmission line impedances=70.7Ω

(ii)Transmission line length=90^0

(iii)Operating frequency f_0=1GHz

5.Design and simulation flow:

1. Open project editor and add insert circuit design
2. .Select microstrip lines from components
3. Connect the all microstrip lines according to diagram
4. Assign line length, impedances, operating frequency according to specifications
5. Connect 4 ports with impedance 50Ω to structure
6. Assign analysis setup i.e from 0.5GHz to 1.5GHz
7. Plot the S-Parameters (S_{11}, S_{21},S_{31}, S_{41}), where S_{11} is the reflection coefficient, S_{21}, S_{31} are transmission coefficients and S_{41} is the isolation

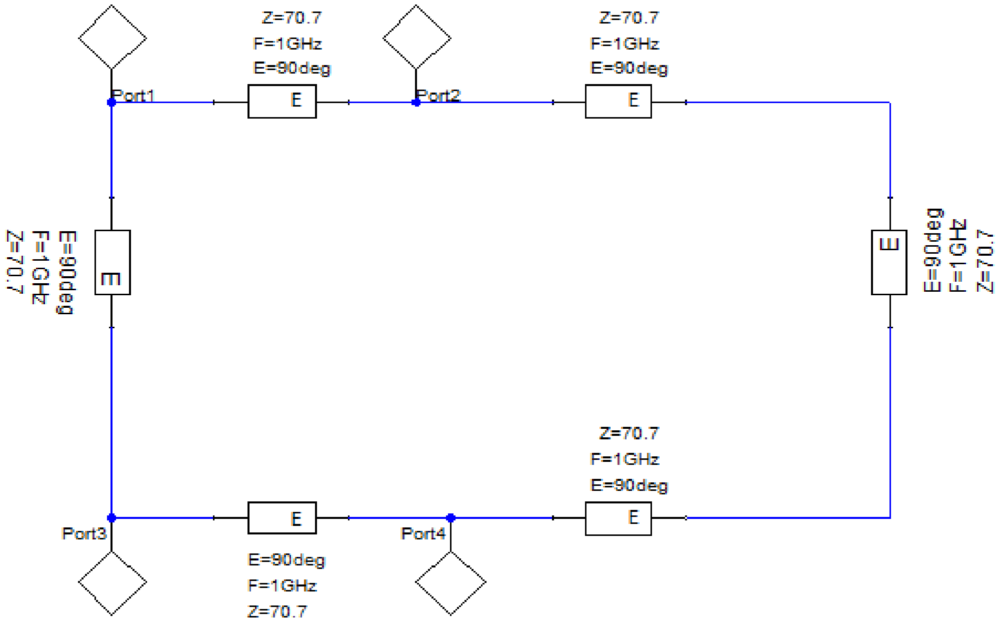


Figure. 10.2 Rat race coupler using ANSYS circuit simulator

6.Results:

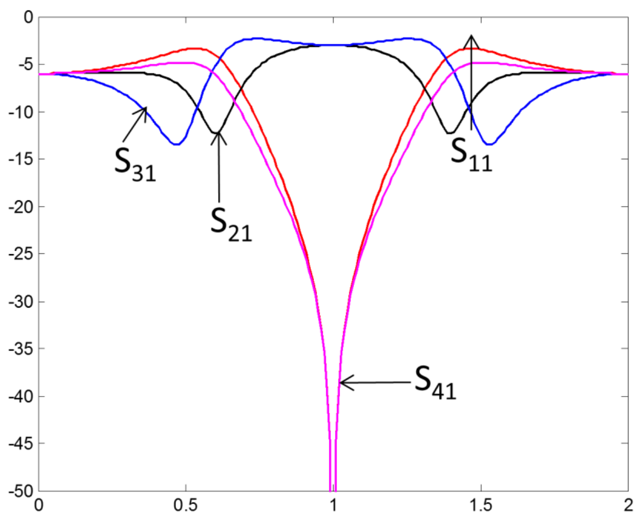


Figure. 10.3. S-Parameters (S_{11}, S_{21},S_{31}, S_{41}) vs Frequency (GHz)

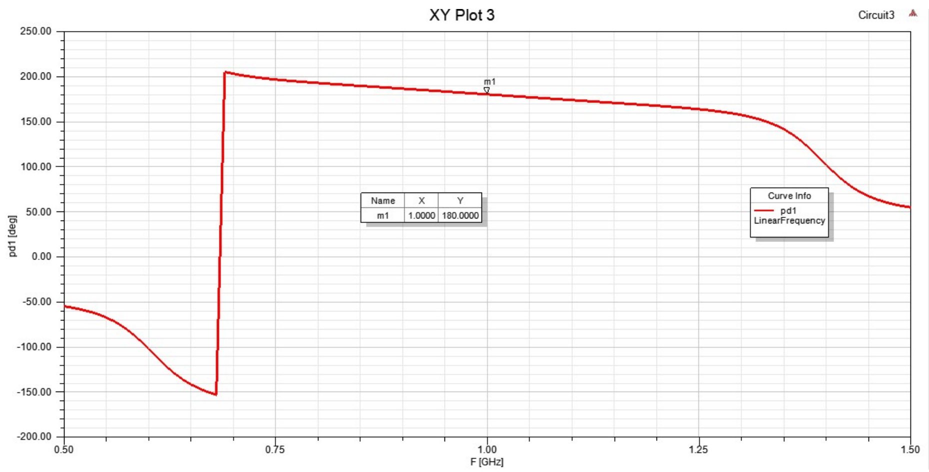


Figure. 10.4. Phase difference at difference port ($\angle S_{24} - \angle S_{34}$) vs Frequency (GHz)

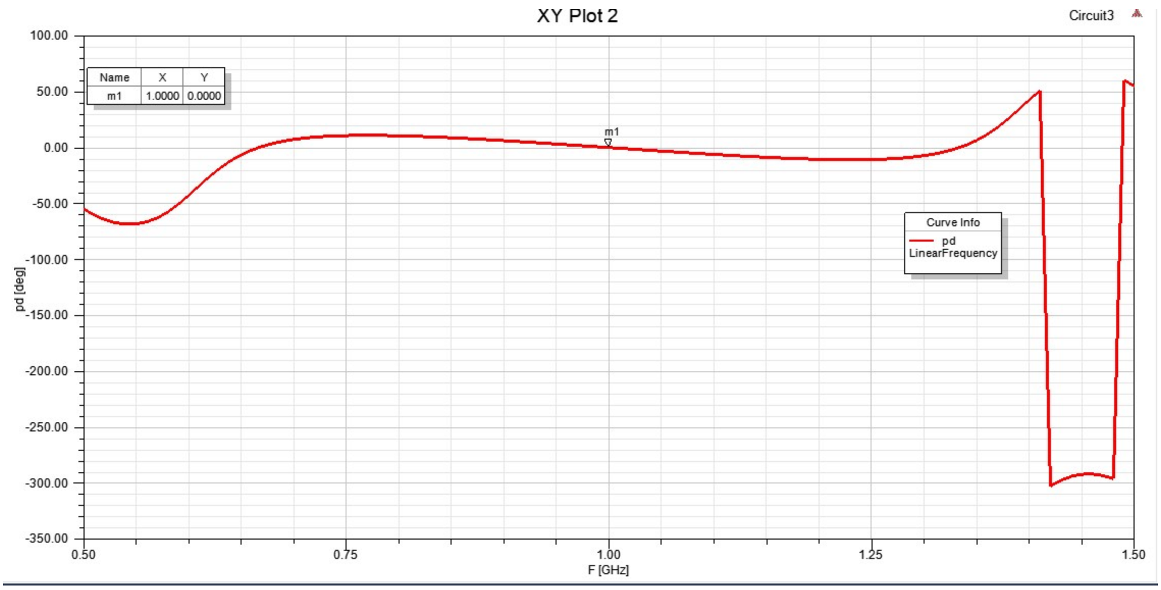


Figure. 10.5 . Phase difference sum port ($\angle S_{21} - \angle S_{31}$) vs Frequency (GHz)

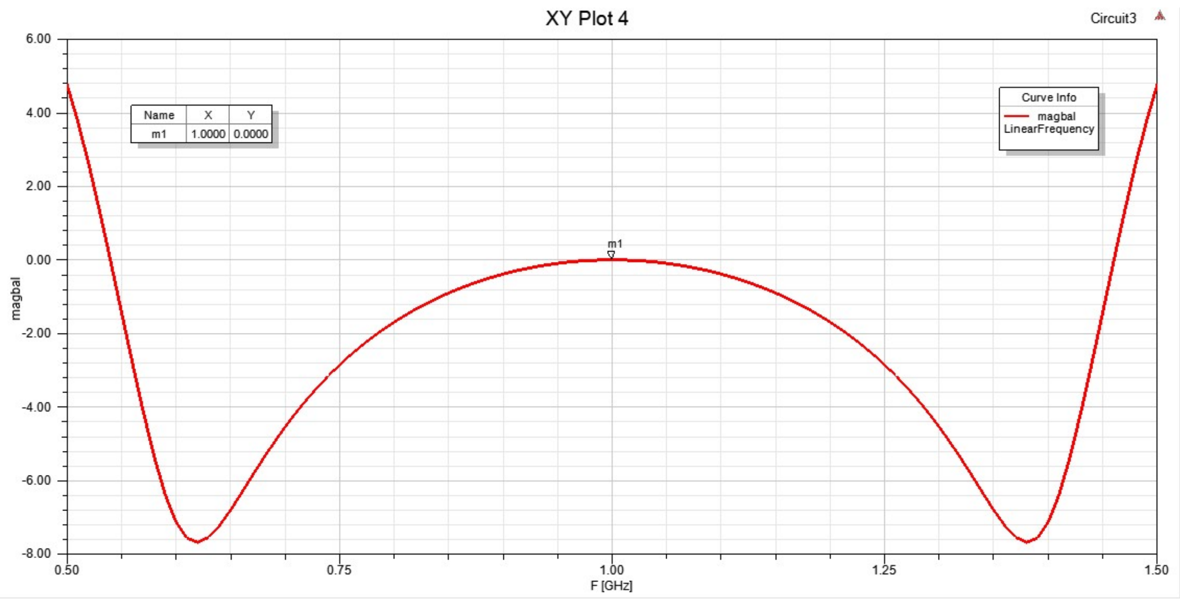


Figure.10.6: Magnitude difference ($|S_{21}|$-$|S_{31}|$) vs Frequency (GHz)

7.Precautions:

1. Save the setup due to power correction.
2. Don't open unnecessary files.
3. Shut down the system before leaving the job.

8.Result:

Rat race coupler is designed, simulated and plot the S-parameters

9.Viva questions

1.Describe the properties of RRC
2.What is the meaning of sum port?
3. What is the meaning of difference port?
4.Mention other name of RRC?

11.S-parameter measurement of microwave band stop filter	EXPT. NO : 11
	DATE :

1Aim: To design a Band Stop Filter (BSF) and, plot the S-parameter magnitudesfrom $0.8f_0$ to $1.2f_0$, where f_0 is the operating frequency.

2.Apparatus & Tools:

1.Ansys HFSS circuit simulator

2.Personal computer

3.Theory:

Band stop filter is one of the indispensable components for radio frequency and microwave circuits' applications. This filter rejects unwanted signals such as harmonic and spurious signals and allows desired signal to pass through. A shunt open-circuited stub is the simplest band stop structure for microwave circuit design. Figure 1 A simple open circuit shunt stub is the simplest way to realize band stop filter that stops the signal at the frequency with stub's electrical length of 90°. The characteristic impedances of the two shunt stubs and the section of transmission line are Z_S and Z_0, respectively. The electrical lengths of all lines are 90°. The cross-coupling is modeled by the capacitor C connecting between the ends of the two stubs.

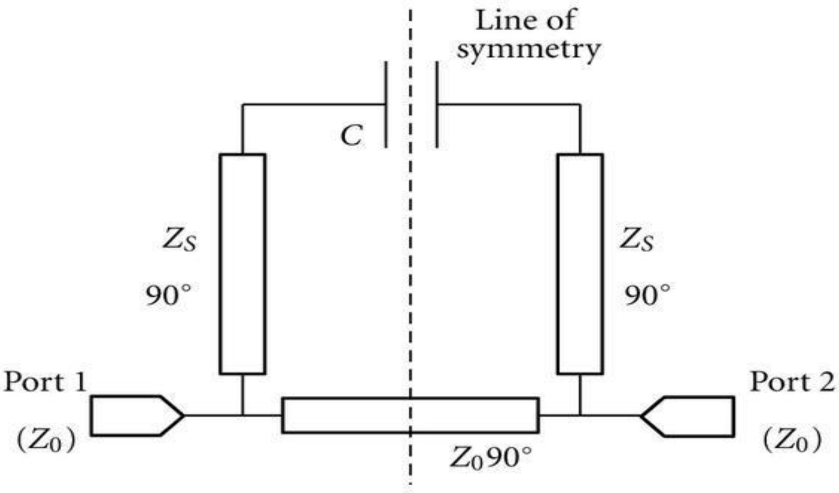


Figure.11.1 Schematic diagram of the band stop filter

4.Design Specifications:

(i) Transmission line impedances=70.7Ω, 50Ω

(ii)Transmission line length=90^0

(iii)Operating frequency f_0=1GHz

5.Design and simulation flow:

1.Open project editor and add insert circuit design

2.Select microstrip lines from components

3.Connect the all microstrip line according to diagram

4.Assign line length ,impedances, operating frequency according to specifications

5.Connect 2 ports with impedance 50Ω to structure

6.Add analysis setup i.e from 0.8GHz to 1.2GHz

7.Plot the S-Parameters(S_{11}, S_{21}), where S_{11} is reflection coefficient and S_{21} is the transmission coefficient

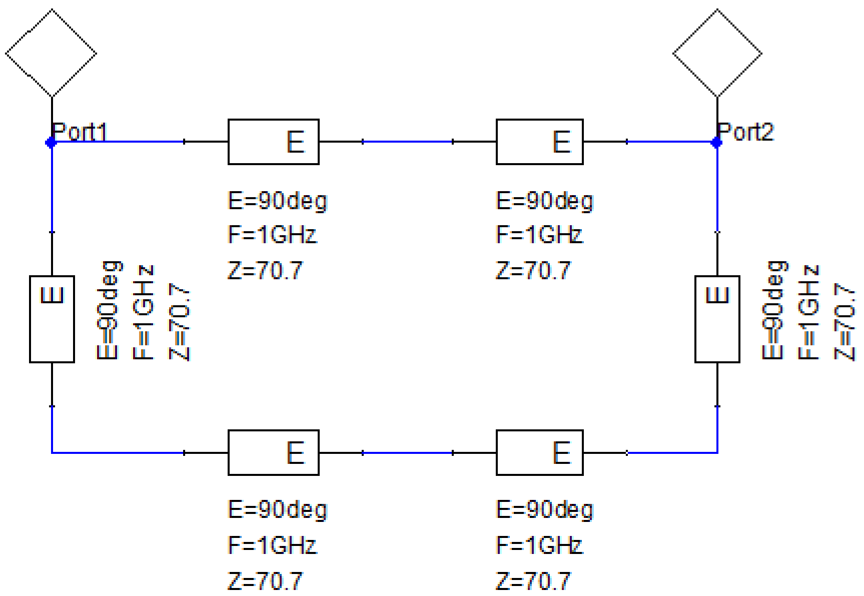


Figure.11.2. Band Stop Filter using ANSYS circuit simulator

6.Results:

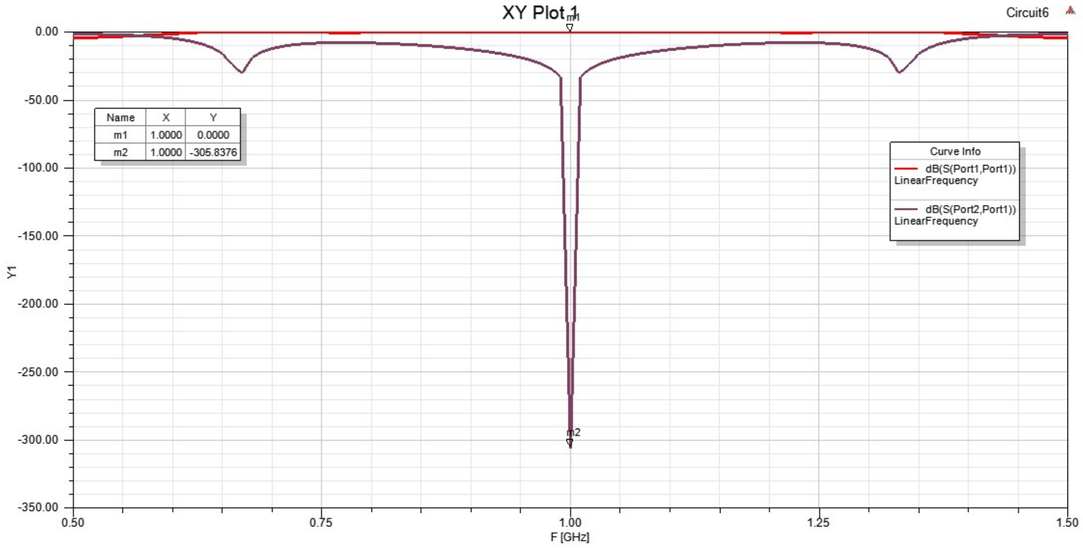


Figure.11.3. S-Parameters (S_{11}, S_{21}) vs Frequency (GHz)

7.Precautions:

1. Save the setup due to power correction.
2. Don't open unnecessary files.
3. Shut down the system before leaving the job

8.Result:

Band stop filter is designed, simulated and plot the S-parameters

9.Viva Questions

1. What is BSF?
2. What are the applications of BSF?
3. Define reflection coefficient?
4. Describe S-parameters of BSF.

12.S-parameter measurement of microwave balun

EXPT. NO : 12

DATE :

1.Aim: To design a microstrip balun and, plot the S-parameter magnitudes from 0.5 f_0 to 1.5 f_0, Where f_0 is the operating frequency.

2.Apparatus & Tools:

1.Ansys HFSS circuit simulator

2.Personal computer

3.**Theory:**

Balun is a device which connects balanced transmission line to unbalanced transmission line. Balun is the short form of Balanced-Unbalanced. It is the device which matches two different impedances.

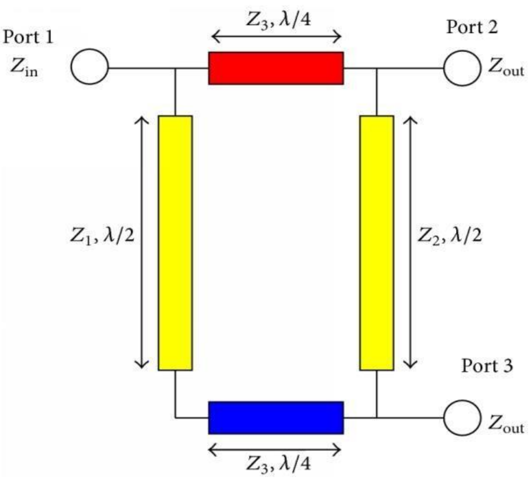


Figure.12.1 Branch line balun

The quarter-wavelength series lines can be used for impedance transformation, while the half-Wave length branches achieve phase shift of 180 degrees required for balun operation.

4.Design Specifications:

(i)Transmission line impedances=70.7Ω

(ii)Transmission line length=90^0

(iii)Operating frequency f_0=1GHz

5.**Design and simulation flow:**

1.Open project editor and add insert circuit design

2.Select microstrip lines from components

3.Connect the all microstrip lines according to diagarm

4.Assign line length ,impedances, operating frequency according to specifications

5.Connect 4 ports with impedance 50Ω to structure

6.Assign analysis setup i.e from 0.5GHz to 1.5GHz

7.Plot the S-Parameters(S_{11}, S_{21},S_{31}) where S_{11} is reflection coefficient and S_{21}, S_{31} are transmission coefficients

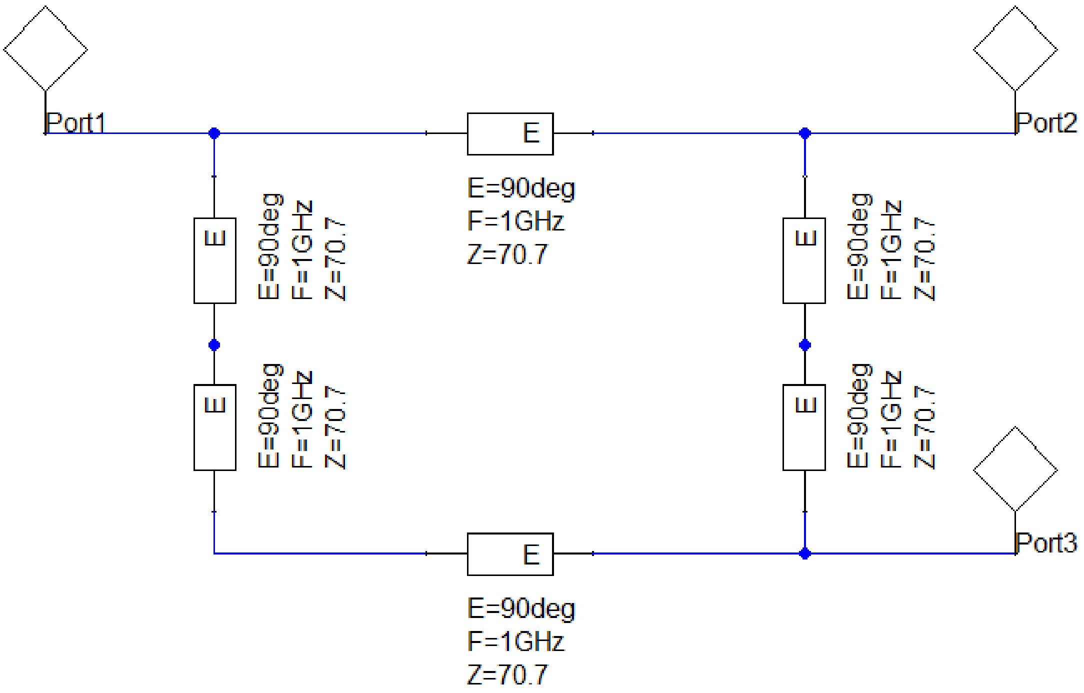


Figure.12.2. Microstrip balun using Ansys circuit simulator

6.Results:

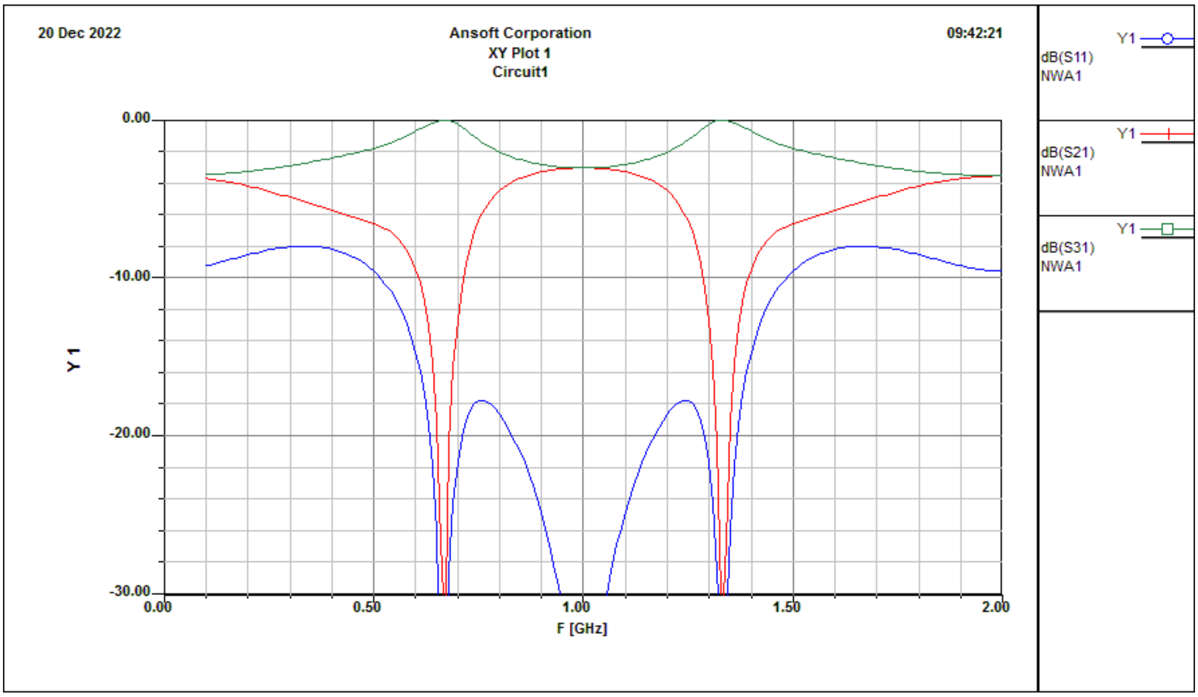


Figure.12.3. S-Parameters (S_{11}, S_{21},S_{31}) vs Frequency (GHz)

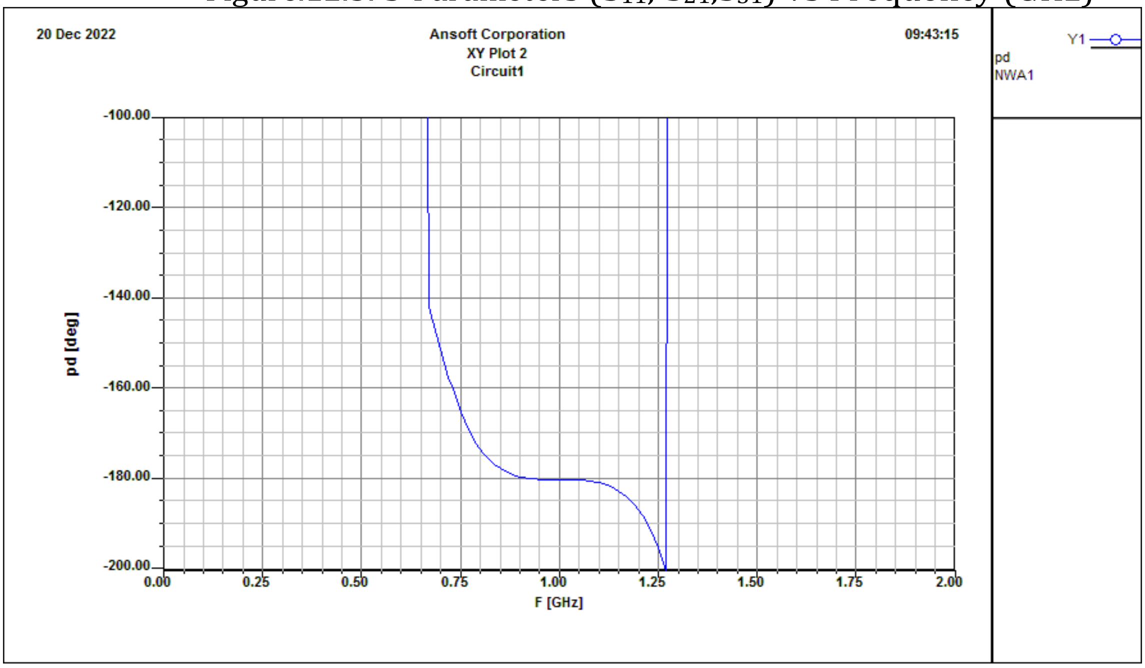


Figure.12.4. Phase difference ($\angle S_{21} - \angle S_{31}$) vs Frequency (GHz)

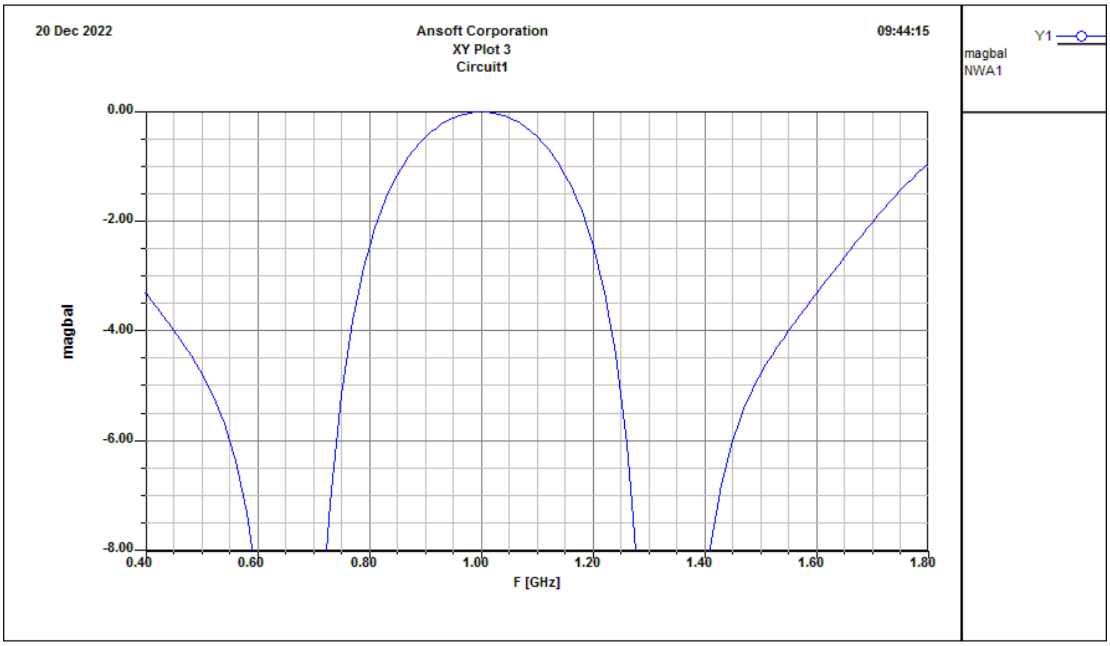


Figure.12.5. Magnitude balance ($|S_{21}|-|S_{31}|$) vs Frequency (GHz)

7.Precautions:

1. Save the setup due to power correction.
2. Don't open unnecessary files.
3. Shut down the system before leaving the job.

8.Results:

Microstrip balun is designed, simulated and plot the S-parameters

9.Viva Questions:

1. Define the meaning of balun?
2. What are the applications of balun?
3. What is the phase difference between output ports in Branch line balun?
4. Differentiate RRC and Branch line balun.