LABORATORY MANUAL

COMMUNICATION SYSTEMS LAB (S7 T)

MICROWAVE LAB

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

COLLEGE OF ENGINEERING

TRIVANDRUM

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

COLLEGE OF ENGINEERING

TRIVANDRUM

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Dept. of ECE
CET

LIST OF EXPERIMENTS

Cycle

1. Gunn Diode Characteristics.
2. Reflex Klystron Mode Characteristics.
3. Measurement of VSWR
4. Verification of the relation between guide wavelength cut off wavelength and free space wavelength
5. Antenna Pattern Measurement.
6. Measurement of E-Plane and H-Plane Characteristics.
7. Directional Coupler Characteristics.
8. Unknown load impedance measurement using smith chart and verification using transmission line equation.
9. Measurement of dielectric constant for given solid dielectric cell.
10. Study of Vector Network Analyzer.

MICROWAVE EXPERIMENTS

INDEX

INTRODUCTION

STUDY OF MICROWAVE COMPONENTS.

WAVEGUIDE

In electromagnetic and communication engineering, the term wave guide may refer to any linear structure that conveys electromagnetic waves between its end points. However, the original and most common meaning is a hollow metal pipe used to carry radio waves. Wave guide is used as a transmission line mostly at microwave frequencies, for connecting microwave transmitters and receivers to their antennas.

A dielectric employs a solid dielectric rod rather than a hollow pipe. An optical fiber is a dielectric guide designed to work at optical frequencies. Transmission lines such as microstrip, coplanar waveguide, stripline or coaxial may also be considered to be waveguides

ISOLATOR

An isolator is a non reciprocal transmission device that is used to isolate one component from reflections of other components in the transmission line. An ideal isolator completely absorbs the power for propagation in one direction and provides lossless transmission in the opposite direction. Thus the isolator is usually called uniline. Isolators are generally used to improve the frequency stability of microwave generators such as klystrons and magnetrons, in which the reflection from the affects the generating frequency. In such cases, isolator placed between the generators and prevents the reflected power from the unmatched load from returned to the generator.

FREQUENCY METER

Frequency meters are used to measure or to standardize the frequency of a microwave system. Practical frequency meters consist of a calibrated tunable cavity of desired shape. These are 3 types of wave meters.

- Transmission type, these pass the signal to which they are tuned.

- Absorption type, which attenuate only the resonant frequency of signal.
- Reaction type, which absorb energy from the transmission line at the resonant frequency.

Transmission and absorption types should be used with matched systems with suitable isolation such as directional couplers. The desirable features of frequency meters are high Q low loss and immunity from all spurious resonance.

ATTENUATOR

In microwave terminology, any dissipative elements inserted in the energy field are called an attenuator. It consists of resistive or lossy surface, sometimes referred to as a card placed in the center of a waveguide through a slot. On increasing the penetration of the card, it absorbs more energy and the attenuation, therefore increases.

Attenuators used in wave-guide circuitry serve two purposes

1. To isolate source from the rest of the equipment.
2. To provide suitable power levels.

End tapered resistive cards are placed parallel to the electric field to attenuate it in case of fixed attenuators while in variable attenuator, either the pad coca is reduced or orientation of the card is changed.

MATCHED TERMINATION

The matched termination is a termination or a load for a microwave setup. Standing waves occur when ever a load doesn’t completely absorb the power reaching it. In the microwave measurements, whether for power or component characteristics e.g. VSWR of slotted section, it is terminated for minimum reflection. The match termination serves this purpose. The closed end has a resistive element of suitable electrical and mechanical characteristics for providing near perfect load.

E PLANE TEE

An e plane tee is designed by fastening a piece of a similar wave guide to the broader wall of waveguide section. The fastened waveguide called the auxiliary arm is parallel to the plane of the electric field of the dominant TE10 mode in the main waveguide, hence this type of junction is also known as e plane tee.

H PLANE TEE

An H plane tee is obtained by fastening the auxiliary waveguide perpendicular to the narrow arm of the main waveguide section.

MAGIC TEE

E - H Tee consists of a section of wave guide in both series and shunt wave guide arms, mounted at the exact midpoint of main arm. Both ends of the section of wave guide and both arms are flanged on their ends. These Tees are employed in balanced mixers, AFC circuits and impedance measurement circuits etc. This becomes a four terminal device where one terminal is isolated from the input terminal.

KLYSTRON POWER SUPPLY

A typical regulated klystron power supply has a conventional bridge full wave rectifier followed by a low-pass filter, which serves as the supply for an electronic voltage regulator. Variable autotransformer in the primary of the high potential supply transformer adjusts the output voltage of the unregulated supply. Electronic regulation is achieved by vacuum triode 812 screwing, as regulator and tube 2C53 is a specially developed high voltage regulator tube and current. Two OD3 voltage regulator tubes in seriesAunder proper operating conditions it draws 1m provide focus and repeller potentials. Diode 6 x 4 in the reflector circuit prevents the reflector from becoming positive with respect to cathode. Since reflector and focus voltages are highly negative with respect to ground, high degree of insulation is provided there in. The modulation is provided through input capacitor to reflector having an insulation rating of 5000v. Filament transformer supplying the klystron and tubes 2C 53 and 6 x 4 has an insulation rating 7000v which is must.

DIRECTIONAL COUPLER

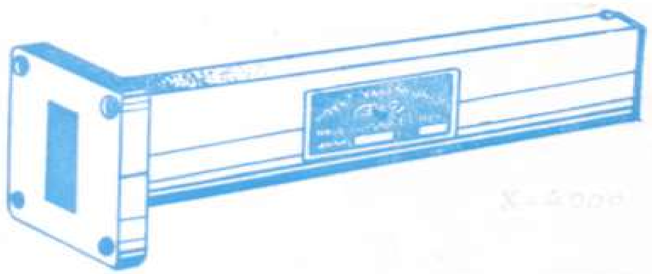
A Directional coupler is a four port waveguide junction it consists of a primary waveguide and secondary waveguide. When all ports are terminated in their characteristic impedance there is a free transmission of power without reflection between port 1 and port 2, and there is no transmission of port between port 1 and port 3 or between port 2 and port 4 because no coupling exist between port 1 and port 3 dependence on the structure of the coupler. The characteristics of a directional coupler can be expressed in terms of its coupling factor and its directivity.

GUNN OSCILLATORS

Gunn Oscillators are solid state microwave energy generators. These consist of waveguide cavity flanged on one end and micrometer driven plunger fitted on the other end. A Gunn-diode is mounted inside the Wave guide with BNC (F) connector for DC bias. Each Gunn oscillator is supplied with calibration certificate giving frequency vs micrometer reading.

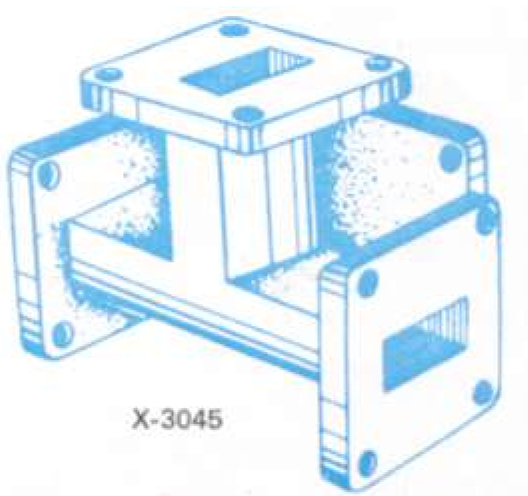
PIN MODULATORS

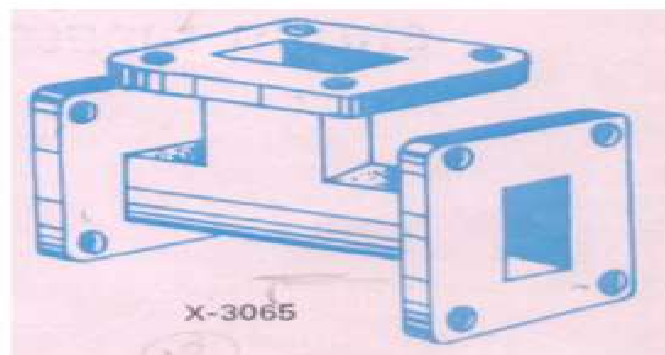
Pin modulators are designed to modulate the continuous wave output of Gunn Oscillators. It is operated by the square pulses derived from the UHF (F) connector of the Gunn power supply. These consist of a pin diode mounted inside a section of Wave guide flanged on its both end. A fixed attenuation vane is mounted inside at the input to protect the oscillator.



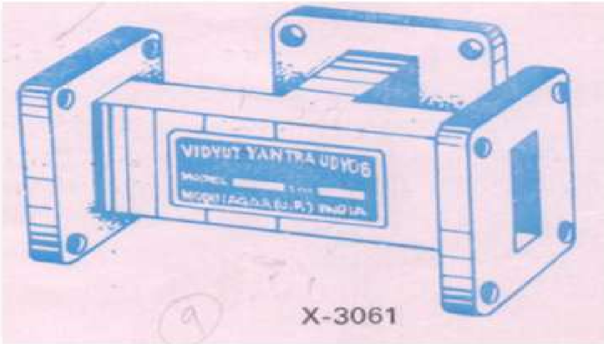
Waveguide

Directional coupler

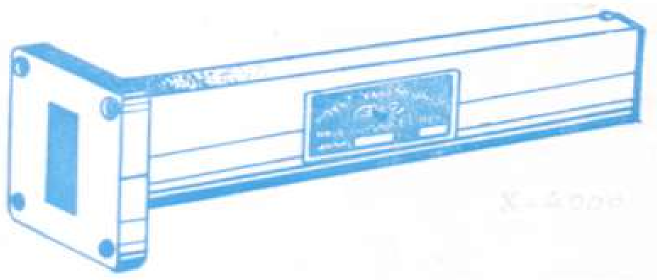




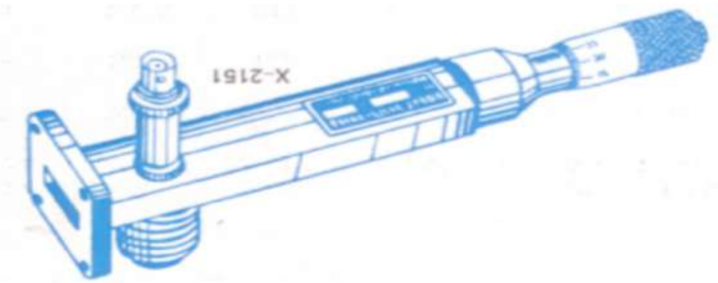
Magic tee **H plane tee**



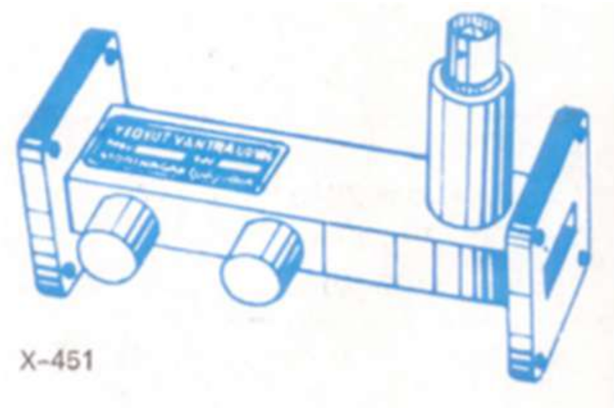
E plane Tee



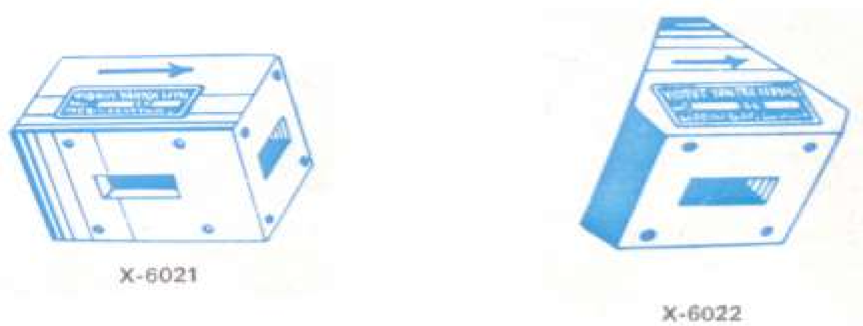
Matched termination



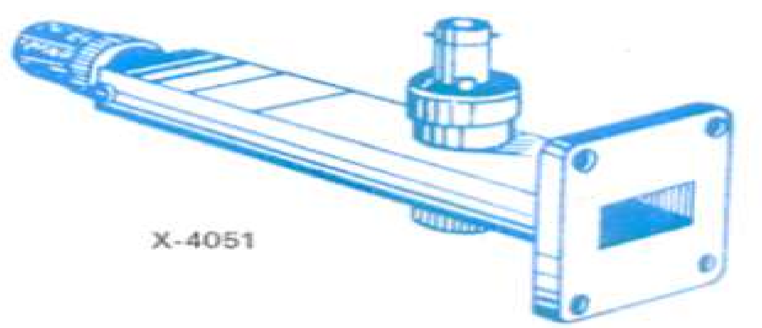
Gunn Oscillator



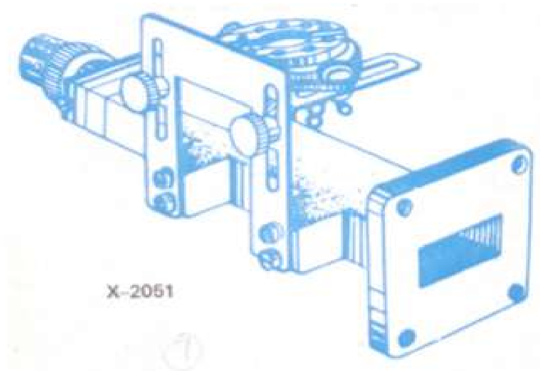
Pin Modulator



Circulator



Waveguide detector mount[Tunable]



Klystron Mount

1. GUNN DIODE CHARATERISTICS

AIM:

To draw V-I characteristics of the given Gunn diode oscillator

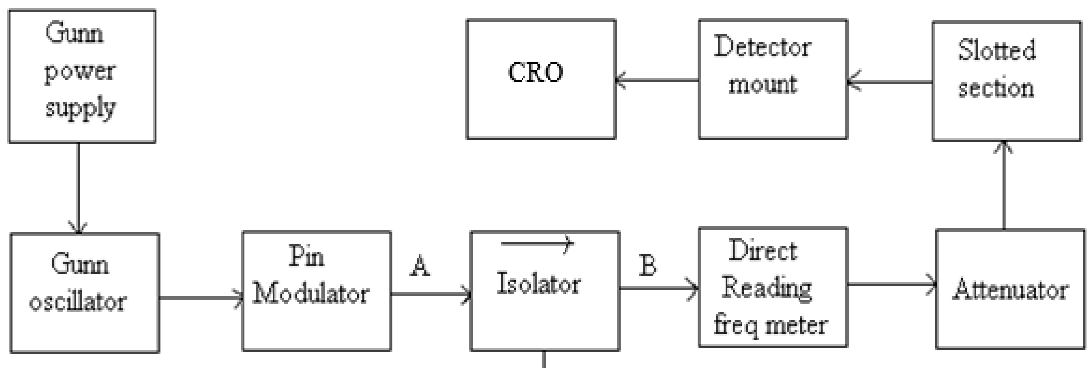
EQUIPMENTS REQUIRED:

Gunn Power Supply, Gunn Oscillator, PIN Modulator, Isolator, Variable Attenuator, Frequency Meter, Detector Mount, Waveguide Stands, VSWR Meter, CRO, Cables and Accessories.

THEORY:

The Gunn oscillator is based on negative differential conductivity effect in bulk semiconductors, which has two conduction bands minima separated by an energy gap. A disturbance at the cathode gives rise to high field region, which travels towards the anode. When this high field domain reaches the anode, it disappears 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 (transit time) gives oscillation frequency. In a Gunn oscillator, the Gunn diode is placed in a resonant cavity. In this case the oscillation frequency is determined by cavity dimension then by diode itself. Although Gunn oscillator can be amplitude modulated with the bias voltage. We have used separate PIN modulator through PIN diode for square wave modulation. A measure of the square wave modulation capability is the modulation depth i.e. the output ratio between, ‘ON’ and ‘OFF’ state.

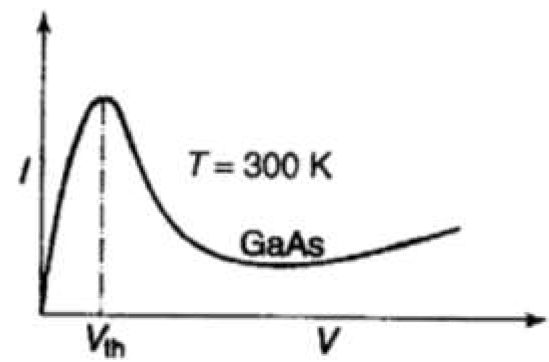
BLOCK DIAGRAM



TABULATION:

Current (mA)	Voltage (V)

-



Model Graph

PROCEDURE:

1. Set the components and equipment as shown in figure.

2. Before switching ON the power supply keep the control knobs of Gunn power supply as below.

Gunn bias and PIN bias knob – Fully anticlockwise
Meter switch – Voltage position.
Selector switch – INT position
Mod Frequency knob – Any position.

3. Initially set the variable attenuator for maximum attenuation.

4. Rotate the knob of frequency meter at maximum position.

5. Set the micrometer of Gunn oscillator for required frequency of operation.

6. Switch ON the Gunn power supply, CRO and cooling fan.

7. Rotate PIN bias knob to around maximum position

8. Increase the Gunn bias voltage control knob up to 7 volts.

9. Measure the Gunn diode current corresponding to the various voltage controlled by Gunn bias

   Knob through the panel meter and meter switch.

10. Plot the voltage and current reading on the graph.

11. Measure the threshold voltage which, corresponds to maximum current.

RESULT:

Thus the characteristics of voltage Vs current are drawn and the threshold voltage is found.

Threshold voltage V_{th}:……………..volts.

2. REFLEX KLYSTRON MODE CHARATERISTICS

AIM:

To study the Mode Characteristics of Reflex Klystron.

EQUIPMENTS REQUIRED:

Klystron Power Supply, Klystron with mount, Isolator, Frequency meter, Variable Attenuator, Slotted section with Probe carriage, CRO, Movable Short.

THEORY

Klystron is a microwave vacuum tube employing velocity modulation. These electrons move towards the repeller (i.e.) the electrons leaving the cavity during the positive half cycle are accelerated while those during negative half cycle are decelerated. The faster ones penetrate further while slower ones penetrate lesser in the field of repeller voltage. But, faster electrons leaving the cavity take longer time to return and hence catch up with slower ones. In the cavity the electrons bunch and interact with the voltage between the cavity grids. It consists of an electron gun producing a collimated electron beam. It bunches pass through grids at time the grid potentials is such that electrons are decelerated they give by energy. The electrons are then collected by positive cavity wall near cathode. To protect repeller from damage, repeller voltage is applied before accelerating voltage.

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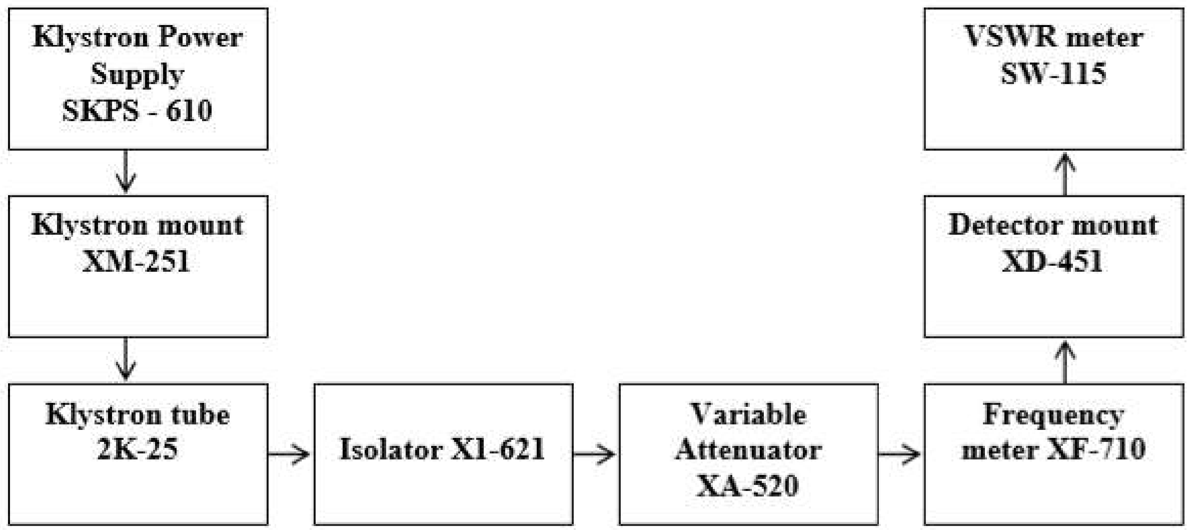


PROCEDURE:

Before switching ON the power supply keep the control knobs of Klystron power supply as below.

- Meter switch – OFF position
- Mod selector switch – AM position AM Frequency
- Amplitude Mid position Beam voltage – Fully anticlockwise
- Reflector voltage – Fully clockwise Standby switch – ON position

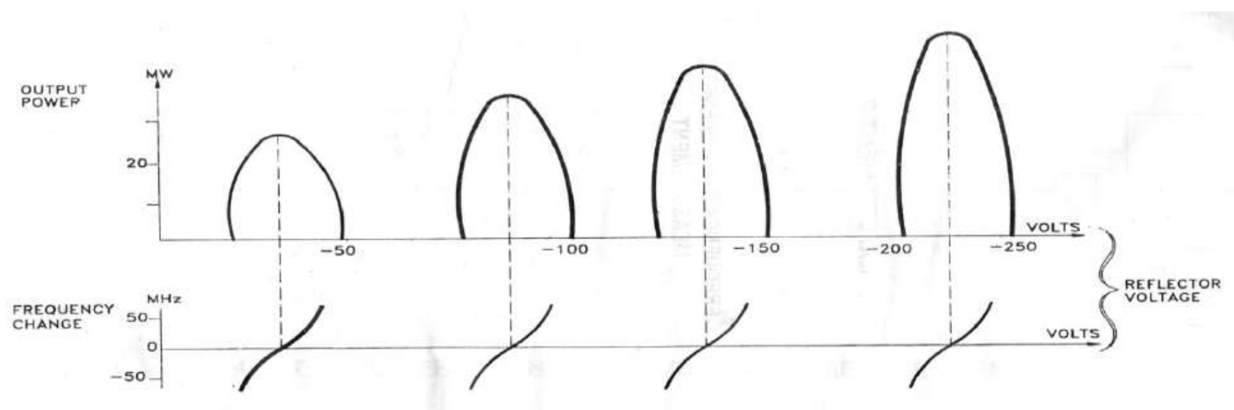
1. Keep the control knob of VSWR meter as below

   Input switch – Low Impedance SWR Range switch – 40dB Meter switch – Normal Gain (course & Fine) – Mid position.

2. Initially set the variable attenuator for maximum attenuation.
3. Rotate the knob of frequency meter at maximum position.
4. Switch 'ON' the Klystron power supply and cooling fan.
5. Change the meter switch to beam voltage position and rotate beam voltage knob clockwise slowly to make beam current 17mA.
6. Rotate the repeller voltage knob to get any mode of klystron tube can be seen on an oscilloscope/meter
7. Take down the readings any three modes, Measure the frequency using frequency meter and corresponding reading of current at ammeter

Plot Output Current Vs Repeller Voltage and Frequency Vs Repeller Voltage

Mode	**Repeller Voltage**	**Ouput Current (μA)**	**Frequency in GHz**
Mode 1			
Mode 2			
Mode 3			



Model graph

RESULT:

The mode characteristics of Reflex Klystron was studied and drawn.

3. MEASUREMENT OF VSWR

AIM:

To measure the Voltage Standing Wave-Ratio and Reflection Co-efficient for matched load.

EQUIPMENTS REQUIRED:

Klystron Power Supply, Klystron Tube with Klystron Mount, Isolator, Variable Attenuator, Frequency Meter, Slotted Section, Tunable Probe, S.S.Tuner, Matched Termination, Waveguide Stands, VSWR Meter, CRO, Cables and Accessories.

THEORY:

The electromagnetic field at any point of transmission line may be considered as the sum of two traveling waves: the ‘Incident Wave’ propagates from generator and the reflected wave propagates towards the generator. The reflected wave is set up by reflection of incident wave from a discontinuity on the line or from the load impedance. The magnitude and phase of reflected wave depends upon amplitude and phase of the reflecting impedance. The super position of two traveling waves, gives rise to standing wave along with the line. The maximum field strength is found where two waves are in phase and minimum where the two waves add in opposite phase. The distance between two successive minimum is half the guide wavelength on the line. The ratio of electrical field strength of reflected and incident wave is called reflection coefficient.

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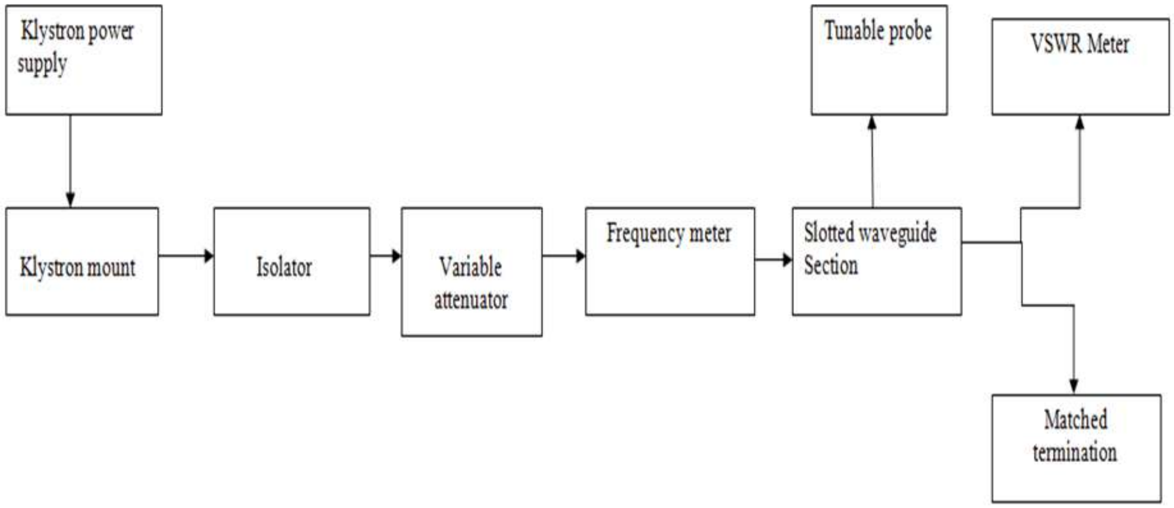

PROCEDURE:

1. Set the components and equipment as shown in figure.

2. Before switching ON the power supply keep the control knobs of Klystron power supply as below.

Meter switch – OFF position
Mod selector switch – AM position
AM Frequency & Amplitude - Mid position
Beam voltage – Fully anticlockwise
Reflector voltage – Fully clockwise
Standby switch – ON position

3. Keep the control knob of VSWR meter as below

Input switch – Low Impedance SWR Range switch – 40dB Meter switch – Normal Gain (course & Fine) – Mid position.

4. Initially set the variable attenuator for maximum attenuation.

5. Rotate the knob of frequency meter at maximum position.

6. Switch ‘ON’ the Klystron power supply, VSWR meter and cooling fan.

7. Turn the meter switch of power supply to beam voltage position and set the beam voltage at 300V with the help of beam voltage knob.

8. Adjust the reflector voltage to get some deflection in VSWR meter.

9. Maximize the deflection with AM amplitude and frequency control knob of power supply.

10. Tune the plunger of klystron mount for maximum deflection.

11. Tune the probe for maximum deflection in VSWR.

12. Tune the frequency meter knob to get dip on the VSWR scale, and note down the frequency directly from the frequency meter.

13. Keep the depth of pin of S.S.Tuner to around 3 – 4mm and lock it.

14. Move the probe along with slotted line to get maximum deflection.

15. Adjust VSWR meter gain control knob such that the meter indicates 1.0 on the normal upper SWR scale.

16. Calculate the reflection co efficient.

Reflection co efficient= [S-1]/[S+1]

RESULT:

Thus the VSWR and reflection co efficient are calculated.

4. VERIFICATION OF THE RELATION BETWEEN GUIDE WAVELENGTH, CUTOFFWAVELENGTH AND FREE SPACE WAVELENGTH

AIM:

To verify relation between Guide Wavelength, free space Wavelength and cut off wave length for .rectangular wave-guide working on TE10 mode.

EQUIPMENTS REQUIRED:

Klystron power supply, Isolator, Variable Attenuator, Frequency Meter, Slotted Section, Detector Mount, Movable Short

THEORY:

Mode represents in wave-guide as either $\mathbf{TE_{m,n}}$ / $\mathbf{TM_{m,n}}$

Where, TE – Transverse electric, TM – Transverse magnetic m – Number of half wavelength variation in broader direction. n – Number of half wavelength variation in shorter direction.

$$\lambda g / 2 = (d_1 - d_2)$$

Where, d_1 and d_2 are the distance between two successive minima / maxima. It is having highest cut off frequency hence dominant mode.

For dominant TE10 mode in rectangular wave-guide

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

Where, λg - guide wave length, λ_0 - free space wave length

λc =2a / m; λc is cut-off wave length For TE_{10} mode, Where, m = 1 in TE10 mode then **a** is the broad dimension of waveguide (22.86mm) and following relationship can be proved.

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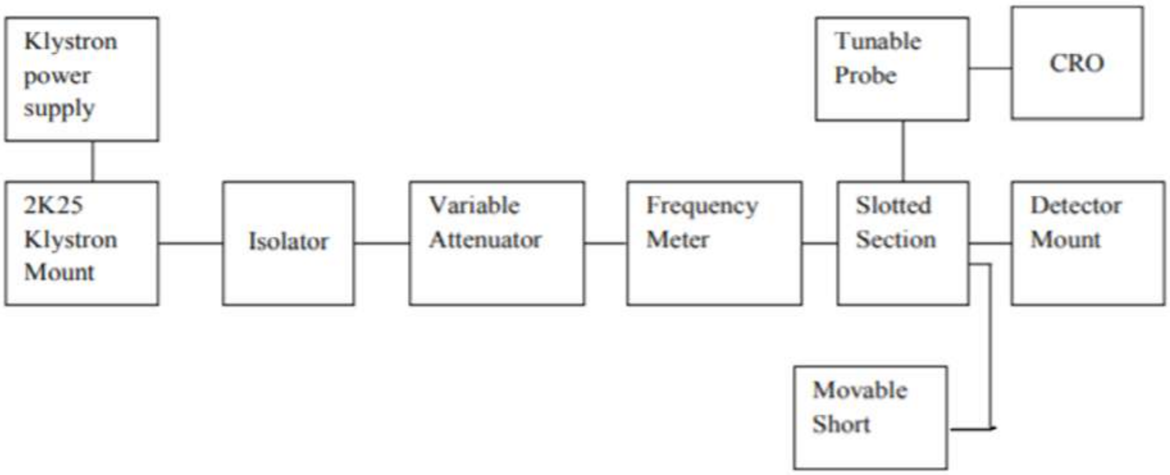

PROCEDURE:

1. Set up the components and equipments
2. Set up the variable attenuator at low attenuation position.
3. Keep the control knobs of Klystron power supply as below. Meter Switch : OFF Mod- Switch : AM Beam voltage knob : Fully anticlockwise Reflector voltage : Fully clockwise AM- Amplitude knob : Around fully clockwise AM- frequency : Around mid position
4. Switch on the klystron power supply, cathode ray oscilloscope (CRO) and cooling fan.
5. Turn the meter switch of power supply to beam voltage position and set beam voltage at 220V with help of beam voltage knob.
6. Adjust the reflector voltage to get a square wave in CRO.
7. Maximize the reading by increasing AM amplitude modulation at power supply, controlling the plunger of slotted line and minimizing the attenuation. on CRO and note down the frequency′dip′
8. Tune the frequency meter to get a directly from frequency meter.
9. Replace the termination with movable short, and detune the frequency meter.

10. Move the tunable probe along with the slotted line to get a square wave in CRO.
11. Move the tunable probe to a minimum amplitude position and record the probe position as d_1.
12. Move the probe to next minimum position and record the probe position again as d_2.
13. Calculate the guide wavelength as twice the distance between two successive minimum positions obtained as above.
14. The measured wave-guide inner broad dimension ‘a’ is around 22.86 mm for X- band.
15. Measure the frequency.
16. Verify the obtained frequency with frequency meter

RESULT:

Frequency:………………….

Wavelength:…………………

Relation between Guide wave length, free space wave length and cut off wave length for rectangular wave-guide working on TE10 mode was verified experimently.

5. ANTENNA PATTERN MEASUREMENT

AIM:

To determine the radiation pattern of an antenna and to measure the Half Power Beam Width (HPBW).

EQUIPMENTS REQUIRED:

Gunn Power Supply, Gunn Oscillator, PIN Modulator, Isolator, Variable Attenuator, Frequency Meter, Detector Mount, Two Horn Antenna, Turn Table, VSWR Meter, CRO, Cables and Accessories.

THEORY:

If a transmission line propagating energy is left open at one end, there will be radiation from this end. In case of a rectangular wave-guide this antenna presents a mismatch of about 2:1 and it radiates in many directions. The match will improve if the open wave-guide is a horn shape. The radiation pattern of an antenna is a diagram of field strength or more often the power intensity as a function of the aspect angle at a constant distance from the radiating antenna. An antenna pattern is of course three-dimensional but for practical reasons it is normally presented as a two dimensional pattern in one or several planes. An antenna pattern consists of several lobes, the main lobe, side lobes and the back lobe. The major power is concentrated in the main lobe and it is required to keep the power in the side lobes and back lobe as low as possible. The power intensity at maximum of the main lobe compared to the power intensity achieved from an imaginary omni-directional antenna (radiating equally in all directions) with the same power fed to the antenna is defined as gain of the antenna.

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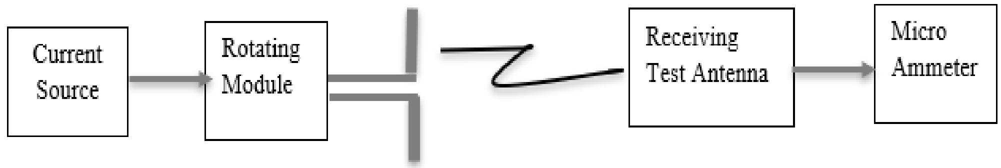


PROCEDURE:

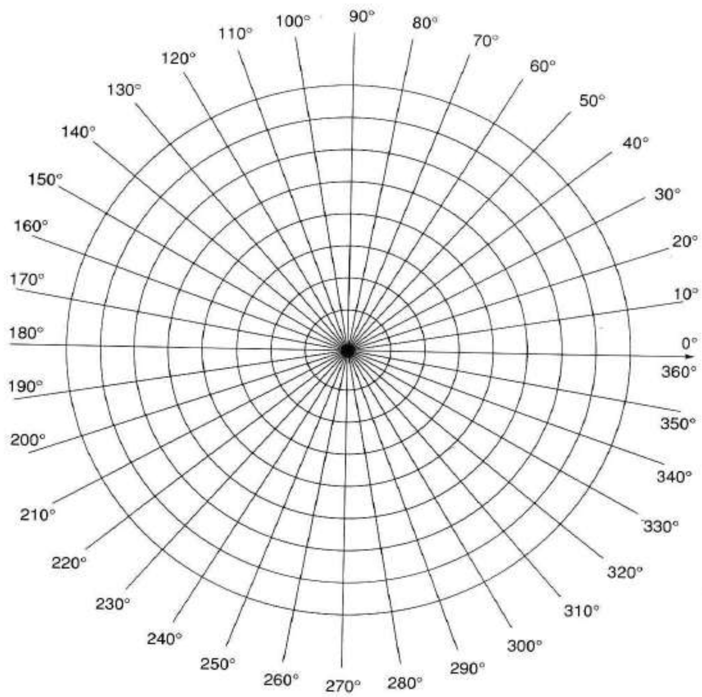
1. Set the components and equipment as shown in figure. Keeping the axis of both antennas in same axis line.
2. Switch on the power supply, and switch on the current source for exciting test antenna.
3. Adjust the Test antenna (Dipole) such that maximum reading is observed on micro ammeter. Note the maximum output current.
4. Test antenna is rotated in a step of 10 degrees anticlockwise and clockwise direction. Record the output current in each case.
5. Plot the power patten (Output current/power vs Angle) in polar plot and find the Half Power Beam Width (HPBW) of Antenna by marking half power point in plot.

TABULATION:

ANGLE	Current(μA)	I_{NORMAL}

RESULT:

Thus the radiation pattern is determined and the Half Power Beam Width are measured.



6. MEASUREMENT OF E AND H PLANE CHARECTERISTICS

AIM:

To determine isolations and coupling coefficients for E and H plane waveguide Tee junctions.

EQUIPMENTS REQUIRED:

Klystron power supply, Klystron with mount, isolator, variable attenuator, slotted section, Magic Tee, Matched termination, detector mount, CRO.

THEORY:

H Plane Tee

H plane tee is an auxiliary waveguide arm is fastened perpendicular to the narrow wall of a main guide, thus it is a three port device in which axis of the auxiliary or side arm is parallel to the planes of the magnetic field of the main of the main guide and the coupling from the main guide to the branch guide is by means of magnetic fields. Therefore, it is also known as H plane tee. The perpendicular arm is generally taken as input and other two arms are in shunt to the input and hence it is also called as shunt tee. Because of symmetry of the tee; equivalent circuit of H plane, when power enters the auxiliary arm, and the two main arms 1 and 2 are terminated in identical loads, the power supplied to each load is equal and in phase with one another. If two signals of equal amplitude and in same phase are fed into two main arms1 and 2, they will be added together in the side arm. Thus H plane tee is an `adder’.

E Plane Tee

E plane tee is an auxiliary waveguide arm is fastened to the broader wall of the main guide. Thus it is also a three port device in which the auxiliary arm axis in parallel to the plane of the electric fields of the main guide, and the coupling from the main guide to the auxiliary guide is by means of electric fields. Therefore, it is also known as E plane tee. It is clear that it causes load connected to its branches to appear in series. So it is often referred to as a series tee. As indicated in fig, the two main guide arms are symmetrical with respect to the auxiliary guide arm. As such if power is fed from the auxiliary arm, it is equally distributed in the two arms 1 and 2 when they are terminated in equal loads. However as depicted in the field configuration, the power flowing out in arm 1 is 180 out of phase to the one in arm 2. As such tee is known as `subtracter' or `differencer'.

Magic tee:

An interesting type of T junction is the hybrid tee, commonly known as `magic tee' which is shown in fig. The device is a combination of the E arm and H plane tees. Arm3, the H arm forms an H plane tee and arm 4, the E arm, forms an E plane tee in combination with arms 1 and 2. The central lines of the two tees coincide and define the plane of symmetry, that is, if arms 1 and 2 are of equal length, the part of structure on one side of the symmetry plane shown by shaded area is the mirror image of that on the other. Arms1 and 2 are sometimes called as the side or collinear arms.

E Plane, H Plane Tee Parameter

Isolation

The isolation of a T junction is the ratio of power supplied from a matched generator to one of the arms, to the power coupled to a matched detector in any other arm when the remaining arm is terminated in a matched load.

Isolation between port 1 and 2
$I_{12} = 10 \log_{10} P_1 / P_2$ dB, $I_{12} = 20 \log_{10} (V_1 / V_2)$ dB,
When matched load and detector are interchanged
$I_{13} = 10 \log_{10} P_1 / P_3$ dB, $I_{13} = 20 \log_{10} (V_1 / V_3)$ dB,
Similarly $I_{31} = 10 \log_{10} P_3 / P_1$ dB, $I_{32} = 20 \log_{10} (V_3 / V_2)$ dB
When matched load and detector are interchanged
$I_{33} = 10 \log_{10} P_3 / P_2$ dB,

$I_{32} = 20 \log_{10} (V_3 / V_2)$ dB, When arm 2 becomes the input, we will have other two values of isolation, I_{21} and I_{23}. Due to reciprocity Property, I_{21} will be the same as I_{12}.

Coupling coefficient:

Coupling coefficient can be calculated by

$$C = 10^{\frac{-\alpha}{20}}$$

Where α is the attenuation in db between the input and detector arm when the third arm is terminated in a matched load.

Magic tee parameters

Isolations

The isolation between E-and H-arms is defined as the ratio of the power supplied by the matched generator connected to E-arms (port-4), to the power detected in H-arm (port-3) by a matched detector when collinear arms (1&2) are terminated in matched loads. It is expressed in db.

$I_{34} = 10 \log_{10} P_4/P_3$,

$I_{34} = 20 \log_{10} (V_4 / V_3)$

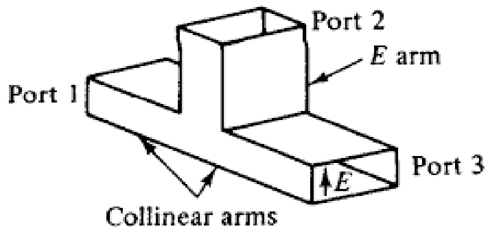
P_4 – power incident on the port 4 [E arm]

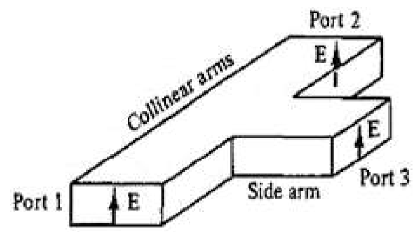
P_3 – power detected on the port 3 [H arm]

Coupling co efficient:

Coupling coefficient can be calculated by

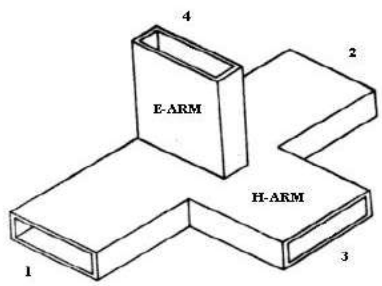
$C = 10^{\frac{-\alpha}{20}}$





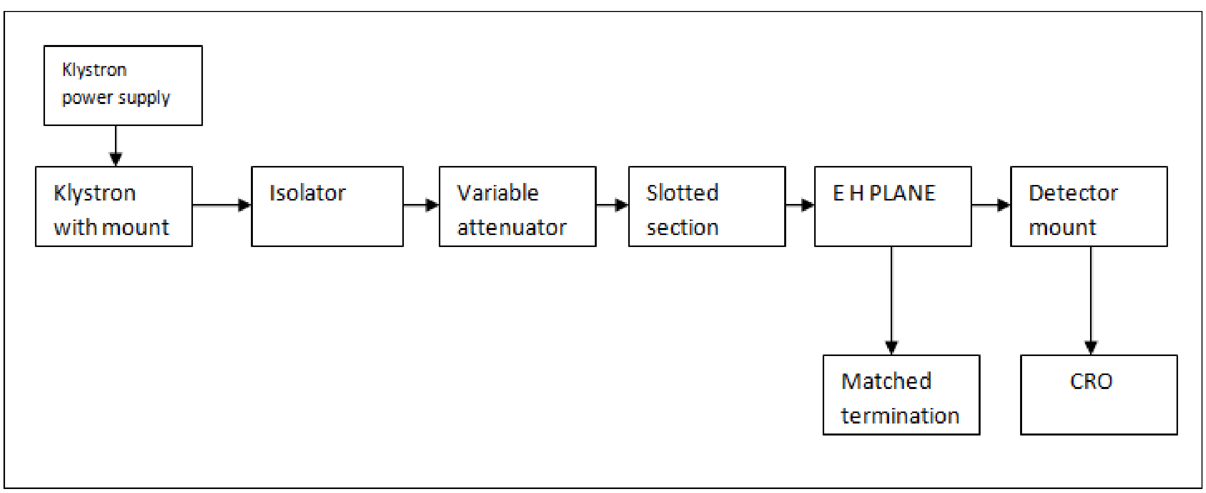
E plane tee

H plane tee



Magic tee

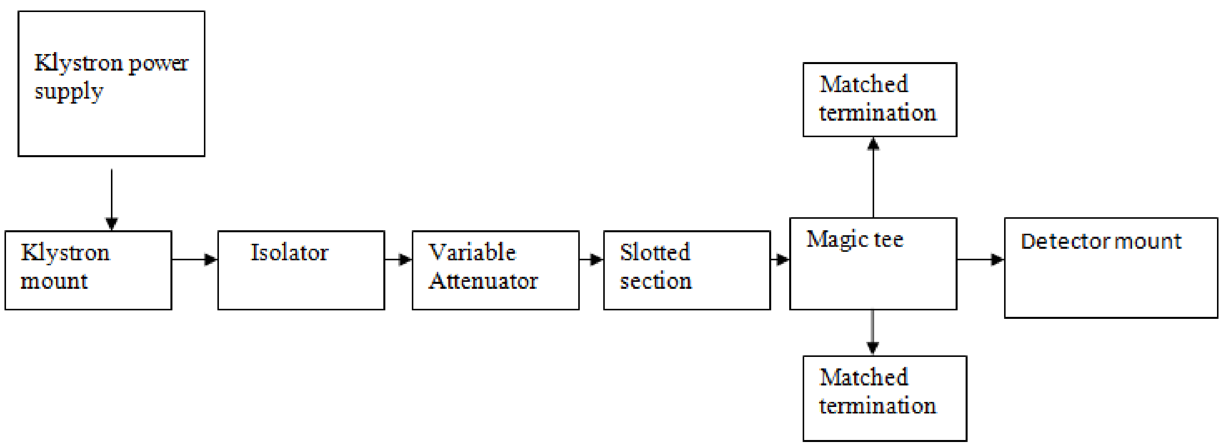
BLOCK DIAGRAM



Characteristics of E and H plane tee

PROCEDURE:

1. Remove the slotted line and Magic Tee/E/H Tee and connect the detector mount.
2. Energize the microwave source and set mode 3.
3. Note down the input voltage as Vi (mv) or Input power (Pi dBm) (should not alter the setting)
4. Now connect the magic tee/E-Plane/H-Plane Tee.
5. Determine the corresponding voltages Vj (mv)/ Power (Pj dBm) for each pair of ports by connecting one port to the source and measuring the output at other port while the remaining ports are connected to matched termination.
6. Determine the isolation and coupling coefficients for the given Tee.



Characteristics of Magic tee

Isolation and coupling co efficient

Tee	**Voltage**		**Isolation**	**Coupling**
	I/P	**Out Put**	**(I_{ij}) dB**	**$C_{ij} = 10^{Iij/20}$**
E Plane	**I^{st} Arm**			
	3^{rd} Arm			
H Plane	**I^{st} Arm**			
	3^{rd} Arm			
Magic Tee	**2^{nd} Arm**			
	3^{rd} Arm			
	4^{th} Arm			

- Generator to port i
- Detector mount to port j
- All other port is terminated using match termination.
- $I_{ij} = 20 \log V_i/V_j$
- $C_{ij} = 10^{\frac{-I_{ij}}{20}}$

Where α is the attenuation in db when i is the input and j the output arm. Thus α (db) = 10 log P_i / P_j where Pi is the power delivered to i arm by a matched generator and Pj is the power detected by a matched detector in arm j. In the case of magic tee, there are 12 coupling constants, one for each of the arms as an input to each of the other three arms as an output. However, if we have a perfectly matched detector and generator, $C_{ij} = C_{ji}$ and also the reciprocity desires $C_{12} = C_{21}$, $C_{32} = C_{31}$ and $C_{41} = C_{42}$.

RESULT:

Isolation and coupling coefficient of E and H plane tee was determined.

7. DIRECTIONAL COUPLER CHARATERISTICS

AIM:

To study the characteristics of multi-hole directional coupler by measuring the following

Parameters: Coupling factor and directivity of coupler.

EQUIPMENTS REQUIRED:

Klystron power supply, Frequency meter, tunable probe, Variable attenuator, Waveguide detector mount, Directional coupler, short and matched termination, slotted line.

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 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 4.The coupling factor is defined as:

Coupling (dB) = 10 log10 $[P_1/P_3]$ where port 2 is terminated

Isolation (dB) = 10 log10 $[P_2/P_3]$ where Port1 is matched.

With built in termination and power entering at port 1, the directivity of coupler is a measure of separation between incident and reflected wave.

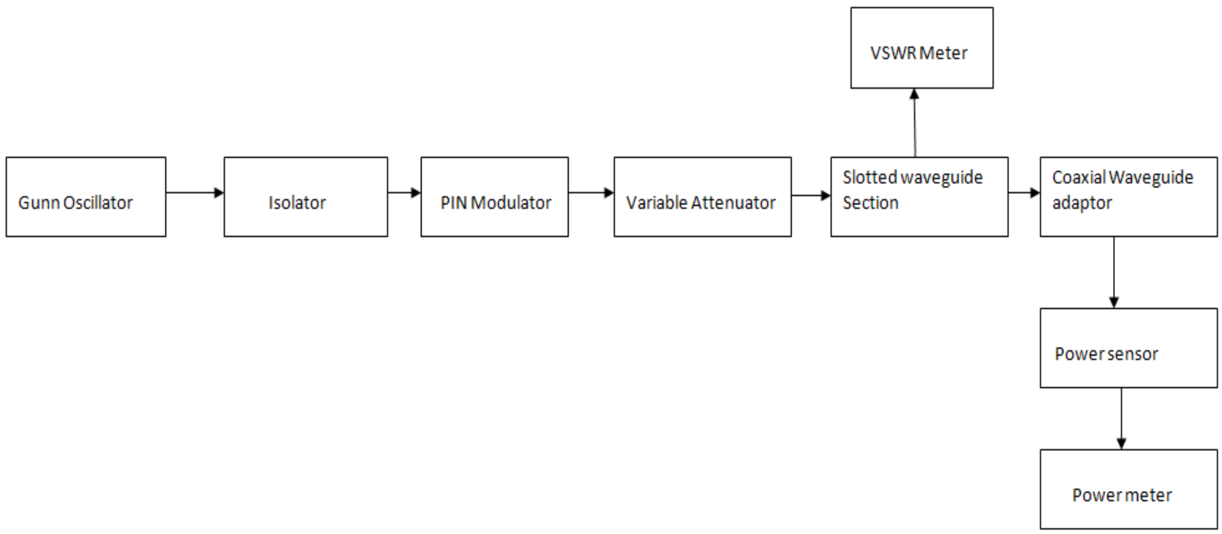
Directivity D (dB) = 10 log10 $[P_1/P_2]$

Main line VSWR is SWR measured, looking into the main line input terminal when the matched loads are placed at all other ports. Auxiliary line VSWR is SWR measured in the auxiliary line looking into the output terminal when the matched loads are placed on other terminals. Main line insertion loss is the attenuation introduced in the transmission line by insertion of coupler, it is defined as:

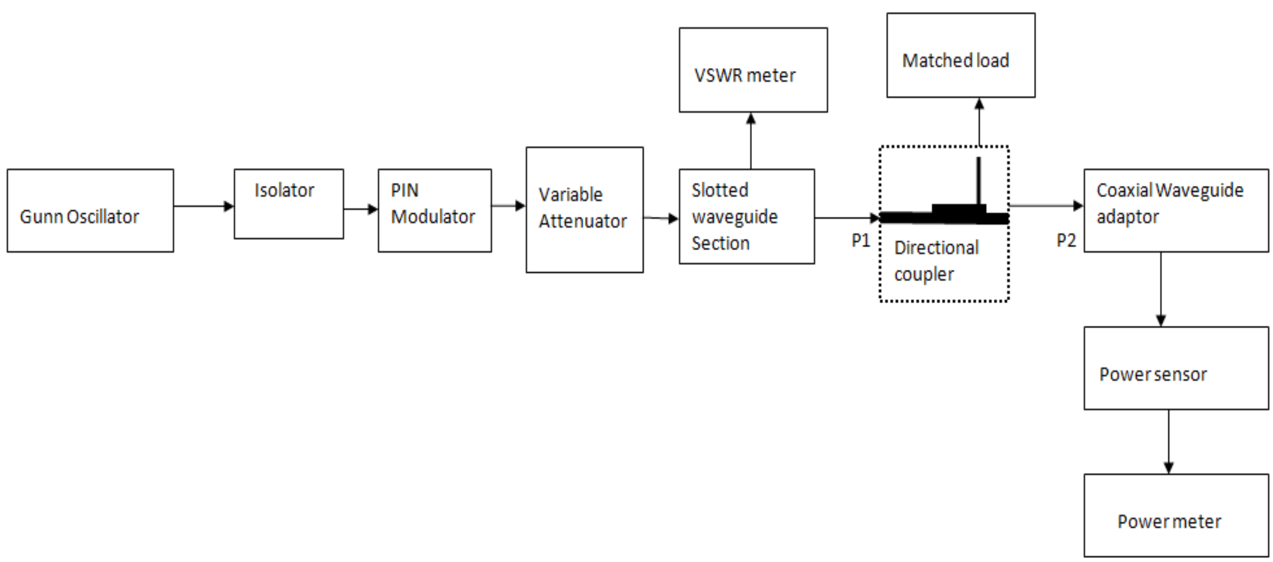
Insertion loss (dB) = 10 log10 $[P_1/P_2]$

Measurement of insertion loss

1] Without connecting the directional coupler measure input power using the power meter.



2] Without changing the gunn bias or any other setting connect the directional coupler.

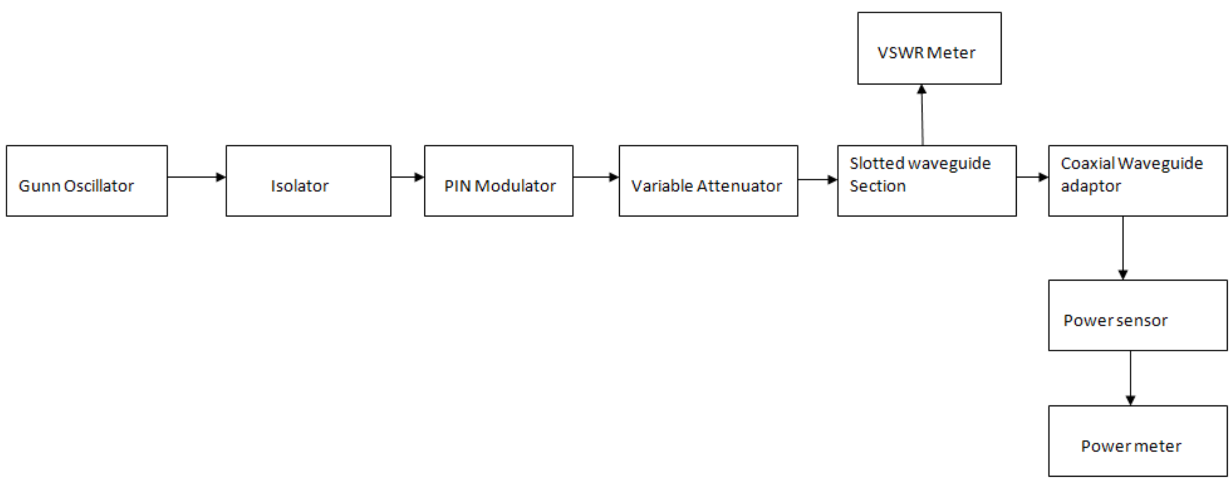


PROCEDURE:

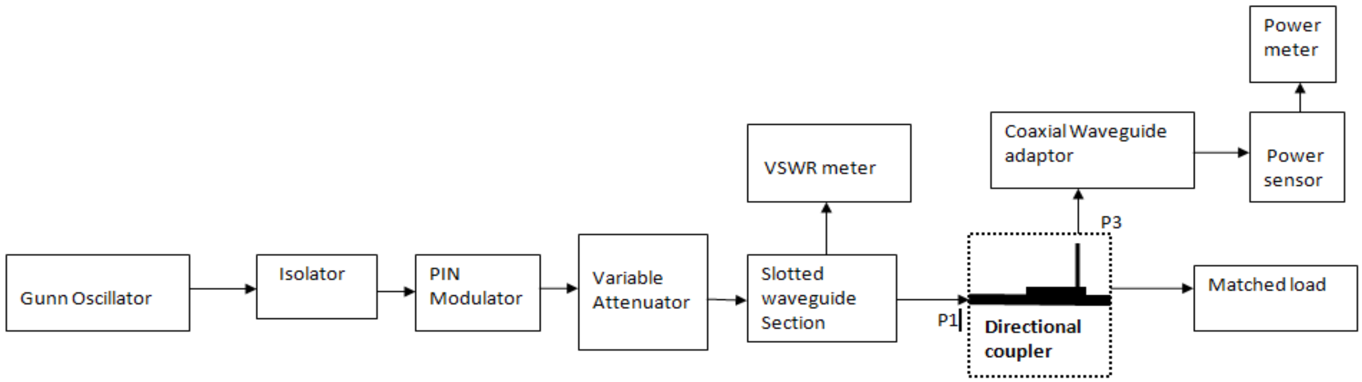
1. Setup the components and equipments.
2. Energize the microwave source for particular frequency of operation.
3. Remove the multi-hole directional coupler and connect the detector mount to the frequency meter. Tune the detector for maximum output note-down the sensor reading.
4. Insert the directional coupler as shown in figure with detector to the auxiliary port 3 and matched termination to port 2, without changing the position of variable attenuator note down the sensor reading.
5. Now carefully disconnect the detector from auxiliary port 3 and match termination from port 2 without disturbing the setup.
6. Connect the matched termination to auxiliary port 3 and detector to port 2 and measure the sensor reading. Compute insertion loss.
7. Repeat steps from 1 to 4.
8. Connect the directional coupler in reverse directions i.e. port 2 to frequency meter side. Matched termination to port 1 and detector mount to port 3. Without disturbing the position of the variable attenuator and repeat the power sensor reading and compute Directivity.

Measurement of coupling factor

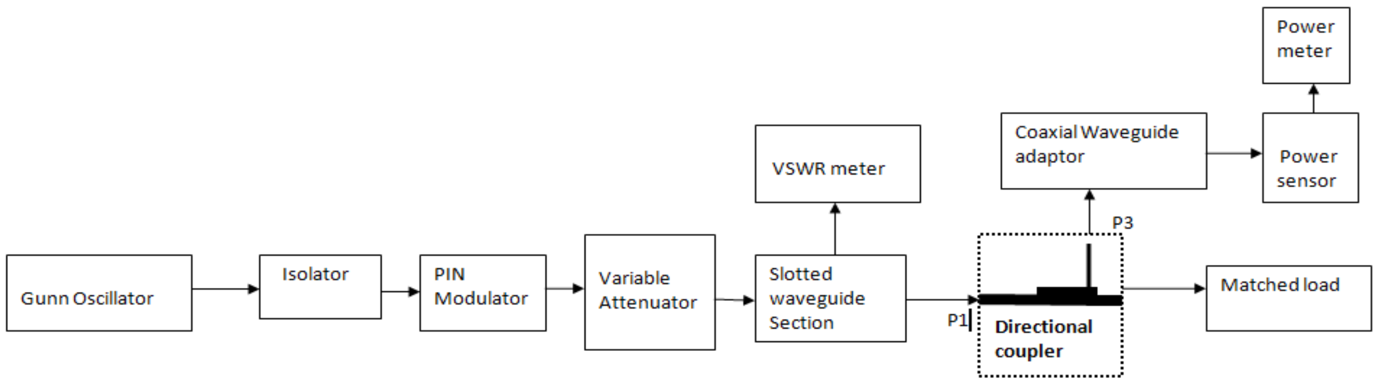
3] Without connecting the directional coupler measure input power using power meter.



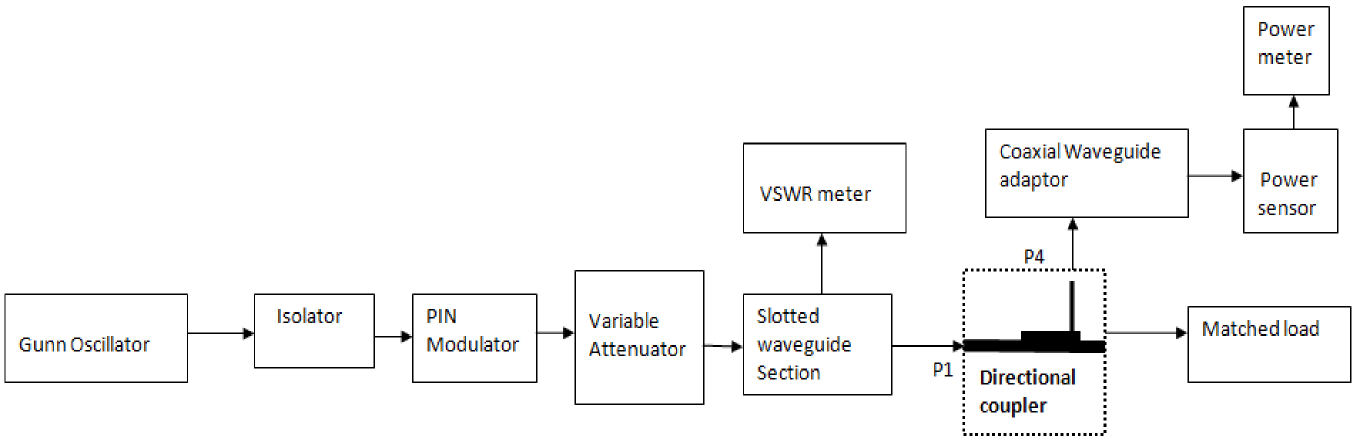
4] Without changing the Gunn bias or any other setting connect the directional coupler.



Measurement of directivity



Reverse the direction of directional coupler



Then Directivity = P_3-P_4dB

RESULT:

Thus the coupling coefficient and directivity of a given directional coupler was measured.

8. UNKNOWN LOAD IMPEDANCE MEASUREMENT USING SMITH CHART AND VERIFICATION USING TRANSMISSION LINE EQUATION

AIM:

To determine the unknown load impedance using smith chart and transmission line equation.

EQUIPMENTS REQUIRED:

Klystron power supply, Reflex klystron tube with mount, isolator, variable attenuator, slotted section with probe, matched termination, SWR meter.

THEORY:

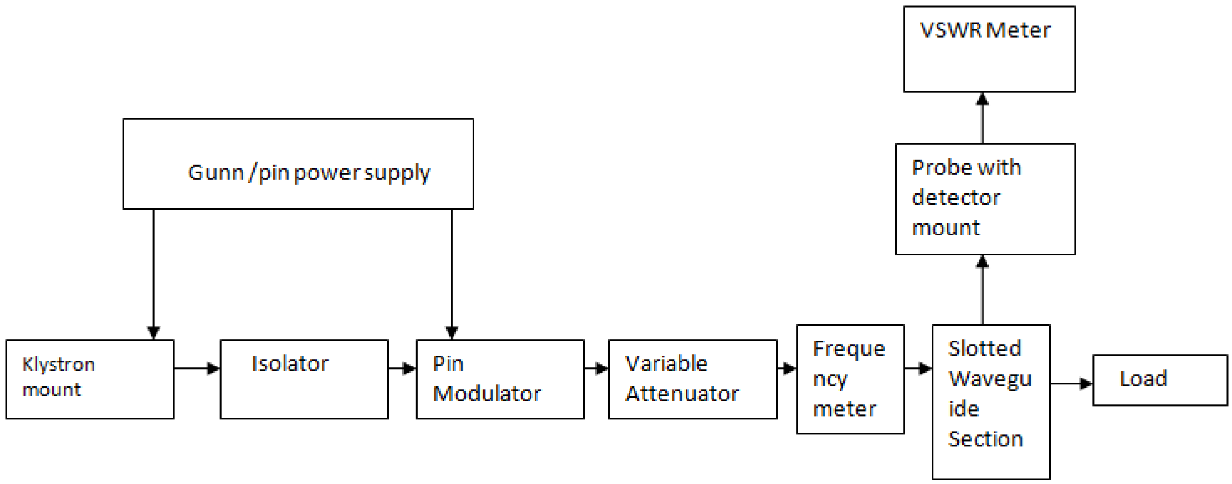
Impedance at microwave frequencies can be determined by measuring VSWR and the distance of the voltage minimum from the load. But in general it is difficult to note the position of first minimum. Therefore it is determined by measuring the VSWR and the shift in the minimum when the load is shorted.

$$Z_L/Z_0 = (1\text{-}jS\tan[2\pi d/go])/(S\text{-}\tan[2\pi d/\pi\lambda_g])$$

Where Z= normalized load impedance , S = VSWR, d = shift in the minimum point when the load is shorted take positive sign when minimum shifts towards the load and negative sign when minimum shifts towards the generator λ_g= guide wave length.

BLOCK DIAGRAM

PROCEDURE



1. Set up the equipments as shown in the above figure.
2. Set the variable attenuator at no attenuation position.
3. Connect S.S tuner after slotted line.
4. Connect matched termination after S.S tuner.
5. Keep the control knobs of SWR meter as below.

   Range dB: 40dB/50 dB position

   Crystal: 200 ohm

   Mode Switch: Normal Position

   Gain (Coarse & fine): Mid Position.

   SWR/dB switch: dB Position

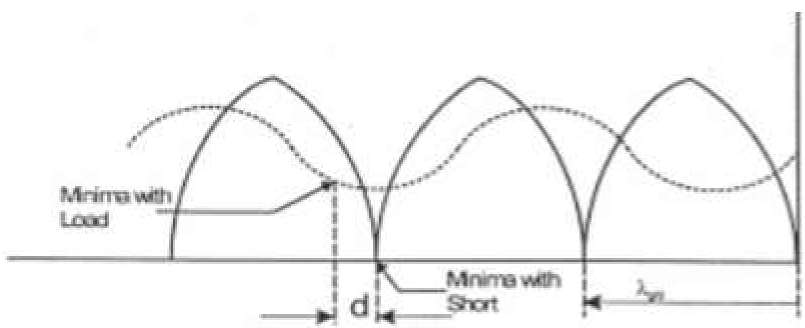
6. Keep the Control knobs of Gunn power supply as below
   Gunn bias: Fully anti- clockwise
   PIN bias supply: Fully anti- clockwise

   PIN Mod frequency: Mid position

   Mod Switch: Internal mod position

7. Set the micrometer of Gunn oscillator at 10mm position.
8. Switch "ON' the Gunn Power Supply, SWR meter and cooling Fan.
9. Observe the Gunn diode current corresponding to the various voltage controlled by Gunn bias voltage.

10. Tune the frequency meter knob to get dip on the SWR scale, and note down the frequency directly from frequency meter. Now you can detune the meter from dip position.
11. Measure the guide wavelength λg as previous experiment $\lambda g = 2 (d_1 - d_2)$
12. . Keep the depth of pin of S.S. Tuner to around 3-4mm and lock it.
13. Move the probe along with slotted line to get maximum reading.
14. Adjust SWR meter gain control knob and variable attenuator unit such that the meter indicates 1.0 on the normal upper SWR scale.
15. Move the probe to next minima point.
16. Select SWR/dB switch to SWR position. Record the SWR reading.
17. At this maximum position of the meter record the probe position from slotted line as X_1.
18. Replace the load by fixed short/movable short & measure the new standing wave positions i.e. shift in minima. Record it as X_2.
19. Calculate X_2-X_1, it will be positive if the minima shift is towards load & negative if it has shifted towards generator.
20. Calculate shift in wavelength (d) = $X_2 - X_1$



Standing waves in impedance measurement

21. Use normalized chart (Smith Chart) & draw a circle with radius = 1/VSWR & take center of circle = 0.00 on the smith chart.
22. Locate a point at a distance d (shift in minima) from the 0.0 moving in clockwise or anti-clockwise direction (depends on getting minima towards generator or load).
23. Join the above point to the centre of smith chart. The intersection of VSWR circle & this line gives load, reactive component or reactive circle & resistive component on real circle.
24. Normalized impedance a+ib where a & b are the real and reactive components.

25. The multiplication with characteristic impedance will give you the load impedance.

RESULT:

The value of impedance was determined for the given load.

9. MEASUREMENT OF DIELECTRIC CONSTANT FOR GIVEN SOLID DIELECTRIC CELL

AIM:

Measurement of dielectric constant for low loss solid dielectric.

EQUIPMENTS REQUIRED:

Klystron power supply, frequency meter, tunable probe, variable attenuator, slotted section, detector mount, sample (dielectric), VSWR meter, solid cell, liquid dielectric cell.

THEORY:

Consider a solid sample of length L_e loaded in rectangular wave guide against short circuit that touches it well. D and D_g are the positions or first voltage minima of the standing wave pattern when waveguide is unloaded and loaded with dielectric. The respective distance from the short circuit will be $(l+L_e)$ and (L_R+L_C).

The impedance are equal so Z_0 and Z_C are respectively the characteristic impedance of empty and dielectric filled waveguide β and βc are respectively the propagation constant.

Expanding tangent sum angle

$$(\tan \beta (D_g - D + L_e))/\beta L_e = \tan\beta_e L_e / \beta_e L_e$$

PROCEDURE:

1. Setup the microwave bench without dielectric cell.
2. Using slotted waveguide section find the distance between two consecutive minima(d_{min})
   Calculate $\lambda_g = 2d_{min}$
   $\beta = 2\pi/\lambda_g$
3. Locate a reference minimum D.
4. Insert the dielectric cell inside movable short [do not switch off power supply and do not change any other settings on the microwave bench)

5. The minimum will shift. Let D_r be the new minima position.
6. Measure the length of the dielectric sample using screw gauge provided on the movable short.
7. Evaluate the following expression for V

$$V = \tan\beta\,(D_r - D + L_e)/\beta L_e$$

8. Now solve the equation for X

$$\tan(X)/X = V$$

Where $X = \beta_e L_e$

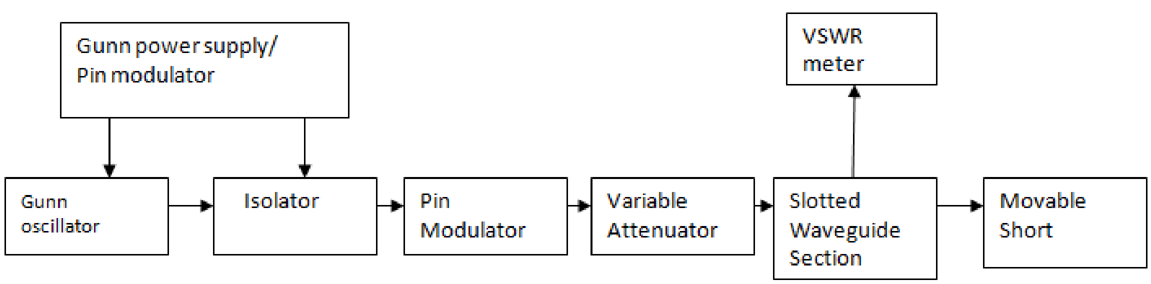
There are infinite numbers of solutions for X. Find the values of X between 0 and 15
9. Evaluate dielectric constant using the following equations for possible values of X between 0 and 15.

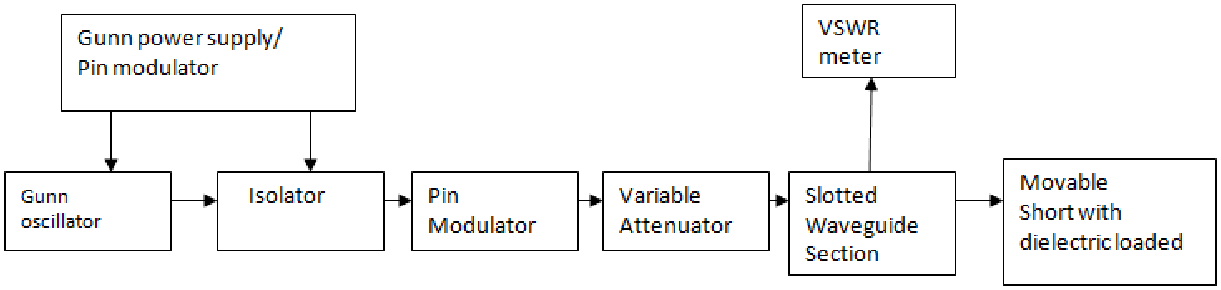
$$\varepsilon_r = \left(\left(\frac{a}{\pi}\right)^2 \left(\frac{\beta_e L_e}{L_e}\right)^2 + 1\right) \div \left(\left(\frac{2a}{\lambda g}\right)^2 + 1\right)$$

where a is the width of the waveguide

Take the appropriate value for the dielectric constant by knowing the material in advance.

BLOCK DIAGRAM:





RESULT:

The dielectric constant of given solid measured.

10. STUDY OF VECTOR NETWORK ANALYSIS

AIM:

To get familiarized with the principle and usage of vector network analyzer (VNA). To use VNA for measuring the network parameters of an RF low pass filter and center fed dipole antenna.

THEORY:

A spectrum analyzer uses Fourier transform to determine the frequency spectrum of an arbitrary signal. While spectrum analyzers are mainly used to measure signal characteristics such as carrier level, side bands, harmonics and phase noise, network analyzers are used to characterize components, devices, circuits, and subassemblies. One distinguishes between scalar and vector network analyzers. A scalar network analyzer measures only the absolute value of a gain or loss with simple power detectors. Vector network analyzers (VNAs) additionally measure the phase, thus obtaining the full transmission or reflection coefficient.

An *n*-port VNA can determine the complete S-matrix (i.e., all S parameters) of a device, which the complex reflection coefficients on all ports, as well as the complex transmission coefficients between all ports. If only one port is available, the Scattering matrix reduces to S_{11}. For a two port VNA, the scattering matrix consists of four elements:

$$\mathbf{b_1 = S_{11}a_1 + S_{12}a_2}$$

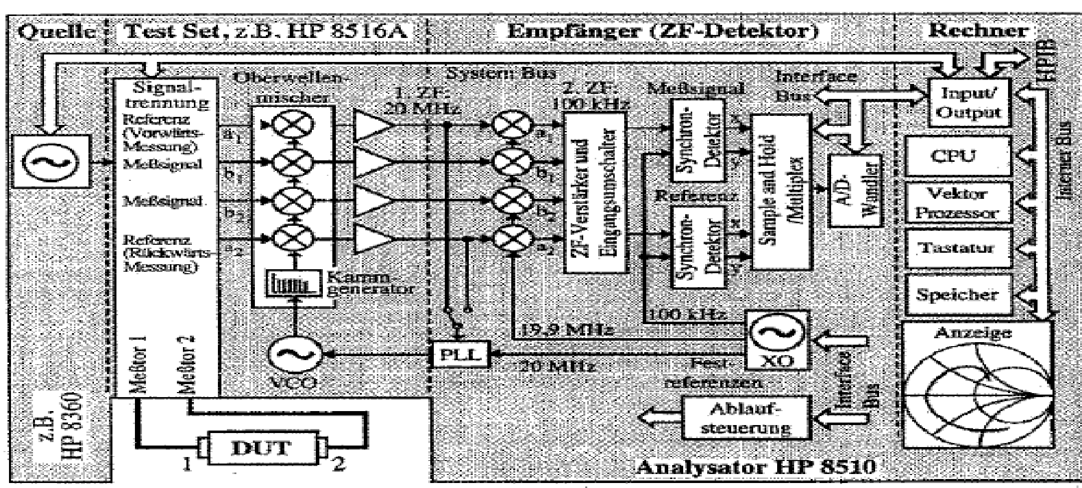
$$\mathbf{b_2 = S_{21}a_1 + S_{22}a_2}$$

S_{11} and S_{22} are the complex reflection coefficients of both ports and S_{21} and S_{12} are the complex transmission factors between the ports. a_{12} and b_{12} are the amplitudes of the outgoing and incoming waves, respectively. Determining the elements of the matrix requires four measurements in total. First a signal is produced at port 1 ($a_2 = 0$) and b_1 and b_2 are measured. Hence S_{11} and S_{21} are obtained. Then a_1 is set to zero and the signal is connected to port 2. Measuring b_1 and b_2 now yields S_{12} and S_{22}. In each case, the applied signal is sinusoidal, and the measurement is repeated at many different frequencies. An n-port VNA proceeds accordingly with more ports, with power being applied to only one port at a time. Of course, it is not always necessary to measure all the components of the S-matrix. Remember that the elements of the scattering matrix are always referred to specific line impedance.

Components of VNA:

- Signal generator.
- Components to separate the incoming and reflected wave. Key elements are directional couplers.
- The receiver groups that down-converts and demodulates the received signal.
- Digital signal processing and a display of the measured data.

A tunable signal generator is used as signal source. The separation of the incoming and the reflected wave is achieved with directional couplers, explained in section. The measured signal is then down-converted in several stages to DC using mixers, so that both the in-phase and out-of phase components (i.e. real and imaginary part) can be extracted and digitized. Between the two mixing stages used for down conversion, the signal is filtered to a narrowband, which provides the desired frequency selectivity and sets the so called intermediate frequency bandwidth (IFBW). By adjusting it, a tradeoff between sensitivity and speed can be made. Modern network analyzers can present the data in various formats. Among these are a logarithmic plot of the amplitude of the scattering parameter, its phase, and it’s trajectory in the complex plane.



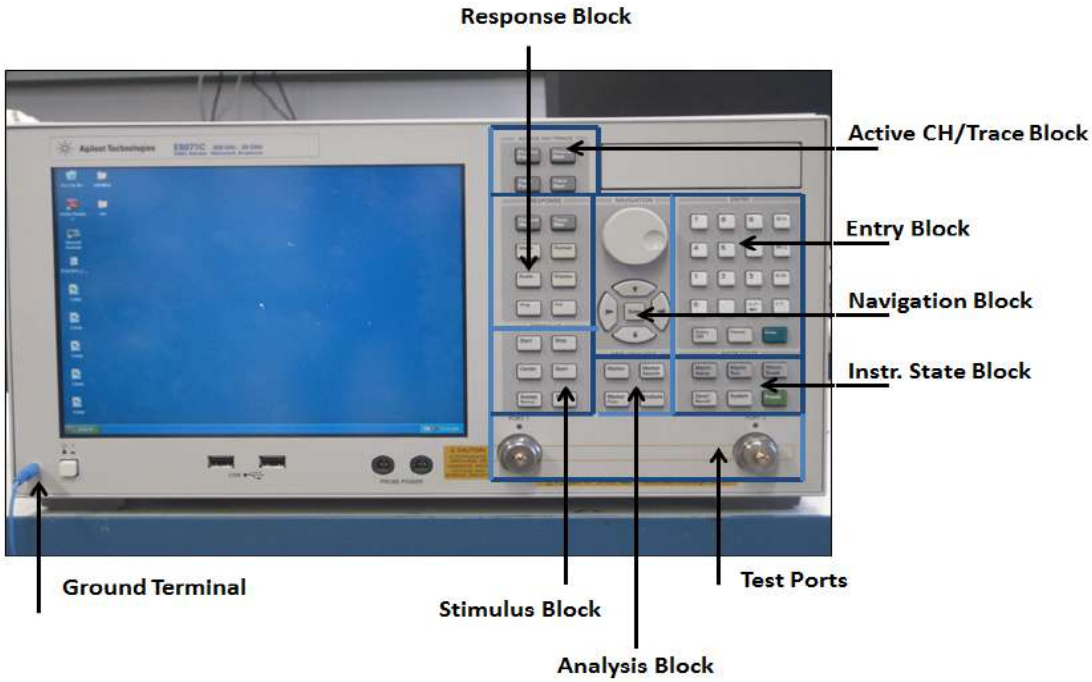
Schematic view of VNA

The network analyzer needs a test signal, and a signal generator or signal source will provide one. Older network analyses did not have their own signal generator, but had the ability to control a standalone signal generator using, for example, a GPIB connection. Nearly all modern network analyzers have a built in signal generator. High performance network analyzers have two built in sources.

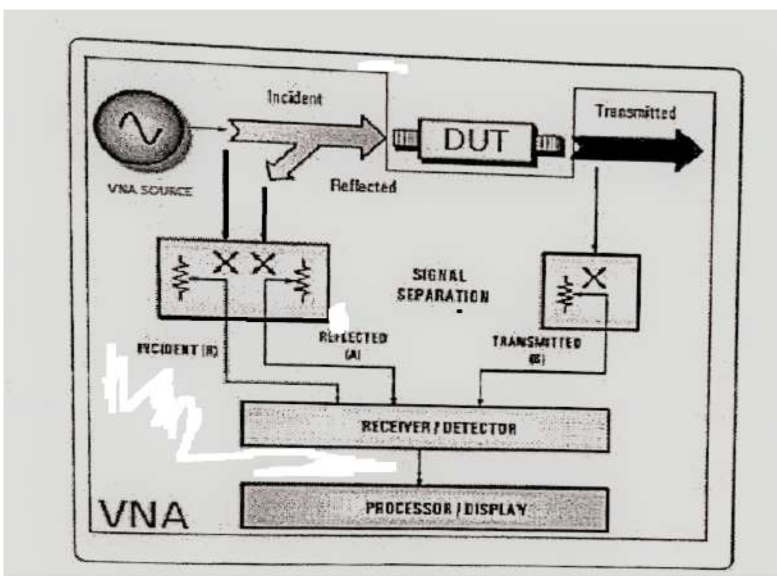
The test set takes the signal generator output and routes it to the device under test, and it routes the signal to be measured to the receivers. It often splits off a reference channel for the incident wave. In a SNA, the reference channel may go to a diode detector whose output is set to the signal generators output and better measurement accuracy. In a VNA the reference channel goes to the receivers; it is needed to serve as a phase reference.

Some microwave test sets include the front end mixers for the receivers (test set for HP 8510).The receivers make the measurements. A network analyzer will have one or more receivers connected to its test ports. The reference test port is usually labeled as r and the primary test ports are A B C.... Some analyzers will dedicate a separate receiver to each test port, but others share one or two receiver among the ports. For the SNA the receiver only measures the magnitude of the signal. A receiver can be a detector diode that operates at the test frequency.

For the VNA the receiver measures both the magnitude and the phase of the signal. It needs a reference channel (R) to determine the phase, so a VNA needs at least two receivers. The usual method down converts the reference and test channels to make the measurements at a lower frequency. The phase may be measured with a quadrature detector.



Front panel and the input keys of the VNA E507IC

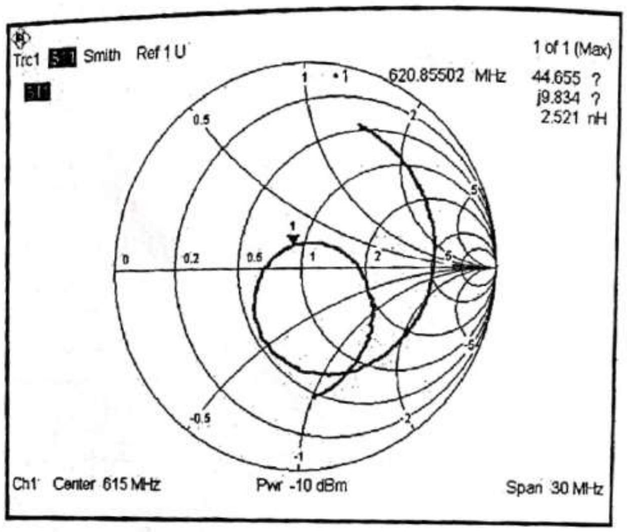


Measurement of network parameters using VNA

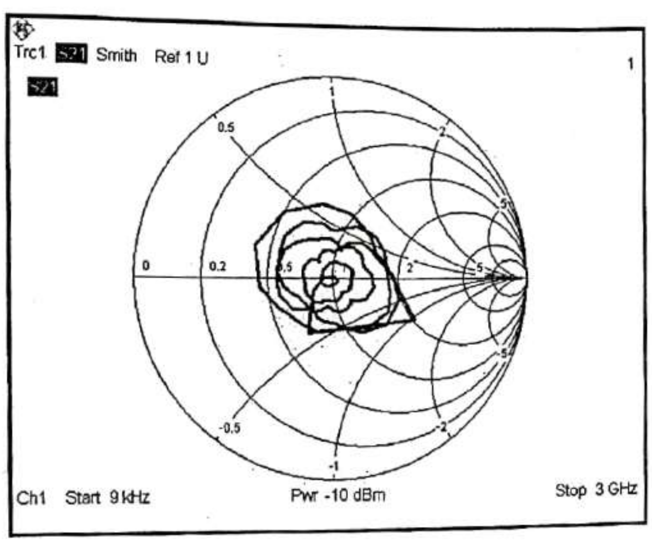
Connector used: Type N

RESULTS:

Measured S_{11} and S_{21} of a low pass filter and Input impedance of Dipole antenna

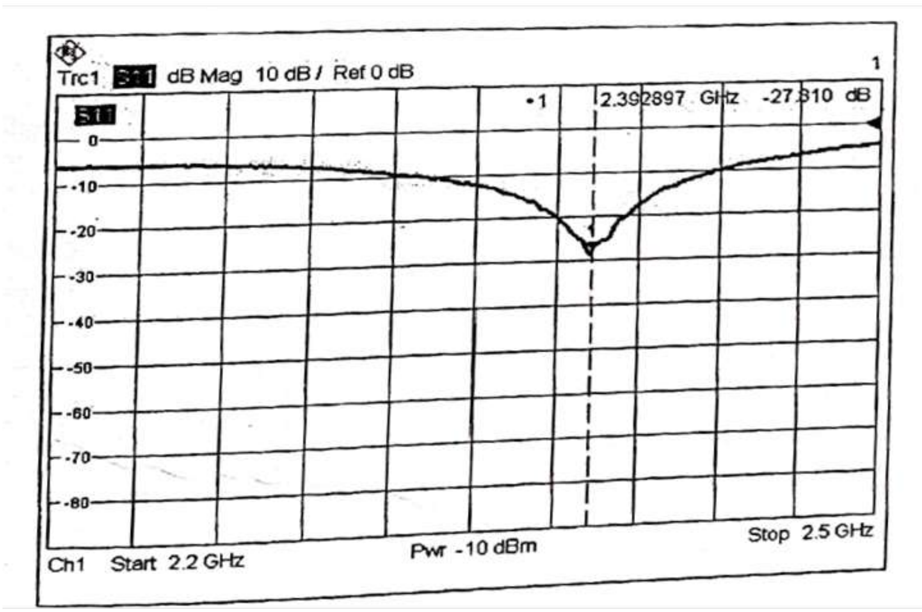


S_{11} in Smith chart for an LPF



S_{12} in Smith chart for an LPF

Measurement of input impedance of a Dipole antenna



S_{11} of a center - fed dipole antenna