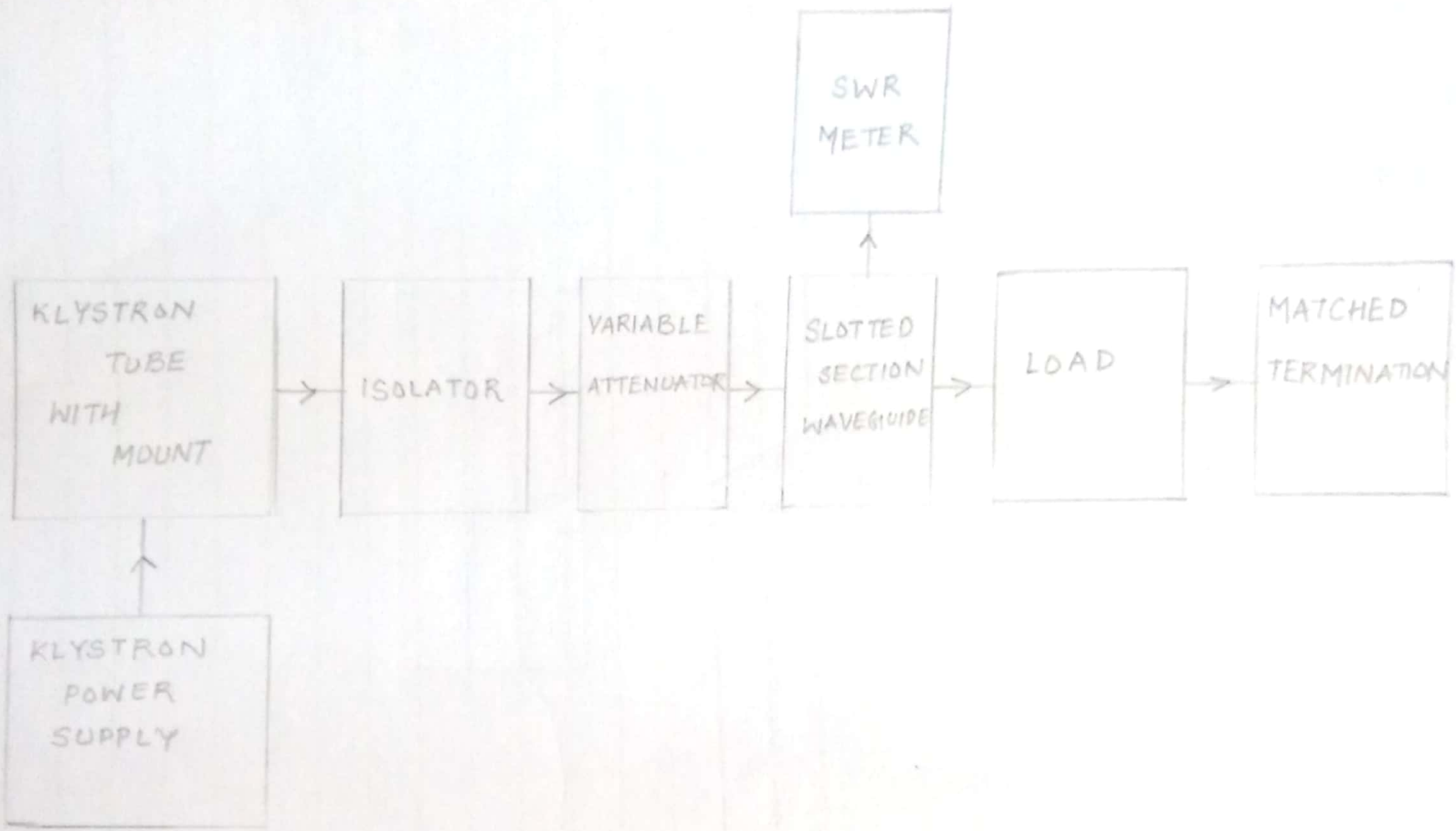
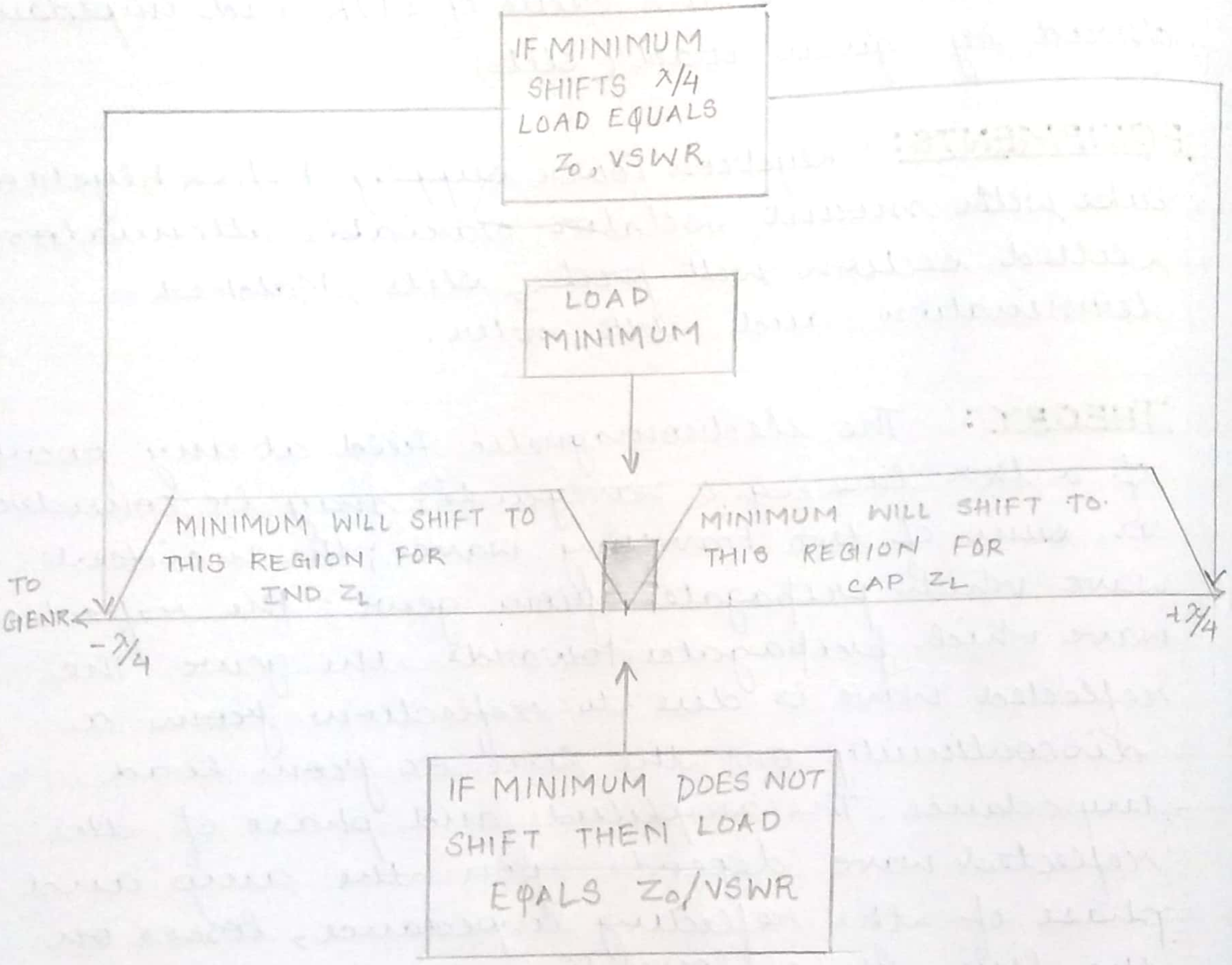
AIM: To determine the value of SWR and impedance offered by given load (slits)

EQUIPMENTS: Klystron Power supply, Reflex klystron tube with mount, Isolator, variable attenuator, slotted section with probe, slits, Matched termination and SWR meter.

THEORY: The electromagnetic field at any point of a txn line (eg. a waveguide) may be considered as sum of two travelling waves; the incident wave which propagates from genr; the reflected wave which propagates towards the genr. The reflected wave is due to reflection from a discontinuity on the line or from load impedance. The amplitude and phase of the reflected wave depends upon the amp and phase of the reflecting impedance, losses on the line. In a lossy line the reflected (and incident) wave will be attenuated. If the line is uniform and infinitely long there would not be reflected wave. The same applies for a line of finite length which is matched ie. has a load equal to the characteristics impedance of the line.



EXPERIMENTAL SETUP : MEASURING SWR & IMPEDANCE


IF MINIMUM SHIFTS λ/4 LOAD EQUALS Z0, VSWR
LOAD MINIMUM
MINIMUM WILL SHIFT TO THIS REGION FOR IND ZL
MINIMUM WILL SHIFT TO THIS REGION FOR CAP ZL
TO GENR
TO LO
-λ/4
+λ/4
IF MINIMUM DOES NOT SHIFT THEN LOAD EQALS Z0/VSWR

The presence of the two travelling waves gives rise to standing waves along the line. The electric and magnetic field varies periodically with distance. The maximum field strength is found where the two waves add in phase and the minimum where the two waves add in opposite phase. Fig 1 shows the voltage standing wave patterns for different load impedances. The distance between two successive minima (or maxima) is half the wavelength on transmission line.

There are several methods for measuring SWR with slotted line available. In the slotted line a small part of the electric fd is fed to a crystal detector via a probe inserted in a waveguide. In the most straig-ht forward method the SWR can be read directly on the VSWR meter connected to xtal o/p.

When the SWR is high a 3-dB method, also known as double minimum method is used. In this method, one measures the distance between the points where xtal output voltage (proportional to half power) is 0.707 time the minimum value $[d_1 - d_2]$

The SWR is given by

$$S \doteq 1 + \frac{1}{\sin\left[\frac{\pi(d_1 - d_2)}{\lambda_g}\right]}$$

where λ_g is waveguide wavelength, when S is larger than about 10.

$$S = \frac{\lambda_g}{\pi(d_1 - d_2)} = \frac{\lambda_g}{\pi(\Delta x)}$$

where d_1 and d_2 are the locations of double minimum points.

Impedance at microwave freq can be determined by measuring VSWR and the distance of voltage minimum from the load. Position of first voltage minimum is determined by measuring VSWR and shift in minimum when load is shorted.

$$Z_L = \frac{1 - j(S)\tan\left[\frac{2\pi(\pm d)}{\lambda_g}\right]}{S - j\tan\left[\frac{2\pi(\pm d)}{\lambda_g}\right]}$$

where Z = Normalised load Impedance

S = V.S.W.R

d = shift in min. pt when load shorted

Take (+ve) sign when min shifts towards load and (-) ve sign when minima shifts towards generator.

λ_g = Guide wavelength

OBSERVATIONS:

1. SHORT CCT

a. d_1 = −64.5 dB (8.07 cm) Maxima = (8.98 cm) −31 dB

b. d_2 = −64.0 dB (10.18 cm)

c. l =

$\lambda_g = 2(d_2 - d_1) = 4.22$ cm

d. f =

e. VSWR =

f. Impedance =

2. OPEN CKT

a. VSWR = 3.33 shift = −0.76 cm in maxima

b. Impedance = $0.071(5.628 + j\,9.162)\,\Omega$

+ve sign indicates inductive load

3. CIRCULAR LOAD

a. Δd = 0.77 cm

b. VSWR = 3.64 shift = −1.16 cm

c. Impedance (Z_L) = $0.052(8.86 - j\,0.582)\,\Omega$

−ve sign indicates capacitive load.

4.

PARAMETER	INDUCTIVE	CAPACITIVE
a. Δd (cm)	0.88	0.77
b. VSWR	3.33	3.64
c. Impedance (Ω)	$0.071(5.628+j\,9.162)$	$0.052(8.86-j\,0.582)$

ATTENUATION MEASUREMENT

AIM: To calibrate the variable attenuation
(a) By power ratio method
(b) By R.F substitution method.

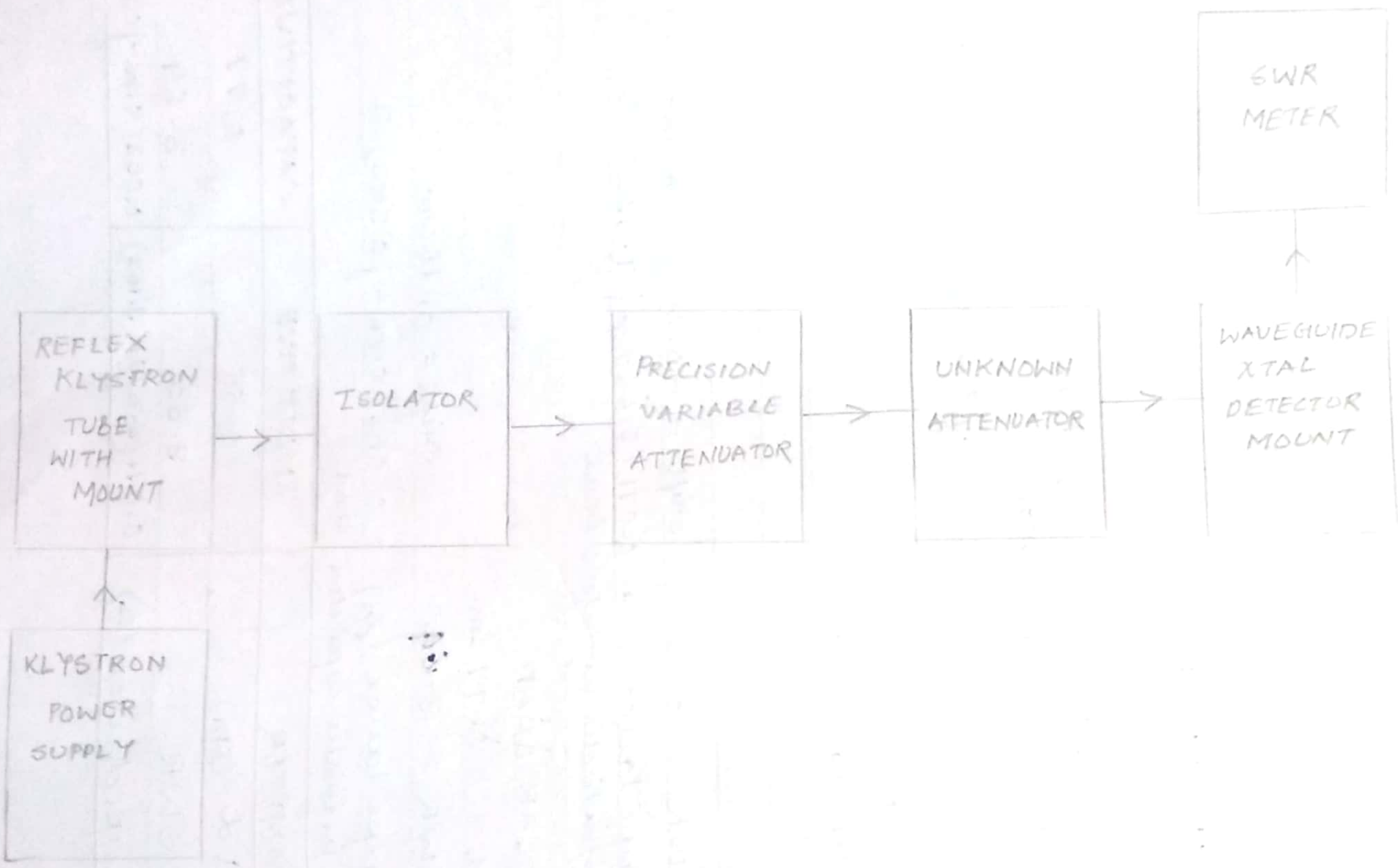
EQUIPMENT: Klystron power supply, Reflex klystron tube, with mount, Isolator, Unknown variable attenuator. Precision variable attenuator Waveguide, Crystal detector mount & SWR meter.

THEORY: The attenuation of a component part of a waveguide system can be measured by either the power ratio method or R.F substitution method.

In power ratio method output of system is measured first with unknown part in place and then without the unknown part. The ratio of two output power yields attenuation expressed in decibels.

$$\text{Attenuation} = 10 \log_{10}\left(\frac{P_1}{P_2}\right)$$

where P_1 = output reading with unknown part out of the system.



EXPERIMENTAL SETUP : MEASUREMENT OF ATTENUATION.

P_2 = Output reading with unknown part in the system.

The inherent disadvantage of power ratio method is that the detector operates at different power levels and at any variation of detector law must be considered in attenuation value determined.

The RF substitution method eliminates the inherent detector error of the power ratio procedure. In this method the output power is held constant by replacing the attenuation to be measured with precisely calibrated variable attenuator. The unknown attenuation is then equal to the value of attenuation which must be inserted to obtain the original reading of power indicator.

OBSERVATIONS:

Beam voltage = 230 V
Repeller voltage = -158 V
Known attenuation = 4.65 mm
SWR = -30 dB

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OBSERVATIONS :

1. POWER RATIO METHOD

SNo.	UNKNOWN ATTENUATION (mm)	SWR READING (dB)	ATTENUATION (dB)
1	10	-30	0
2	9	-30.2	0.2
3	8	-31.3	1.2
4	7	-32.6	2.6
5	6	-34.5	4.5
6	5	-37	7.0
7	4	-39.5	9.5
8	3	-42.4	12.4
9	2	-45.5	15.5
10	1	-49	19

2. RF SUBSTITUTION METHOD

SNo.	UNKNOWN ATTENUATION (μm)	UNKNOWN ATTENUATION (μm)	ATTENUATION (dB)
1	0.78	9.5	30.5 - 29.5 = 1.0
2	0.87	8.5	30.5 - 28.8 = 1.7
3	1.50	7.5	30.5 - 27.4 = 3.7
4	2.0	6.5	30.5 - 26.0 = 5.5
5	2.73	5.5	30.5 - 22.4 = 8.1
6	3.17	4.5	30.5 - 19.8 = 10.7
7	3.66	3.5	30.5 - 15.5 = 15
8	4.16	2.5	30.5 - 10.8 = 20.5
9	4.75	1.5	30.5 - 7.2 = 23.3
10	4.88	0.5	30.5 - 3.3 = 27.2

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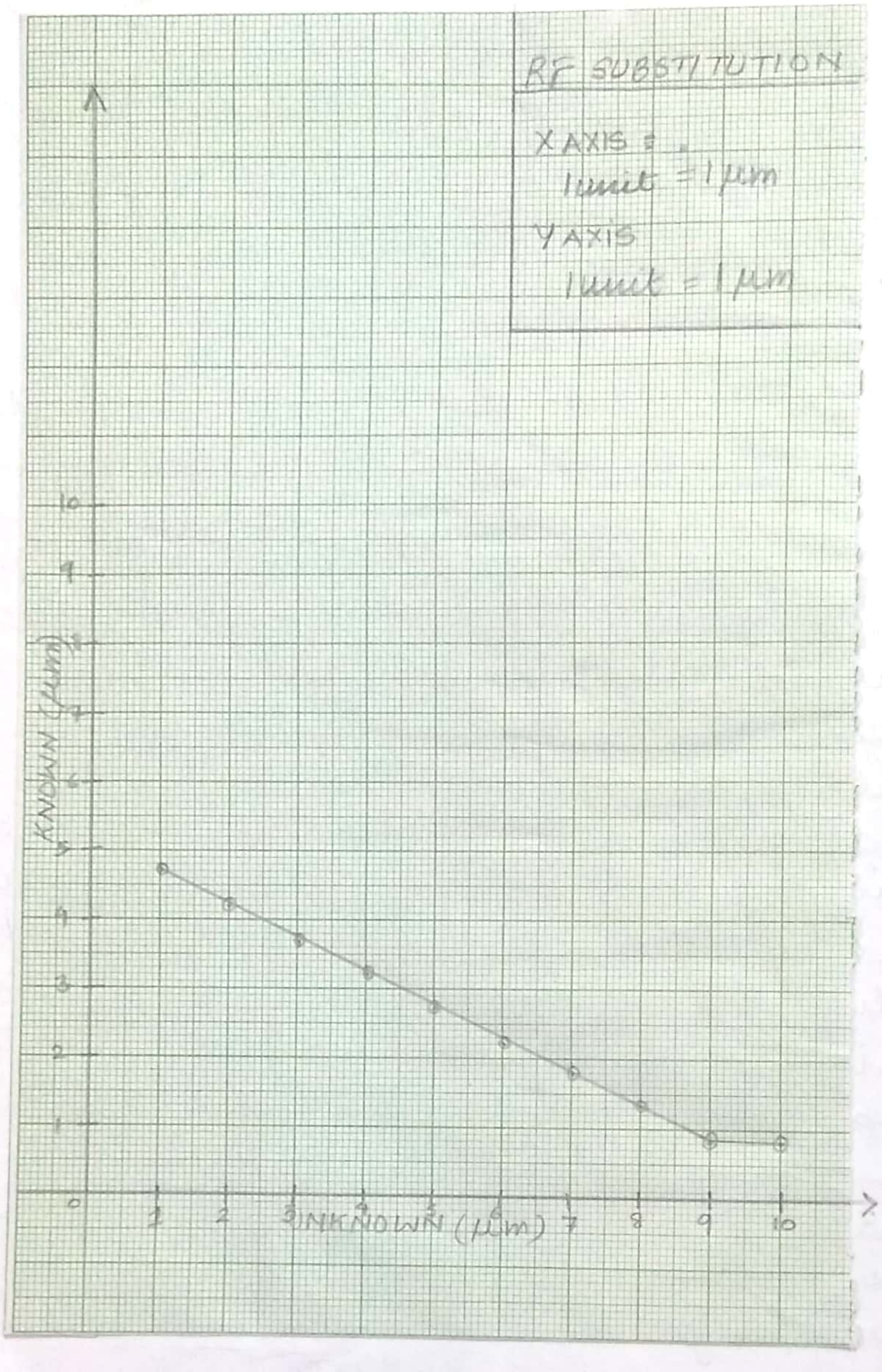

CALIBRATION CURVE

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CONCLUSIONS AND RESULT :

The attenuation is measured using both the power ratio method and RF substitution method and the trend observed using both the methods is same. except that the detector error introduced due to variable power levels does not exist in RF substitution method. Thus, the attenuation was precisely calculated using bothe the value methods.

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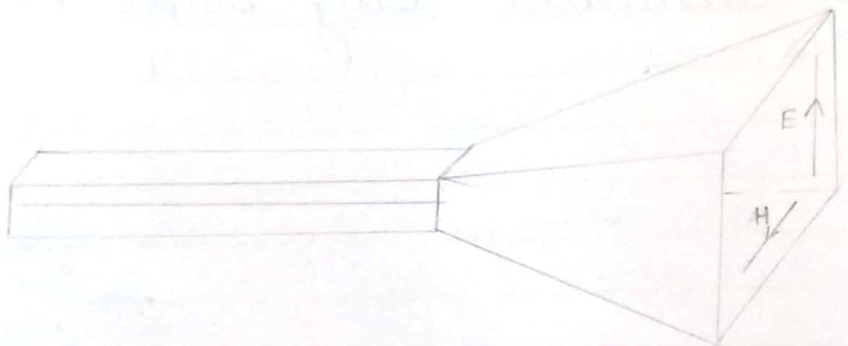
ANTENNA CHARACTERISTICS

AIM: To measure radiation characteristics of an antenna (Pyramidal Horn Antenna)

EQUIPMENTS: Reflex Klystron tube with mount, Klystron power supply, Isolator, Cavity freq meter, slotted line with probe, SWR meter, Tunable waveguide, mount, turn table, Receiving antenna (standard horn of known)

THEORY: There are four important parameters which may be used to characterise antenna.
(a) Radiation Pattern
(b) Gain or Directivity
(c) Input Impedance
(d) Polarization.

RADIATION PATTERN: Graphical representation of Radiation intensity (power density) or field strength as a function of space coordinates at a constant distance in far fd region. Typical Radiation pattern consists of a main lobe, a back lobe, and several side lobes. Major portion of radiated power is concentrated in main lobe which is defined as radiation lobe containing direction



E & H Plane in a Pyrimidal Horn Antenna

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of maximum radiation. Side lobes are radiation lobes in any direction other than the main lobe direction. Side lobe just at back of antenna is called Back lobe.

GAIN: There are two types of gain defined
(i) Directive Gain: 4π times the ratio of radiation intensity in given direction to total power radiated in same direction. The value of directive gain in direction of max value is called Directivity

(ii) Power Gain: Ratio of power density from an antenna to power density from reference antenna (generally an isotropic antenna or standard horn) at same location in far fd.

HALF POWER BEAMWIDTHS: In a plane containing the direction of maximum radiation of beam, the angle between the two dimensions in which the power intensity is half the max power.

POLARIZATION OF ANTENNA: In a given direction, the polarization of wave radiated by radiated antenna.

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Antenna measurements are normally made in free space or inside the anechoic chamber when measurements carried out in lab, reflections from nearby objects should be minimum and distance between the antennas (Receiving and Transmitting) should be much greater than $\left(\frac{2D^2}{\lambda}\right)$

where λ is signal wavelength and D is the largest dimension of antenna under test.

OBSERVATIONS

(a) Radiation Pattern E plane

Beam voltage = 29.5 V

Max Gain = -34 dB

ANGLE (°)	POWER (dB)	ANGLE (°)	POWER (dB)
0	-34	100	-60
10	-32	110	-57
20	-43	120	-60
30	-49	130	-60
40	-54	140	-56
50	-58	150	-59
60	-56	160	-55
70	-61	170	-45
80	-64	180	-46
90	-60	190°	-50

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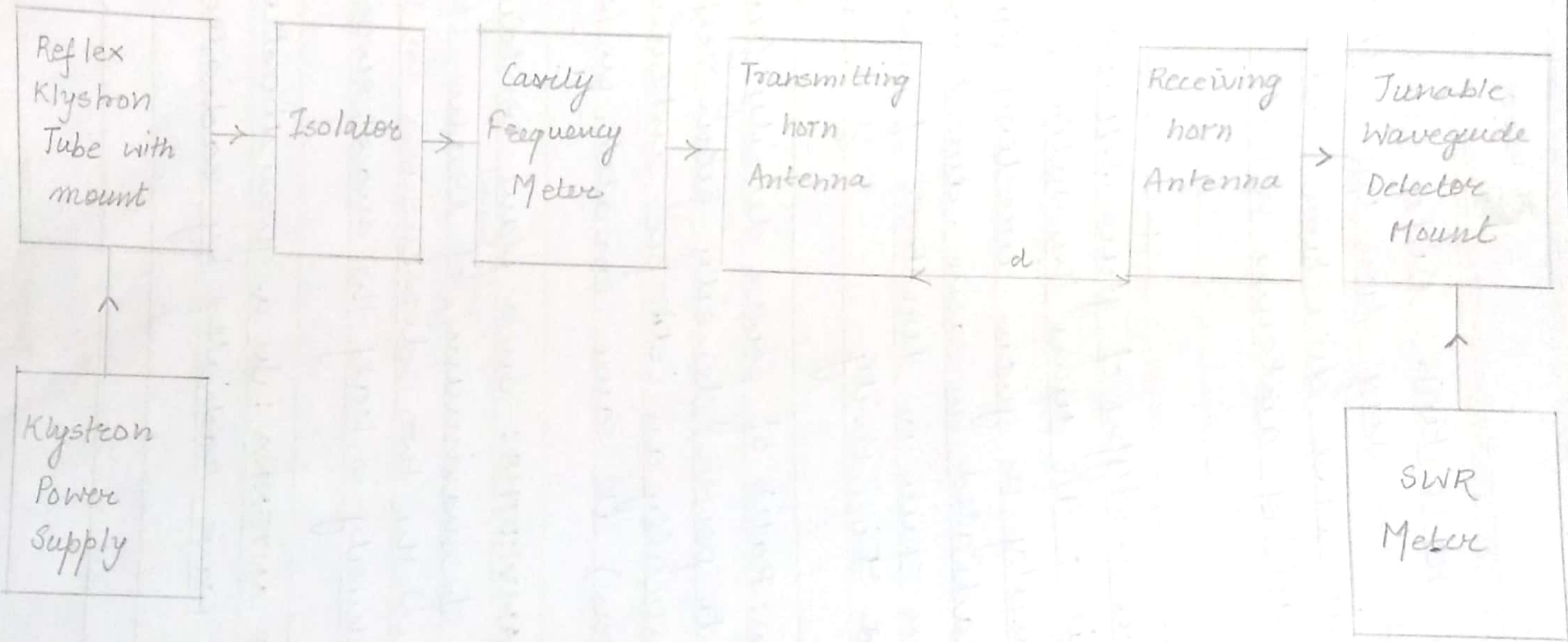

EXPERIMENTAL SETUP : STUDYING RADIATION PATTERN

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200	-50	290	-63
210	-60	300	-60
220	-60	310	-56
230	-61	320	-48
240	-63	330	-44
250	-62	340	-40
260	-61	350	-34
270	-60	360	-34
280	-60		

b) Radiation Pattern H Plane

ANGLE (°)	(dB) SWR Gain	ANGLE (°)	SWR GAIN (dB)
0°	-33	140°	-60
10°	-34	150°	-60
20°	-39	160°	-59
30°	-42.2	170°	-56
40°	-50	180°	-41
50°	-47	200°	-54
60°	-47	220°	-57
70°	-55	240°	-58
80°	-60	260°	-60
90°	-60	280°	-54
100°	-53	300°	-56
110°	-61	320°	-54
120°	-60	340°	-44
130°	-60	360°	-34

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(c) Gain :-

Using the test antenna in H-plane at 0° $P_T = -35dB$
Using the antenna at reference H plane at 0° $P_r = -34dB$

Gain of reference H-plane horn antenna
$G = +15dB$
Gain of test antenna $G_T = G + P_T - P_r$
$= +14 dB$

RESULT & DISCUSSION

(a) Antenna radiation pattern is studied for both E & H plane
(b) Gain of test antenna $= +14 dB$

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MEASUREMENT OF DIELECTRIC CONSTANT

AIM: To measure the dielectric constant and loss tangent of given material.

EQUIPMENT: Reflex klystron tube with mount, Isolator variable attenuator, slotted section with probe, short dielectric material, specimens of approximately of length, and SWR meter.

THEORY: For electromagnetic purposes, the properties of a homogenous material may be described by two complex constants known as complex permittivity (dielectric constant) λ and complex permeability μ. The real and imaginary parts of these constants are indicated in the equation

$$\lambda = \lambda' - j\lambda''$$

$$\mu = \mu' - j\mu'' = \mu_0 \text{ for non metallic mtrls}$$

where λ' = Dielectric constant = $\lambda_r \lambda_0$

λ_r = Relative dielectric constant

λ_0 = Permittivity of vaccuum.

λ'' = Loss Factor

μ_0 = Permeability of vacuum.

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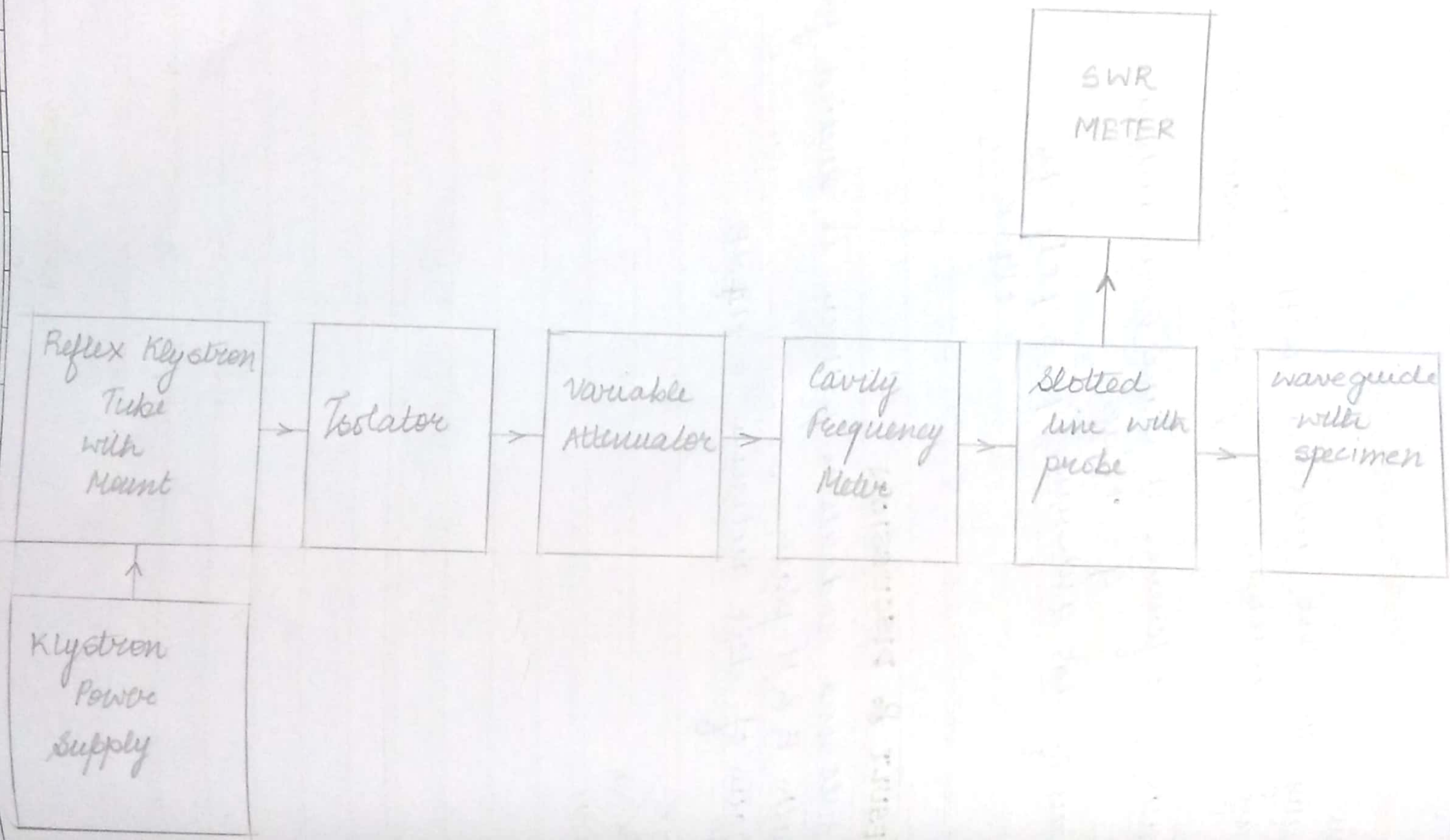
EXPERIMENTAL SETUP : MEASURE DIELECTRIC CONSTANT



λ' is associated with the ability of dielectric material to store energy and λ'' with the dielectric losses that occur in the material. A measure of energy lost in form of heat is called loss Tangent ($\tan\delta$) and defined as ratio of the power dissipated to power stored per cycle.

$$\tan\delta = \frac{\lambda''}{\lambda'}$$

Dielectric constant depends on freq but stays constant over relatively small portions of frequency spectrum. It also depends upon temprature and humidity but for practical purposes for small variations of these quantities, it may be assumed constant.

The dielectric properties may be determined at microwave frequencies by measuring the propagation characteristics of the electromagnetic wave through the dielectric. There are many experimental techniques for measuring dielectric constant such as transmission line, cavity methods and cavity perturbation methods.

The technique used for a particular measurement depends upon freq, dielectric properties of material and the amount and form of availaible material.

The most widely used and versatile measurement method to determine the charecteristic of low loss material used transmission techniques (Measurement of input impedance of short circuited transmission line with or without dielectric sample). In practice the positon of voltage minimum, spacing between half power point (3dB) and standing wave ratio with and without the specimen are measured by slotted line. The shift in minimum (when sample is inserted) is measured of the dielectric constant and the decrease in standing wave ratio is a measure of loss tangent. In this method the approximates value of line.

For impedance Eqn

$$Z_0 \tan(Kl) = -Z_\epsilon \tan(K_\epsilon l_\epsilon) \quad \text{—(i)}$$

also, $$Z_0 \tan(K l_R + l_\epsilon) = 0 \quad \text{—(ii)}$$

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Now,

$$\tan(K(D_R - D + l_\epsilon)) = \tan(K(l_R + l_\epsilon) - l)$$
$$= -\tan Kl \quad \text{— (iii)}$$

$$\tan(K(D_R - D + l_\epsilon)) = -\left(-\frac{Z_\epsilon}{Z_0}\right)\tan(K_\epsilon l_\epsilon)$$

But $\frac{Z_\epsilon}{Z_0} = \frac{K}{K_\epsilon}$

$$\tan(K(D_R - D + l_\epsilon)) = -\left(-\frac{K_\epsilon}{K_0}\tan(K_\epsilon l_\epsilon)\right)$$

where,

K_ϵ = propagation constant in dielectric
K = propagation constant in air
Z_0 = characteristic impedance without sample in waveguide
Z_ϵ = impedance of dielectric sample
l_ϵ = length of tube
D_R = position of first minima without sample
D = position of first minima with sample

OBSERVATIONS & CALCULATIONS

l_ϵ = 4.5 for wax (in cm) ; 3.5 cm for glass
Beam voltage = 230 V
Repeller voltage = -125 V

a) Without dielectric constant

1^{st} maxima position of 6.48 cm
1^{st} minima position of 8.92 cm

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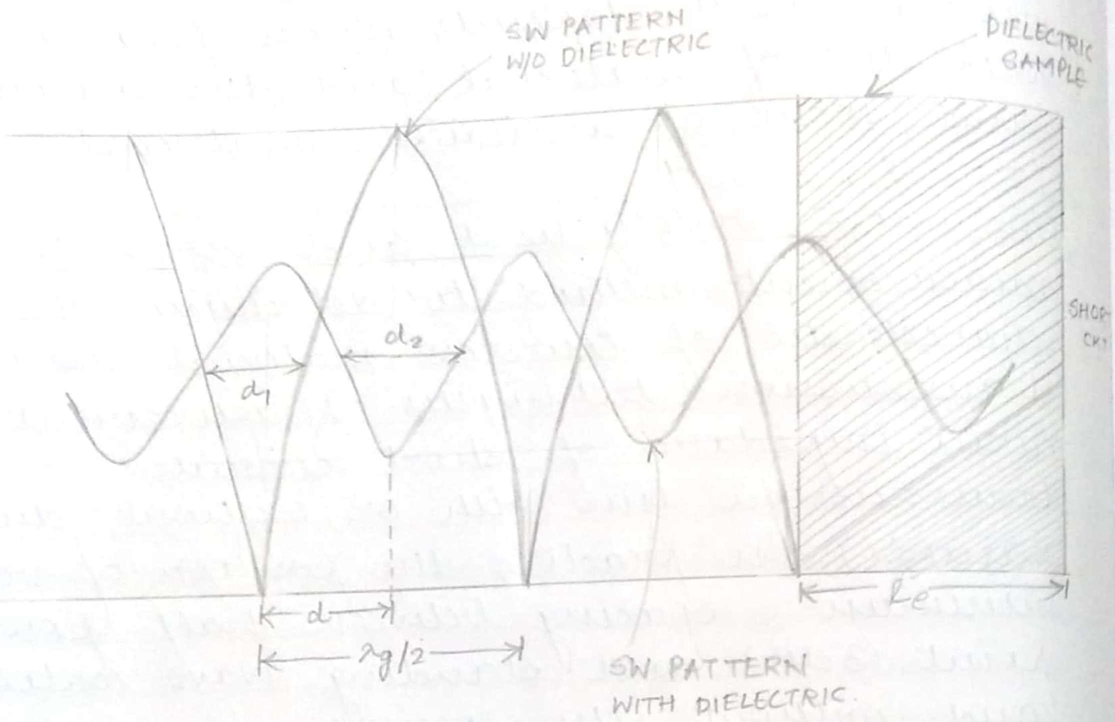

SW PATTERN INSIDE THE WAVEGUIDE

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II^{nd} maxima position at 11.15 cm
II^{nd} minima position at 13.45 cm

3 dB points of II^{nd} minima position — 13.23 cm, 13.67 cm

Distance b/w two succesive minima w/o sample

$$\lambda_{g/2} = (13.45 - 8.31)$$

$$\lambda_g = 9.06 \text{ cm}$$

$$K = \frac{2\pi}{\lambda_g} = \frac{2 \times 3.14}{9.06} = 0.693 \text{ cm}^{-1}$$

2. For Wax (linear material)

1^{st} maxima position at 6.94 cm
1^{st} maxima position at 9.05 cm ; SWR = −67.5 dB

II^{nd} maxima position at 10.85 cm ; SWR = −46 dB.

3 dB points of II^{nd} maxima position — 10.01 cm, 12.4 cm

Shift in position of minima (1^{st}) $d = 9.05 - 8.92$
$= 0.13$ cm

Distance between 3dB points without specimen

$$d_1 = 13.67 - 13.23 = 0.44 \text{cm}$$

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Distance between 3dB pts with specimen $d_2 = 2.03cm$

From transcendental Eqn

$$\frac{\tan x}{x} = \frac{\lambda g}{2\pi l} \tan\left(\frac{2\pi}{\lambda g}(l+d)\right)$$

$$\frac{\tan x}{x} = \frac{9.06}{2\times(4.5)} \tan\left(\frac{2\pi}{\lambda g}(4.5+0.12)\right)$$

$$= 0.32 \tan(3.2) = 0.017$$

$$x = 3.20$$

Dielectric Constant $\gamma' = \left(\frac{x\lambda_0}{2\pi d}\right)^2 + \left(\frac{\lambda_0}{\lambda_c}\right)^2$

$$= \left(\frac{3.2\times 7.48}{2\pi \times 0.13}\right)^2 + \left(\frac{7.48}{2\times 2.185}\right)^2$$

$$= \frac{4.23}{2} = 2.11 \ F/m$$

loss tangent $= \tan\delta = \frac{d_1 - d_2}{\gamma' l}\left(\frac{\lambda_0}{\lambda g}\right)^2 = 0.009667$

$$\simeq 0.009667$$

<u>For Fiber Glass</u>

$l_E = 3.5 \text{ cm}$

$D = 8.57 - 5.03 = 3.54 \text{ cm}$

$D_R = 8.20 - 5.03 = 3.17 \text{ cm}$

$\Gamma = 59.5 \text{ dB (VSWR)}$

$$\phi = 2(23.255\pi)\left(\frac{-3.13}{100}\right) = -262.04^\circ$$

$$CL-\psi = \frac{0.391}{j}\left[\frac{1-0.998\,e^{j(-262.04)}}{1+0.998\,e^{j(-262.04)}}\right]$$

$$C = -0.4495$$

Solving transcendental equation

$$\frac{\tan h(x)}{x} = -0.4495$$

$$x = 2.107\ cm$$

$$\varepsilon' = \frac{2.107 + 0.8738}{1.8738}$$

$$\varepsilon' = 1.6228 \quad F/m$$

3. For loss Tangent

d_1 = Distance b/w 3 dB points without speimen

= 9.87 − 9.26 = 0.61 cm

d_2 = Distance b/w 3 dB points with specimen

d_{21} = for what = 1.95 (7.40 − 5.45)

d_{21} = for fibre glass = 2.02 (7.34 − 5.32)

$$\tan\delta_{wax} = \frac{d_1 - d_2}{\varepsilon' l_\varepsilon}\left(\frac{\lambda_0}{\lambda_g}\right)^2$$

$$= 0.0463$$

$$\tan \delta_{glass} = \frac{2.02 - 0.61}{1.622(3.5)} \left(\frac{6.46}{8.6}\right)^2$$

$$= 0.138$$

RESULT

The dielectric constant and loss tangent for wax and fiber glass are

	WAX	FIBER GLASS
DIELECTRIC CONSTANT	3.291	1.6338
LOSS TANGENT	0.009667	0.0226

DISCUSSION

(a) Dielectric constant of wax 3.291 comes out to be greater than glass 1.6338. This means that two molecular dipole become much more prominent in wax than in fiber glass.

(b) Loss tangent of wax 0.009667 is less than glass 0.0226 enumerates that it is much easier to arrange the molecular dipoles along the dirn of external electric fd in wax than in glass. Thus wax is better than glass in terms of polarisation.

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Expt. No. 05

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AIM: To measure coupling coefficient and directivity of a waveguide directional coupler.

EQUIPMENT: Reflex Klystron tube with mount, isolator, variable attenuator, waveguide detector mount, directional coupler, short & matched termination.

THEORY:

Directional coupler is a 4 port microwave network used to couple a fraction of power flowing in a particular direction through transmission line. The 4 ports are termed as :

1. Input port 1, incident port for power
2. Transmitted port 2, output port
3. Coupled port 3, forward coupled port.
4. Isolated port 4, inverse & coupled port.

Coupling coeff : It is the ratio of power output at coupled port to power input at the input port on long scale, expressed in dB, given as

$$C = -10 \log_{10} \left(\frac{P_3}{P_1}\right) dB$$

Isolation : Expressed in dB on log scale as ratio of power output at isolator port, P_4 to input power at port 1. ie P_1

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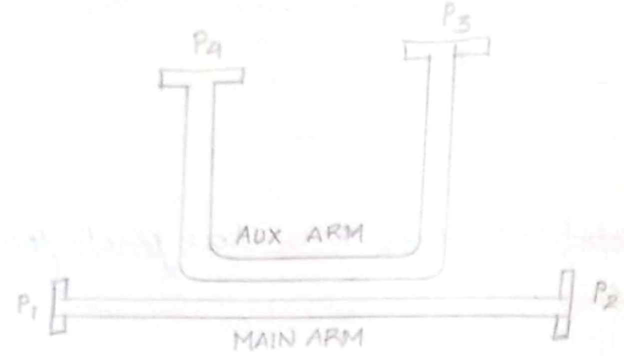
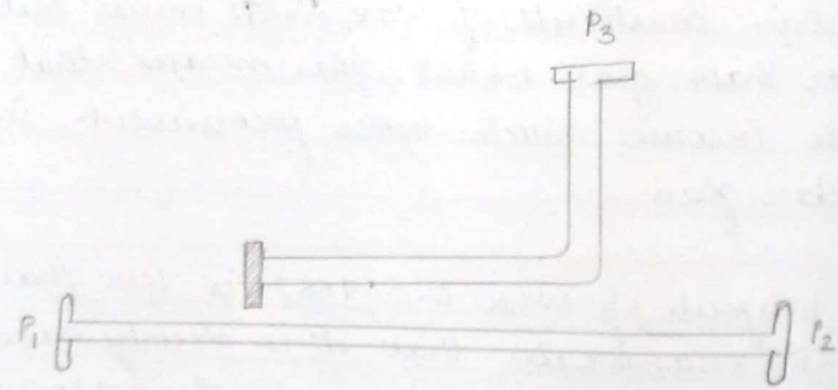


4- PORT DIRECTIONAL COUPLER



DIRECTIONAL COUPLER WITH MATCHED TERMINATION AT PORT 1

$$I = -10\log_{10}\left(\frac{P_4}{P_1}\right) \text{ dB}$$

Directivity : It is ratio of power output at port 4 ie. isolated port to power output at coupled port P_3. Therefore, it is given as

$$D = I - C = -10 \log\left(\frac{P_4}{P_3}\right) \text{ dB}$$

Insertion loss: It is the ratio of power output at port 2 to power input P_1 given as

$$L = -10 \log\left(\frac{P_2}{P_1}\right) \text{ dB}$$

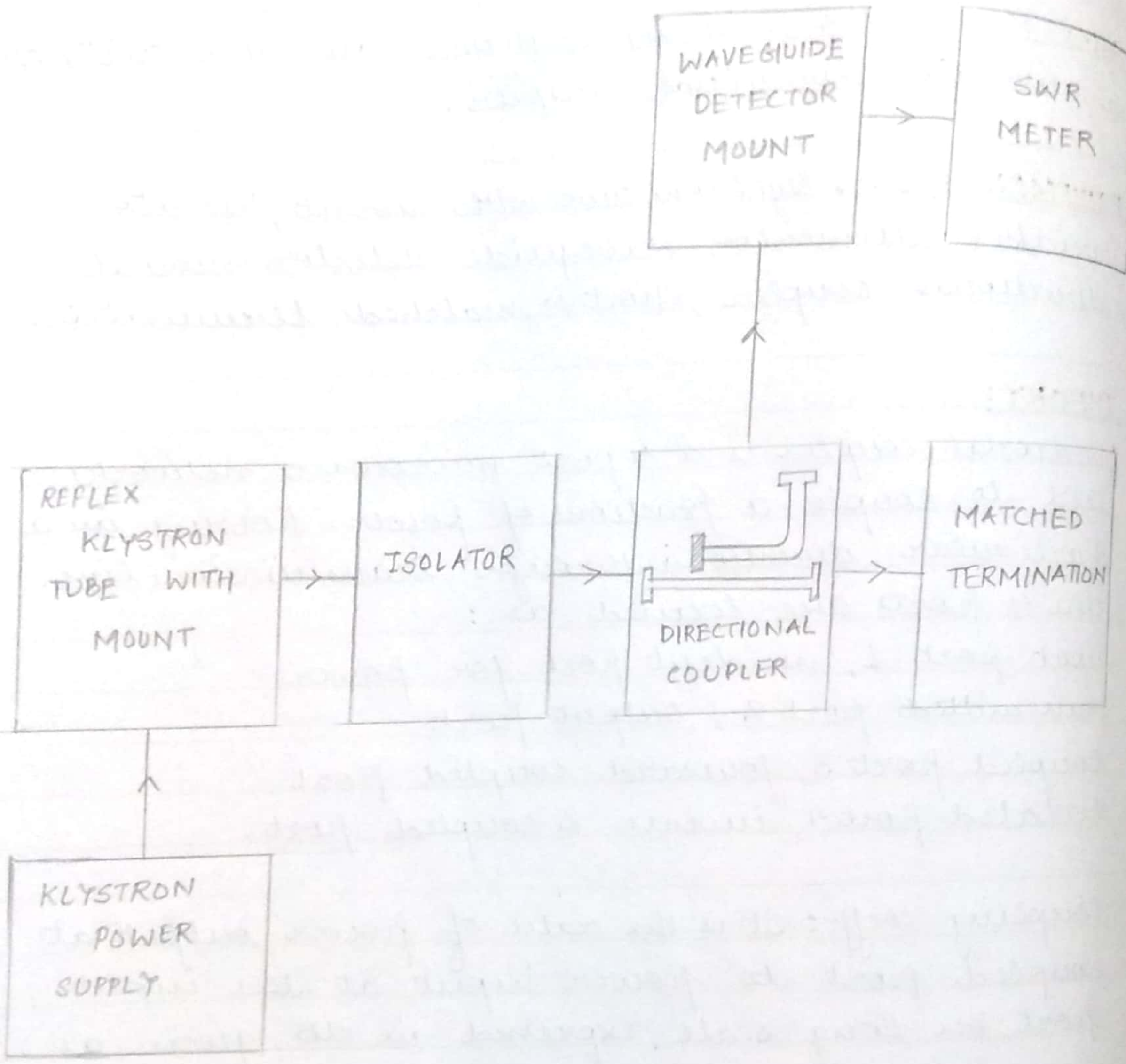
OBSERVATIONS

Beam voltage = 247V ✓
Repeller voltage = - 179V ✓
Input Power (P_1) = - 20 dB ✓

(a) 3 dB coupler

Port 2 Power $P_2 = -22.8$ dB
Port 3 Coupled Power $P_3 = -22.6$ dB
Port 4 Isolated Power $P_4 = -61$ dB

Coupling coeff $= P_1 - P_3$
$= -20 - (-22.8) = 2.8$ dB



BLOCK DIAGRAM FOR MEASUREMENT OF COUPLING COEFFICIENT

Insertion loss $= P_1 - P_2$
$= -20 - (-22.8) = 2.8\,dB$

Isolation $= P_1 - P_4$
$= -20 - (-61) = 41\,dB$

Directivity $= I - C = P_3 - P_4$
$= -22.6 - (-61) = 38.4\,dB$

(b) 10 dB coupler

Port 2 Power $P_2 = -20.7\,dB$
Port 3 Coupled power
Port 4 Isolated power

Coupling coeff $= P_1 - P_3$
$= -20 + 29.5 = \underline{9.5\,dB}$

Insertion loss $= P_1 - P_2$
$= -20 - (-20.7) = +0.7\,dB$

Isolation $= P_1 - P_4$
$= 50\,dB$

Directivity $= P_3 - P_4$
$= 40.5\,dB$

(c) 20 dB coupler

Port 2 Power $= -20.4\,dB$
Port 3 Coupled power $= -43\,dB$
Port 4 Isolated power $= -67.5\,dB$

coupling coeff $= P_1 - P_3$

$= -20.0 - (-43) = 23\,dB$

Insertion loss $= P_1 - P_2$

$= -20 - (-20.4) = 0.4\,dB$

Isolation $= P_1 - P_4$

$= -20 - (-67.5) = 47.5\,dB$

Directivity $= P_3 - P_4$

$= -43 - (-67.5) = 24.5\,dB$

RESULT & DISCUSSION

coupling coeff & directivity of waveguide directional coupler of 3 dB, 10 dB, 20 dB were determined and verified.

05/11/18

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AIM: To study charecterstics of different types of wave guides tees E-plane, H-plane and Magic Tees

EQUIPMENT: Reflex klystron, klystron power supply, E-plane, H-plane, magic tee, E & H bends, E-H tuner, slotted line, VSWR meter, matched load, variable short, phase shifter

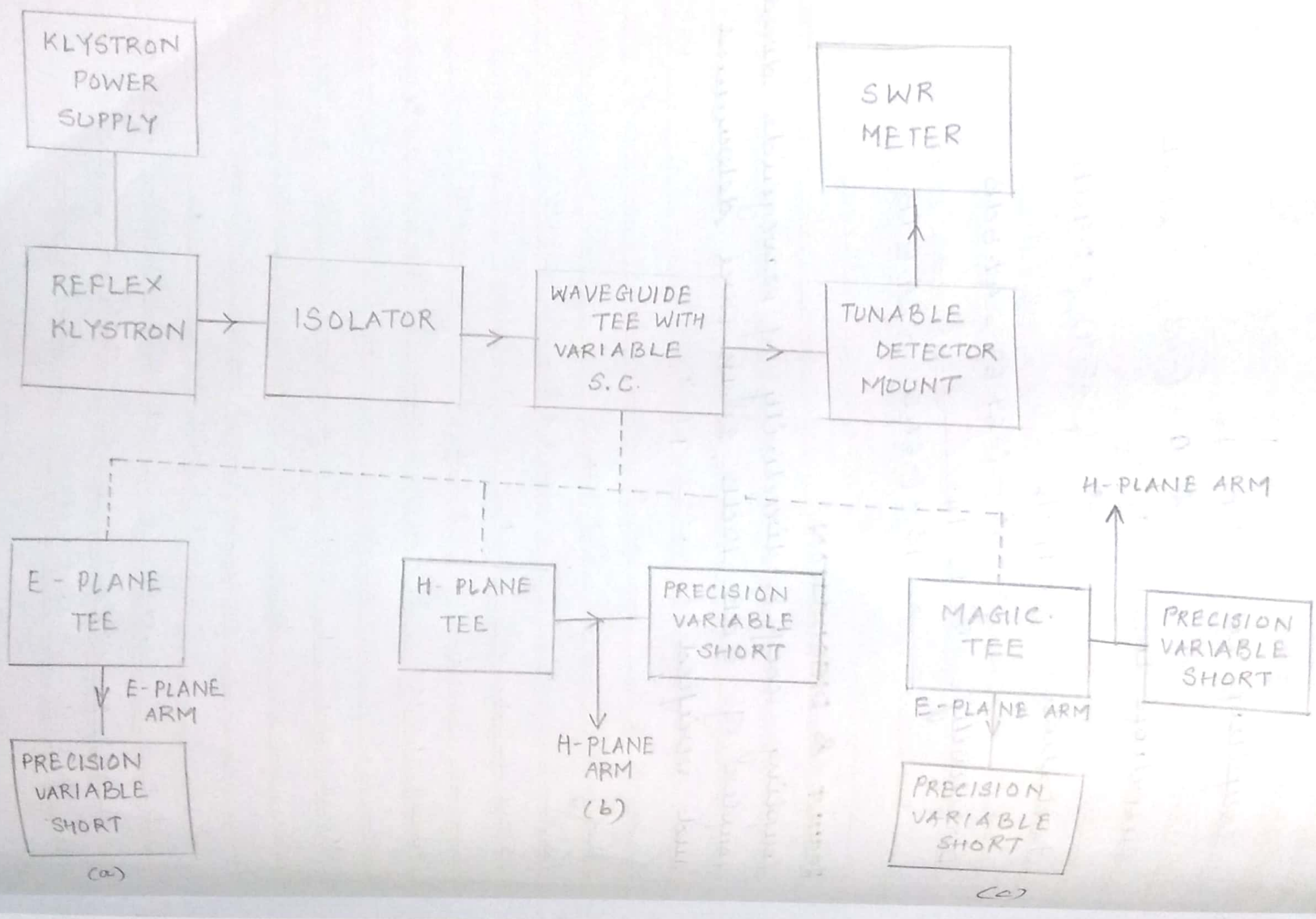
THEORY: A tee is a three (or more) port microwaves network. An E-plane tee is said to be formed if to a waveguide (main arm), we attach another waveguide (side arm) in E-plane. Similarly, in an H-plane tee, the side arm lies in H-plane of the main arm. A magic tee is the combination of both E- and H-plane tees.

PROPERTIES

1. If wave enters through side arm of E-plane then the wave leaving the main arm would be equal in magnitude and opposite in phase under symmetrical junction.
2. If two field waves, enter waveguide through two ends of main arm of an E-plane tee, then resultant field leaving the junction through side arm is proportional to difference between fields.

Teacher's Signature ....

SETUP FOR WAVEGIUIDE TEES - E PLANE , H-PLANE & MAGIC TEE



3. If in a symmetrical H-plane tee, wave enters through side arm then waves leaving main arms are equal in phase and magnitude.
4. If two fields enter through two ends of main of H-plane tees, then resultant field is proportional to sum of two fields.
5. By placing a short in the side arm of tee junction it is possible to obtain perfect transmission or perfect isolation between two ends of main arm
6. If in a hybrid tee, waves of equal magnitude and phase enters the E & H plane arms, the E field cancels in one of main arm and adds in another.
7. Conversly, if Energy is applied at either end of the main arm it is divided equally between E & H plane arms, none emerging from the opposite side.

OBSERVATIONS

The position of variable short in the E-H plane is varied & SWR meter reading is noted in magic tee, the short is applied in both E & H plane arms & position of both E & H plane arms is kept same ie they are varied equally

$V_R = -125V$

$V_p = 232V$

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1. E - PLANE TEE

SHORT POSITION (mm)	POWER (dB)	SHORT POSITION	POWER (dB)
23.5	-24	19	-20.6
23	-26	18.5	-19
22.5	-29	18	-18
22	-36	17	-17
21.5	-50	16	-16.5
21	-49	15	-16.5
20.5	-33.2	14	-16.5
20	-25	13	-16.5

2. H- PLANE TEE

SHORT POSITION (mm)	POWER (dB)	SHORT POSITION (mm)	POWER (dB)
23.65	-30	19	-29
23	-33.4	18	-29
22.5	-26.5	17	-30
22	-24	16	-30
21.5	-26	15	-30.6
20	-30.8	14	-30.8
20.5	-31.4	13	-31
20	-30.2	12	-31.5

Teacher's Signature ....

3. MAGIC TEE

SHORT POSITION (mm)	POWER (dB)
23.5	-20
23	-20.2
22.5	-20.6
22	-20.8
21.5	-21
21	-21.4
20.5	-21.4
20	-21.4

SHORT POSITION (mm)	POWER (dB)
19	-21.6
18	-21.4
17	-22
16	-22
15	-22.2
14	-22.2
13	-22.4
12	-22.6

RESULTS

The power ratio for all the tees first decreases reach a minimum and then increases as location of the short is varied. The value saturates to extreme at extreme position of short.

DISCUSSION

The sensitivity of reflex klystron is studied & upon shorting the side arms of E&H plane tee, the wave enters the main arm, goes to side arms. Changing the location of short changes the standing wave pattern in side arm & hence power of reflected wave reaching the main arm.

The tees can be used as power container of power divider. It is usually lossless so all power from one ports assumed to exit the remaining ports.

Date ....

Expt. No. 07

Page No. ....

AIM: To measure the phases shift of an unknown phase shiftor.

EQUIPMENT: Reflex klystron tube with mount, klystron power supply, Isolator, Precision short circuit, unknown phase shifter, slotted section with probe and SWR meter.

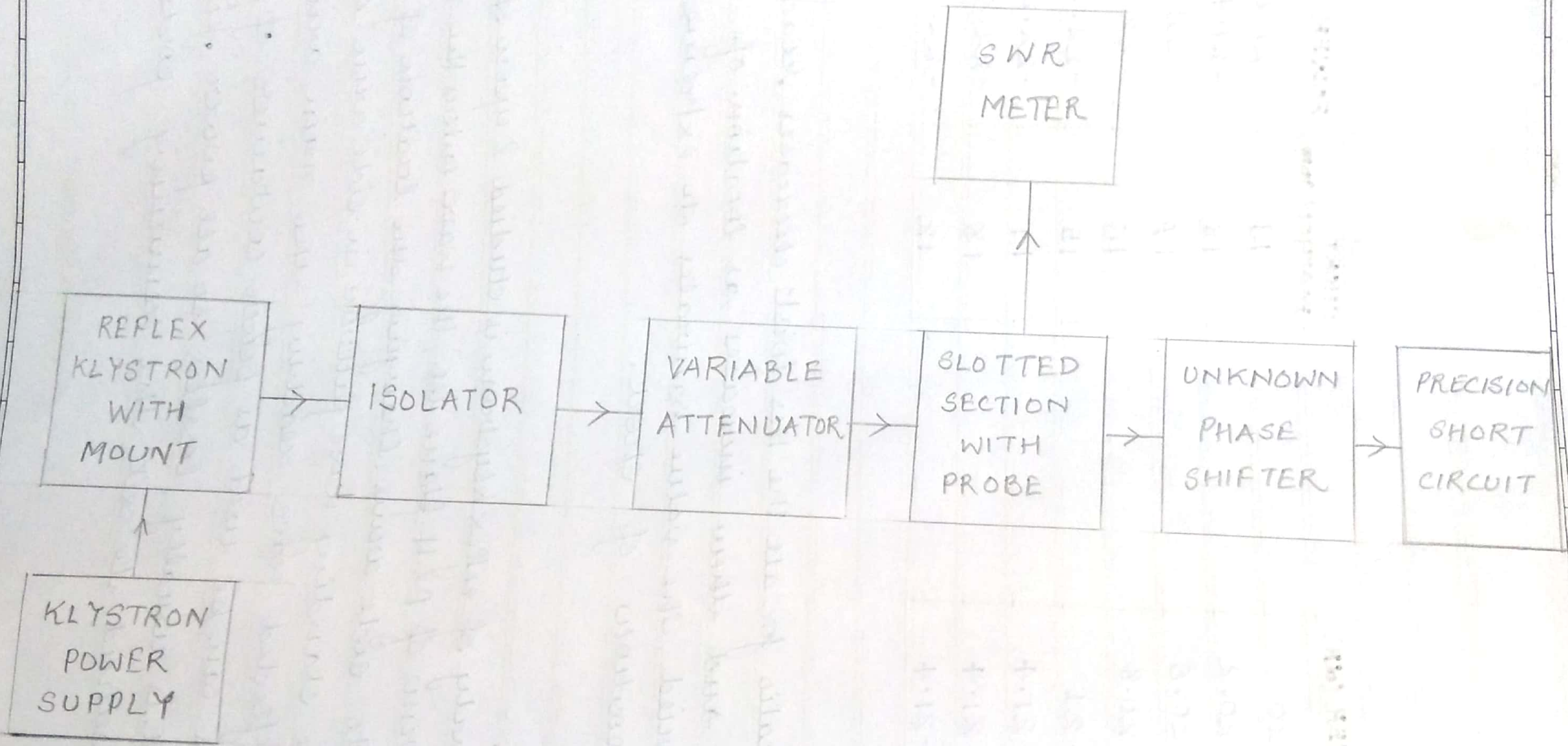
THEORY: Phase shift can be calculated by measuring shift in the position of minima in a shorted line with and without unknown phase shifters and then using fwg expressions

$$\phi = \frac{2\pi d}{\lambda_g}$$

ϕ = phase shift (degree)
d = shift in position of minima
λ_g = waveguide wavelength

Accuracy of method depends on the matching of phase shifter under test and the source. since, the phase shifter are met perfectly matched. errors are introduced because of interaction between signal reflected from short circuit and the signal reflected from mismatch of the phase. The error can be eliminated by using two channel sys.

Teacher's Signature ....



PHASE SHIFT MESUREMENT SYSTEM

OBSERVATIONS :

For maxima power output from the klystron tube as read on SWR meter. by short ccting the slotted section the following specification were observed. for the klystron power supply.

$V_{repeller} = -114V$
Current $= 15 mA$
$V_{beam} = 250 V$

Position of minima without phase shift
Minima $_1$ $= 7.75$ cm
Minima $_2$ $= 10.03$ cm
$\lambda g = 2(10.03 - 7.75) = 4.56$ cm

With phase shifter following reading are obtained

PHASE SHIFTER READING	POSN OF IST MINIMA	SHIFT IN Ist MINIMA d	PHASE SHIFT CALCULATED ($2\pi d/\lambda g$)
0°	10.03 cm	10.03 − 10.03 = 0.0 cm	0°
✓45	9.53 cm	10.03 − 9.53 = 0.5 cm	40°
90°	9.20 cm	10.03 − 9.20 = 0.83 cm	87°
180°	8.28 cm	10.03 − 8.32 = 0.71 cm	162°

RESULTS: The wavelength of the waveguide at frequency of operation was calculated. The phase shifter's phase at different position was measured.

DISCUSSION:

The result clearly show that on rotating the phase shifter position, a phase shift proportional to the rotation was introduced in the wave. This because the cross section of the dielectric present in the phase shifter, which was exposed to the wave changed and so the distance the wave had to travel through it.

The measured value of the phase shift is not exactly equal to theoretical value because the equipments are not ideal and readings are also taken with approximation. However, this phase shifter finds great application as introducing progressive phase shift in array antenna.

07/11/18

AIM: (i) To study the charecterstics of crystal detector especially square law behaviour.
(ii) To determine the response law of crystal detector.

EQUIPMENT: Klystron power supply, Reflex klystron tube, isolator, precision variable attenuator, stading wave meter, crystal detector, variable short, slotted section with probe, microammeter.

THEORY: Microwave usually detected using diode. A microwave detector diode produces a dc. output current when the microwave power applied across terminals. Three different diode designs utilized: the point contact, shottky barrier and backward diode.

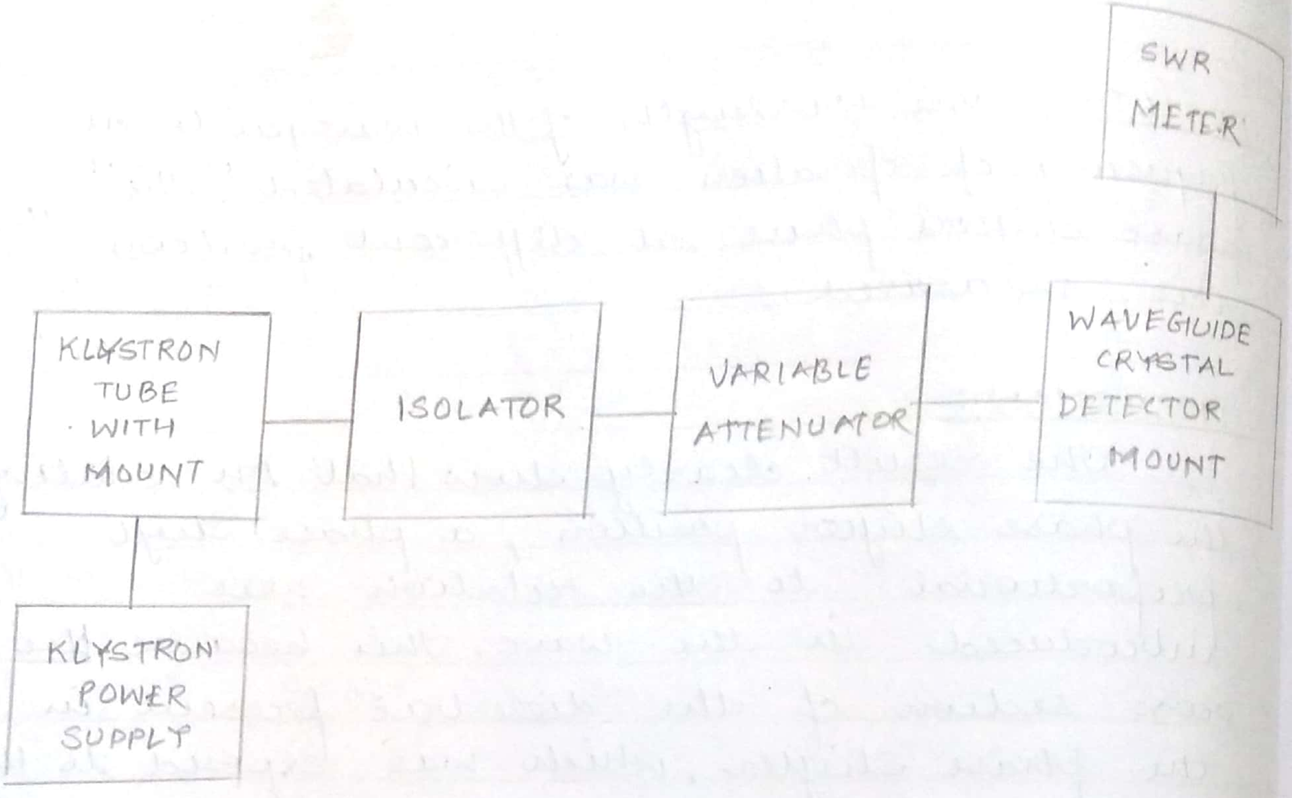
Generally, for detecting microwave point contact diodes commonly known as crystal detectors are used due to simplicity, low cost, and sensitivity. Crystal detector characteristics approximated by

$$i = a_0 + a_1 v + a_2 v^2 + a_3 v^3 + \ldots\ldots$$

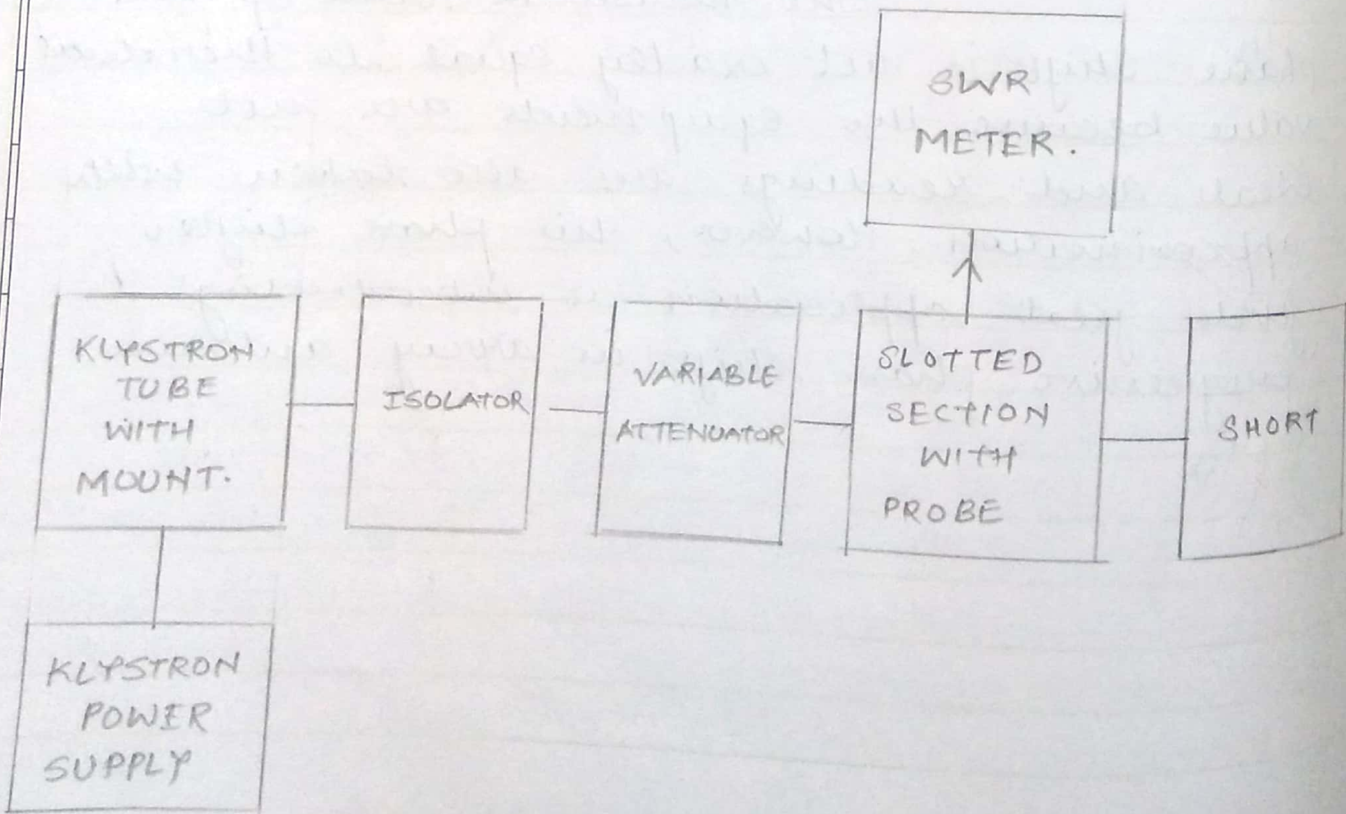
If $v = 0$ then $i = 0$ so $a_0 = 0$

Let $v = A \cos \omega t$

$$i = A \cos\omega t . a_1 + a_2 A^2 \cos^2 \omega t + a_3 A^3 \cos^3 \omega t + \ldots$$



SET UP FOR SQUARE LAW BEHAVIOR



SET UP FOR RESPONSE LAW BEHAVIOR

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$$i = a_1 A \cos\omega t + \frac{a_2}{2} A(1+\cos 2\omega t) + \cdots$$

This indicates that current includes a dc. component which will flow through micro ammeter and is proportional to square of amplitude A of microwave voltage.

Let the average rectified crystal current be related to RF voltage by :-

$$I = KV^n$$

The value of n depends on crystal and magnitude of applied voltage, Generally $n=2$. electric fd of standing wave in short circuit waveguide varies with distance λ from a null as

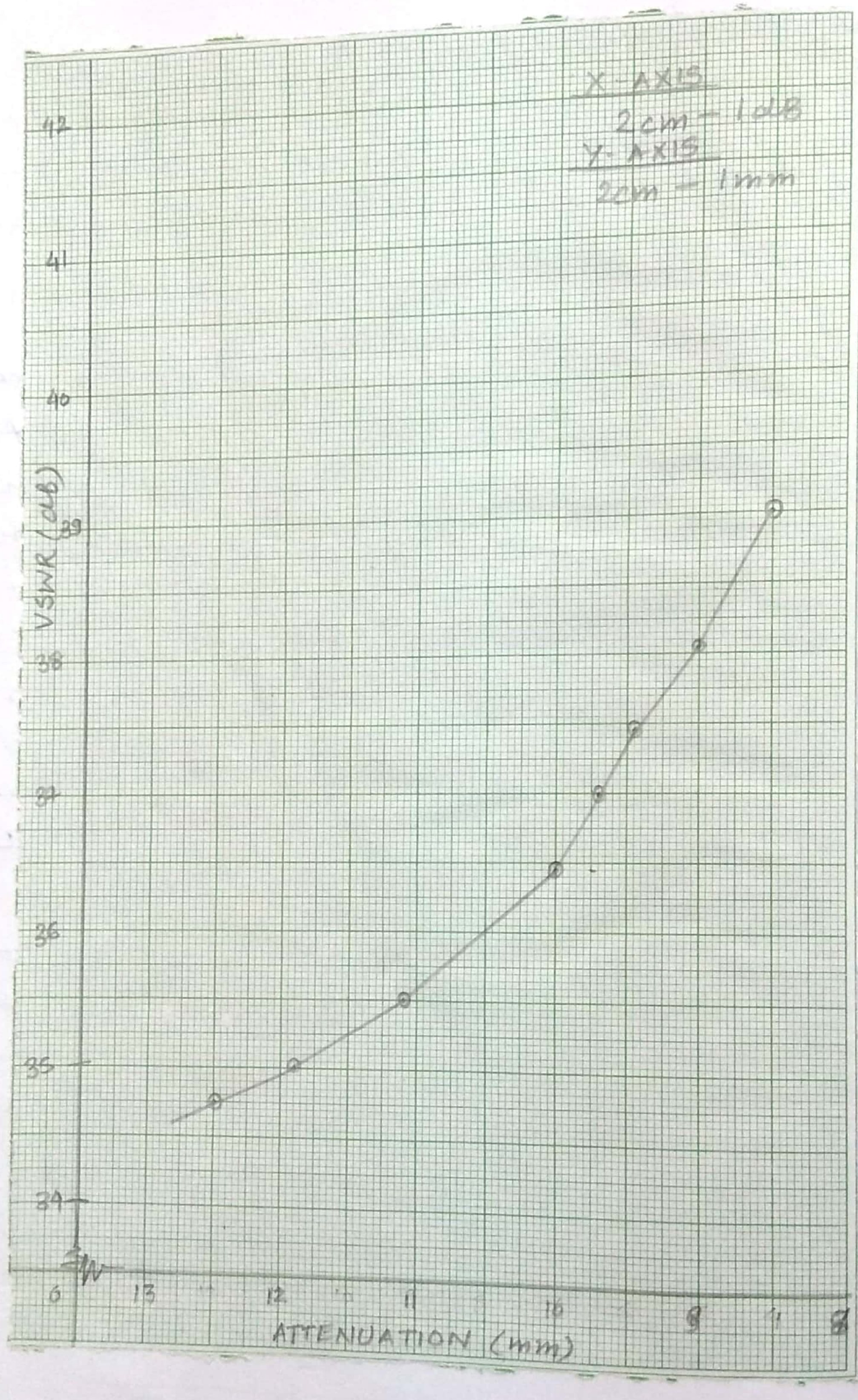
$$E = E_m \sin\left(\frac{2\pi l}{\lambda g}\right)$$ λg: guide wavelength

$$V = K\left[K_1 \sin\left(\frac{2\pi l}{\lambda g}\right)\right]^n$$

$$= K'\left[\sin\left(\frac{2\pi l}{\lambda g}\right)\right]^n$$

If the crystal current is plotted as a function of $\sin\left(\frac{2\pi l}{\lambda g}\right)$ on a log scale, the slope of the curve is equal to n.

Teacher's Signature ....



SQUARE LAW

OBSERVATIONS :

(a) Square Law Behaviour.

$V_p = 230\,V$

$V_r = -165\,V$

ATTENUATOR READING (mm)	VSWR(dB)
12.50	−34.75
12.35	−34.5
11.7	−35.0
11.11	−35.4
11.30	−35.8
10.50	−36.2
10.08	−36.6

ATTENUATOR READING (mm)	VSWR (dB)
9.79	−37.0
9.45	−37.4
9.12	−38.2
8.7	−38.6
8.5	−39.0
8.15	−39.5
07.9	−40.0

(b) Response Law

$V_b = 260\,V$

$V_r = -131\,V$

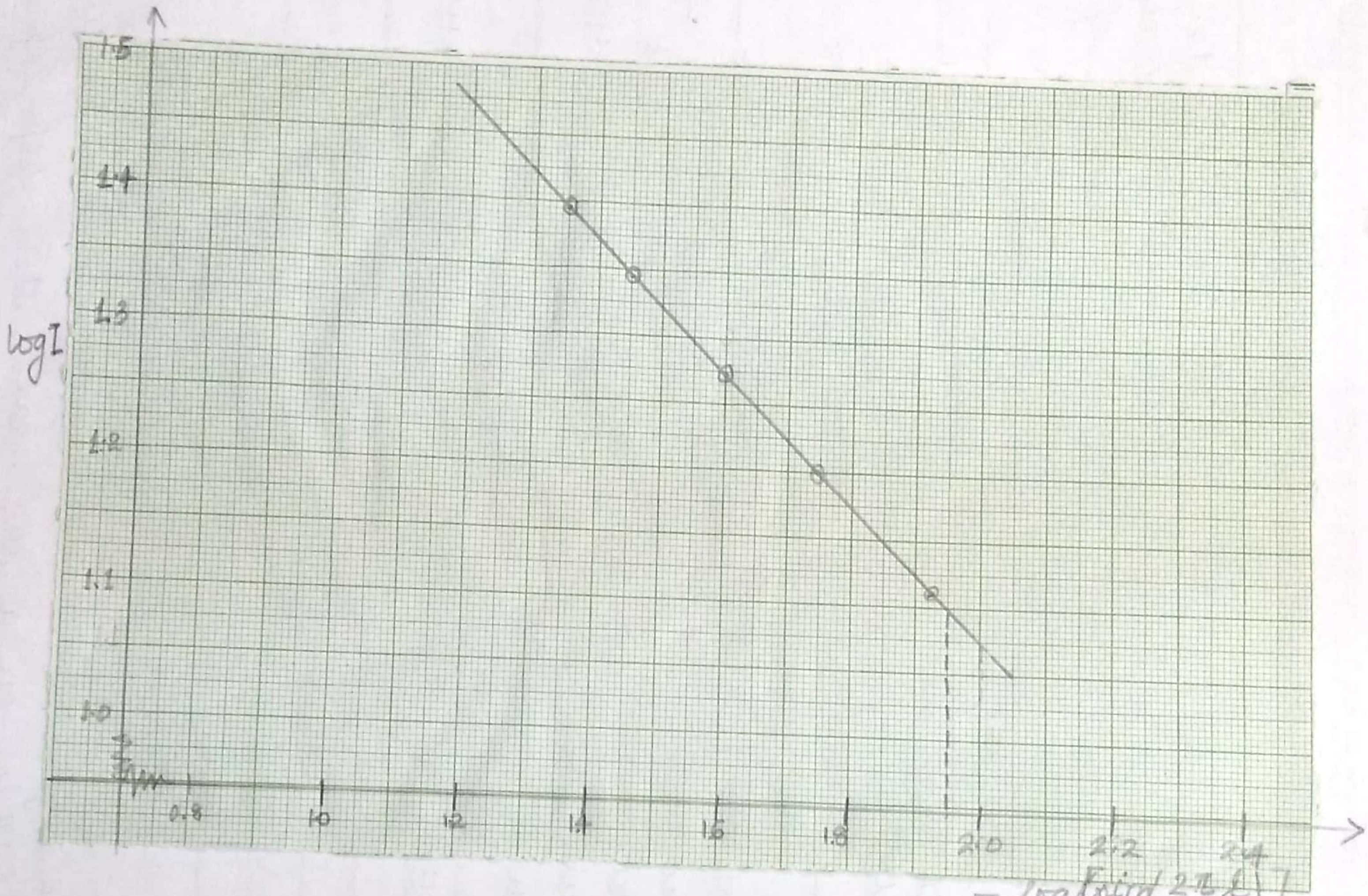
Attenuator at 12.5 mm

Minima = 10.6 cm, 12.4 cm

$\frac{\lambda_g}{2} = 1.8\,cm$

SLOTTED LINE READING (cm)	$l = X - 10.6$ (cm)	$\sin\left(\frac{2\pi l}{\lambda_g}\right)$	$-\log \sin\left(\frac{2\pi l}{\lambda_g}\right)$	I (μA)	log I
10.6	0	0	−	11	1.04
10.7	0.1	6.09×10^{-3}	2.215	12	1.08
10.8	0.2	12.1×10^{-3}	1.917	13	1.17
10.9	0.3	0.0183	1.717	16	1.20

Teacher's Signature ....



RESPONSE LAW DETECTOR

Slope

$$\left|\frac{1.49-1.11}{1.37-1.917}\right| = 0.695$$

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11.0	0.4	0.0244	1.612	20	1.30
11.1	0.5	0.0304	1.517	26	1.41
11.2	0.6	0.0365	1.437	29	1.46
11.4	0.8	0.0487	1.312	30	1.48
11.6	1.0	0.0670	1.215	29	1.46
11.8	1.2	0.0791	1.136	27	1.43
12.0	1.4	0.0912	1.069	26	1.41
12.3	1.7	0.1094	0.985	20	1.30
12.6	2.0	0.1215	0.915	19	1.28
12.7	2.1	0.1275	0.894	24	1.38

RESULT & DISCUSSION :

(a) Square law Behaviour : We plot a curve between standing wave indicator (dB) vs attenuation (mm). This is expected to be nearly linear. At the operating frequency, a linear graph is obtained at small values of L and VSWR. Graph deviates from linearity to a constant at higher values

(b) Response laws : We plot a graph between log I and $\log\left(\frac{\sin 2\pi l}{\lambda g}\right)$, where l is minimum of VSWR, slope of curve is equal to n, which was expected to be 2. From the graph the slope comes out to be 0.695. This is response law of detector i.e. current is proportional to 0.695 times power of voltage.

Teacher's Signature ....

AIM: To determine wavelength inside the waveguide for dominant mode and frequency of oscillation of reflex klystron.

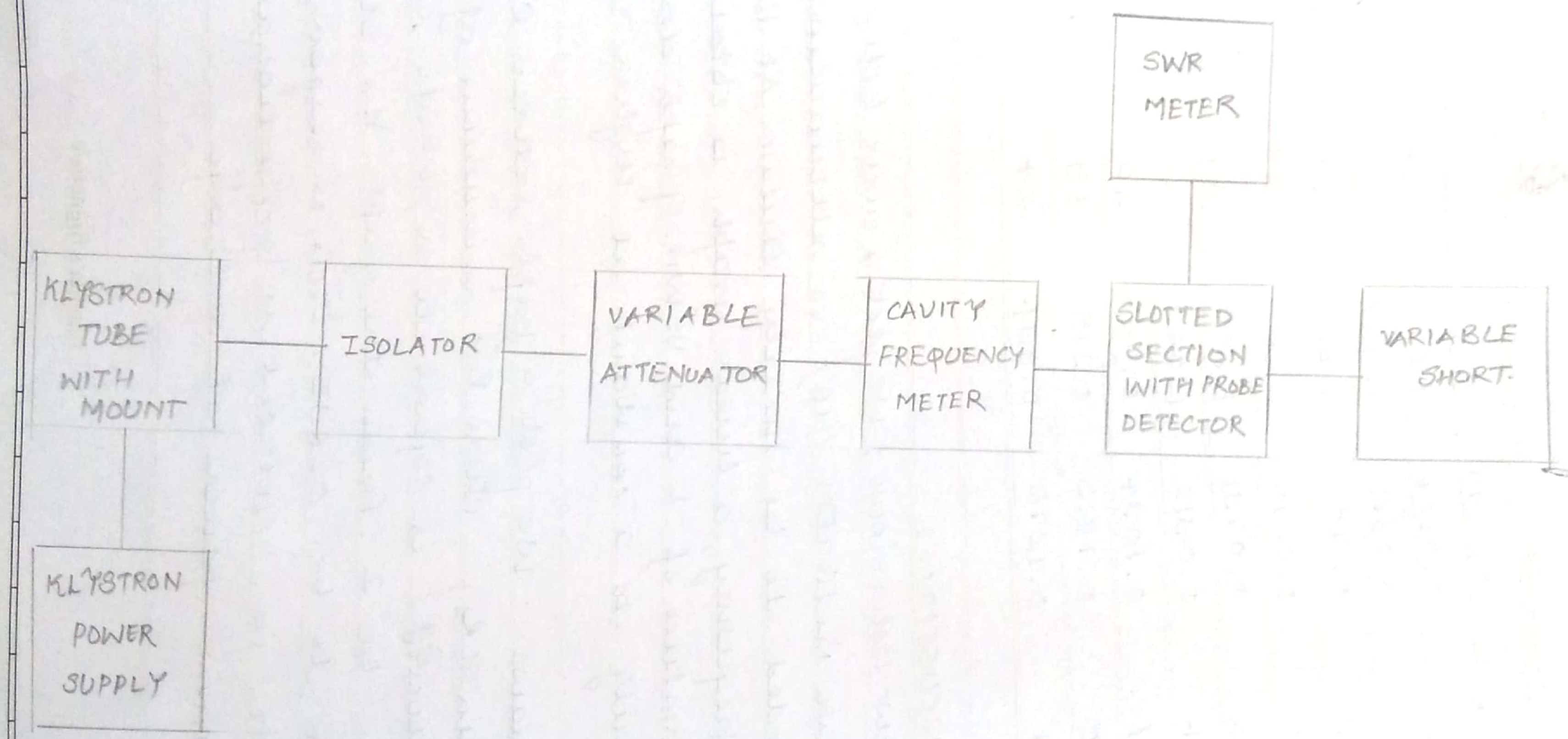
EQUIPMENT: Reflex klystron tube with mount, klystron power supply, Isolator variable attenuator, slotted section with tunable probe, SWR meter and variable short.

THEORY: The mechanical device for measuring the frequency of microwave signal commonly use resonant cavities and slotted lines. The most popular freq meter is cavity wavemeter due to fact that instrument is simple, straight forward, and has high accuracy.

Wavelength inside the waveguide can be measured by measuring distance between 2 successive minimas in standing waves pattern. The value can be calculated by knowing cut off wavelength and free space wavelength by using expression.

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

λ_0: wavelength in free space.
λ_c: cut off wavelength of waveguide.



SET UP FOR MEASUREMENT OF WAVELENGTH & FREQUENCY

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$$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}$$

a: broad dimension of waveguide
b: narrow dimension of waveguide.

For dominant mode TE_{10} ; $m=1$, $n=0$.

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

$$\lambda_0 = \frac{1}{\sqrt{\left(\frac{1}{\lambda_g}\right)^2 + \left(\frac{1}{2a}\right)^2}} = \frac{c}{f}$$

c: velocity of wave in free space
f: freq of signal.

OBSERVATIONS AND CALCULATIONS:

$V_R = -180 V$

$V_{beam} = 240 V$

$V_{min_1} = 9.83$ cm

$V_{min_2} = 11.84$ cm

$\lambda_g/2 = 11.84 - 9.83 \Rightarrow \lambda_g = 3.9$ cm ≈ 4 cm

Teacher's Signature ....

$$\lambda_0 = \frac{1}{\sqrt{\left(\frac{1}{4}\right)^2 + \frac{1}{(4.57\times10^{-2})^2}}}$$

$$f = 3\times10^8 \sqrt{\left(\frac{1}{4}\right)^2 + \left(\frac{1}{4.572\times10^{-2}}\right)^2} = 9.96 \text{ GHz}$$

Corresponding freq measured from freq meter = 9.6 GHz.

$$\text{ERROR }(\%) = \frac{f_{calculated} - f_{observed}}{f_{calculated}} = \frac{9.96 - 9.6}{9.96} = 3.16\ \%$$

RESULT: For the case of $f_0 = 9.6$ GHz measured value of guide wavelength $\lambda_g = 4$ cm, free space wavelength $\lambda_0 = 3.011$ cm and operating freq, $f_0 = 9.96$ GHz.

DISCUSSION:
The value measured of operating freq from freq meter and VSWR meter are not exactly equal. This is because reading of slotted line and SWR meter might not be accurate as frequency meter. The guide length and frequency is calculated for dominant TE_{10} mode. ie $\lambda_c = 2a$

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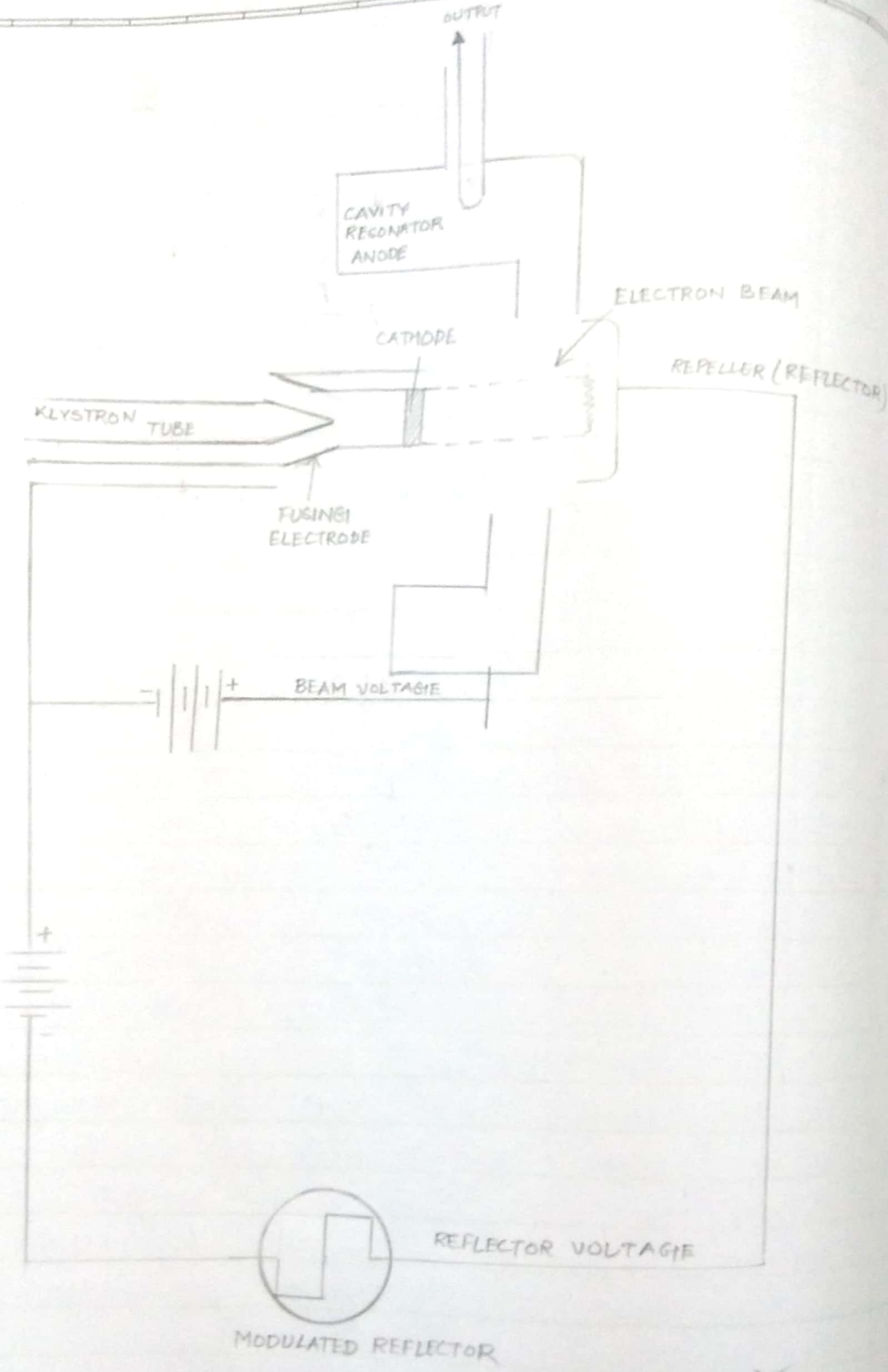
AIM: 1) To determine variation of output of reflex klystron with reflector voltage.
2) To determine variation of freq of oscillation with reflector voltage.

EQUIPMENT: Reflex klystron tube with mount, klystron power supply, isolator, variable attenuator, frequency meter, waveguide thermistor mount power meter.

THEORY:
The fig.(1) shows a schematic of reflex klystron tube which proper voltage applied to different electrode for proper operation. When the reflex klystron is oscillating, an alternating source of voltage appears across gap of resonator.
Electrons emitted from cathode are accumulated and are velocity modulated when they pass through the fd because of difference in velocity electrons leaving the at different part of it. As a result the electron group together in bunches as they return through the gap. they react with the voltage appearing across the gap and deliver energy to cavity resonator if the gap voltage cycle should be such that electron are slowed down, to sustain oscillation.

Teacher's Signature ....



SCHEMATIC OF REFLEX KLYSTRON TUBE

Oscillations will occur, when the e⁻ transit time in the reflector is $\left(n+\frac{3}{4}\right)$ cycles of resonant frequency, where n is an integer including zero. The freq of oscillation can be changed by changing the transit time between anode - reflector region ie adjusting reflector voltage for fixed anode voltage.

OBSERVATIONS

$V_{beam} = 230\,V$

$V_{repeller} = V_R$

Reflector Voltage V_R (V)	Current (μA) Ammeter Reading	Remarks
−40	0	
−50	0	
−60	0	
−62	10	
−64	15	
−66	22	Ist MAXIMA
−68	10	
−70	0	
−80	0	
−90	10	
−92	30	
−94	40	
−96	54	IInd MAXIMA

REFLECTOR VOLTAGE V_R (V)	FREQUENCY (GHz)	REMARKS
-60	9.60	
-63	9.64	
-66	9.70	
-69	9.72	
-71	9.78	
-85	9.60	
-90	9.65	
-92	9.68	
-96	9.71	
-100	9.76	
-105	9.82	
-130	9.62	
-132	9.64	
-134	9.66	
-136	9.69	
-142	9.73	
-144	9.79	
-150	9.88	

RESULTS

a) If the klystron reflector voltage vs relative output power (current) curve is studied and it shows peaks in certain reflector bands only.

b) The relative frequency of operation is formed to be constant at the peak of relative output power.

DISCUSSION

Reflex klystron tube is a device which efficiently converts DC to μwaves power supply. thus required in almost all experiments in lab The flexible diaphragm makes it possible to use it over a wide range of freq. by adjusting cavity dimensions thereby having control on resonant freq.

08/11/18

REFLECTOR VOLTAGE V_R (V)	CURRENT (μA) AMMETER READING	REMARKS
−100	33	
−102	15	
−105	0	
−110	0	
−120	0	
−130	0	
−134	25	
−136	76	
−138	84	
−140	90	
−142	93	IIIrd MAXIMA
−144	87	
−146	80	
−148	30	
−150	0	
−160	0	

Date ....

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AIM: Using radar, determine doppler frequency of moving or vibrating objects and determine the time period or frequency of their motion with help of radar kit.

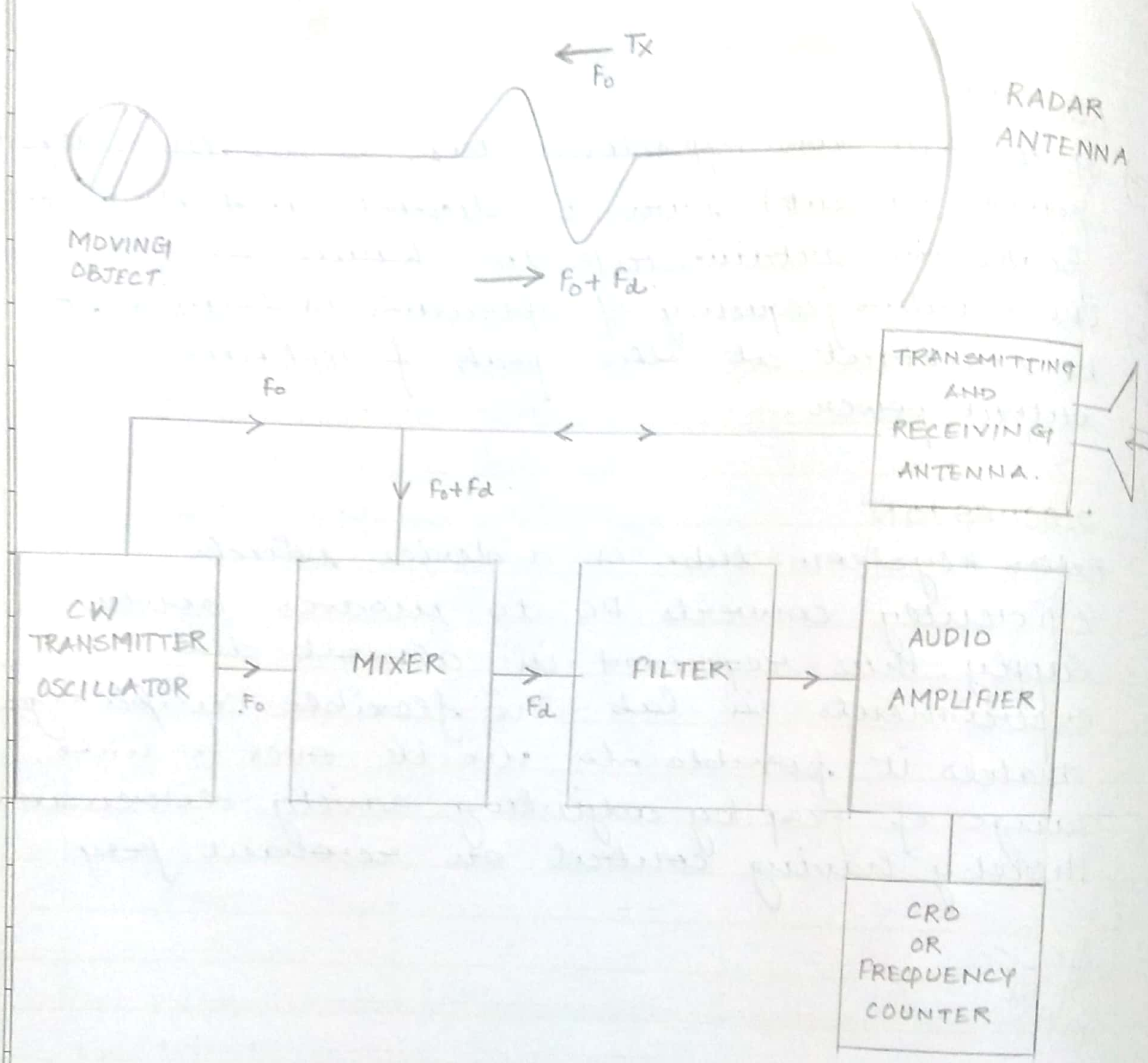
EQUIPMENT: Radar trainer NV 2001 (both freq software and hardware) incl CW transmitting antenna (horn), receiving horn antenna, transmitting oscillator, mixer, audio amplifier and filter alarming ckt, object counting circuitry, LED indicator, various objects such as pendulum, tuning fork etc.

THEORY: When the tgt is moving relative to the radar an apparent shift in carrier frequency of the received signal will result. This effect is called the Doppler effect and it is equal to basis of CW continuous wave radar. The Doppler frequency

$$F_d = \frac{2V_r}{\lambda} \text{ Hz} = \frac{2V_r F_0}{C} \text{ Hz}$$

V_r = Relative velocity of tgt
λ = Wavelength of transmitted wave
F_0 = Frequency of transmitting wave
C = Speed of wave in travelling wave.

Teacher's Signature ....



CW.DOPPLER RADAR

(i) To understand the principle of Doppler radar of time and frequency measurement with the help of moving pendulum.

The time period of pendulum is

$$T = 2\pi\sqrt{\frac{l}{g}}$$

when pendulum moves to and fro, the doppler Radar draws signal twice. so the time period T is to be measured between any point (first) and third peak of the signal. The waveforms is obtained alongside. for length of pendulum

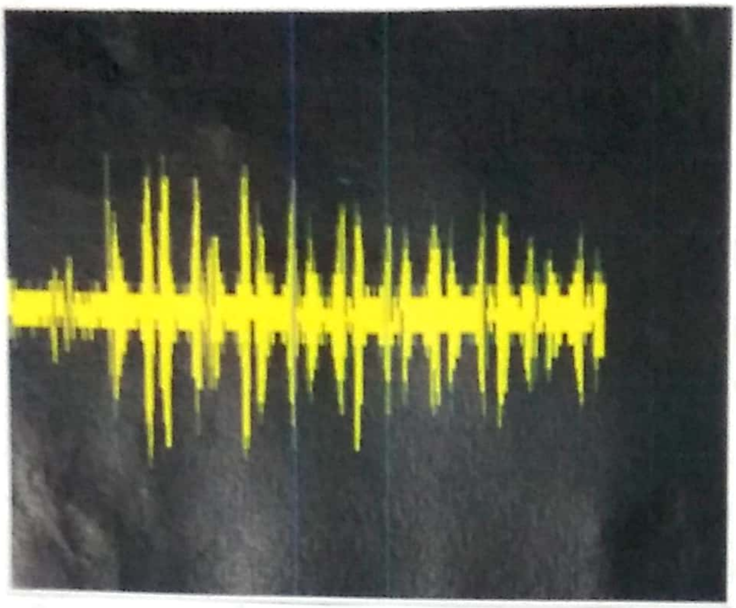
ii) To study the detection of vibrations of different training forks. Take a tuning fork with pre defined resonant frequency and strike it for frequency vibration operations.

iii) Determine rotation of per minute of moving fan. A rotating fan is placed in front of antenna and the waveforms is captured by radiating doppler frequency. the rpm of fan is calculated

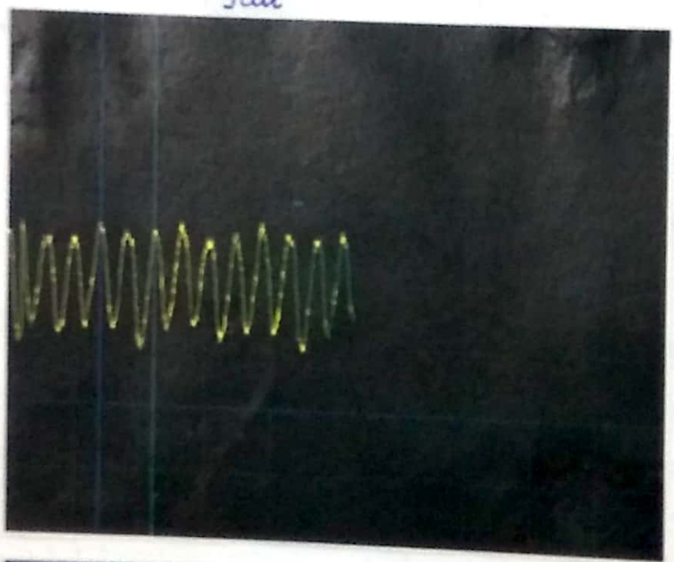
$$f_o = 125\ \text{Hz}$$

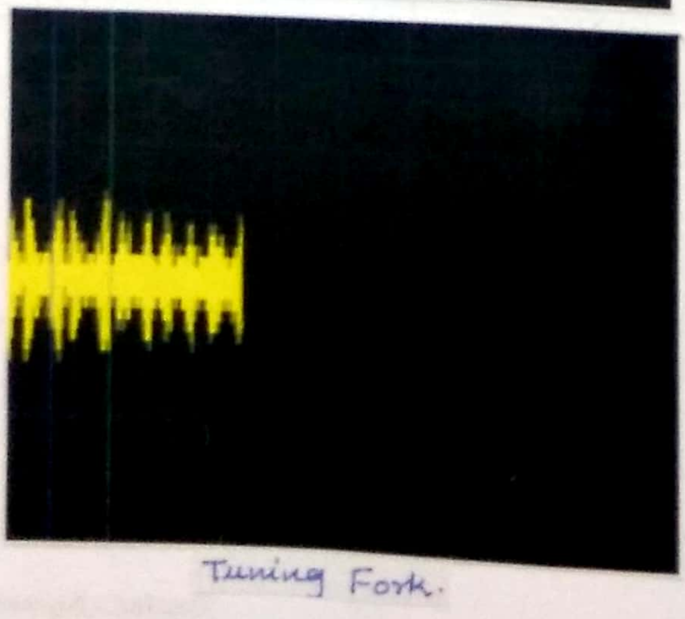
$$RPM = f_o \times 60 = 7500$$

Pendulum



Fan





Tuning Fork.

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RESULT :

The waveform for above three situations were plotted to determine frequency and RPM of different objects.

DISCUSSION :

The doppler radar can therefore be used for variety of applications. It can be used to estimate the count of objects crossing the radar beam, set out an alarm system when an object is detected in an otherwise still beam, estimate velocity of obstacle present by observing signal strength, acquire the knowledge about freq or time period of vibration of to or fro motion.

The various experiments performed using radar kit indicates that result provided by the doppler radar are highly accurate and practically usable.

02/11/18

Teacher's Signature ....

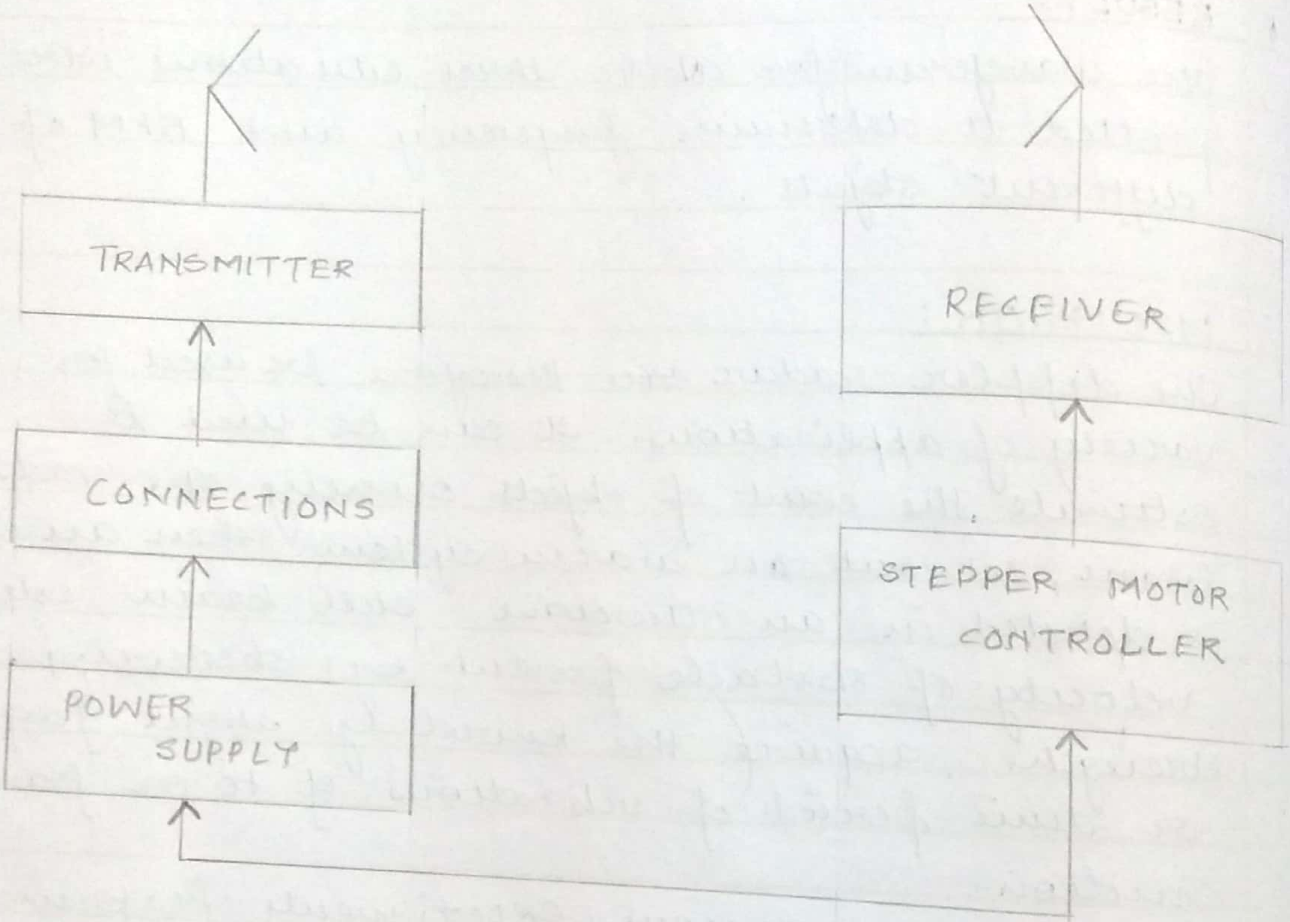
AIM: To study radiation charecteristic and gain of Yagi uda antenna.

EQUIPMENT : Yagi uda antenna (3 element / 4 element)

THEORY : Radiation pattern and gain are the most important charecterstic of antenna

a) Radiation Pattern : It is the graphical representation of the radiation intensity as a function of space coordinate of a constant distance in far field region. But here it is measured as two dimensional pattern in two different planes ie Eplane and H-plane. For a linearly polarized antenna the plane containing electric fd vector and the direction of maximum radiation is called E-plane. The plane containing magnetic fd vector and direction of maximum radiation is called H-plane.

b) Gain : The power gain is the ratio of power density of an antenna to the power density from reference antenna whose gain is known. Dielectric gain is 4π times value of ratio of radiation intensity in given direction to total power radiated by ant in all directions.



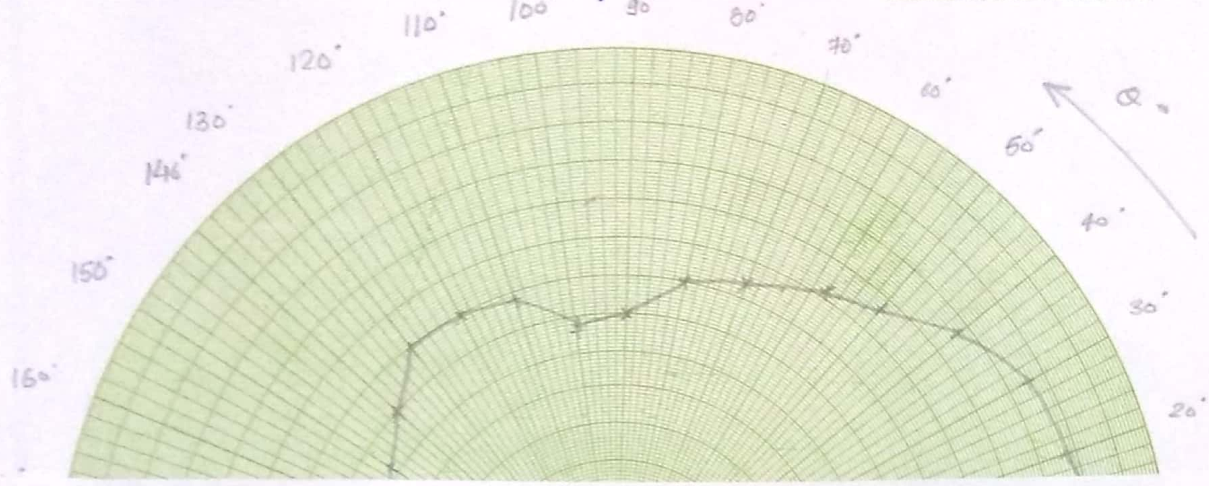
BLOCK DIAGRAMS FOR RADIATING PATTERN OF YAGII UDA ANTENNA

OBSERVATIONS :- Following reading are for 3 element yagi-uda : frequency of operator = 800 MHz. Length of dipole {middle element of Yagi uda antenna = 25 = $\lambda/2$

ANGLE (DEGREES)	E-PLANE FIELD	H-PLANE FIELD
0	30.4	32.0
10	30.1	31.3
20	30.9	30.9
30	30.0	30.0
40	26.4	29.4
50	24.0	28.1
60	21.1	26.2
70	16.5	25.5
80	8.5	24.8
90	10.6	29.5
100	18.1	22.0
110	20.6	24.0
120	20.2	23.0
130	22.2	25.4
140	23.0	22
150	24.4	20.8
160	24.5	19
170	24.0	20.4
180	24.0	24.5
190	23.0	22.2

Teacher's Signature ....

3-element Yagi-Uda
H-plane.



3 - element Yagi - Uda
E-plane.

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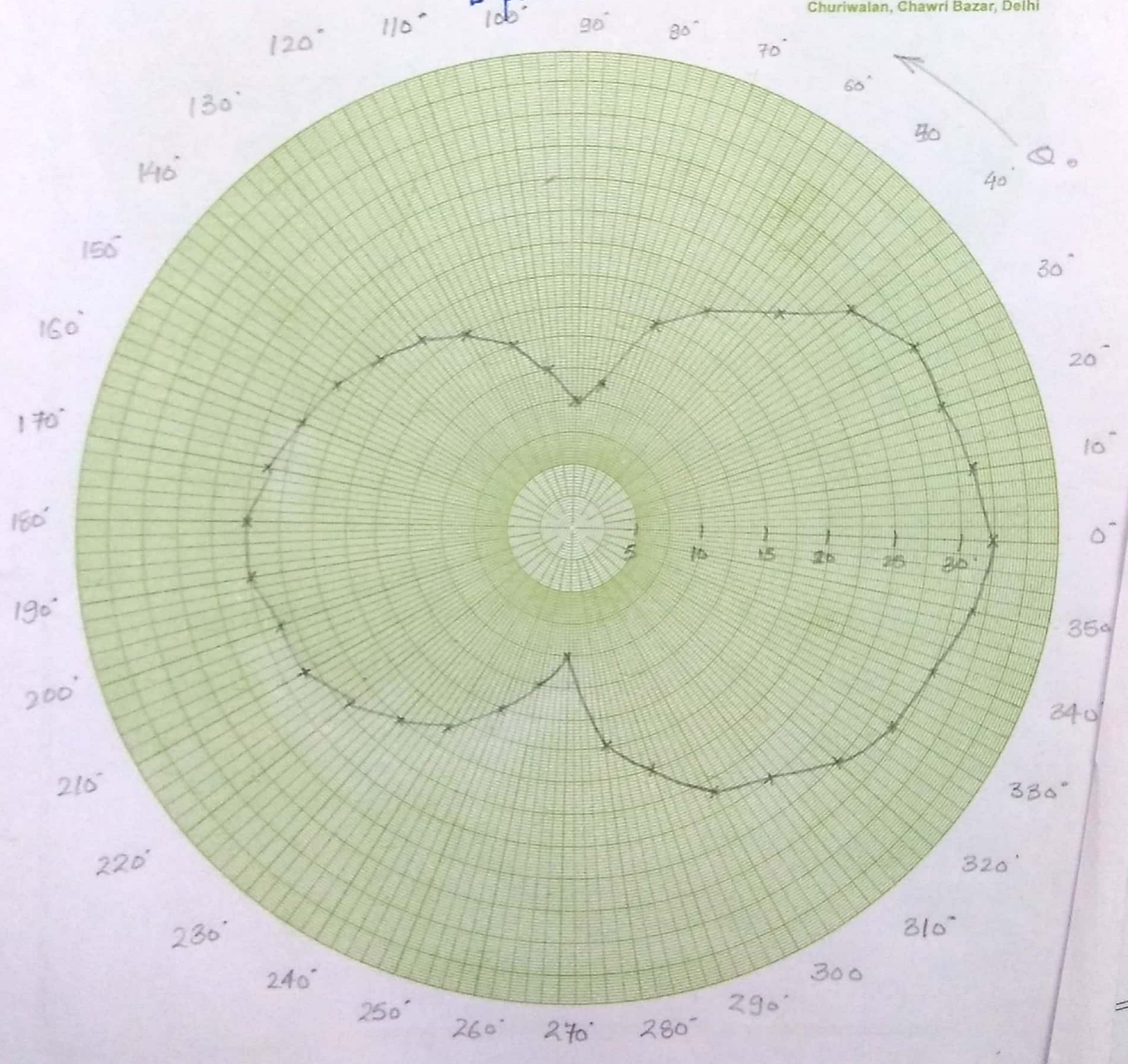
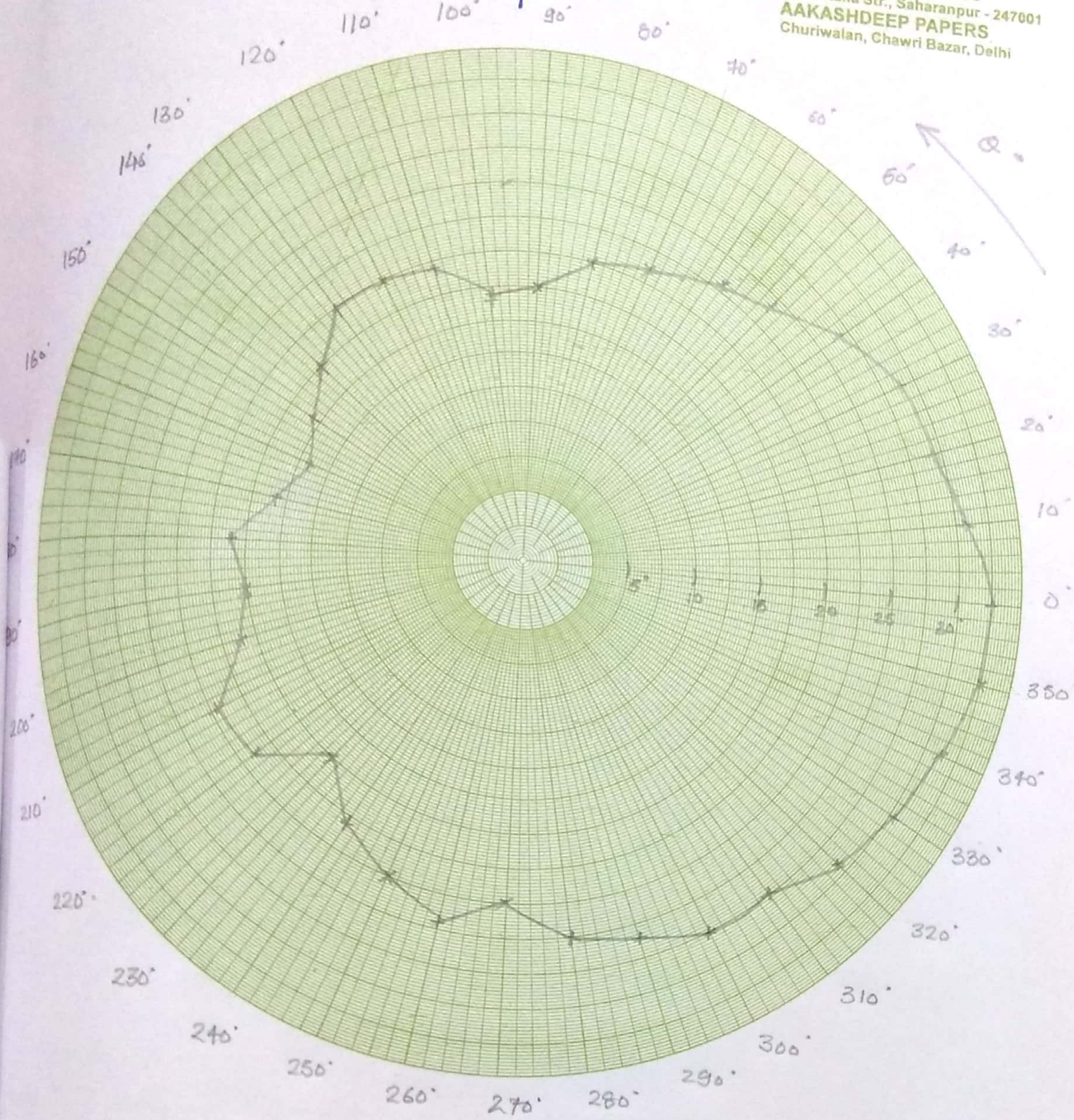


3-element Yagi-Uda

H-plane.



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RESULT:

The radiation pattern of field measurements of E-plane & H-plane were measured and noted. The radiation pattern were drawn on polar graph to verify characteristics.

Teacher's Signature ....

SNo.	ANGLE	E-PLANE FD	H-PLANE FD
	200	23.0	20.0
	210	22.2	24.0
	220	21.7	20.5
	230	21.2	23.0
	240	19.0	23.0
	250	15.8	24.5
	260	10.0	27.2
	270	7.5	29.1
	280	16.9	28.0
	290	20.4	29.1
	300	23.3	32.0
	310	25.4	32.7
	320	27.5	31.8
	330	30.1	35.0
	340	31.6	34.1
	350	32.3	35.0

AIM:

To measure the unloaded Q, loaded Q, the external Q and coupling co-efficient for a major single ended cavity

EQUIPMENT: Variable freq, signal source generator isolator, cavity wave meter, slotted section with probe, SWR meter, single ended cavity meter under test, power supply.

THEORY: At the position of a voltage antimode a quarter wavelength away from the voltage mode, the cavity appears as a series resonant circuit

$$Q = \frac{WU}{P}$$

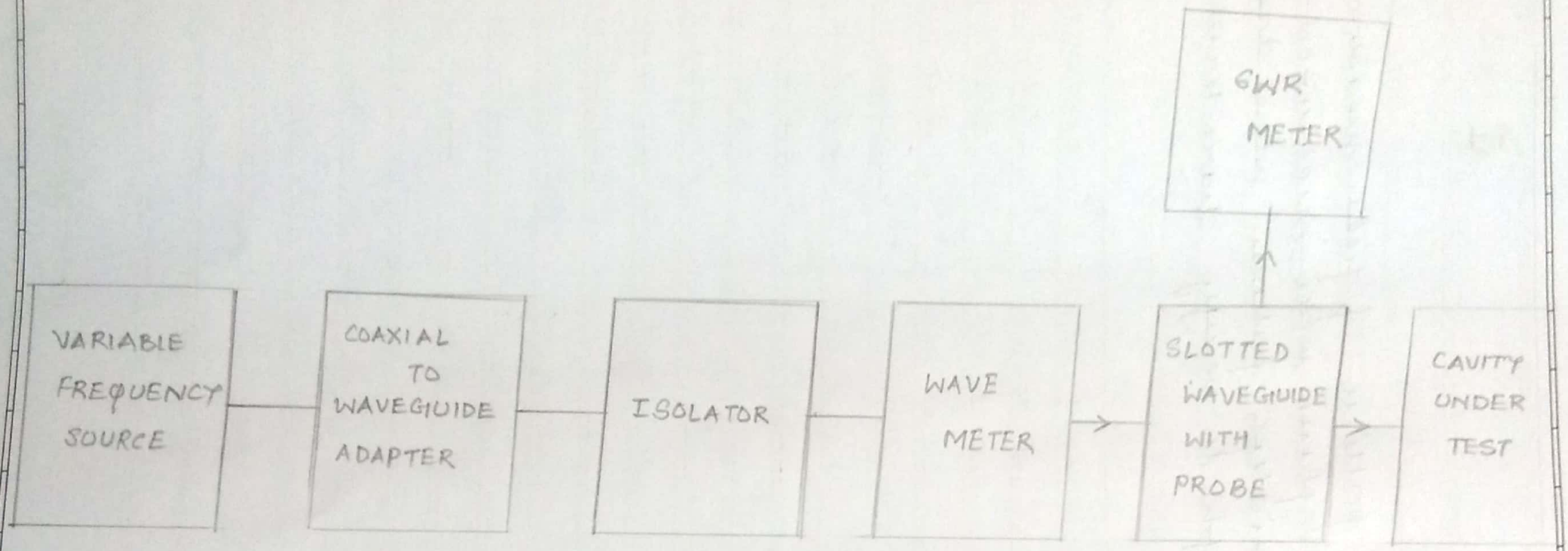
where, U is energy stored
P is the power dissipated in the circuit

The unloaded Q (Q_0) includes losses in the cavity alone.

$$Q_0 = \frac{W_0 L}{R}$$

Loaded Q (Q_L) is the Q of entire circuit

$$Q_L = \frac{W_0 L}{R + Z_0}$$



BLOCK DIAGRAM FOR Q FACTOR MEASUREMENT

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$$Q_L = \frac{Q_0}{1 + Z_0/R}$$

External Q includes only the exterior sources of dissipation

$$Q_{ext} = \frac{W_0 L}{Z_0}$$

Coupling parameters is defined as $\beta = Z_0/R$. VSWR at resonance will be unity for critically coupled case, β for over coupled case and $1/\beta$ for an under coupled case.

OBSERVATIONS:

FREQUENCY (GHz)	VSWR (dB)	
9.24	4	
9.25	3.5	
9.26	2.8	
9.27	2.4	
9.28	2.0	
9.29	1.75	
9.30	1.65	
9.31	1.55	
9.32	1.50	
9.33	1.45	
9.34	1.40	
9.35	1.38	

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From frequency vs VSWR plot, minimum SWR point is 1.06 at frequency 9.43 GHz.
so, $S_0 = 1.06$ $f_0 = 9.43$ GHz and $S_1 = 4.0$ away from resonant frequency.

CALCULATIONS :

$$S_{1/2} = \frac{\sqrt{2}(S_0+1)(S_1+1) + \left[(S_0-1)^2(S_1+1)^2+(S_0+1)^2(S_1-1)^2\right]^{1/2}}{\sqrt{2}(S_0+1)(S_1+1) - \left[(S_0-1)^2(S_1+1)^2+(S_0+1)^2(S_1-1)^2\right]^{1/2}}$$

$$= \frac{\sqrt{2}(2.06)(5) + \left[0.06^2\, 5^2 + 2.06^2\, 3^2\right]^{1/2}}{\sqrt{2}(2.06)(5) - \left[0.06^2\, 5^2 + 2.06^2\, 3^2\right]^{1/2}}$$

$$= 2.746$$

corresponding values of frequency from graph

$f_1 = 9.28$ GHz

$f_2 = 9.98$ GHz.

$\Delta f = f_2 - f_1 \qquad = 0.32$ GHz.

$$Q_L = \frac{f_0}{\Delta f} = \frac{9.43}{0.32} = 47.15$$

$\beta \rightarrow 1/S_0 \qquad = 0.9434$

$$Q_L = \frac{Q_0}{1+\beta} \qquad \Rightarrow Q_0 = 91.087$$

$$Q_{ext} = \frac{Q_0}{\beta} = 97.128$$

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FREQUENCY(GHz)	VSWR(dB)
9.36	1.34
9.37	1.30
9.38	1.28
9.39	1.20
9.40	1.16
9.41	1.14
9.42	1.10
9.43	1.07
9.44	1.06
9.45	1.12
9.46	1.26
9.47	1.90
9.48	2.0
9.49	3.50
9.50	4

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RESULT :

For a single ended cavity unloaded $Q = Q_0 = 1.087$, loaded Q, $Q_2 = Q_L = 47.433$
External Q, $Q_{ext} = 97.128$ and
coupling factor $\beta = 0.9434$

DISCUSSION :

If the coupling factor is 1, this answer means that cavity is perfectly matched with transmission line, ie. maximum power is delivered to cavity. The matching decreases as β shifts from 1 to Here $\beta = 0.9434$ which is less than 1, therefore the characterstic impedance of transmission line is less than impedance provided by cavity. So, the cavity is not perfectly matched and is undercoupled.

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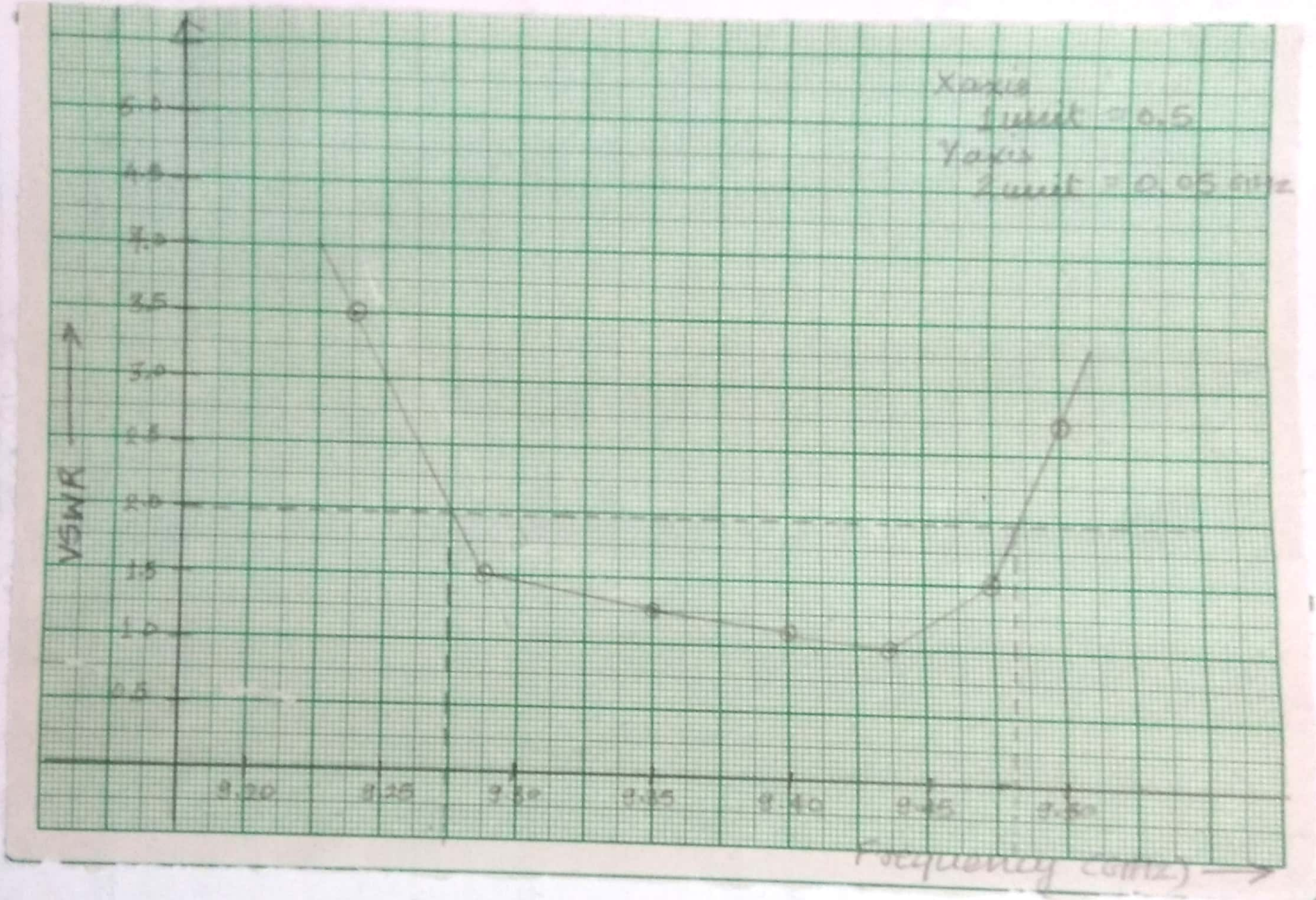

Q MEASUREMENT