SIDDHARTHA
INSTITUTE OF TECHNOLOGY & SCIENCES
Korremula Road, Narapally, Ghatkesar Mandal, Ranga Reddy District.

LABORATORY MANUAL

For

MICROWAVE & OPTICAL COMMUNICATIONS LAB

(IV B. Tech ECE- I Semester- R18 .AY:2022 - 23)

Prepared by

Department of

Electronics & Communication Engineering

2022

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1. REFLEX KLYSTRON CHARACTERISTICS

I. AIM:

To study the characteristics of the reflex klystron tube and to determine its electronic tuning range.

II. (i) EQUIPMENT AND COMPONENTS:

1. **APPARATUS**
    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. Detector mount XD-451
    8. Waveguide stands X4-535
    9. VSWR meter SW-215

(ii) DESCRIPTION OF EQUIPMENT:

1. Klystron power supply SKPS – 610

The model Klystron Power Supply SKPS-610 is general purpose laboratory power supply which is specially designed to use for reflex klystron tubes of S to X band frequency range. It is reliable power source with very high regulation and low ripple contents.

The klystron power supply SKPS-610 has built in modulation facilities of amplitude and frequency modulation. Amplitude modulation can be applied with 0-110V (p.p.) Square wave and with frequency of 500 Hz to 2.5 KHz. This amplitude modulation is generally used along with VSWR measurements in slotted line technique. Frequency modulation is used for direct study of klystron modes on the Oscilloscope. Pure carrier wave operation and in external modulation facilities is also provided with the instrument for generalized use.

The klystron power supply also provides all the other D.C. Voltages required for operation of reflex klystron tube such as beam, heater and reflector voltage. The ranges of all these voltages are given in the specification data sheet.

2. Klystron tube 2k25

The klystron tube 2k25 is a single cavity variable frequency microwave generator of low power and low efficiency. It consists of an electron gun, a filament surrounded by cathode and a focusing electrode at cathode potential. The electrons emitted by the cathode travel

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towards the reflector through an anode kept at higher potential compared to the cathode. When they approach the anode, the electrons form bunches and the bunches ultimately return towards the anode cavity after traveling a small distance towards the reflector. The power is taken from the anode reentrant cavity.

3. Isolator XI-621

It is a two port device which provides very small amount of attenuation for transmission from port 1 to port 2 and provides maximum attenuation for transmission from port 2 to port 1. It is very much desirable when we want to match a source with variable load. It allows power flow only from the generator towards the load and suppresses any reflected power.

4. Frequency meter XF-710

It is also called wave meter. Usual construction of it consist a cylindrical cavity mounted on a shaft. By rotating the shaft the volume in the cavity is changed and it becomes resonant and gives minimum impedance at the resonant frequency. The scale calibrated and the resonant frequency can be directly read from the scale after observing a dip in the output meter.

5. Variable attenuator XA-520

This is a wave guide piece having a groove on the lateral side. By rotating the screw the depth of penetration of resistive pad changes, there by introducing some attenuation. Attenuators are commonly used for measuring power game or loss in dBs for providing isolation between instruments for reducing the power input to a particular stage to prevent over loading and also for providing the signal generators with means of calibrating there outputs accurately. Variable attenuator provide continuous or step wise variable attenuation.

6. VSWR meter SW-215

AVSWR meter basically consists of a high gain; high Q low noise voltage amplifier normally tuned at a fixed frequency at which the microwave signals is modulated. The VSWR meter uses the detector signal out of the microwave detector as its input, amplifies the same and provides the output on the calibrated volt meter. The meter itself can be calibrated in terms of VSWR

III.THEORY:

The reflex klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated and passed through the positive resonator towards negative reflector, which retards and finally reflects the electrons towards the resonator.

The accelerated electrons have the resonator with increased velocity and the retarded electrons leave at reduced velocity. As the electrons bunch pass through resonator, they interact with voltage at resonator grids. If the bunches pass the grid, at such time, that the electrons are slowed down by the voltage, energy will be delivered to the resonator and the klystron will oscillate.

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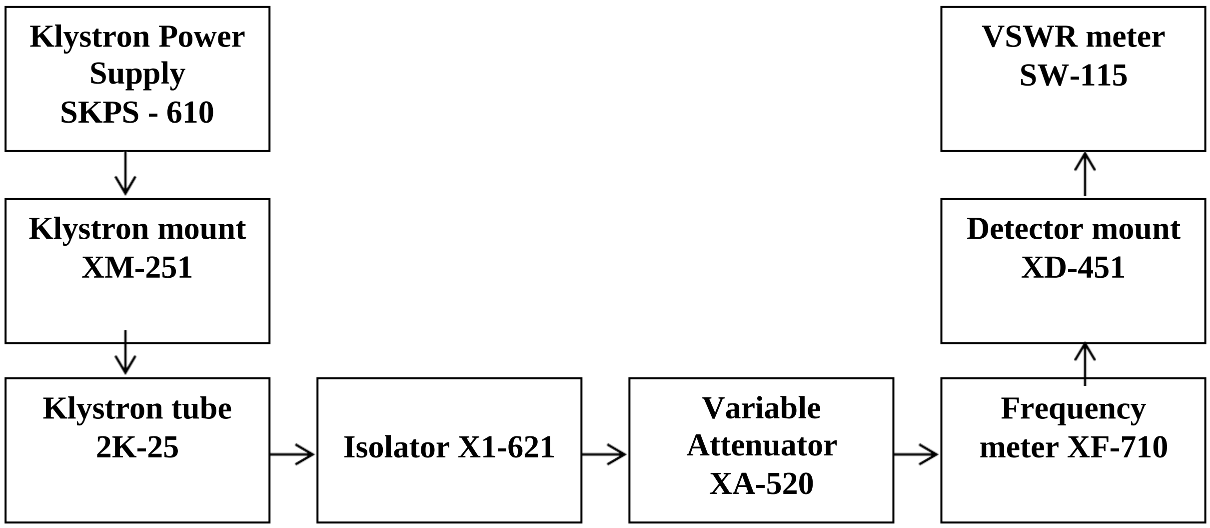
IV. BLOCK DIAGRAM:



V. PROCEDURE:

i. Connect the components and equipments as shown.
ii. Set the variable attenuator at minimum position.
iii. Switch ‘ON’ the power supply, VSWR meter and cooling fan.
iv. Put ‘ON’ the beam voltage switch and rotate the beam voltage knob clockwise in supply slowly and watch VSWR meter set the voltage for maximum deflection on the meter.
v. Change the repeller voltage slowly & watch the VSWR meter. Set the voltage for maximum deflection on the meter.
vi. Rotate the knob of frequency meter slowly and stop at that position where there is lowest O/P on VSWR meter.
vii. Read directly, the frequency meter between two horizontal fine marks.
viii. Change the repeller voltage and read the power and frequency for each repeller voltage.

VI. OBSERVATIONS:

Repeller voltage (Volts)	Output power in dB	Output power in (watts)	Frequency (GHZ)

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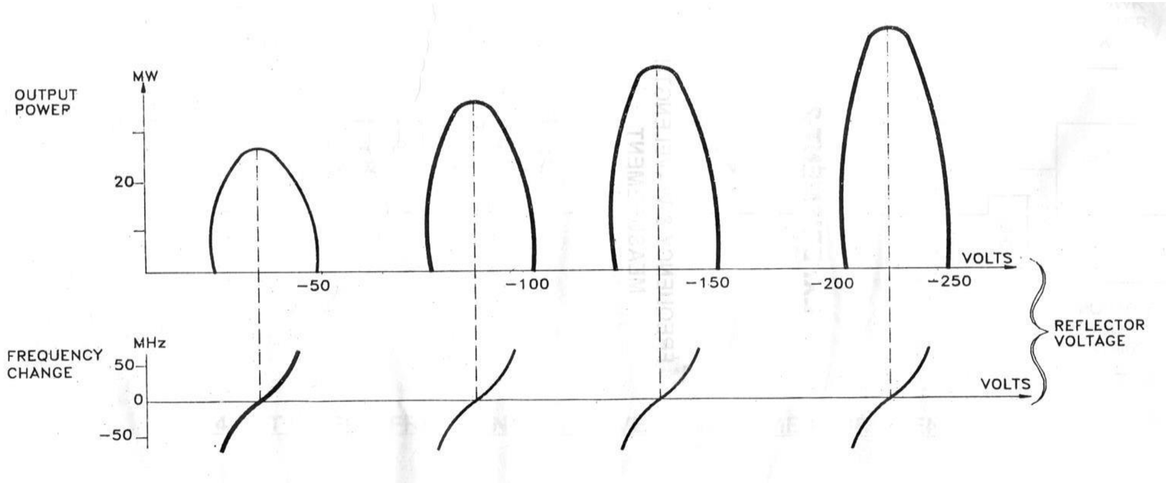
VII. CALCULATIONS:

Tuning range of $1\frac{3}{4}$ mode is

Po = $10^{(x/20)}$ watts, where x is dB reading in VSWR meter.

VIII. GRAPH:



IX. RESULT:

Hence the characteristics of the reflex – klystron has been studied.

The tuning range of $1\frac{3}{4}$ mode is

X. INFERENCES:

The power output is high in the first mode of operation of the reflex klystron. Tuning range is achieved for different modes of operation as the repeller voltage increases the power output also increases.

XI. PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch ‘ON’ the power supply of VSWR / Klystron power supplies.
   Note: For klystron power supply “HT” should be ‘OFF’ before switching ‘ON’ the main supply.

ii. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.

iii. Switch on the main supply and give some warm up time to get current / accurate reading.

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iv. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.

v. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

vi. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto -270V.

XII. APPLICATIONS:

This is most widely used in applications where variable frequency is desired.

i. In radar receivers
ii. Local oscillator in microwave receivers
iii. Signal source in microwave generator of variable frequency
iv. Pump oscillator in parametric amplifier.

XIII. EXTENSIONS:

i. By taking the values of repeller voltage we can calculate the mode number

$N_1 =$ n+3/4 with $V_2 =$
$N_2 =$ (n+1)+3/4 with $V_1 =$

N_1 , N_2 are the respective mode numbers

ii. ETS (Electronic Tuning Sensitivity) = $f_2 - f_1 / V_2 - V_1$ MHz / V

XIV. TROUBLE SHOOTING:

FAULT		DIAGNOSIS
i. No output	:	Check the wave guide alignment

XV. QUESTIONS:

i. Explain the operation of the reflex klystron tube.
ii. What is the basic principle involved in microwave tubes.
iii. What is the difference between velocity modulation and current density modulation?
iv. What happens to the power output as the repeller voltage increases?
v. What are the various modes of operation in the reflex klystron?
vi. How electronic tuning is achievable in klystron.
vii. What changes occurs in the frequency due to the repeller voltage variation.
viii. What is the maximum theoretical efficiency, frequency range of the reflex klystron?
ix. How bunching is achieved in reflex klystron.
x. What is the advantage of reflex klystron over two cavity klystron?

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2. GUNN DIODE CHARACTERISTICS

I AIM:

To study the characteristics of Gunn Diode and to determine the threshold voltage.

II EQUIPMENTS AND COMPONENTS:

i. APPARATUS

1. Gunn Power supply GS-610
2. Gunn oscillator XG-11
3. Isolator XL-621
4. Frequency meter XF-710
5. Pin Modulator
6. Matched termination XL-400

(ii) DESCRIPTION OF EQUIPMENT:

1. Gunn Power Supply (GS-610)

The type GS-610 Gunn Power supply comprises of an electronically regulated power supply and a square wave generator designed to operate a Gunn Oscillator type XG-11 and PIN Modulator XM-55. The DC Voltage is variable from 0 to -12 volts. However, the output voltage will not exceed +11 Volts because of over voltage Zener protection (Max. operating voltage for Gunn Oscillator is +12 Volts). The frequency of the square wave modulation can be continuously varied from 800 to 1100 Hz. The front panel meter indicates the Gunn voltage and the current drawn by the Gunn diode. The power supply has been designed to protect the Gunn diode in following conditions:-

1. Reverse Voltage application
2. Over voltage transients
3. Low frequency oscillations generated by the negative resistance of the Gunn Diode.

Voltage Range	:	0 to 12 Volts (Positive)
Current		: 750 mA (max.)
Stability	:	0.2% for ±10% variations in the mains voltage.
Ripple	:	1 mV rms.
Modulation Voltage	:	0 - ±10 Volts (P-P)
Frequency	:	800 – 1100 Hz.
Output connector	:	BNC Female for Gunn Oscillator
		TNC Female for Pin Modulator

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2. Gunn Oscillator (XG-11)

The Gunn Oscillator XG-11 is stable and low noise microwave source. The Gunn diode is mounted in waveguide cavity, and source frequency can be tunable over the range 8.5 – 12.0 GHz by a micrometer controlled tuning plunger. Maximum power output is 25 mW, but it varies with frequency, minimum about 5 mW.

3. Isolator XI-621

It is a two port device which provides very small amount of attenuation for transmission from port 1 to port 2 and provides maximum attenuation for transmission from port 2 to port 1. It is very much desirable when we want to match a source with variable load. It allows power flow only from the generator towards the load and suppresses any reflected power.

4. Frequency meter XF-710

It is also called wave meter. Usual construction of it consist a cylindrical cavity mounted on a shaft. By rotating the shaft the volume in the cavity is changed and it becomes resonant and gives minimum impedance at the resonant frequency. The scale calibrated and the resonant frequency can be directly read from the scale after observing a dip in the output meter.

5. Pin Modulator (XM-55)

The Pin Modulator XM-55 has been designed to amplitude modulate the CW output of the Gunn Oscillator XG-11. Modulating Voltage of 1 KHz, obtained from the Gunn Power Supply GS-610 to drives the modulator. It has built in 6 db attenuation to avoid any loading on the Pin Diode.

III. THEORY:

Transferred Electron Devices (TED’s) are bulk devices that do not have any junctions or gates. They are fabricated with the compounds like GaAs, InP, CdTe. These operate on hot electrons. The Gunn diode is one such example. This also exhibits property of –ve resistance. Gunn observed that periodic fluctuations of current passing through n-type GaAs specimen, when the applied voltage exceeded a certain critical value (2.4 kV/ cm).
Basic mechanism involved in the operation of bulk n-type GaAs devices is the transfer electrons from low conduction valley to upper subsidiary valley the u-valley.
The current increases till a certain value and falls off after crossing a certain voltage level and increases further linearly.

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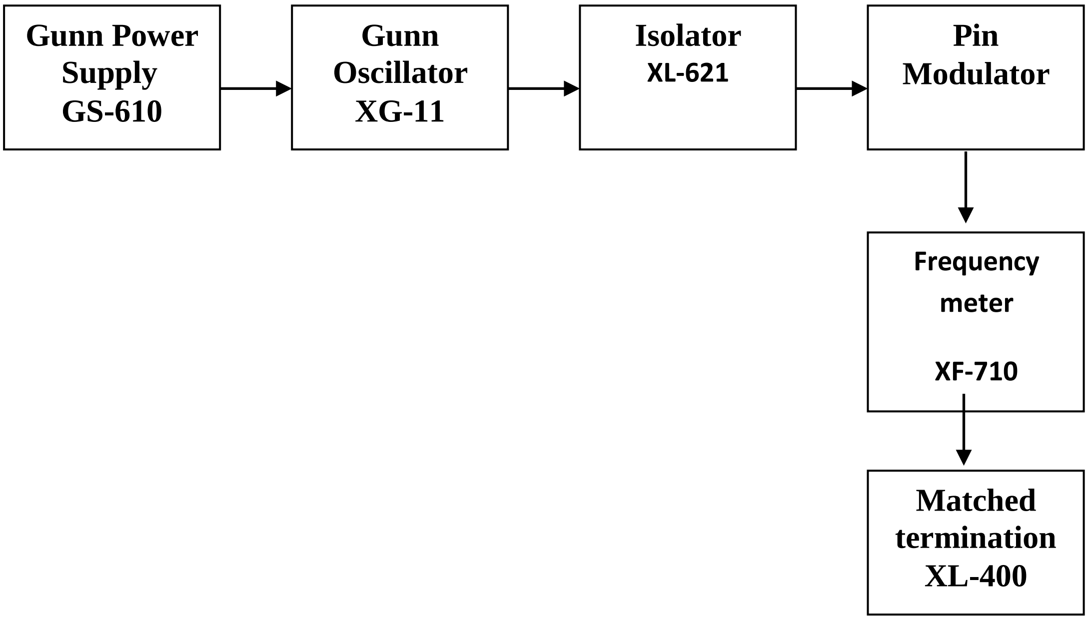
IV. CIRCUIT DIAGRAM:



V. PROCEDURE:

1. Set the components as shown in figure.
2. Keep the control knobs of Gunn power supply as below
    - Meter switch should be off
    - Gunn bias knob-fully anticlockwise
    - Pin bias knob (mod amp) – fully anticlockwise
    - Pin mode frequency – any position
3. Set the micrometer of Gunn oscillator for required frequency of operation.
4. Switch on the Gunn power supply.
5. Measure the Gunn diode current corresponding to various Gunn bias voltages through the digital panel meter and meter switch. Do not exceed the bias voltage above 10V.
6. Plot the voltage and current reading on the graph and compare with expected graph.
7. Measure the threshold voltage which corresponds to maximum current.

VI. OBSERVATIONS:

S. No	Voltage (V)	Current (mA)

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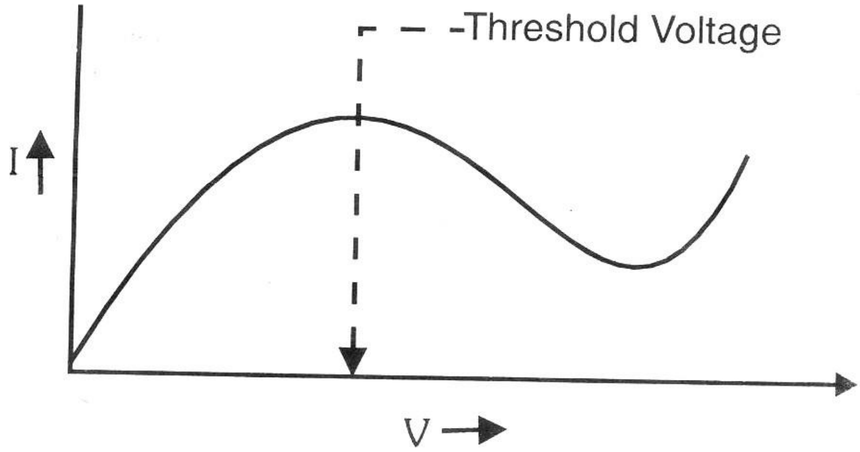
VII. CALCULATIONS:

V_T (Threshold voltage) = ___________

I_{max} = ___________

VIII. GRAPH:



IX: RESULT:

The V-I characteristics of Gunn diode has been observed. The threshold voltage is ________

X: INFERENCE:

1. Thus the characteristics of Gunn diode had been verified.
2. At the threshold voltage maximum current is observed
3. Negative resistance region is achieved

XI: PRECAUTIONS:

i. Do not keep Gunn bias knob position at the threshold position for more than 10-15 seconds

ii. Reading should be obtained as fast as possible otherwise due to excessive heat Gunn diode may burn

iii. Care should be taken such that the bias voltage should not exceed above 10V

XII. APPLICATIONS:

i. In radar transmitters.

ii. Broadband linear amplifiers.

iii As pump sources in par amp.

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iv. Low and medium power oscillator in microwave receivers.
v. Fast combinational and sequential logic circuits.

XIII. EXTENSION:

i. The Experiment can be carried out from the determination of Transconductance.
ii. The experiment can be carried our from the determination of negative resistance region.

XIV. TROUBLE SHOOTING:

FAULT		DIAGNOSIS
1. No reading in meter	:	wave guide alignment
2. No variation in the current	:	Vary the pin modulator slowly

XV. QUESTIONS:

i. What is the principle involved in Gunn diode?
ii. What are the various characteristics of Gunn diode?
iii. How negative resistance region is achieved in Gunn diode?
iv. Explain about the two valley theory.
v. Compare TEDS with the microwave transistors.
vi. What are the various modes of operation possible in Gunn diode?
vii. How domain is formed in Gunn diode?
viii. When the transit time domain mode is formed?
ix. What is the principle involved in TEDS?
x. In which mode of operation the power output and efficiency is high.

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3. ATTENUATION MEASUREMENT

I. AIM:

To study the substitution method for measurement of attenuation and hence.

i) To determine attenuation due to a component under test.
ii) To study variations in its attenuation with the frequency.

II. (i) EQUIPMENT AND COMPONENTS:

1. APPARATUS

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 Detector mount XD-451
8 Waveguide stand X4-535
9 VSWR meter SW-215
10. Tunable probe XP-655
11. Fixed attenuator – XA-503, XA-506, XE-510

(ii) DESCRIPTION OF EQUIPMENT:

1. Klystron power supply SKPS – 610

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The klystron power supply also provides all the other D.C. Voltages required for operation of reflex klystron tube such as beam, heater and reflector voltage. The ranges of all these voltages are given in the specification data sheet.

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3. Isolator XI-621

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4. Frequency meter XF-710

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5. Variable attenuator XA-520

This is a wave guide piece having a groove on the lateral side. By rotating the screw the depth of penetration of resistive pad changes, there by introducing some attenuation. Attenuators are commonly used for measuring power game or loss in dBs for providing isolation between instruments for reducing the power input to a particular stage to prevent over loading and also for providing the signal generators with means of calibrating there outputs accurately. Variable attenuator provide continuous or step wise variable attenuation.

6. VSWR meter SW-215

AVSWR meter basically consists of a high gain; high Q low noise voltage amplifier normally tuned at a fixed frequency at which the microwaves signal is modulated. The VSWR meter uses the detector signal out of the microwave detector as its input, amplifies the same and provides the output on the calibrated volt meter. The meter itself can be calibrated in terms of VSWR

III.THEORY:

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

$$\text{Attenuation A (dB)} = 10 \log \left[\frac{P1}{P2}\right]$$

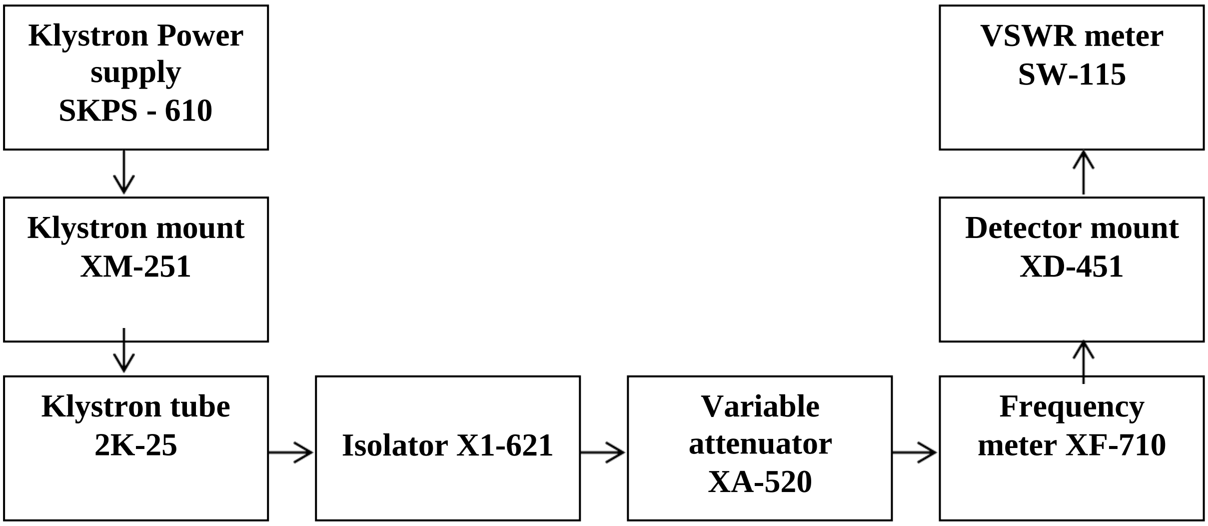
Where P_1 = Power detected by the load without the attenuator in the line.

P_2 = Power detected by the load with the attenuator in the line.

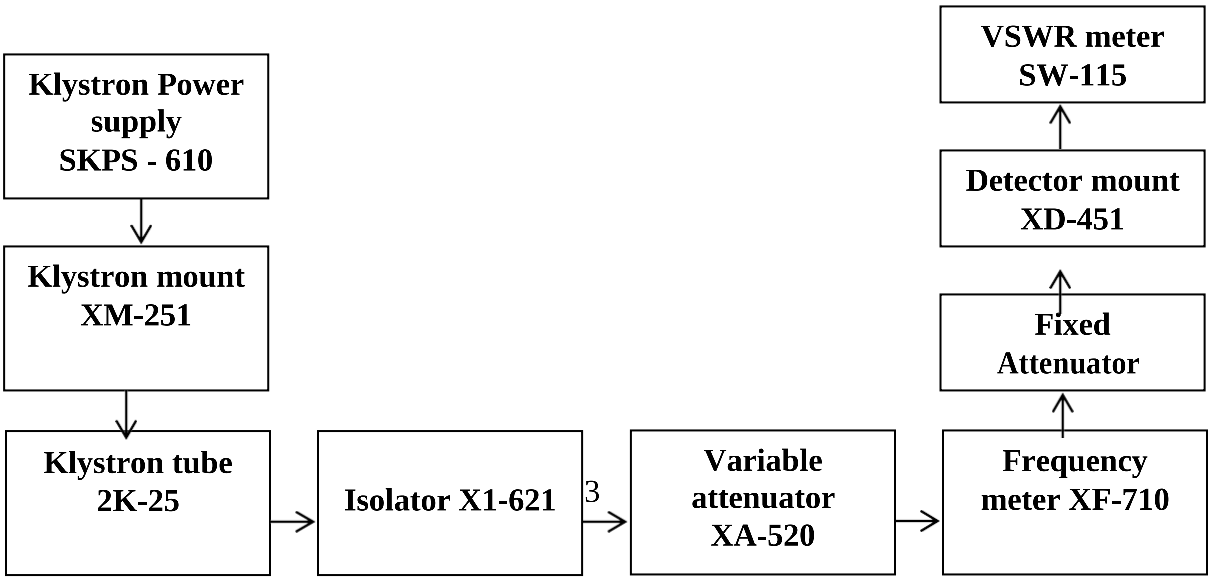
The attenuators consists of a resistive vane inside the waveguide to absorb microwave power according to its position with respect to sidewall at centre in TE_{10} mode, the attenuation will be maximum if the vane is placed at centre towards the sidewall, attenuation decreases. In the fixed attenuator the vane position is fixed whereas changed by the help of micrometer of by other methods.

IV. BLOCK DIAGRAM:

Set up 1: = "0 dB setting"



Set up 2: To determine the insertion loss.



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V. PROCEDURE:

i. Remove the tunable probe, attenuator and matched termination from the slotted section in the above setup.

ii. Connect the detector mount to the slotted line and tune the detector mount also for maximum deflection on VSWR meter. (Detector mounts output should be connected to VSWR meter).

iii. Set any reference level on the VSWR meter with the help of variable attenuator (not test attenuator) and gain control knob of VSWR meter. Let it be P_1.

iv. Set any reference level

Carefully disconnect the detector mount the slotted line and detector mount to the other port of test variable attenuator to zero and record the reading of VSWR meter. Let it be P_2 then the insertion loss of test attenuator will be P_1-P_2 dB.

v. In case of variable attenuator, change the micrometer reading and record the VSWR meter. Find out attenuation value for different position of micrometer reading and plot a graph.

VI. OBSERVATIONS:

Fixed Attenuator (P1)	**Observed Value (P2)**	**Insertion loss (P2-P1)**

VII. CALCULATIONS:

Insertion loss = observed value – the test value

Attenuation A(dB) = 10 log $\left[\frac{P1}{P2}\right]$

Where P_1 = Power detected by the load without the attenuator in the line.

P_2 = Power detected by the load with the attenuator in the line.

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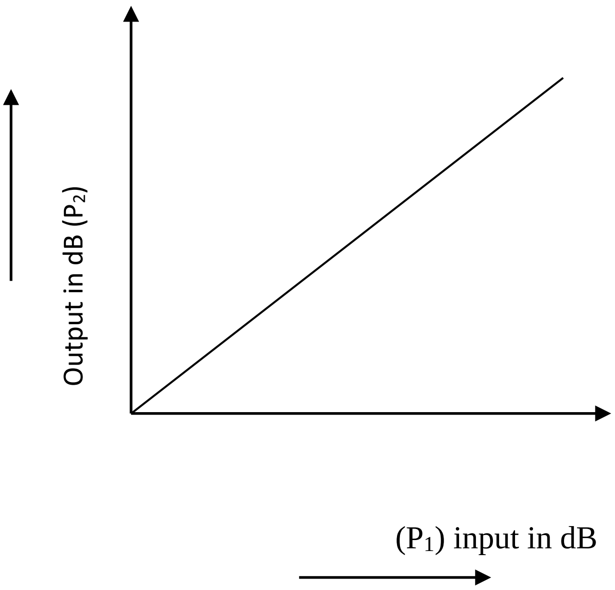
VIII. GRAPH:



IX. RESULT:

Thus, various fixed attenuators have been studied.

X. INFERENCES:

The test attenuator value is approximately equal to the value measured.

XI. PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch ‘ON’ the power supply of VSWR / Klystron power supplies.
Note: For klystron power supply “HT” should be ‘OFF’ before switching ‘ON’ the main supply.

ii. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.

iii. Switch on the main supply and give some warm up time to get current / accurate reading.

iv. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.

v. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

vi. Don’t increase the repeller voltage more than -70V (i.e.) it should be between -70Vto -270V.

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XII. APPLICATIONS:

Attenuators mainly used for

i. Measuring power gain or loss in dB
ii. For providing isolation between the instruments.
iii. For reducing the power input to a particular stage to prevent overloading.

XIII. EXTENSIONS:

By placing a precision calibrated attenuator which can be adjusted to obtain the some power as measured by the Test attenuator.

XIV. TROUBLE SHOOTING:

FAULT		DIAGNOSIS
1. No variation in VSWR meter	:	check the wave guide alignment Vary the repeller voltage slowly
2. No dip in VSWR meter	:	check the match termination

XV. QUESTIONS:

i. What is the purpose of attenuator in the microwave bench?
ii. What is the difference between Flap Attenuator and Movable Vane Attenuator?
iii. With what type of materials the attenuators are made up of?
iv. Where attenuators are mainly used?
v. What is the difference between fixed attenuator and variable attenuator?
vi. With what type attenuators the vane type attenuator is made up of?
vii. Where the rotary vane precision attenuator is preferable?
viii. What is the difference between attenuator and isolator?
ix. List out the applications of the attenuator.
x. With what type of material the glass vane is being coated.

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4. MICROWAVE FREQUENCY MEASUREMENT

I AIM:

To determine the frequency and wavelength of a microwave in a rectangular waveguide operated in TE_{10} mode.

II. (i) EQUIPMENT AND COMPONENTS:

1. APPARATUS

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 Detector mount XD-451
8 Waveguide stands X4-535
9 VSWR meter SW-215
10. Movable short XT-481
11. Matched termination xl-400
12. Slotted section XS-651
13. Tunable probe XP-655

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3. Isolator XI-621

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5. Variable attenuator XA-520

This is a wave guide piece having a groove on the lateral side. By rotating the screw the depth of penetration of resistive pad changes, there by introducing some attenuation. Attenuators are commonly used for measuring power game or loss in dB for providing isolation between instruments for reducing the power input to a particular stage to prevent over loading and also for providing the signal generators with means of calibrating there outputs accurately. Variable attenuator provide continuous or step wise variable attenuation.

6. VSWR meter SW-215

AVSWR meter basically consists of a high gain; high Q low noise voltage amplifier normally tuned at a fixed frequency at which the microwaves signal is modulated. The VSWR meter uses the detector signal out of the microwave detector as its input, amplifies the same and provides the output on the calibrated volt meter. The meter itself can be calibrated in terms of VSWR

III.THEORY:

Microwave frequency can be measured by either electronic or mechanic techniques.
Electronic Technique: These techniques are more accurate but expensive. Frequency counters

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are used. The unknown frequency is compared with harmonics of a known lower frequency, by use of a low frequency generator, as harmonic generator and a mixer.

Mechanical Technique: These include slotted line and cavity meter techniques whose operation and accuracy depends on the physical dimensions of mechanical devices.
Slotted-Line Technique: A slotted line is a piece of transmission line so constructed that the voltage and current along it can be measured continuously over its length.

For measuring the frequency, the distance between maxima (or) minima is measured on the slotted line horizontal scale from the above setup.

$$\frac{\lambda g}{2} = \mathbf{d_2 - d_1} \ \ \mathbf{cm}$$

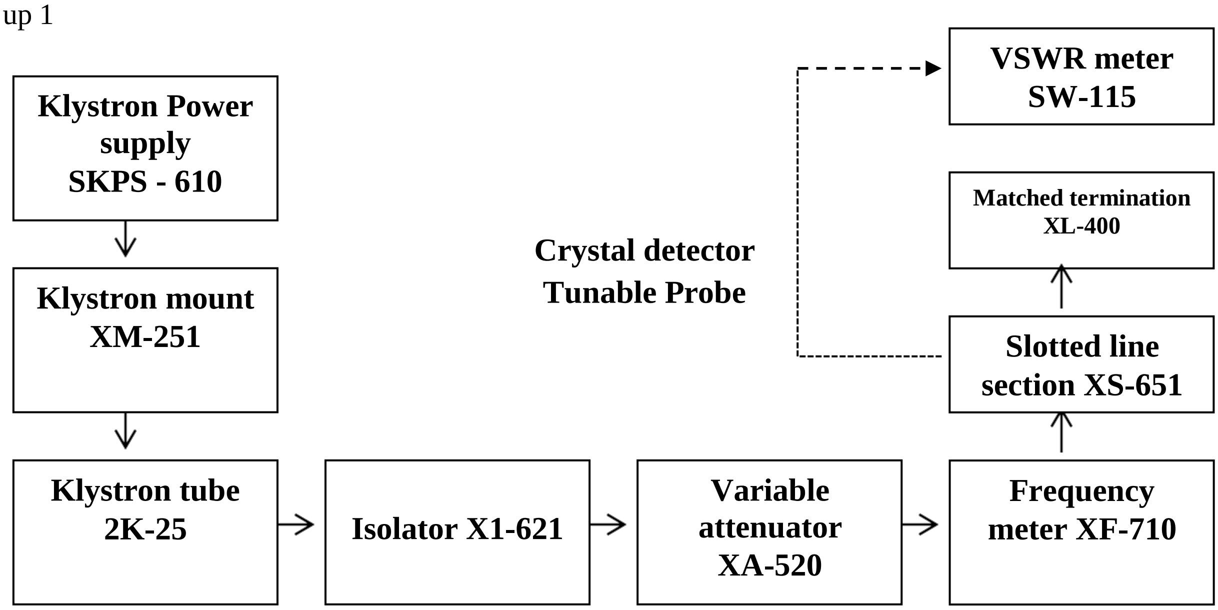
$$\lambda_g = 2(d_2 - d_1) \ \ cm$$

$$\lambda_g = \frac{\lambda o}{\sqrt{1-(\lambda o/\lambda o)^2}}$$

For TE$_{10}$ Mode, λ_C = 2a where **'a'** is the waveguide dimension **(22.86mm)**.
The frequency so measured is not very accurate.

IV. BLOCK DIAGRAM:

Set up 1



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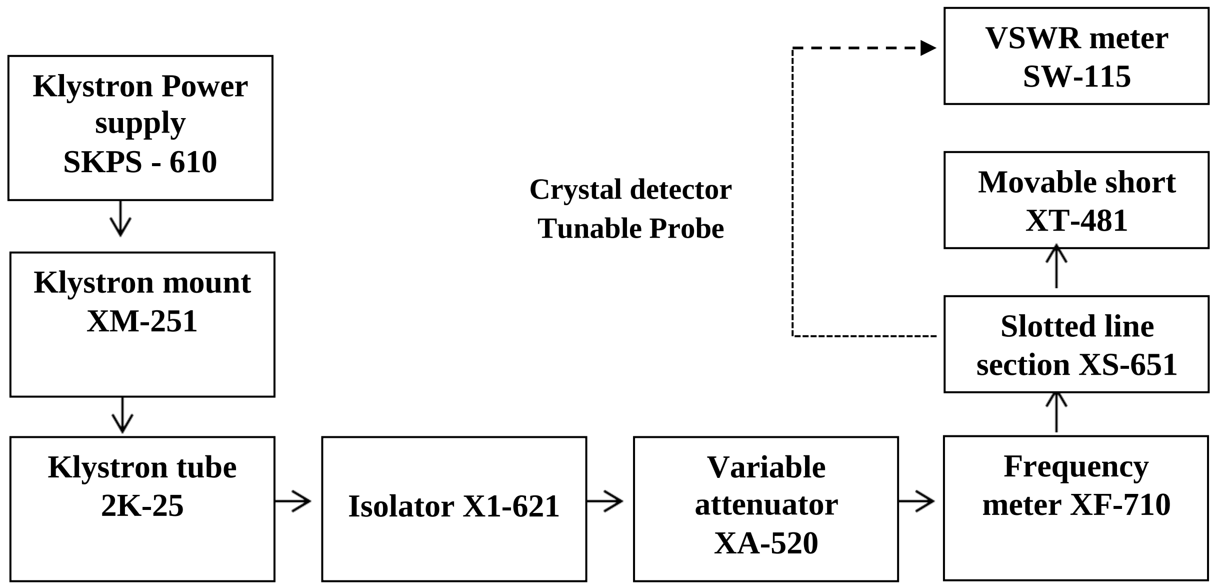
Set up 2



V.PROCEDURE:

i. Setup the components and equipments as shown in the figure.
ii. Setup the variable attenuator at minimum attenuation position.
iii. Keep the control knobs of VSWR meter as shown below:
   a) Range 40 dB
   b) Input switch – crystal low impedance
   c) Meter switch – normal position
   d) Gain (coarse and fine) = mid positions

iv. Keep the control knobs of klystron power supply as:
   a) Beam voltage – off
   b) Mod switch – AM
   c) Beam voltage knob – fully anticlockwise.
   d) Repeller voltage = fully clockwise
   e) AM amplitude knob = around fully clockwise.
   f) AM frequency knob = around mid position.

v. Switch the klystron power supply, VSWR meter and cooling fan switch.
vi. Switch 'ON' the beam voltage switch to set beam voltage at **300V** with the help of beam voltage knob.
vii. Adjust the repeller voltage to get some deflection in VSWR meter.
viii. Maximize the deflector with AM amplitude and frequency control knob of power supply.
ix. Tune the plunger of klystron mount for maximum deflection.
x. Tune the reflector voltage knob for maximum deflection.
xi. Tune the probe for maximum deflection in VSWR meter.
xii. Tune the probe frequency meter knob to get a dip on the VSWR scale and note down the frequency meter.
xiii. Replace the termination with movable short and detune the frequency meter.

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xiv. Move the probe along the slotted line.

xv. Move the probe to next minimum position and record the probe position again.

xvi. Calculate the guide wavelength as twice the distance between two successive minimum positions obtained as above.

xvii. Measure the waveguide inner broad dimension **‘a’** which will be around **22.86mm** for **X-band**.

xviii. Calculate the frequency by following equation

Xix. Verify the frequency obtained by frequency meter.

VI OBSERVATIONS:

Distance (in cm)	Power (in dB)

VII. CALCULATIONS:

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

λ_g = 2($d_2 - d_1$) cm

λ_C = 2a where a = 2.286 cm.

$$\lambda_g = \frac{\lambda_0}{\sqrt{1 - \left(\frac{\lambda_0}{\lambda_c}\right)^2}}$$

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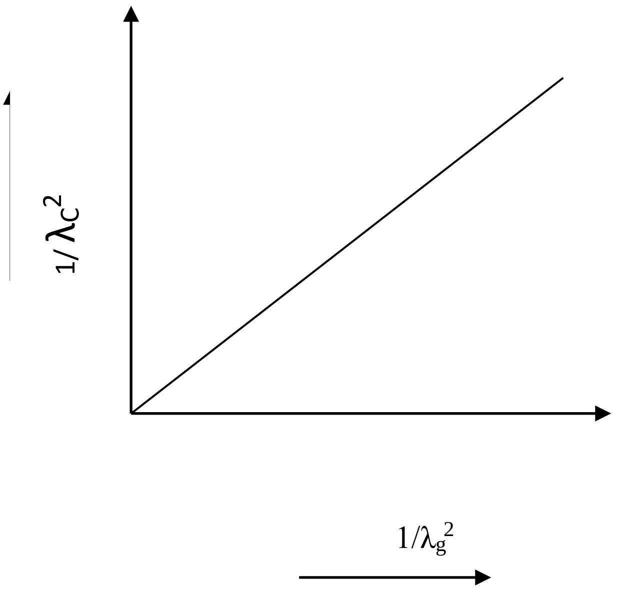
VIII. GRAPH:



IX. RESULT:

Thus the frequency and wavelength of rectangular waveguide has been determined.

Frequency = _________
wave length = _________

X. INFERENCES:

The frequency observed from the frequency meter and the measured frequency by the slotted line technique is almost equal.

XI. PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch ‘ON’ the power supply of VSWR / Klystron power supplies.
Note: For klystron power supply “HT” should be ‘OFF’ before switching ‘ON’ the main supply.

ii. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.

iii. Switch on the main supply and give some warm up time to get current / accurate reading.

iv. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.

v. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

vi. Don’t increase the repeller voltage more than **-70 V**(i.e.) it should be between **-70V** to **-270V.**

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XII. APPLICATIONS:

It is used for Measurement of unknown impedance and Measurement of reflection coefficient.

XIII. EXTENSIONS:

Determination of VSWR for different conditions: open circuit and short circuit

XIV. TROUBLE SHOOTING:

FAULT		DIAGNOSIS
Meter reading fluctuating	:	keep it in low dB De tune the frequency meter.
No dip observe	:	adjust it very slowly around 9.5 GHz.

XV. QUESTIONS:

i. How slotted line technique is used to measure frequency and wavelength?
ii. What is the purpose of slotted line in the microwave bench?
iii. What type of wave is propagating in the wave guide?
iv. What is meant by guide wavelength?
v. Bring out a relationship between the guide wave length and cut of wavelength?
vi. How the guide wavelength can be determined by using the slotted line?
vii. What is the purpose of crystal detector probe?
viii. Which technique is preferable for the measurement of frequency?
ix. What is the cut of wavelength of the dominant mode in the wave guide?
x. How waveguide acts as a high pass filter?

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5. MEASUREMENT OF IMPEDANCE OF GIVEN LOAD

I. AIM:

To measure an unknown impedance using smith chart.

II. (i) EQUIPMENT AND COMPONENTS:

1. APPARATUS

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	Detector mount XD-451
8	Waveguide stands X4-535
9	VSWR meter SW-215
10	Movable short XT-481
11	Matched termination xl-400
12	Slotted section XS-651
13	Tunable probe XP-655

(ii) DESCRIPTION OF THE EQUIPMENT:

1. Klystron power supply SKPS – 610

The model Klystron Power Supply SKPS-610 is general purpose laboratory power supply which is specially designed to use for reflex klystron tubes of S to X band frequency range. It is reliable power source with very high regulation and low ripple contents.

The klystron power supply SKPS-610 has built in modulation facilities of amplitude and frequency modulation. Amplitude modulation can be applied with 0-110V (p.p.) Square wave and with frequency of 500 Hz to 2.5 KHz. This amplitude modulation is generally used along with VSWR measurements in slotted line technique. Frequency modulation is used for direct study of klystron modes on the Oscilloscope. Pure carrier wave operation and in external modulation facilities is also provided with the instrument for generalized use.

The klystron power supply also provides all the other D.C. Voltages required for operation of reflex klystron tube such as beam, heater and reflector voltage. The ranges of all these voltages are given in the specification data sheet.

2. Klystron tube 2k25

The klystron tube 2k25 is a single cavity variable frequency microwave generator of low power and low efficiency. It consists of an electron gun, a filament surrounded by cathode and a focusing electrode at cathode potential. The electrons emitted by the cathode travel

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towards the reflector through an anode kept at higher potential compared to the cathode. When they approach the anode, the electrons form bunches and the bunches ultimately return towards the anode cavity after traveling a small distance towards the reflector. The power is taken from the anode reentrant cavity.

3. Isolator XI-621

It is a two port device which provides very small amount of attenuation for transmission from port 1 to port 2 and provides maximum attenuation for transmission from port 2 to port 1. It is very much desirable when we want to match a source with variable load. It allows power flow only from the generator towards the load and suppresses any reflected power.

4. Frequency meter XF-710

It is also called wave meter. Usual construction of it consist a cylindrical cavity mounted on a shaft. By rotating the shaft the volume in the cavity is changed and it becomes resonant and gives minimum impedance at the resonant frequency. The scale calibrated and the resonant frequency can be directly read from the scale after observing a dip in the output meter.

5. Variable attenuator XA-520

This is a wave guide piece having a groove on the lateral side. By rotating the screw the depth of penetration of resistive pad changes, there by introducing some attenuation. Attenuators are commonly used for measuring power game or loss in dB for providing isolation between instruments for reducing the power input to a particular stage to prevent over loading and also for providing the signal generators with means of calibrating there outputs accurately. Variable attenuator provide continuous or step wise variable attenuation.

6. VSWR meter SW-215

AVSWR meter basically consists of a high gain; high Q low noise voltage amplifier normally tuned at a fixed frequency at which the microwave signal is modulated. The VSWR meter uses the detector signal out of the microwave detector as its input, amplifies the same and provides the output on the calibrated volt meter. The meter itself can be calibrated in terms of VSWR

III.THEORY:

The impedance at any point on a transmission line can be written in the form R+jx. For comparison SWR can be calculated as:

$$S = \frac{1+|R|}{1-|R|} \text{ where}$$

Reflection coefficient

$$R = \frac{Z - Zo}{Z + Zo}$$

Where Zo = characteristic impedance of waveguide at operating frequency.

Z = Load Impedance.

The measurement is performed in the following way:

The unknown device is connected to the slotted line and the position of one minima is determined. The unknown device is replaced by movable short to the slotted line. Two

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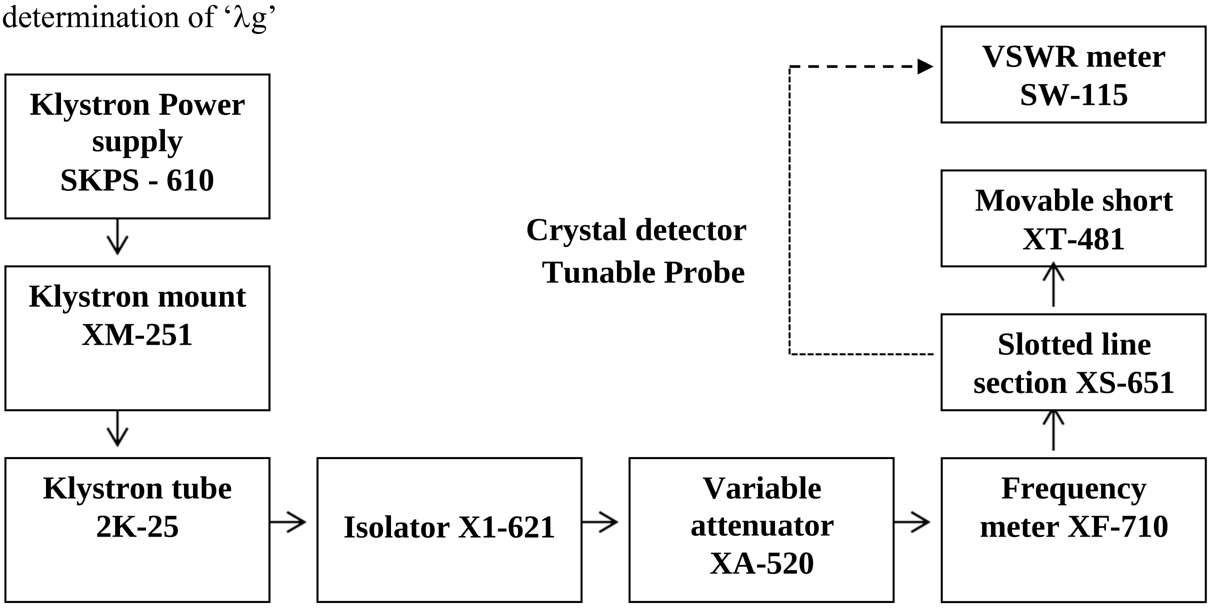
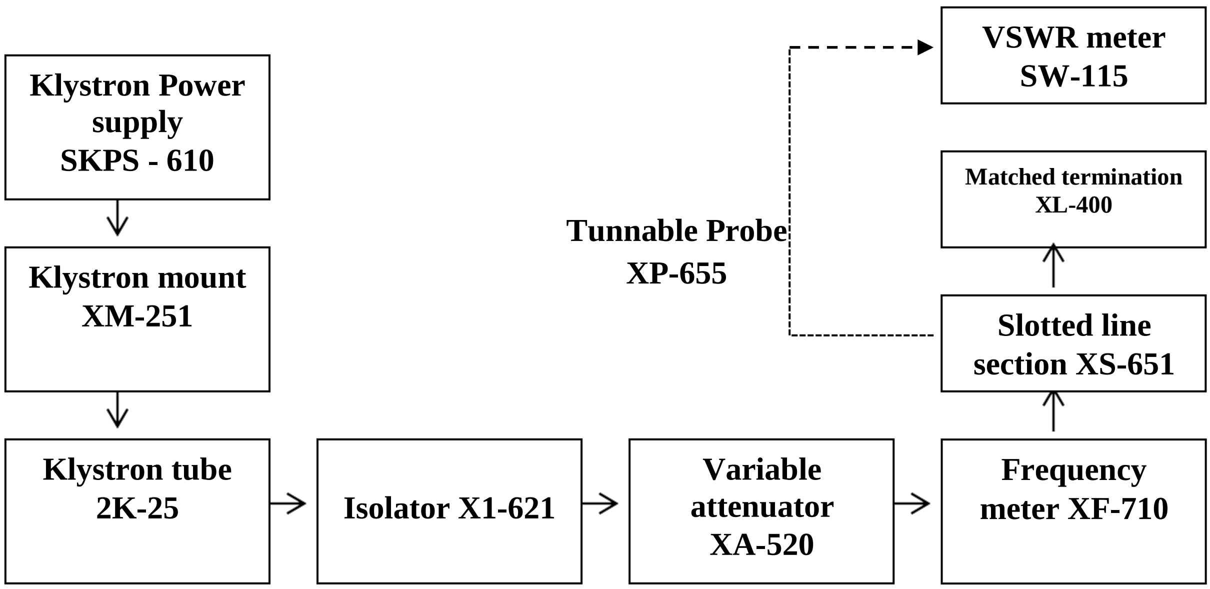
successive minima positions are noted. The twice of the difference between minima positions will be guide wavelength. One of the minima is used as reference for impedance measurement. Find the difference of reference minima and maxima position obtained from unknown load. Let it be‘d’. Take a smith chart, taking ‘I’ as centre draw a circle of radius equal to ‘S_O’. Mark a point on the circumference of smith chart towards load side at a distance equal to d/1g. Join the centre with this point. Find the point where it cuts the drawn circle. The co-ordinates of this point will show normalized impedance of load.

IV. BLOCK DIAGRAM:

For determination of ‘λg’



Set up 2: For measuring SWR and maximas and minimas



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V. PROCEDURE:

i. Setup the components and equipments as shown in the figure.
ii. Setup the variable attenuator at minimum attenuation position.
iii. Keep the control knobs of VSWR meter as shown below:
  a) Range 40 dB
  b) i/P switch – crystal low impedance
  c) meter switch – normal position
  d) Gain (coarse and fine) = mid positions

iv. Keep the control knobs of klystron power supply as:
  a) Beam voltage – off
  b) Mod switch – AM
  c) Beam voltage knob – fully anticlockwise.
  d) Repeller voltage = fully clockwise
  e) AM amplitude knob = around fully clockwise.
  f) AM frequency knob = around mid position.

v. Switch the klystron power supply, VSWR meter and cooling fan switch.
vi. Switch 'ON' the beam voltage switch to set beam voltage at 300v with the help of beam voltage knob.
vii. Adjust the repeller voltage to get some deflection in VSWR meter.
viii. Maximize the deflector with AM amplitude and frequency control knob of power supply.
ix. Tune the plunger of klystron mount for maximum deflection.
x. Tune the reflector voltage knob for maximum deflection.
XI. Tune the probe for maximum deflection in VSWR meter.
xii. Tune the frequency meter knob to get a 'dip' on the VSWR scale and note down the frequency directly from frequency meter.
xiii. Move the probe along the slotted line to get maximum deflection.
xiv. Adjust VSWR meter gain control knob and variable attenuator until the meter indicates 10 on the normal dB SWR scale.
xv. Move the probe to next minima position and note down the SWR 'S_O' on the scale. Also note down the probe position. Let it be d.
xvi. Note the position of 2 successive (maxima) or minima positional Let it be as d_1 and d_2.
  Hence $\lambda_g = 2(d_2-d_1)$
xvii. Calculate λ_g
xviii. Find out normalized impedance as described.
xix. Repeat above for different frequencies.

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VI. OBSERVATIONS:

i. Movable short:

Distance (cm)	Power (dB)
	(min-1)
	(max-1)
	(min-2)
	(max-2)

ii. Matched Termination

Distance (cm)	Power (dB)
	(min-1)
	(max-1)
	(min-2)
	(max-2)

VII. CALCULATIONS:

$\lambda_g = 2(d_2 - d_1)$
where d2 – is distance at min-2 or max-2
d1 - is distance at min-1 or max-1

VIII. GRAPH:

IX.RESULT:

The unknown impedance has been determined using smith chart

X.INFERENCES:

Impedance of unknown termination can be measured.

XI. PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.
   Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.
ii. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.
iii. Switch on the main supply and give some warm up time to get current / accurate reading.
iv. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.
v. If the main supply failed in the middle of the experiment, come to 1^{st} condition (i.e.) keep all the knobs in minimum positions and switch off main switches.
vi. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto -270V.

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XII. APPLICATIONS:

VSWR can be measured by knowing the impedance.

XIII. EXTENSIONS:

Measurement of impedance can be done by using directional couplers.

XIV. TROUBLE SHOOTING:

FAULT		DIAGNOSIS
No variation in VSWR reading	:	check the matched load connections Check the probe connection.
No variation in the meter	:	adjust the slotted line properly

XV. QUESTIONS:

i. What are the various methods used for the measurement of impedance?
ii. How impedance can measured by using slotted line?
iii. How can you determine whether the impedance is inductive or capacitive?
iv. How impedance can be measured by using magic tee?
v. What is the purpose of slotted line for the measurement of impedance?
vi. How impedance can be measured by using reflectometer?
vii. What is the purpose of variable attenuator?
viii. How impedance can be determined by using directional couplers?
ix. Why standing waves are produced in the wave guide?
x. What is meant by reflection coefficient and how impedance can be determined?

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6. DIRECTIONAL COUPLER CHARACTERISTICS

I. AIM:

To study the characteristics of multi-hole directional coupler by measuring the following parameters: Coupling factor and directivity of coupler.

II. (i) EQUIPMENT AND COMPONENTS:

1. APPARATUS

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. Detector mount XD-451
8. Waveguide stands X4-535
9. VSWR meter SW-215
10. Movable short XT-481
11. Matched termination XL-400
12. Slotted line XS-651
13. Tunable probe XP-655
14. Multi-hole Directional Coupler XK-620

(ii) DESCRIPTION OF THE EQUIPMENT:

1. Klystron power supply SKPS – 610

The model Klystron Power Supply SKPS-610 is general purpose laboratory power supply which is specially designed to use for reflex klystron tubes of S to X band frequency range. It is reliable power source with very high regulation and low ripple contents.

The klystron power supply SKPS-610 has built in modulation facilities of amplitude and frequency modulation. Amplitude modulation can be applied with 0-110V (p.p.) Square wave and with frequency of 500 Hz to 2.5 KHz. This amplitude modulation is generally used along with VSWR measurements in slotted line technique. Frequency modulation is used for direct study of klystron modes on the Oscilloscope. Pure carrier wave operation and in external modulation facilities is also provided with the instrument for generalized use.

The klystron power supply also provides all the other D.C. Voltages required for operation of reflex klystron tube such as beam, heater and reflector voltage. The ranges of all these voltages are given in the specification data sheet.

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2. Klystron tube 2k25

The klystron tube 2k25 is a single cavity variable frequency microwave generator of low power and low efficiency. It consists of an electron gun, a filament surrounded by cathode and a focusing electrode at cathode potential. The electrons emitted by the cathode travel towards the reflector through an anode kept at higher potential compared to the cathode. When they approach the anode, the electrons form bunches and the bunches ultimately return towards the anode cavity after traveling a small distance towards the reflector. The power is taken from the anode reentrant cavity.

3. Isolator XI-621

It is a two port device which provides very small amount of attenuation for transmission from port 1 to port 2 and provides maximum attenuation for transmission from port 2 to port 1. It is very much desirable when we want to match a source with variable load. It allows power flow only from the generator towards the load and suppresses any reflected power.

4. Frequency meter XF-710

It is also called wave meter. Usual construction of it consist a cylindrical cavity mounted on a shaft. By rotating the shaft the volume in the cavity is changed and it becomes resonant and gives minimum impedance at the resonant frequency. The scale calibrated and the resonant frequency can be directly read from the scale after observing a dip in the output meter.

5. Variable attenuator XA-520

This is a wave guide piece having a groove on the lateral side. By rotating the screw the depth of penetration of resistive pad changes, there by introducing some attenuation. Attenuators are commonly used for measuring power game or loss in dB for providing isolation between instruments for reducing the power input to a particular stage to prevent over loading and also for providing the signal generators with means of calibrating there outputs accurately. Variable attenuator provide continuous or step wise variable attenuation.

6. VSWR meter SW-215

AVSWR meter basically consists of a high gain, high Q low noise voltage amplifier normally tuned at a fixed frequency at which the microwave signal is modulated. The VSWR meter uses the detector signal out of the microwave detector as its input, amplifies the same and provides the output on the calibrated volt meter. The meter itself can be calibrated in terms of VSWR

7. MHD Coupler XK-620

It is a wave guide used for the measurement of low standing wave ratios, to sample a small amount of powers. It consists of two transmission lines the main arm and auxiliary arm,

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electro-magnetically coupled to each other. Here, for a two hole directional coupler the two holes are at a distance of $\lambda_g/4$.

III.THEORY:

A directional coupler is a device with which it is possible to measure the incident and reflected wave separately.

i. 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 $\left[\frac{P1}{P3}\right]$ where port 2 is terminated

Isolation (dB) = 10 log10 $\left[\frac{P2}{P3}\right]$ where Port1 is matched.

ii. 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 is measured as follows.

Hence **Directivity D (dB) = 10 log10** $\left[\frac{P2}{P1}\right]$ **= I-C**

Main line VSWR is SWR measured, looking into the main line input terminal when the matched loads are placed at all other ports.

iii. 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 $\left[\frac{P1}{P2}\right]$

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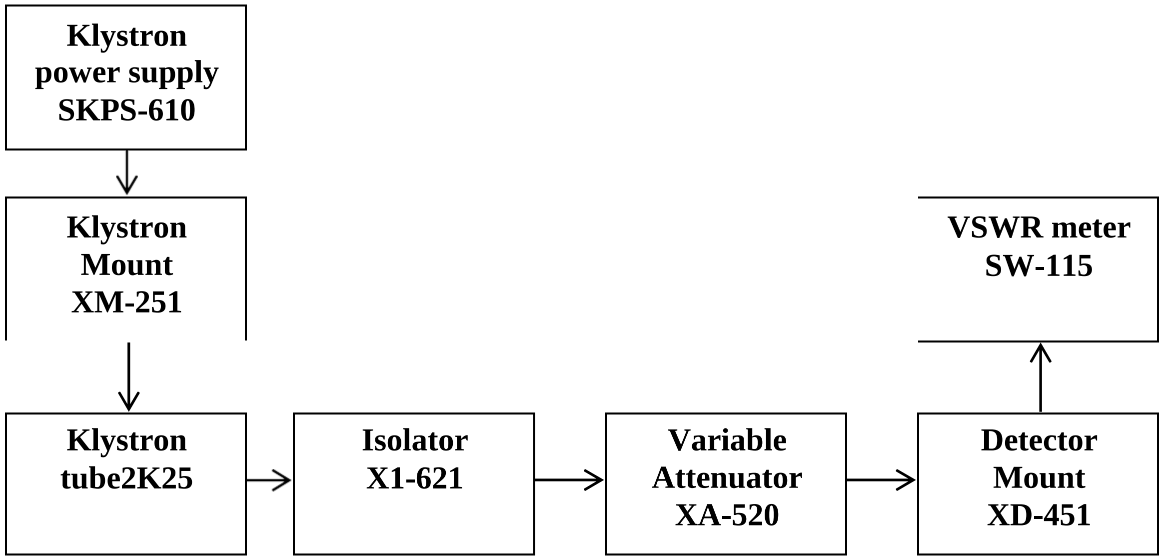
IV. BLOCK DIAGRAM:

Set up 1: Reference level **"x dB"**



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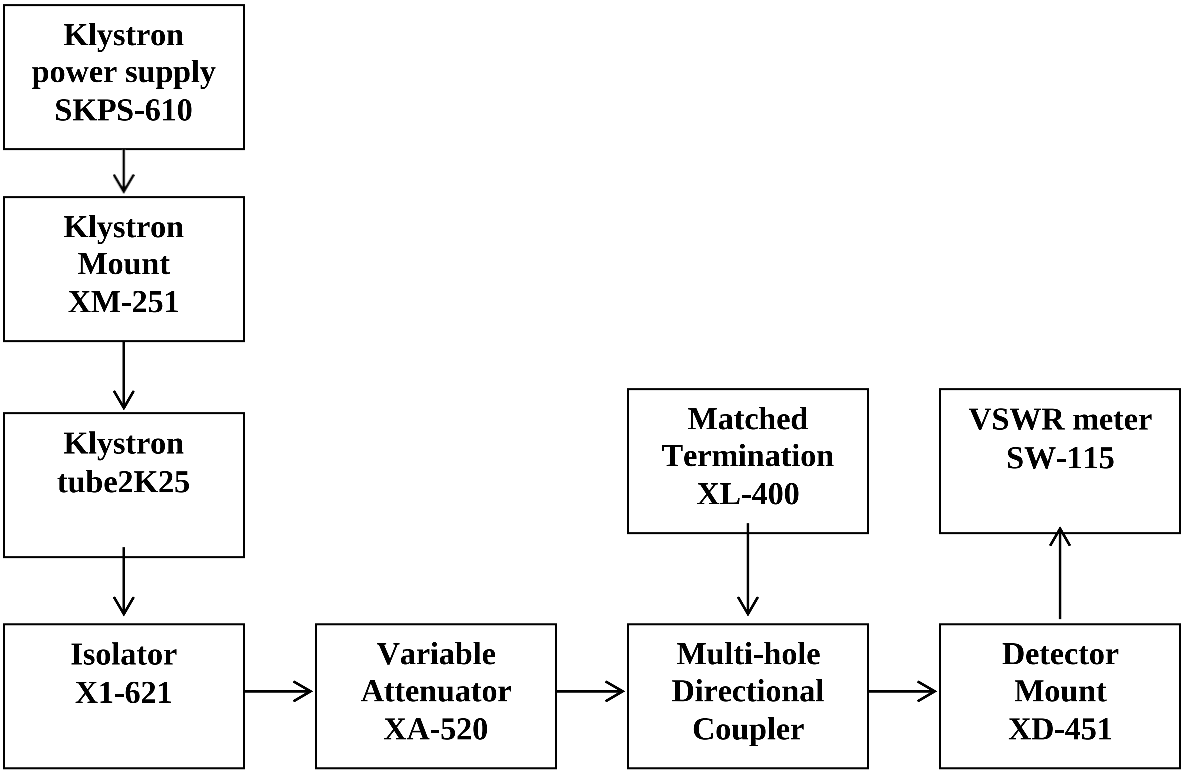
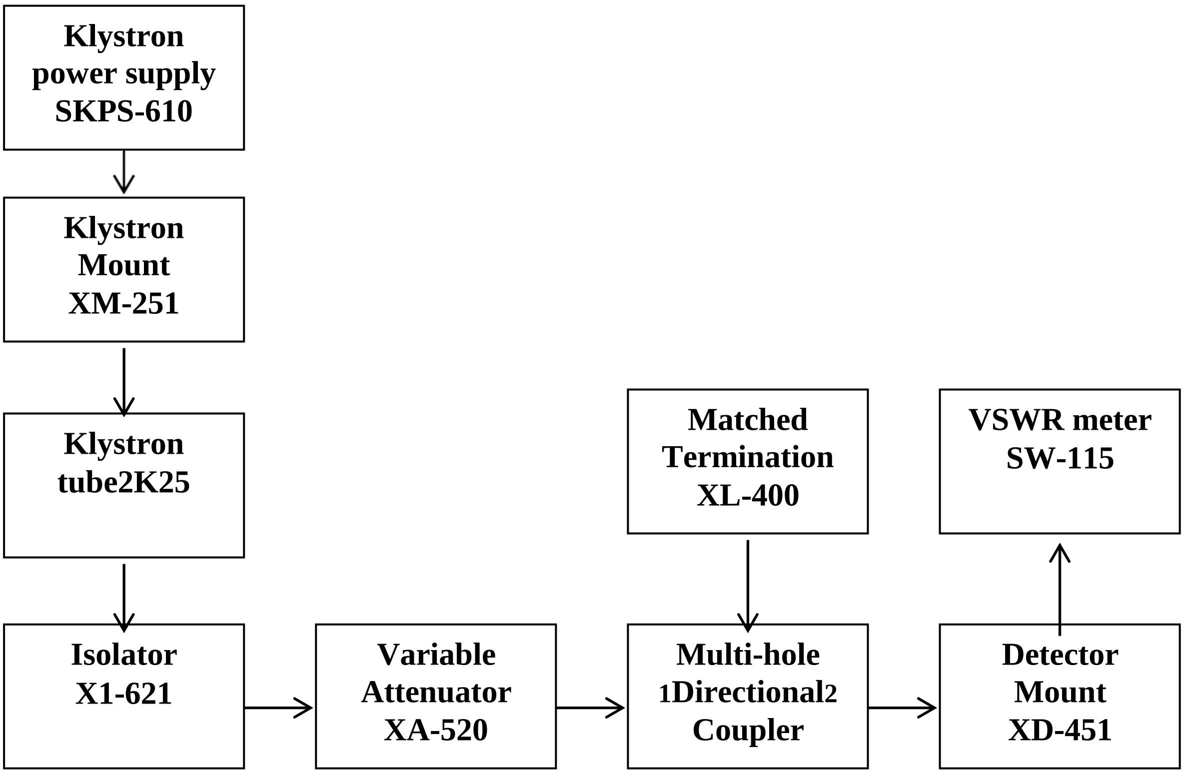
Set up 2: To determine the coupling factor 'X-Y dB"



Set up 3: To determine insertion loss **"X-Z dB**"



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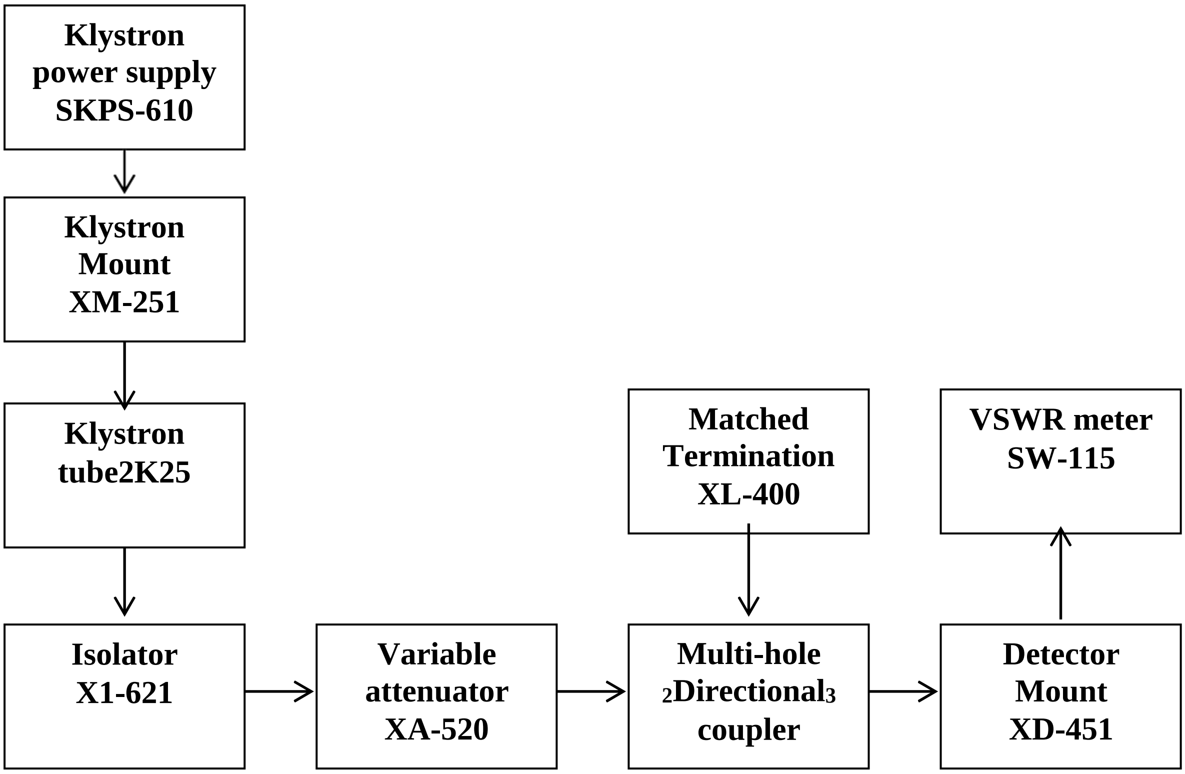
Set up 4: To determine isolation “X-Y dB”



V. PROCEDURE:

i. Setup the components and equipments as shown in figure.

ii. Energize the microwave source for particular frequency of operation.

iii. Remove the multi-hole directional coupler and connect the detector mount to the frequency meter. Tune the detector for maximum output.

iv. Set any reference level of power on VSWR meter with the help of variable attenuator, gain control knob of VSWR meter and note-down the reading.

v. 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 and gain control knob of VSWR meter.

vi. Note down the reading on VSWR meter on the scale with the help of range –db switch if required. Let it be **‘Y’**

vii. Calculate coupling factor which will be
C (dB) = X – Y

viii. Now carefully disconnect the detector from auxiliary port 3 and match termination from port 2 without disturbing the setup.

ix. Connect the matched termination to auxiliary port 3 and detector to port 2 and measure the reading on VSWR meter. Suppose it is **Z.**

x. Compute insertion loss **X-Z in dB**.

XI. Repeat steps from 1 to 4.

Xii. 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 gain control knob of VSWR meter.

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Xiii. Measure and note down the reading on VSWR meter. Let it be **Yd.**

X-Y gives isolation **I(dB).**

Xiv. Compute the directivity as

Y-Yd = I-C

xv. Repeat the same for other frequencies.

VI. OBSERVATIONS:

Input Port	Output Port	Matched Termination	S-parameters
1	**2**	**3**	**S12**
1	**3**	**2**	**S13**
2	**1**	**3**	**S21**
2	**3**	**1**	**S23**
3	**1**	**2**	**S31**
3	**2**	**1**	**S32**

VII.CALCULATIONS:

Coupling (dB) = 10 $\log_{10}\left[\frac{P1}{P3}\right]$ where port 2 is terminated

C (dB)= X-Y

Isolation (dB) = 10 $\log_{10}\left[\frac{P2}{P3}\right]$ where Port1 is matched.

I (dB) = X – Yd

Hence Directivity D (dB) = 10 $\log_{10}\left[\frac{P2}{P1}\right]$ = I-C

VIII. GRAPH:

IX. RESULT:

The multi-hole directional coupler characteristic has been studied by measuring its scattering parameters.

i. Coupling factor

ii. Isolation

iii. Insertion loss

iv. Directivity

X. INFERENCES:

By knowing the power output at various ports we can measure various loses in directional couplers.

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XI. PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.
   Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.
ii. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.
iii. Switch on the main supply and give some warm up time to get current / accurate reading.
iv. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.
v. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.
vi. Don't increase the repeller voltage more than **-70V**(i.e.) it should be between **-70V to -270V.**

XII. APPLICATIONS:

i. It is used to measure incident and reflected powers
ii. It can sample a small amount of micro power for measurement purposes.
iii. Provides signal path to a receiver.

XIII. EXTENSIONS:

This experiment can be extended to four port directional couplers.

XIV. TROUBLE SHOOTING:

FAULT		DIAGNOSIS
1. No output at ports	:	Vary the repeller voltage slowly Check for proper alignment
2. Meter reading fluctuating	:	Place the power dB knob to 20 or 30 dB

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XV. QUESTIONS:

i. What is the purpose of employing directional couplers?

ii. What are the desirable operations that can be performed by the directional coupler?

iii. What is coupling factor?

iv. What is significance of directivity?

v. What are the scattering parameters of directional coupler?

vi. What should be the distance between the holes in the multi-hole directional coupler?

vii. How high amount of directivity can be achieved in with directional coupler?

viii List out different types of directional couplers?

ix. What is the main advantage of using directional coupler?

x. Explain briefly the operation of directional coupler.

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7. MEASUREMENT OF SCATTERING PARAMETERS OF CIRCULATOR

I. AIM:

To study the properties of 3-port circulator and determine the scattering parameters of circulator.

II. (i) EQUIPMENT AND COMPONENTS:

1. APPARATUS

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 Detector mount XD-451
8 Waveguide stands X4-535
9 VSWR meter SW-215
10 Movable short XT-481
11 Matched termination XL-400
12 Slotted section XS-651
13 Tunable probe XP-655
14.T circulator XC-621

(ii) DESCRIPTION OF EQUIPMENT:

1. Klystron power supply SKPS – 610

The model Klystron Power Supply SKPS-610 is general purpose laboratory power supply which is specially designed to use for reflex klystron tubes of S to X band frequency range. It is reliable power source with very high regulation and low ripple contents.

The klystron power supply SKPS-610 has built in modulation facilities of amplitude and frequency modulation. Amplitude modulation can be applied with 0-110V (p.p.) Square wave and with frequency of 500 Hz to 2.5 KHz. This amplitude modulation is generally used along with VSWR measurements in slotted line technique. Frequency modulation is used for direct study of klystron modes on the Oscilloscope. Pure carrier wave operation and in external modulation facilities is also provided with the instrument for generalized use.

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The klystron power supply also provides all the other D.C. Voltages required for operation of reflex klystron tube such as beam, heater and reflector voltage. The ranges of all these voltages are given in the specification data sheet.

2. Klystron tube 2k25

The klystron tube 2k25 is a single cavity variable frequency microwave generator of low power and low efficiency. It consists of an electron gun, a filament surrounded by cathode and a focusing electrode at cathode potential. The electrons emitted by the cathode travel towards the reflector through an anode kept at higher potential compared to the cathode. When they approach the anode, the electrons form bunches and the bunches ultimately return towards the anode cavity after traveling a small distance towards the reflector. The power is taken from the anode reentrant cavity.

3. Isolator XI-621

It is a two port device which provides very small amount of attenuation for transmission from port 1 to port 2 and provides maximum attenuation for transmission from port 2 to port 1. It is very much desirable when we want to match a source with variable load. It allows power flow only from the generator towards the load and suppresses any reflected power.

4. Frequency meter XF-710

It is also called wave meter. Usual construction of it consist a cylindrical cavity mounted on a shaft. By rotating the shaft the volume in the cavity is changed and it becomes resonant and gives minimum impedance at the resonant frequency. The scale calibrated and the resonant frequency can be directly read from the scale after observing a dip in the output meter.

5. Variable attenuator XA-520

This is a wave guide piece having a groove on the lateral side. By rotating the screw the depth of penetration of resistive pad changes, there by introducing some attenuation. Attenuators are commonly used for measuring power game or loss in dBs for providing isolation between instruments for reducing the power input to a particular stage to prevent over loading and also for providing the signal generators with means of calibrating there outputs accurately. Variable attenuator provide continuous or step wise variable attenuation.

6. VSWR meter SW-215

AVSWR meter basically consists of a high gain; high Q low noise voltage amplifier normally tuned at a fixed frequency at which the microwave signal is modulated. The VSWR meter uses the detector signal out of the microwave detector as its input, amplifies the same and provides the output on the calibrated volt meter. The meter itself can be calibrated in terms of VSWR

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7. Circulator

It is a four port microwave device each terminal is connected only to the next clock wise terminal i.e. port one is connected to port two only and not to the port 3 and port 4 and port 2 is connected only port 3 not to the port 4

III.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 the other ports. This is depicted in figure. Circulator can have any number of ports. Circulator is a multi-port junction. A wave incident in port 1 is coupled to port 2 only, a wave incident at port 2 is coupled to port 3 only and so on. Following is the basic parameters of isolator and circulator.

Insertion Loss:

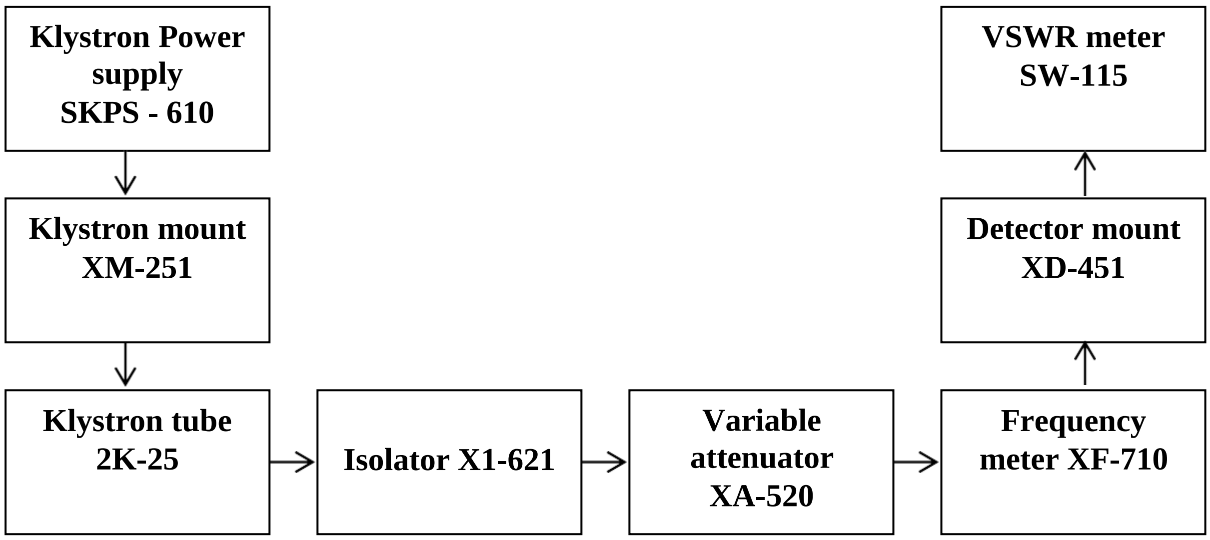
Insertion loss is the ratio of power detected at output port to power supplied by source to the input port, measured with other ports terminated in matched load. It is expressed in dB.

Isolation:

Isolation is ratio of power applied to output to that measured at that input. This ratio is expressed in dB. The relation of a circulator is measured with 3rd port terminated in a matched load.

IV. BLOCK DIAGRAM:

Set up 1: for 0 setting



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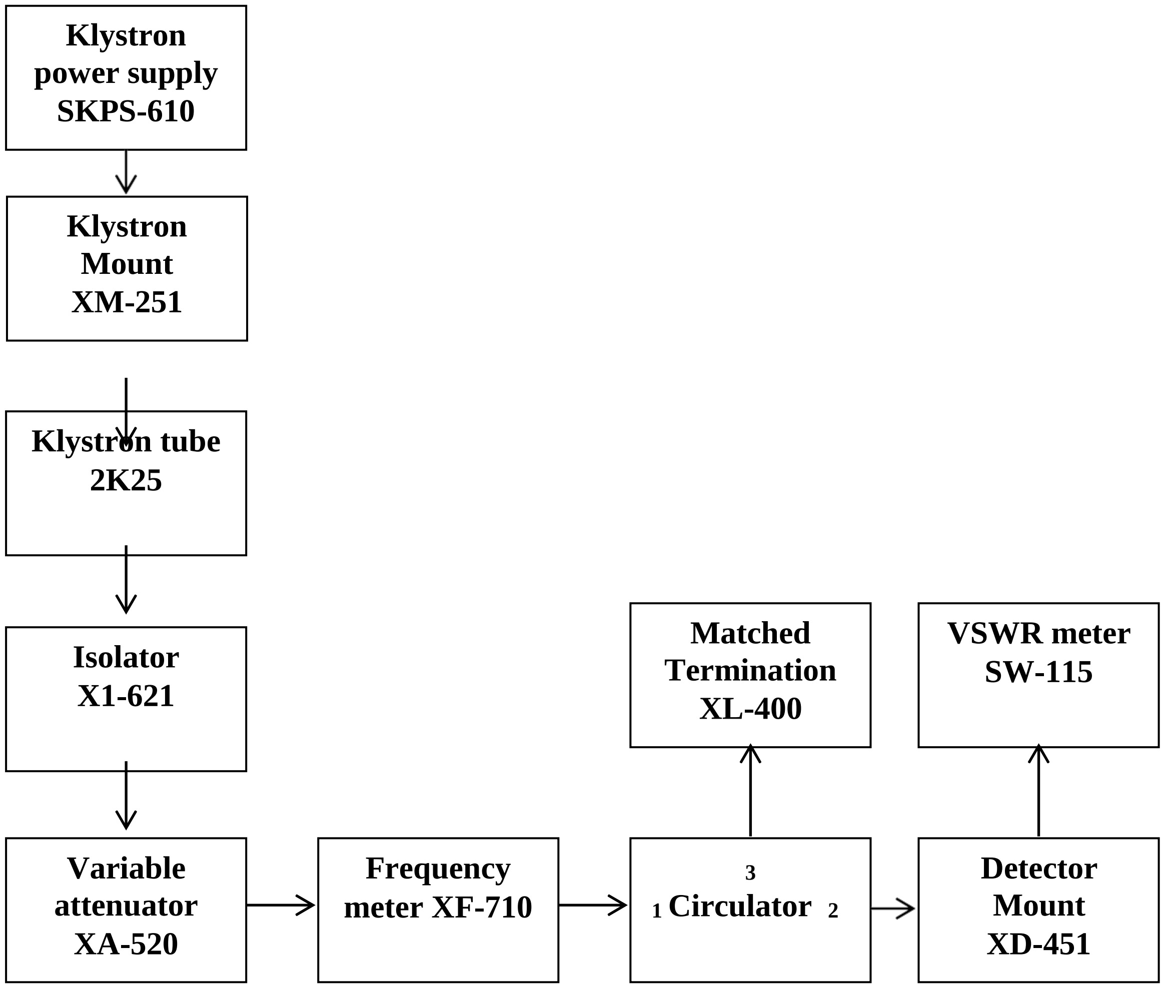
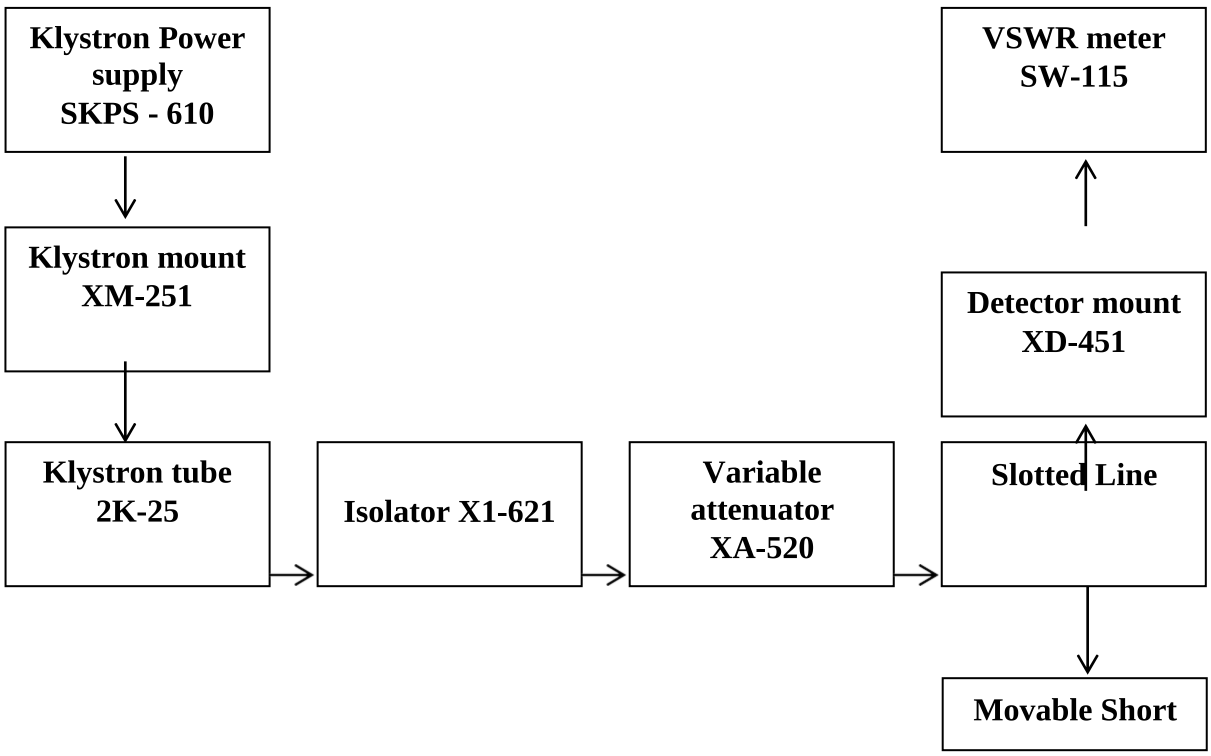
Set up 2: To Measure scattering parameters.



Set up 3: To Measure s_{11} s_{22} and s_{33}



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V. PROCEDURE:

i. Remove the probe and circulator or isolator from slotted line and connect the detector mount to slotted section. The output of detector mount should be connected with VSWR meter.

ii. Energize the microwave source for maximum output for a particular frequency of operation. Tune the detector mount for maximum output in VSWR meter.

iii. Set any reference level of power in VSWR meter with the help of variable attenuator and gain control knob of VSWR. Let it be P_1.

iv. Carefully remove the detector mount from the setup. i.e. slotted line disturbing the position of setup. Insert the circulator between slotted line and detector mount. Keep input port to slotted line and detector to its output port. A matched termination should be placed at 3rd port in case of circulator.

v. Record the reading in the VSWR meter. If necessary, change range (dB) switch to high or lower position and read 10 dB changes for each set change of switch position. Let it be P_2.

vi. Compute insertion loss given as P_1-P_2 dB.

vii. For measurement of isolation, the circulator has to be connected in reverse i.e. output port to slotted line and detector to input port with other port terminated by matched termination.

viii. Record the reading of VSWR meter after and let it be P_3.

ix. Compute isolation as **P_1-P_3** in **dB.**

x. The same experiment can be done for other ports of circulator.

xi. Repeat the above experiment for other frequencies of needed.

VI. OBSERVATIONS:

Input Port	Output Port	Matched Termination	S-parameters
1	2	3	S12
1	3	2	S13
2	1	3	S21
2	3	1	S23
3	1	2	S31
3	2	1	S32
1	1	2,3	S11
2	2	1,3	S22
3	3	1,2	S33

VII. CALCULATIONS:

Insertion Loss = **P1 – P2**

Isolation = **P1 – P3**

P1 $\longrightarrow$ without circulator -- > reference level (0 dB)

P2 $\longrightarrow$ Port 1 (input)
Port 2 (output)
Port 3 (matched termination)

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P3 ⟶ Port 3 (input)
Port 1 (output)
Port 2 (matched)

VIII. GRAPH:

IX. RESULT:

Thus, the circulator has been studied. The scattering matrix has been founded. The insertion loss and isolation have been measured.
Insertion Loss = 1.5 dB
Isolation = 30 dB

X. INFERENCES:

i. The power input given at port 1 is given to port 2 only but not to port 3, the power input port 2 is given to port 3 only but not to port 1.
ii. Here each terminal is connected only to the next clockwise terminal.
iii. All the ports are perfectly matched to the junction.

XI. PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.
Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.
ii. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.
iii. Switch on the main supply and give some warm up time to get current / accurate reading.
iv. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.
v. If the main supply failed in the middle of the experiment, come to 1^{st} condition (i.e.) keep all the knobs in minimum positions and switch off main switches.
vi. Don't increase the repeller voltage more than **-70 V** (i.e.) it should be between **-70Vto -270V.**

XII. APPLICATIONS:

i. Used as duplexer for a radar antenna system.
ii. Two three port circulators can be used in tunnel diode or parametric amplifiers.
iii. Used as low power devices as they can handle low powers only.

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XIII. EXTENSIONS:

The experiment can be extended N-port circulator.

XIV. TROUBLE SHOOTING:

FAULT		DIAGNOSIS
Meter reading fluctuation	:	De tune the frequency meter Keep it in low dB
No output at ports	:	check for matched terminations Check probe connections

XV. QUESTIONS:

i. What is the principle involved in circulators?

ii. What is Faraday rotation?

iii. Why the power applied at one port is given to the next clockwise port only but not to other ports?

iv. Explain briefly the construction of circulator?

v. Where circulators are extensively used?

vi. What is the peculiar property of ferrites?

vii. What are the types of polarized waves present in circulators?

viii. Given expression for angle of rotation.

ix. What are the microwave devices that make use of Faraday rotation?

x. What are the differences between circulator and isolator?

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8. MEASUREMENT OF SCATTERING PARAMETERS OF MAGIC TEE

I AIM:

To study the properties of magic tee and determine the scattering parameters of magic tee.

II. (i) EQUIPMENT AND COMPONENTS:

1.APPARATUS

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 Detector mount XD-451
8 Waveguide stands X4-535
9 VSWR meter SW-215
10 Movable short XT-481
11 Matched termination XL-400
12 Slotted section XS-651
13 Tunable probe XP-655
14.Magic Tee XE-520

(ii) DESCRIPTION OF EQUIPMENT:

1. Klystron power supply SKPS – 610

The model Klystron Power Supply SKPS-610 is general purpose laboratory power supply which is specially designed to use for reflex klystron tubes of S to X band frequency range. It is reliable power source with very high regulation and low ripple contents.

The klystron power supply SKPS-610 has built in modulation facilities of amplitude and frequency modulation. Amplitude modulation can be applied with 0-110V (p.p.) Square wave and with frequency of 500 Hz to 2.5 KHz. This amplitude modulation is generally used along with VSWR measurements in slotted line technique. Frequency modulation is used for direct study of klystron modes on the Oscilloscope. Pure carrier wave operation and in external modulation facilities is also provided with the instrument for generalized use.

The klystron power supply also provides all the other D.C. Voltages required for operation of reflex klystron tube such as beam, heater and reflector voltage. The ranges of all these voltages are given in the specification data sheet.

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2. Klystron tube 2k25

The klystron tube 2k25 is a single cavity variable frequency microwave generator of low power and low efficiency. It consists of an electron gun, a filament surrounded by cathode and a focusing electrode at cathode potential. The electrons emitted by the cathode travel towards the reflector through an anode kept at higher potential compared to the cathode. When they approach the anode, the electrons form bunches and the bunches ultimately return towards the anode cavity after traveling a small distance towards the reflector. The power is taken from the anode reentrant cavity.

3. Isolator XI-621

It is a two port device which provides very small amount of attenuation for transmission from port 1 to port 2 and provides maximum attenuation for transmission from port 2 to port 1. It is very much desirable when we want to match a source with variable load. It allows power flow only from the generator towards the load and suppresses any reflected power.

4. Frequency meter XF-710

It is also called wave meter. Usual construction of it consist a cylindrical cavity mounted on a shaft. By rotating the shaft the volume in the cavity is changed and it becomes resonant and gives minimum impedance at the resonant frequency. The scale calibrated and the resonant frequency can be directly read from the scale after observing a dip in the output meter.

5. Variable attenuator XA-520

This is a wave guide piece having a groove on the lateral side. By rotating the screw the depth of penetration of resistive pad changes, there by introducing some attenuation. Attenuators are commonly used for measuring power game or loss in dBs for providing isolation between instruments for reducing the power input to a particular stage to prevent over loading and also for providing the signal generators with means of calibrating there outputs accurately. Variable attenuator provide continuous or step wise variable attenuation.

6. VSWR meter SW-215

AVSWR meter basically consists of a high gain, high Q low noise voltage amplifier normally tuned at a fixed frequency at which the microwave signal is modulated. The VSWR meter uses the detector signal out of the microwave detector as its input, amplifies the same and provides the output on the calibrated volt meter. The meter itself can be calibrated in terms of VSWR

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7. Magic Tee

It is a four port device port one and port two are collinear arms port 3 is H-arm and port 4 is E-arm in this magic tee if any two ports are perfectly match to the junction then the remaining two ports are automatically match to the junction.

III.THEORY:

The device magic tee is a combination of E and H-plane tee as shown in the figure. Arm 3 is the H-arm and arm-4 is the E-arm. If the power is fed into arm 3 (H-arm), the electric field divides equally between 1 and 2 arms with the same phase and no electric field exists in arm 4 (E-arm), it divides equally into arm-1 and arm-2 but out of phase with no power to arm-3, further if the power is fed in arm-1 and arm-2 simultaneously it is added in arm-3 (H-arm) and it is subtracted in E-arm i.e. arm-4.

The basic parameters to be measured for magic tee are defined below:

i. **Input VSWR:** Value of SWR corresponding to each ort as a load to the line while other ports are terminated in matched load.

ii. **Isolation:** The isolation between E & H arms is defined as the ratio of the power supplied by the generators connected to the E-arm (port 4) to the power detected at H-arm (port 3) when side arms-1 and 2 are terminated in matched load. Hence

Isolation I(dB) = 10 $\mathbf{\log_{10}}$ $\left[\dfrac{P4}{P3}\right]$**,** similarly isolation between other ports may be defined.

iii. **Coupling Factor:** It is defined as $\mathbf{C_{ij} = 10^{-}}\dfrac{a}{20}$ where ‘**a**’ is attenuation / isolation in dB when ‘i’ is the input arm and j is the output arm.

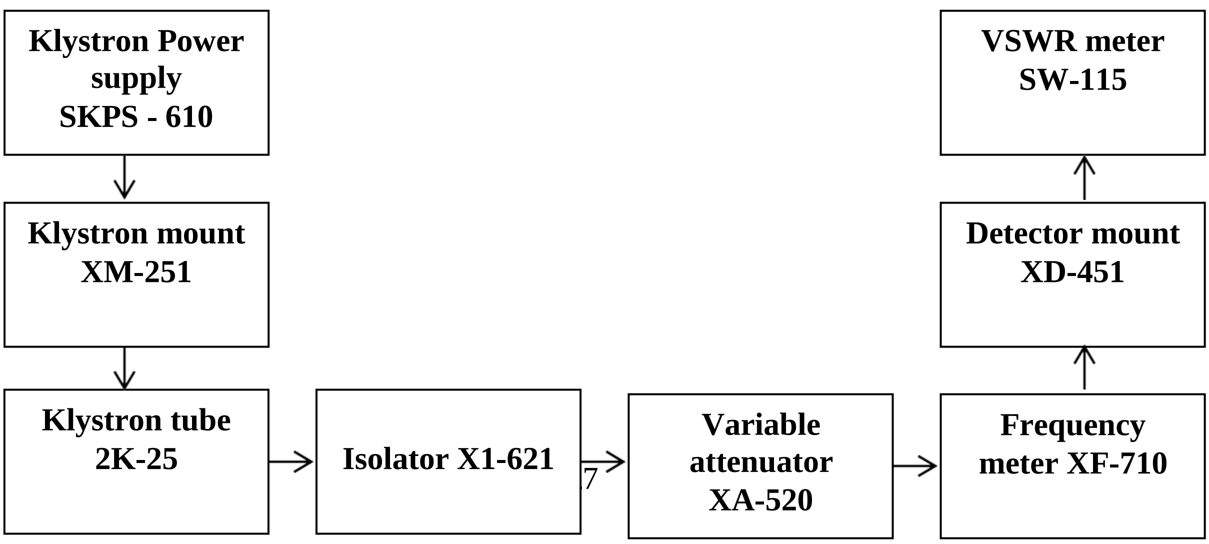
Thus **a = 10 $\mathbf{\log_{10}}$** $\left[\dfrac{P4}{P3}\right]$

Where, P_3 = power delivered to arm-i

P_4 = power detected at j-arm

IV. BLOCK DIAGRAM:

Set up 1: for 0 dB setting



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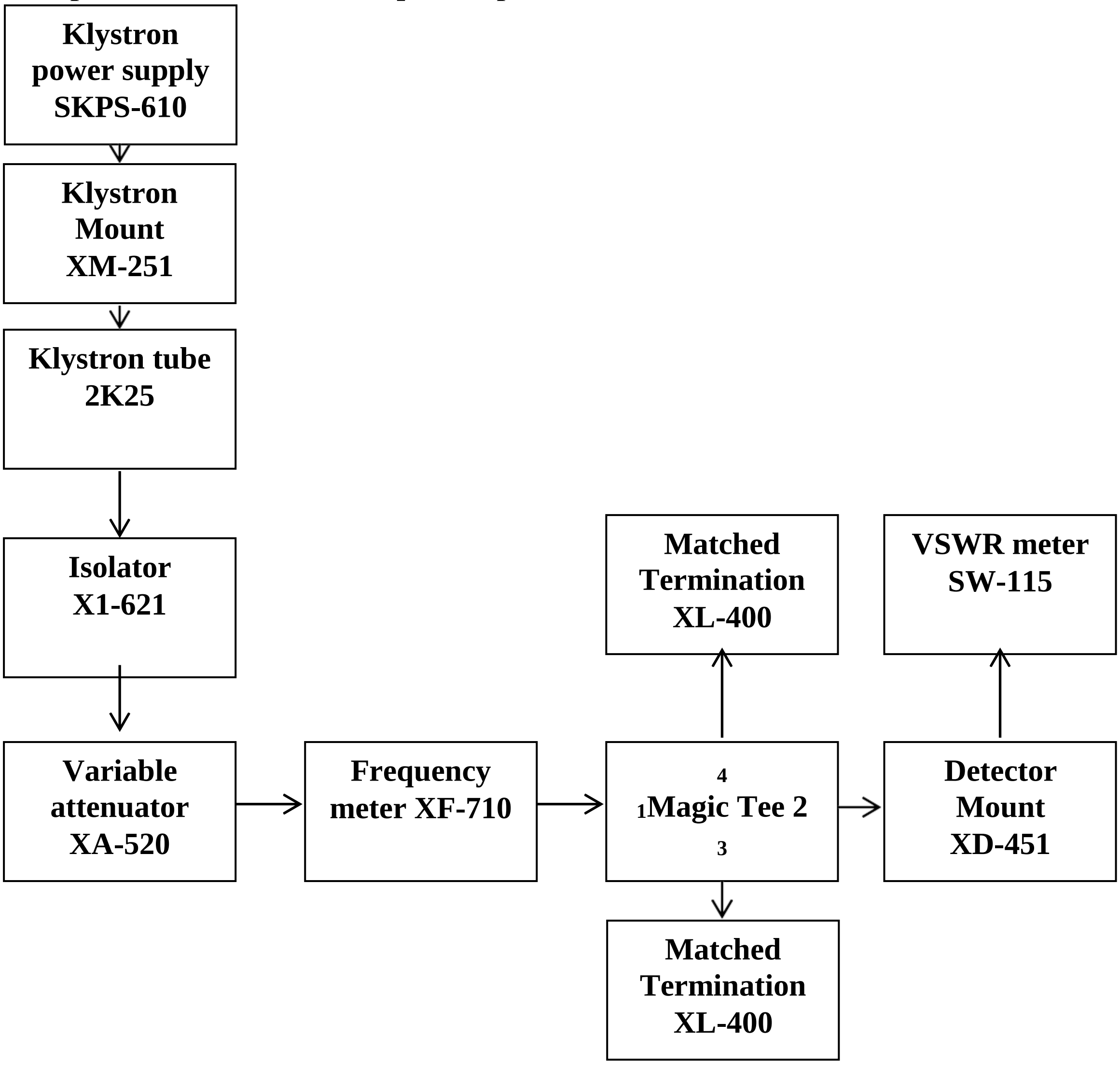
Set up 2: "Measurement set-up for S-parameters"



V. PROCEDURE:

i. Remove the tunable probe and magic tee from the slotted line and connect the detector mount to slotted line.
ii. Energise he microwave source for particular frequency of operation and tune the detector mount for maximum output.
iii. With the help of variable attenuator and gain control knob of VSWR meter, set any power level in the VSWR meter and note down. Let it be P_3.
iv. Without disturbing the position of variable attenuator and gain control knob, carefully place the magic tee after slotted line keeping H-arm connected to slotted line. Detector to E-arm and matched termination to arm-1 and arm-2. Note down the reading of VSWR meter. Let it be P_4.
v. Determine the isolation between port 3 and 4 as P_3-P_4 (dB).
vi. Determine coupling coefficient from equation given in theory port.
vii. The same experiment may be repeated for other ports also.
viii. Repeat the above experiment for other frequencies.

VI. OBSERVATIONS:

Input Port	Output Port	Matched Termination	Matched Termination	Power output
1	2	3	4	P2
1	3	2	4	P3
1	4	2	3	P4
2	1	3	4	P5
2	3	1	4	P6
2	4	1	3	P7
3	1	2	4	P8
3	2	1	4	P9
3	4	1	2	P10
4	1	2	3	P11
4	2	1	3	P12
4	3	1	2	P13

VII. CALCUALTIONS:

$$\begin{bmatrix} S_{11} S_{12} S_{13} S_{14} \\ S_{21} S_{22} S_{23} S_{24} \\ S_{31} S_{32} S_{23} S_{34} \\ S_{41} S_{42} S_{43} S_{44} \end{bmatrix}$$

S12 = P2 – P1	S21 = P5 – P1	S31 = P8 – P1	S41 = P11 – P1
S13 = P3 – P1	S23 = P6 – P1	S32 = P9 – P1	S42 = P12 – P1
S14 = P4 – P1	S24 = P7 – P1	S34 = P10 – P1	S43 = P13 – P1

VIII. RESULT:

Thus, we have studied the functions of magic tee by measuring its parameters and compared with its properties.

IX. INFERENCES:

i. The E-Plane Tee property is observed.
ii. The H-Plane Tee property is observed.
iii. All the ports are matched to junction.
iv. The power applied at port 1 does not goes to port 2 and vice versa, the power applied at port 3 does not goes to port 4 and vice versa.
v. Addition of powers is done when the power is at port 3 (H-arm) and subscription of powers at port 4 (E-arm).

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X. PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.
   Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.
ii. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.
iii. Switch on the main supply and give some warm up time to get current / accurate reading.
iv. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.
v. If the main supply failed in the middle of the experiment, come to 1^{st} condition (i.e.) keep all the knobs in minimum positions and switch off main switches.
vi. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto -270V.

XI. APPLICATIONS:

i. Used for the measurement of impedance.
ii. It is used as a duplexer.
iii. Used as a mixer.
iv. Is used in microwave discriminator, Microwave Bridge.

XII. EXTENSIONS:

The experiment can be extended for any four port device.

XIII. TROUBLE SHOOTING:

FAULT		DIAGNOSIS
No dip in VSWR meter	:	check for probe connections Vary reference voltage
No reading in meter	:	check the wave guide alignment

XIV. QUESTIONS:

i. Why E-H Plane Tee is called as a Magic Tee.
ii. How magic tee acts as a duplexer?
iii. What are the properties of magic tee?
iv. Which ports are isolated ports in the magic tee?
v. At what port (Arm) the powers can be added.
vi. Why all the ports are perfectly matched in the magic tee?
vii. How magic tee acts as a mixer?
viii. If the powers are applied at port 3, port 4 then what is the power output at port 1, port 2.
ix. If the power is applied only at port 3 then what are the power outputs of the magic tee.
x. What are the characteristics of microwave components?

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9: VSWR MEASUREMENT

I. AIM:

To determine the standing wave ratio and reflection coefficient

II. (i) EQUIPMENT AND COMPONENTS:

1. APPARATUS

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. Detector mount XD-451
8. Waveguide stands X4-535
9. VSWR meter SW-215
10. Movable short and S-S tuner

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The klystron power supply also provides all the other D.C. Voltages required for operation of reflex klystron tube such as beam, heater and reflector voltage. The ranges of all these voltages are given in the specification data sheet.

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3. Isolator XI-621

It is a two port device which provides very small amount of attenuation for transmission from port 1 to port 2 and provides maximum attenuation for transmission from port 2 to port 1. It is very much desirable when we want to match a source with variable load. It allows power flow only from the generator towards the load and suppresses any reflected power.

4. Frequency meter XF-710

It is also called wave meter. Usual construction of it consist a cylindrical cavity mounted on a shaft. By rotating the shaft the volume in the cavity is changed and it becomes resonant and gives minimum impedance at the resonant frequency. The scale calibrated and the resonant frequency can be directly read from the scale after observing a dip in the output meter.

5. Variable attenuator XA-520

This is a wave guide piece having a groove on the lateral side. By rotating the screw the depth of penetration of resistive pad changes, there by introducing some attenuation. Attenuators are commonly used for measuring power game or loss in dBs for providing isolation between instruments for reducing the power input to a particular stage to prevent over loading and also for providing the signal generators with means of calibrating there outputs accurately.
Variable attenuator provide continuous or step wise variable attenuation.

6. VSWR meter SW-215

AVSWR meter basically consists of a high gain; high Q low noise voltage amplifier normally tuned at a fixed frequency at which the microwave signal is modulated. The VSWR meter uses the detector signal out of the microwave detector as its input, amplifies the same and provides the output on the calibrated volt meter. The meter itself can be calibrated in terms of VSWR.

III. THEORY:

The reflex klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. The electromagnetic field at any point of transmission line may

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be considered as the sum of to traveling waves the instant wave propagates from generator and the reflected wave propagates towards the generator. The reflected wave is set up by the reflection of instant wave from a discontinuity on the line or from the load impedance. The magnitude and face of the reflector wave depends up on amplitude and face of the reflecting impedance. The maximum field strength is found were two wave are in face and minimum were the two waves adds in opposite face. The distance between two successive minimum (or maximum) is half the guide wave length on the line.

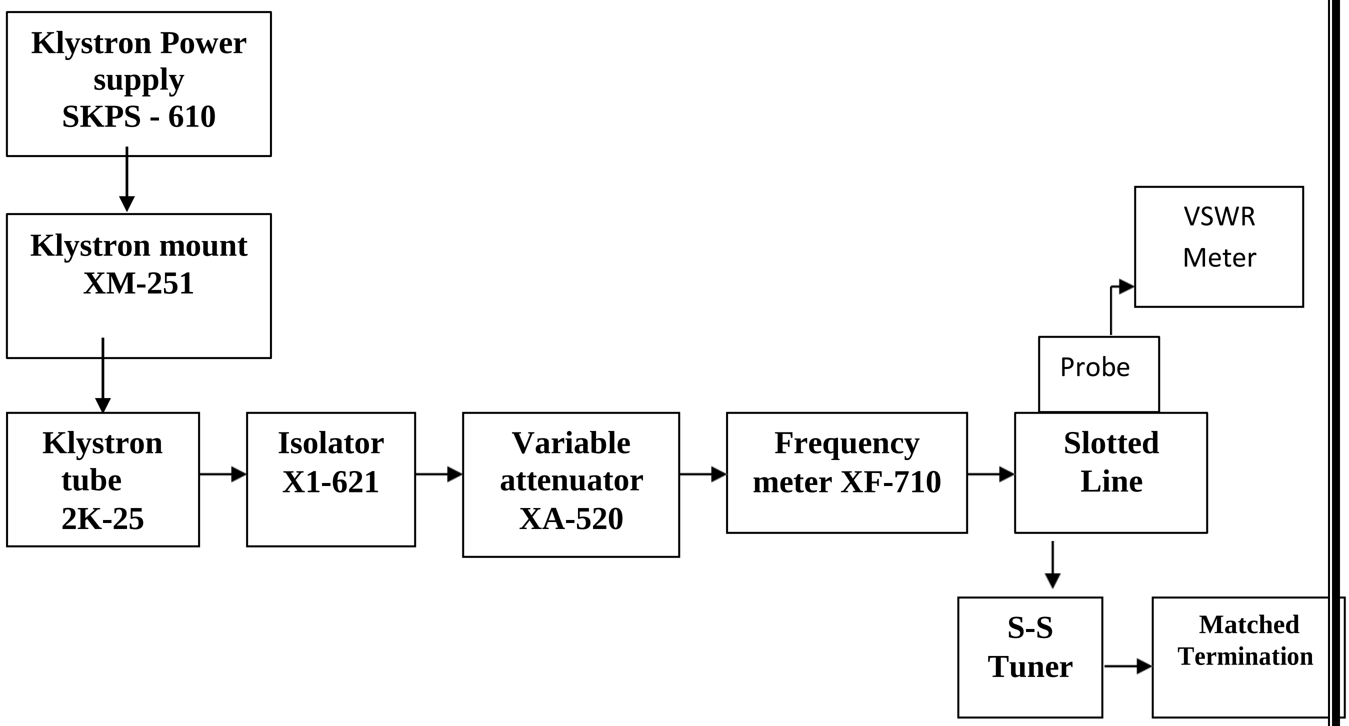
The ratio electrical field strengths of reflected and incidents wave is called reflection coefficient.VSWR (voltage standing wave ratio) is defined as the ratio between maximum and minimum field strength along the line.

$$VSWR(S)\text{-}E_{MAX}/E_{MIN}$$

Reflection coefficient $\rho = \dfrac{E_x}{E_I}$

$$|\rho| = \frac{s-1}{s+1}$$

IV. BLOCK DIAGRAM:



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V. PROCEDURE:

To fire klystron correctly, adopt the following procedure.

i. Set the cooling fan to blow air across the tube and turn on the filament voltage, and then wait for a few minutes.

ii. Set the attenuator at a suitable level, say at 3 db value.

iii. Apply the repeller voltage to its maximum value, say –250 V.

iv. Then apply beam voltage say 250 V, to obtain an electron beam indicated by beam current meter. Klystron is thus set to be oscillates and power output is indicated.

v. Adjust the repeller voltage to have maximum power output (micro ammeter current).

vi. Also adjust the Klystron mounting plunger for maximum power output.

vii. Set the depth of S-S tuner slightly more for maximum VSWR.

viii. Move the probe along with slotted line until a minimum is indicated.

ix. Adjust the VSWR meter gain control knob a variable attenuator to obtain a reading of 3 dB of normal dB of VSWR.

x. Move the probe to the left on the slotted line until full scale deflection is obtain note and record the probe position on slotted line let it be d_1.

xi. Repeat step ix & x and then move the probe right along with slotted until full scale deflection is obtained let it be d_2.

xii. Replace the S-S.Tuner and termination movable short.

xiii. Measure the distance between two successive minima position of probe, twice this distance is guide wave length λ_g.

$$SWR = \frac{\lambda_g}{\pi(d_1 - d_2)}$$

VI. OBSERVATIONS:

Repeller voltage	Depth of S-S tuner	
	d_1	**d_2**

VII. CALCULATIONS:

$$SWR = \frac{\lambda_g}{\pi(d_1 - d_2)}$$

VIII. GRAPH:

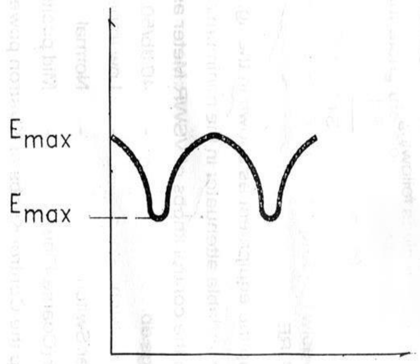

FIG. 6 STANDING WAVE

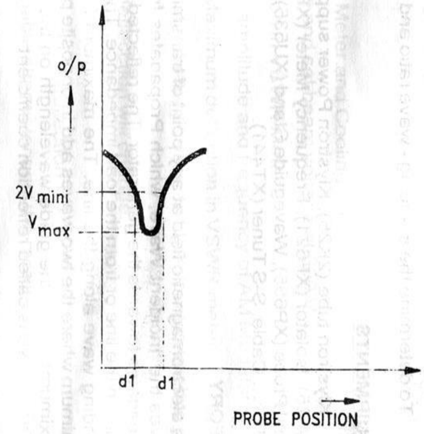

FIG. 7 DOUBLE MINIMA METHOD

IX. INFERENCE:

As the depth tuner is variate, voltage standing wave ratio also varies and a maximum value of 10 to 20 can be obtained.

X. PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.
Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

ii. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.

iii. Switch on the main supply and give some warm up time to get current / accurate reading.

iv. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.

v. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

vi. Don't increase the repeller voltage more than **-70 V** (i.e.) it should be between **-70V to -270V.**

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XI. TROUBLE SHOOTING:

FAULT	DIAGNOSIS
No output	changes the depth of SS tuner.

XII. RESULT:

Hence the VSWR is measured using double minimum method

XIII. EXTENSION:

By knowing the VSWR we can measure the unknown impedance.

XIV. APPLICATIONS:

i. Standing wave ratio in transmission.
ii. In selecting the load impedance.

XV. QUESTIONS:

i. Define VSWR.
ii. Define reflection coefficient
iii. What are the maxima and minima values of reflection coefficient?
iv. What are the maxima and minima values of VSWR?
v. Mention the different techniques in measuring the VSWR.
vi. Which method is used to measure VSWR>10.
vii. What is the relation between VSWR and guided wavelength?
viii. Explain about SS tuner.
ix. Why standing waves are obtaining from transmission.
x. How to reduce standing waves?

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