SRI VENKATESWARA UNIVERSITY : TIRUPATI

SRI VENKATESWARA UNIVERSITY COLLEGE OF ENGINEERING

Department of Electrical and Electronics Engineering

MICROWAVE LAB MANUAL

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LIST OF EXPERIMENTS

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2. WAVEGUIDE PARAMETERS [F AND λ] MEASUREMENTS
3. VSWR MEASUREMENTS
4. DIRECTIONAL COUPLES
5. ATTENUATION MEASUREMENT

1. REFLEX KLYSTRON CHARACTERISTICS - I

Aim : To draw the characteristics of reflex klystron oscillator (X-band) output (Vs) reflector voltage (V_R).

Apparatus :

Reflex Klystron oscillator with power supply
Fixed Attenuator
Detector mount
Micro ammeter
Frequency meter.

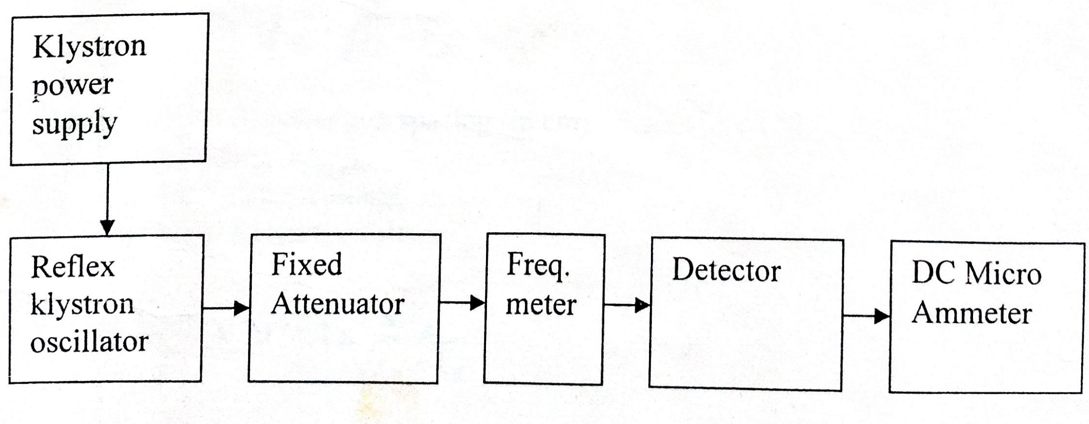
Specifications :

Heater voltage	6.3V, 50Hz.
Beam current	20-25mA
Beam voltage	300V d.c.
Reflector voltage	-40 to -180 V DC

Theory :

Reflex klystron makes use of velocity modulation to transform a continuous electron beam into microwave power electron emitted from the accelerated and passed through the positive resonators towards negative reflector, which retards and finally, reflects the electrons and the electron turns back through the resonator. The electrons leaving the resonator will need different time to return, due to change in velocities. Thus electron bunches are formed. As electron bunches 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 oscillate. The frequency is primarily determined by the dimension of resonant cavity. Hence, by changing the volume of resonator, mechanical tuning range of klystron is possible. Also, a small frequency change can be obtained by adjusting the reflector voltage. This is called electronic tuning range.

Experimental set up :



Procedure :

1) The beam voltage is kept about 300V dc. The reflector voltage is varied from 40 to 180V dc.
2) It is observed in the detector that the klystron oscillates only during short intervals of reflector voltage succeeded by periods of silence and if you happen to measure the frequency we note that the frequency is not the same at each reflector voltage during the period of oscillation.
3) Also the DC output current in the detector meter is varied for every step. The particular reflector voltage is marked when the output is maximum and in steps of 2V on either side of the peak. The reflector voltage is varied and the detector current together with the relevant frequency of operation is noted simultaneously till the output falls near to zero.
4) It is predicted that three or four such modes of operation are obtained when the reflector voltage is varied from 40 to 180V. With observation, it is found that the frequency at the peak of each mode is constant for a particular set of parameters.

Observations :

Reflector voltage -40 to -180V	D.C. Output current	Frequency (GHz)

Draw graphs – (1) V_R Vs d.c. output current
(2) V_R Vs frequency

Calculate : 1) Mode number

$$N = 2(S^1+S_g) + \sqrt{\frac{m_e}{q_e}} \cdot \frac{\sqrt{V_a}}{\sqrt{V_a - V_R}}$$

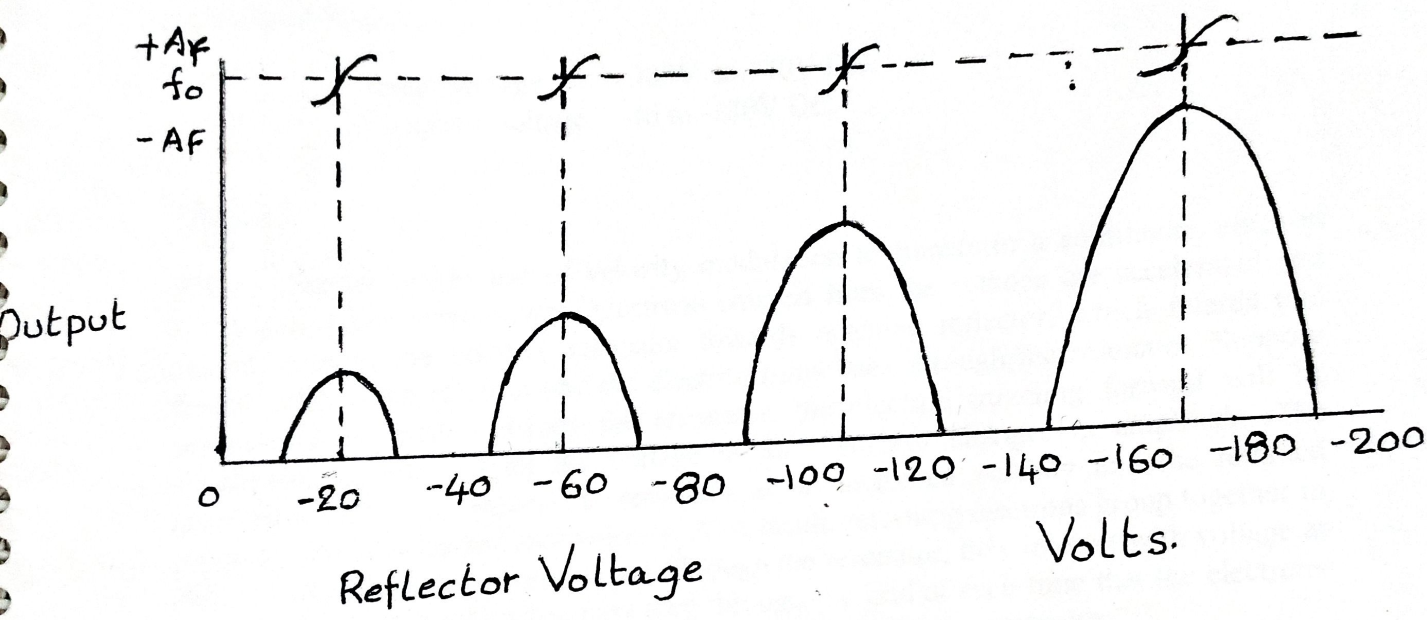
Where S^1 = Repeller gap spacing (in cm)
S_g = Gap length
V_a = Beam voltage
V_R = Reflector voltage

$$N = \frac{13.34}{2} \times 10^{-3} \times f \times \frac{\sqrt{V_a}}{\sqrt{V_a - V_R}}$$

DISCUSS :

1) Why a stabilized power supply is required for energizing the klystron
2) What is the function of flap attenuator.
3) How can the frequency of the reflex klystron be altered.
4) What is meant by electronic tuning?
5) Where is the energy removed from the reflex klystron by what method?
6) What do you understand by mode number?

Model graph



Result : The characteristics of reflex klystron detector output Vs reflector voltage are drawn and observed that frequency of oscillations can be varied by varying reflector voltage (V_R)

3. WAVEGUIDE PARAMETERS – (f and λ) MEASUREMENTS

Aim : To measure guide wavelength (λ_g) and free space wave length (λ_0) and frequency of microwave waveguide.

Apparatus :

- Reflex Klystron (RK)
- RK power supply
- Attenuator
- Frequency meter
- Slotted line
- Detector mount
- VSWR meter
- Short circuit section

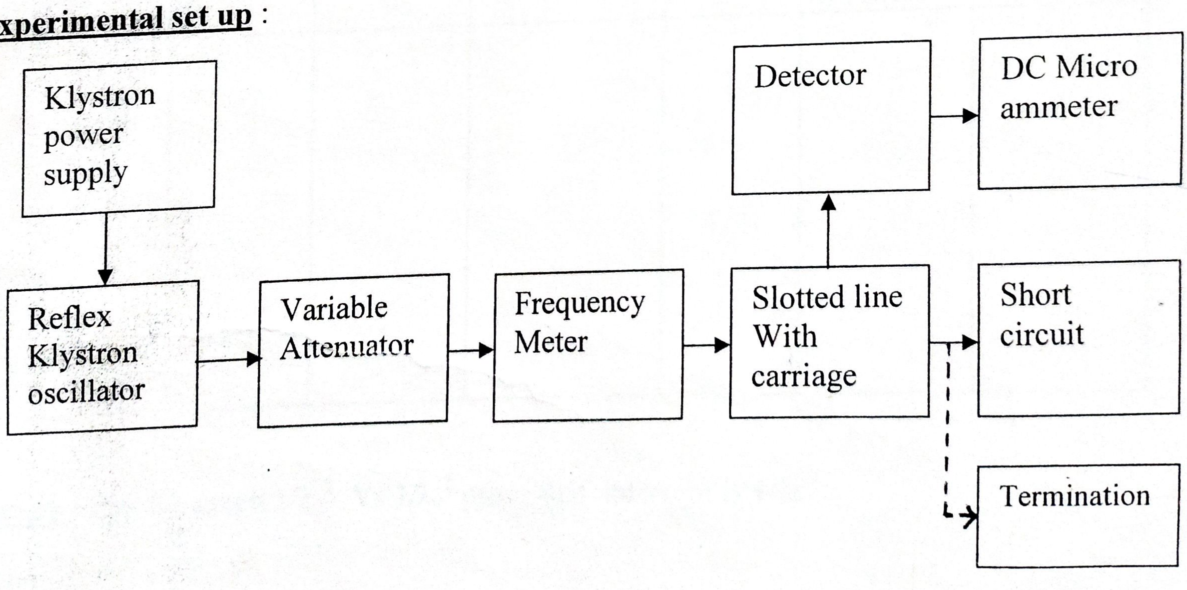
Theory :

For dominant TE_{10} mode, in rectangular waveguide, λ_0, λ_g and λ_c are related as below

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

Where λ_0 = free space wavelength
λ_c = cutt off wavelength
λ_g = Guide wavelength
For TE_{10} mode, $\lambda_c = 2a$ where a is the broad dimension of the waveguide. The following relation can be proved $c = \lambda_0 . f$
Where c is the velocity of light and f is frequency

Experimental set up :



Procedure :

1) The equipment is set up as shown in fig.
2) The variable attenuator is adjusted to give a suitable power level such that a maximum deflection on VSWR meter is obtained.

Slide parameters :

Signal generator 620 can be used for frequency 7-11 kmcs. The exact frequency of generation is measured from the frequency meter. Using the usual formula, the free space wave length is evaluated. Using V.G. slotted section and the associated detector probe the guide wavelength 'λ_g' is determined. This is accomplished by using distance between two minima (for obvious reasons minimum are preferred. Otherwise there is no harm if maximum are taken into consideration). Accuracy can be improved if the distances are averaged over a large number of minimas. The distance between the minima is half guide wavelength.

Using the formula

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

TC = 4.57.

Tg

$\lambda_c = 2a$

a= 2.285 cm

The cut-off wavelength (λ_c) is calculated for the waveguide. The broad dimension of the waveguide is measured and checked if $\lambda_c = 2a$.

The free space wavelength (λ_0) and guide wavelength (λ_g) are calculated for a number of frequencies and are noted down.

Reflector Bias voltage (V)	d_1 (cm)	d_2 (cm)	$\lambda_g = 2(d_1 - d_2)$ (cm)	λ_0 (cm)	$f_0 = \frac{c}{\lambda_0}$ (GHz)	Meter Reading (GHz)

Graph : Plot the graph $1/\lambda_g^2$ Vs $1/\lambda_0^2$ prove that intercept is $1/\lambda c^2$

Calculations :

1. Intrinsic impedance = $\dfrac{\eta_o}{\sqrt{1-\left(\dfrac{\lambda_0}{\lambda_c}\right)^2}}$

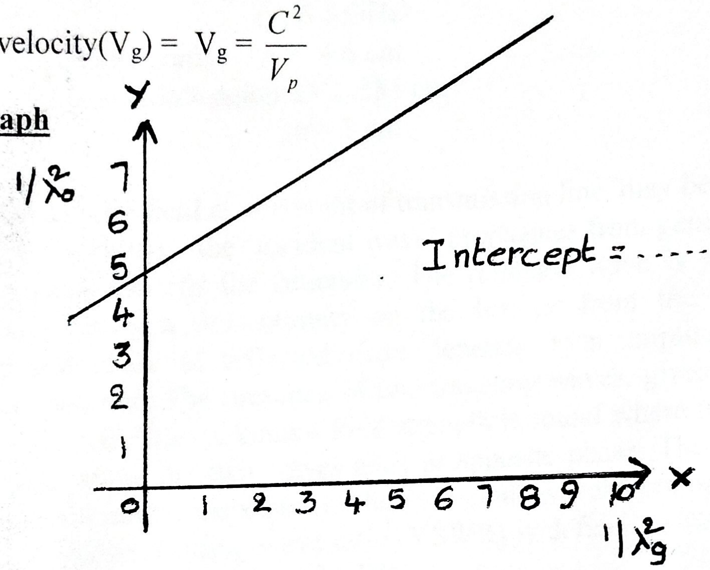
2. Characteristic impedance (Z_0) TE_{10}=

3. Phase shift constant $\beta = \dfrac{2\pi}{\lambda_g}$

4. Phase velocity (V_p) = $\dfrac{C_o}{\sqrt{1-\left(\dfrac{\lambda_0}{\lambda_c}\right)^2}}$

5. Group velocity(V_g) = $V_g = \dfrac{C^2}{V_p}$

Model graph



DISCUSS :

1) The advantage of using waveguides in microwave transmission.
2) Cutoff wave length is constant for a given waveguide
3) Dominant mode of propagation
4) Concept of phase and group velocities
5) Why we have utilized voltage minima and not voltage maxima in finding guides wavelength.
6) The change of cutoff frequency when a dielectric material other than air is inserted in the waveguide.
7) Effect of reactive obstacles in the waveguide.
8) What are the factors that determine the optimum value of (smaller dimension).
9) Why waveguides are not used at comparatively lower frequencies say 300MHz.
10) Plot the graph $\dfrac{\lambda}{\lambda_g}$ Vs $\dfrac{\lambda}{\lambda_c}$ and draw relevant.

Result : Waveguide parameters are measured, the graph is plotted between $1/\lambda_g^2$ and $1/\lambda_0^2$ and from that it is proved that the intercept is $1/\lambda c^2$

4. VSWR MEASUREMENTS

Aim : To measure

1. Low and medium VSWR (1 to 5)
2. High VSWR by double minima method (>5)

Apparatus : Klystron power supply
Klystron oscillator
Variable Attenuation
Slotted line
Matched termination
Detector

X-BAND : Frequency range : 8 – 12 GHz
f_c : 6.5 GHz
Wave guide c = 4.6 cm
Guide dimension a = 2.285 cm
b = 1 cm

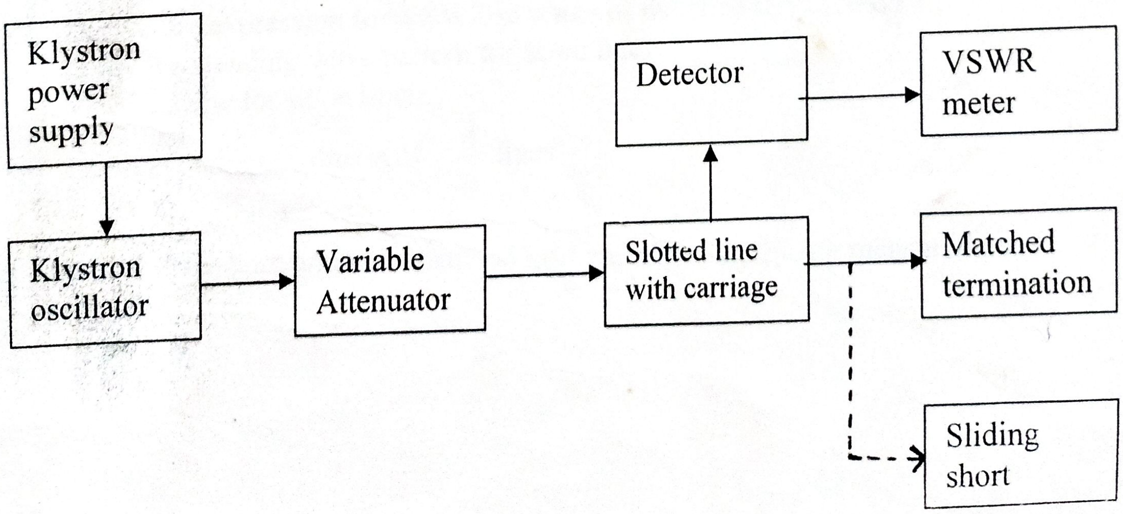
Theory :

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 presence of two traveling waves, gives line 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 adds in apposite phase. The distance between two successive minimum (or maximum) is half the guide wavelength on the line.

The Voltage standing wave ratio (VSWR) is defined as ratio between maximum and minimum field strength along the line.

Hence VSWR, $$S = \frac{E_{max}}{E_{min}} = \frac{|E_I| + |E_x|}{|E_I| - |E_x|}$$

Experimental set up :



Procedure :

(1) Low and medium VSWR measurements :

The probe was moved along the slotted line to get a maximum deflection is VSWR. The VSWR meter was adjusted to read 1.0m on the scale. To get a minimum, the probe was moved along the slotted line. The VSWR value was directly given on the VSWR.

(2) High VSWR (Double minima method):
When the VSWR is high, probe depth was increased to obtain voltage minima. In this method, probe depth does not introduce an error. The probe was inserted to the depth were the minima was read without difficulty, and then moved to a point where the power was twice the minimum power. This position was denoted by d_1.
The probe was moved to twice power point on the other side of the minima and the corresponding point was noted as (d_2).

Then high VSWR is $\dfrac{\lambda_g}{\pi(d_1 - d_2)}$

Guide wavelength $\lambda_g = 2$ x distance between two successive minima.

$d_1 = 10.3$

Observations :

1. VSWR for Horn antenna (Low VSWR) =

2. VSWR for Matched load (medium VSWR) =

3. VSWR for Short circuit (high VSWR) =

DISCUSS:

1) Define voltage standing wave ratio.
2) What is the ideal value of VSWR
3) Derive the expression for VSWR in terms of matched termination
4) Draw the standing wave pattern for sc/oc line.
5) S_{in} of T_X line for sc/oc lines.
6) Concept and applications of $\frac{\lambda}{u}$ lines

Result : VSWR for horn antenna, matched load and short circuit are measured.

5. DIRECTIONAL COUPLERS

Aim : To measure Coupling factor and Directivity of given directional coupler

Apparatus :

Klystron power supply
Klystron oscillator
Variable Attenuation
Detector mount
Matched termination
Waveguide stand
Micro ammeter

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, electromagnetically coupled to each other. In the figure, the power entering port 1 in the main arm divides between port 2 and port 3 and almost no power comes out in port 4. Power entering port 2 it is divided between port 1 and 4.
The coupling factor is defined as below.

$$\text{Coupling factor (dB)} = 10 \log_{10}\left(\frac{P_A}{P_C}\right)$$

Where port D is terminated with built in termination and power is entering at P_A

The directivity of the coupler is a measure of separation of incident and the reflected wave. It is measured on the radio of the two power outputs from the auxiliary line when a given amount of power is successively applied to each terminals of the main lines with other port terminated by material loads.

$$\text{Hence directivity } D(\text{dB}) = 10 \log_{10}\left(\frac{P_C}{P_D}\right)$$

Where P_C and P_D is the power measured at port C and port D with equal amount of power fed to port A and port B respectively.

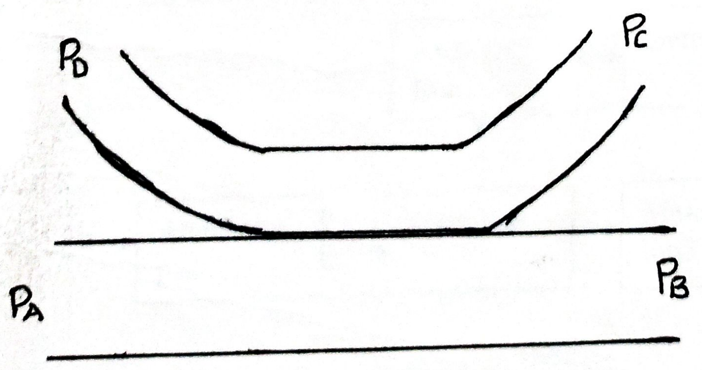


Fig.1. Directional coupler

FORWARD DIRECTION P_C

REVERSE DIRECTION P_D

Experimental set up :

(a) BLOCK DIAGRAM TO MEASURE COUPLING FACTOR

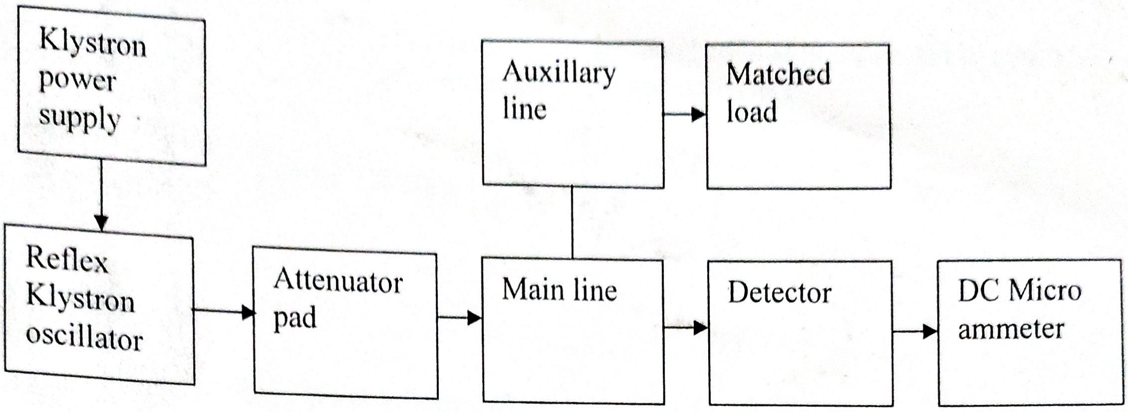


Fig.2.

Procedure :

a) Measurement of Coupling factor :

1. The arrangements are made as shown in Fig 2. and the micro ammeter readings is noted as P_D. (at the output of the auxillary line.
2. The directional coupler is removed and the power output is measured at point A and noted as P_A at the out put of attenuator.

   Coupling factor C (dB) = $10 \log_{10}\left(\frac{P_A}{P_C}\right)$
3. The experiment is repeated for 2 or 3 directional couplers with different coupling factors and of different designs.

(b) BLOCK DIAGRAM TO MEASURE DIRECTIVITY

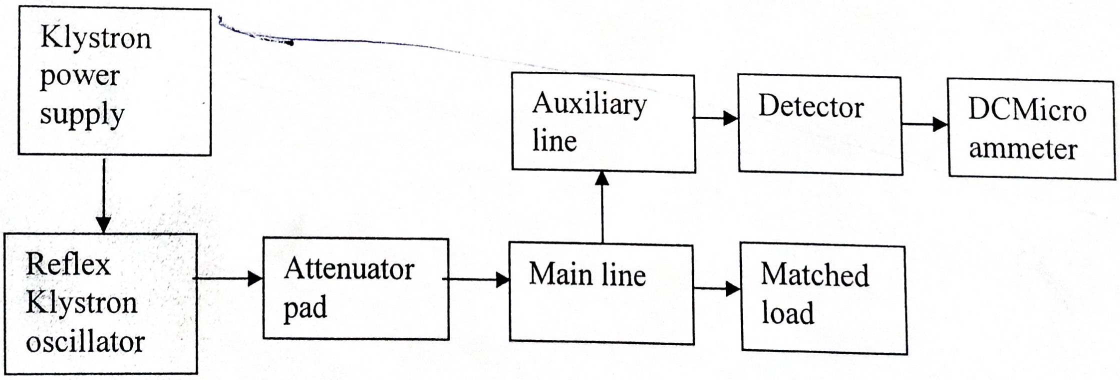


Fig.3.

Procedure :

b) Measurement of Directivity :

1. The arrangements are made as shown in Fig 3. and the micro ammeter readings are noted as P_D.
2. The directional coupler is reversed and the matched load is connected to end A.
3. The power is measured by micro ammeter and noted as P_C.

$$\text{Directivity } D(dB) = 10 \log_{10}\left(\frac{P_C}{P_D}\right)$$

DISCUSS :

1) Why directivity is not infinite (∞)
2) What are the different types of couplers.
3) Why dB scale is preferred for measuring directivity and coupling factor.
4) What will happen if we interchange port 'A' and port 'B'.
5) What will happen if we interchange main waveguide and auxiliary waveguide.

Result : The coupling factor and directivities of given directional couplers are measured.

6. ATTENUATION MEASUREMENT

Aim : To measure the attenuation introduced by a given network using
(a) Substitution method (b) Direct method

Apparatus : Klystron power supply
Klystron oscillator
Variable Attenuation pad
Precision attenuator network
Micro ammeter

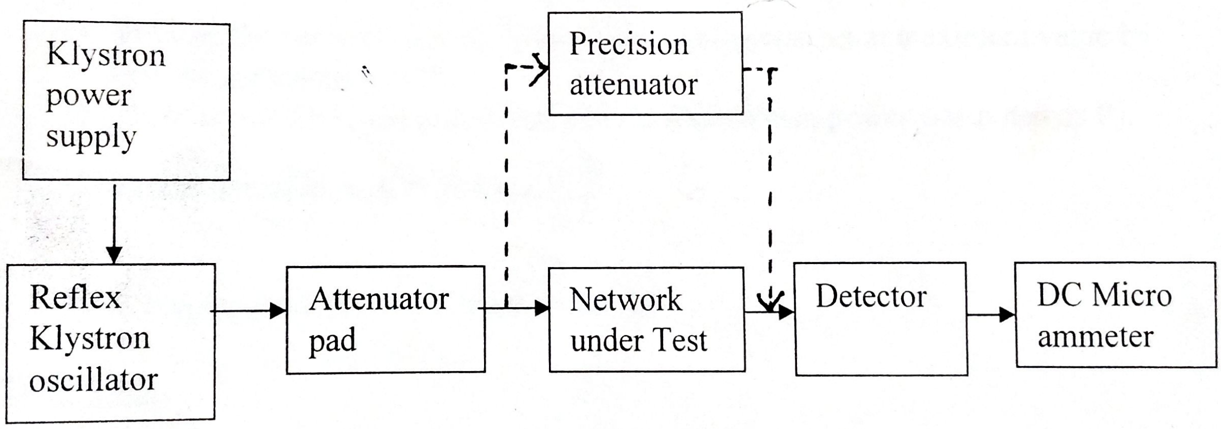
Theory :

Microwave components and devices almost always provide same degree of attenuation. Attenuation is the ratio of input power to output power and is normally expressed in dB.

$$\text{Attenuation (dB)} = 10 \log \left(\frac{P_{in}}{P_{out}} \right)$$

Experimental set up :

(a) Substitution method :



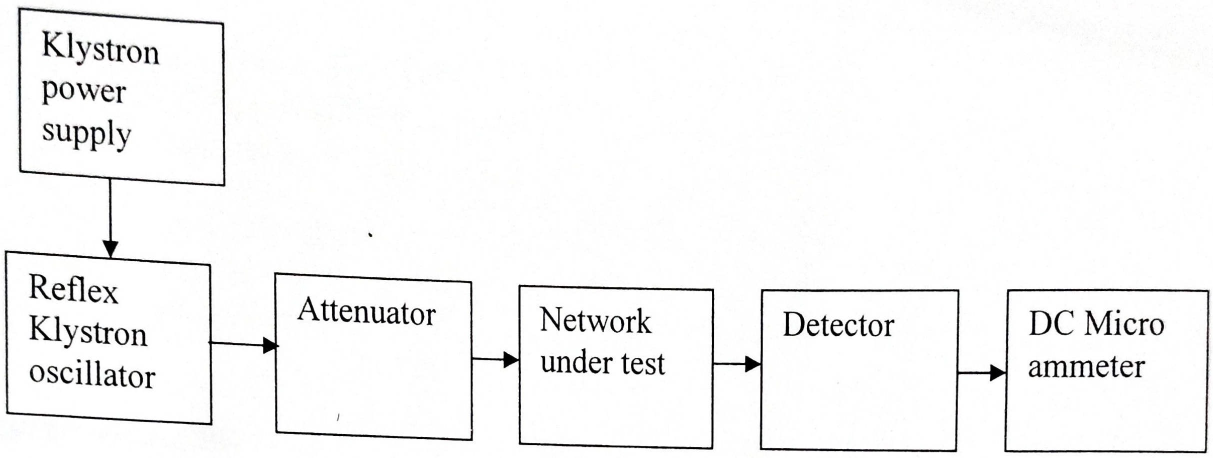
Procedure :

a) Substitution method :

1) The micro ammeter reading was noted with the network under test.
2) Precision attenuator was substituted for the network and it was adjusted until the meter reading is same as before. The dial of the precision attenuator now indicates the attenuator of the network directly.

Experimental set up :

b) Direct method



Procedure :

b) Direct method :

1) Without the network the micro ammeter reading was set at maximum value by adjusting attenuator as P_1.
2) Then the network was introduced and the reduction in power was noted as P_2,

   then attenuation in dB= $10 \log_{10} \left(\frac{P_1}{P_2} \right)$

3) It was repeated for two or three networks.

DISCUSS :

1) What are different materials used for attenuation of microwave power.
2) How precision attenuators are made
3) Out of the two methods which method is accurate? Why ?

Result : The attenuation of given network was measured by using substitution method and direct method.