MICROWAVE ENGINEERING LAB - EC431

Laboratory Manual

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CONTENTS

STUDY OF MICROWAVE COMPONENTS

AIM

To study the microwave components in detail.

RECTANGULAR WAVE GUIDE

Wave guides are manufactured to the highest mechanical and electrical standards and mechanical tolerances. L and S band wave guides are fabricated by precision brazing of brass-plates and all other wave guides are in extrusion quality. W.G. sections of specified length can be supplied with flanges, painted outside and silver or gold plated in side.

SPECIFICATIONS

X Band

EIA No. : WR - 90

Frequency : 8.2 - 12.4 GHZ Width : 2.286cm Height : 1.1016cm Width : 2.54 cm

Height : 1.27cm ± Tol. (µm) : 7.6 Material : Brass/Copper.

FIXED ATTENUATORS

Series 5000 fixed Attenuators are meant for inserting a known attenuation in a wave guide system. These consists of a lossy vane inserted in a section of wave guide, flanged on both ends. These are useful for isolation of wave guide circuits, padding and extending the range of measuring equipments.

Fixed Attenuators are available for 3,6 or 10 dB attenuation values, but any attenuation valve between 0 and 30dB can be provided.

SPECIFICATIONS

Model No: X-5000

Frequency : 8.12 - 12.4 GHZ
Attenuation (dB) : 3,6,10
CallibrationAccuracy : ± 0.2dB
AvgPower : 2W/Max VSWR : 1.10/Max Insertion Loss (dB) : 0.2/W.G. Type: WG – 90/Flange Type (UG/U) : 39.

A precision built probe carriage has a centimeter scale with a vernier reading of 0.1mm least count and a dial gauge can be mounted easily if precise readings are required.
Model No. : X - 6051
Freq (Ghz) : 8.2 - 12.4
Max Residual VSWR : 1.01

WG type (WR-) : 90
Flange Type (UG-/U) : 39

TUNABLE PROBE

Model 6055 Tunable probe is designed for use with model 6051 slotted sections. These are meant for exploring the energy of the EF in a suitably fabricated section of wave guide.

The depth of penetration into a wave guide - section is adjustable by the knob of the probe. The tip pick up the RF power from the line and this power is rectified by crystal detector, which is then fed to the VSWR meter or indicating instrument.

Model No. : X6055   Freq (Ghz) : 8.2 - 12.4
output Connector : BNC(F)   Detector : IN23.

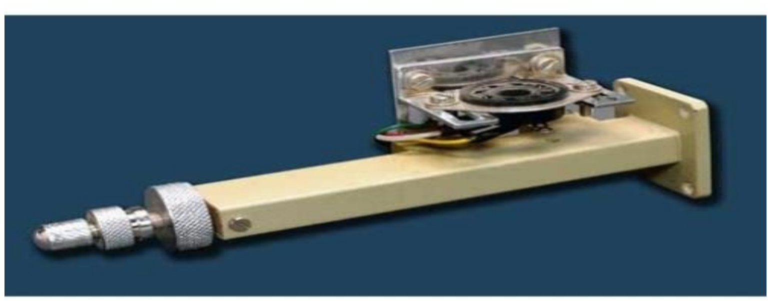
WAVEGUIDEDETECTORMOUNT(TUNABLE)

Model 4051 Tunable Detector Mount is simple and easy to use instrument for detecting microwave power through suitable detector. It consists of a detector crystal mounted in a section of a Wave guide and shorting plunger for matching purpose. The output from the crystal may be fed to an indicating instrument. In K and R bands detector mounts the plunger is driven by a micrometer.

Model No. : X - 4051 | Freq. Range (Ghz) : 8.2 - 12.4
O/P Connector : BNC (F) | Wave guide type (WR-) : 90
Flange Type (UG/U) : 39 | Detector : IN23

KLYSTRON MOUNT

Model 2051 Klystron mounts are meant for mounting corresponding Klystrons such as 2K25, 723A/B, 726A or RK - 5976 etc. These consists of a section of wave guide flanged on one end and terminatedwith a movable short on the other end. An octalbase with cable is provided for Klystron.



Klystron mount

Klystron tube

Model No. : X – 2051 Freq. Range (GHz) 8.2 - 12.4

WG Type (WR-) : 90 Flange Type (UG-/U): 39

CIRCULATORS

Model 6021 and 6022 are T and Y types of three port circulators respectively. These are precisely machined and assembled to get the desired specifications. Circulators are matched three port devices and these are meant for allowing Microwave energy to flow in clockwise direction with negligible loss but almost no transmission in the anti-clockwise direction.

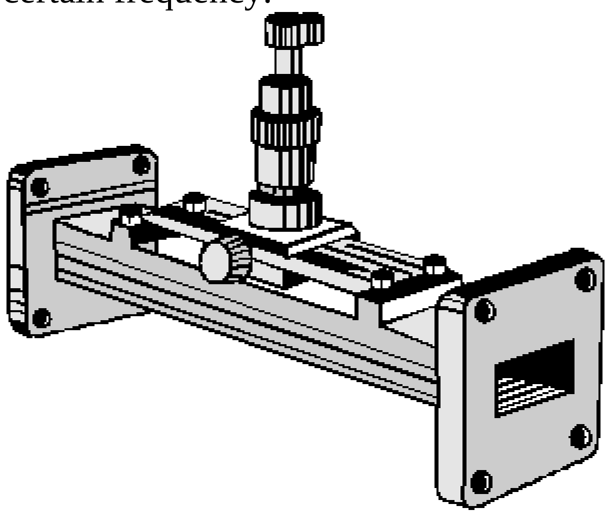
T type and Y type Circulator

Model No. : X - 6021 Frequency Range (Ghz) : 8.6 - 10.6 or 10.2 - 12.2
Min. Isolation (dB) : 20 Max. Insertion Loss (dB) : 0.4
Max. VSWR : 1.20

SLIDE SCREW TUNERS

Model 4041 slide screw tuners are used for matching purposes by changing the penetration and position of a screw in the slot provided in the centre of the wave guide.

These consists of a section of wave guide flanged on both ends and a thin slot is provided in the broad wall of the Wave guide. A carriage carrying the screw, is provided over the slot. A VSWR upto 20 can be tuned to a value less than 1.02 at certain frequency.



Model No. : X – 4041	Freq. Range (Ghz) : 8.2 - 12.4
WG Type (WR-) : 90	Flange type (UG/U) : 39

MULTIHOLE DIRECTIONAL COUPLERS

Model 6000 series Multihole directional couplers are useful for sampling a part of Microwave energy for monitoring purposes and for measuring reflections and impedance. These consists of a section of Wave guide with addition of a second parallel section of wave guide thus making it a four port network. However the fourth port is terminated with a matched load. These two parallel sections are coupled to each other through many holes, almost to give uniform coupling; minimum frequency sensitivity and high directivity. These are available in 3,6,10,20 and 40dB coupling.

Model No. : X - 6003 Frequency Range (Ghz) : 8.2 - 12.4
Coupling (dB) : 3,10,20,40 Directivity (dB) : 35
Wave guide type (WR-) : 90 Flange type (UG/U) : 39

E PLANE TEE

Model 3061 E - plane tee are series type T - junction and consists of three section of wave guide joined together in order to divide or compare power levels. The signal entering the first port of this T - junction will be equally dividing at second and third ports of the same magnitude but in opp. Phase

Model No. : X - 3061 Frequency Range (Ghz) : 8.2 - 12.4
WG Type (WR-) : 90 Flange Type (UG/U) : 39

H - PLANT TEE

Model 3065 H - Plane Tee are shunt type T - junction for use in conjunction with VSWR meters, frequency - meters and other detector devices. Like in E-plane tee, the signal fed through first port of H - plane Tee will be equally divided in magnitude at second and third ports but in same phase.

Model No. : X - 3065 Frequency Range (GHz) : 8.2 - 12.4
WG Type (WR-) : 90 Flange Type (UG-/U) : 39

MAGIC TEE

Model 3045 E - H Tee consists of a section of wave guide in both series and shunt wave guide arms, mounted at the exact midpoint of main arm. Both ends of the section of wave guide and both arms are flanged on their ends. These Tees are employed in balanced mixers, AFC circuits and impedance measurement circuits etc. This becomes a four terminal device where one terminal is isolated from the input terminal.

Model No. : X - 3045 Frequency Range (Ghz) : 8.2 - 12.4
WG Type (WR-) : 90 Flange Type (UR-/U) : 39

MOVABLE SHORT

Model 4081 movable shorts consists of a section of waveguide, flanged on one end and terminated with a movable shorting plunger on the other end. By means of this noncontacting type plunger, a reflection co-efficient of almost unity may be obtained.

Model No. : X - 4081 Frequency Range (GHz) : 8.2 - 12.4
WG Type (WR-) : 90 Flange Type (UG-/U) : 39

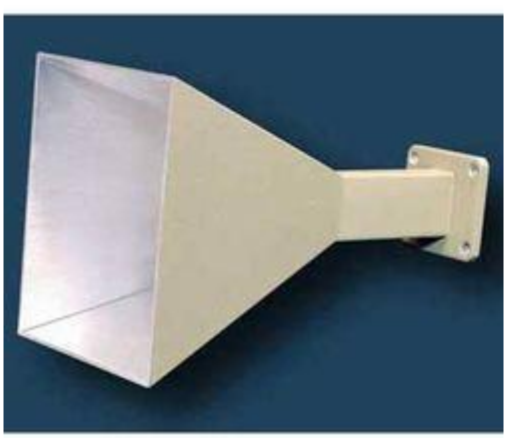
MATCHED TERMINATION

Model 4000 are low power and non-reflective type of terminations. It consists of a small and highly dissapative taper flap mounted inside the centre of a section of wave guide. Matched Terminations are useful for USWR measurement of various waveguide components. These are also employed as dummy and as a precise reference loads with Tee junctions, directional couplers and other similar dividing devices.

Model No. : X - 4000, Freq. Range (Ghz) : 8.2 - 12.4 Max VSWR : 1.04
AV Power : 2W, WG Type (WR-) 90, Flange Type (UG-/U) : 39

PYRAMIDAL WAVEGUIDE HORN ANTENNA

Model 5041 pyramidal Wave guide Horn antenna consists of waveguide joined to pyramidal section fabricated from brass sheet. The pyramidal section shapes the energy to concentrate in a specified beam. Wave guide horns are used as feed horns as radiators for reflectors and lenses and as a pickup antenna for receiving microwave power.



Model No. : X - 5041   Frequency Range (Ghz) : 8.2 - 12.4
Max VSWR : 1.20   WG Type (WR-) : 90
Flange Type (UG-/U) : 39

GUNN OSCILLATORS

Model 2151 Gunn Oscillators are solid state microwave energy generators. These consists of waveguide cavity flanged on one end and micrometer driven plunger fitted on the other end. A gunn-diode is mounted inside the Wave guide with BNC (F) connector for DC bias. Each Gunn osciallator is supplied with calibration certificate giving frequency vs micrometer reading.

Model No. : X – 2152   Freq : 8.2 - 12.4 Ghz
Min output power : 10 MW   WG Type (WR-) : 90 Flange Type (UG-/U) : 39

PIN MODULATORS

Model 451 pin modulators are designed to modulate the cw output of Gunn Oscillators. It is operated by the square pulses derived from the UHF(F) connector of the Gunn power supply. These consists of a pin diode mounted inside a section of Wave guide flanged on it's both end. A fixed attenuation vane is mounted inside at the input to protect the oscillator.

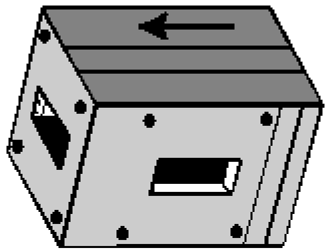
Model No. : X - 451 Frequency Range (Ghz) : 8.3 - 12.4
Max RF Power : 1W WG Type (WR-) : 90 Flange Type (GHz) : 39

GUNN POWER SUPPLY

Model X-110 Gunn Power supply comprises of an regulated DC power supply and a square wave generator, designed to operate Gunn-Oscillator model 2151 or 2152, and pin modulators model 451 respectively. The DC voltage is variable from 0 - 10V. The front panel meter monitors the gunn voltage and the current drawn by the Gunn diode. The square wave of generator is variable from 0 - 10V. in amplitude and 900 - 1100 Hz in frequency. The power supply has been so designed to protect Gunn diode from reverse voltage application over transient and low frequency oscillations by the negative resistance of the Gunn-diode.

ISOLATORS

The three port circulators Model 6021 may be converted into isolators by terminating one of its port into matched load. these will work over the frequency range of circulators. These are well matched devices offering low forward insertion loss and high reverse isolation.



Model No. : X - 6022 Frequency Range (GHz) : 8.6 - 12.2
Min Isolation (dB) : 20 Max Insertion Loss (dB) : 0.4 Max VSWR : 1.20 .

Thus all the microwave components were studied in detail. **REVIEW QUESTIONS**

1. What is microwave?
2. Mention the frequency band for a millimeter wave.
3. List some of IEEE microwave frequency bands.
4. List some of characteristic feature of microwave.
5. List some of the application of microwave technology.
6. Draw a simple microwave system.
7. What are waveguide `Tees'?
8. List the basic type of waveguide tees.
9. What is an isolator?
10. What is a circulator?
11. What is a directional coupler?
12. What is velocity modulation?
13. Mention the Principle used in Klystron?
14. When the o/p power of reflex klystron maximum?
15. What is meant by attenuator?

1. MODE CHARACTERISTICS OF REFLEX KLYSTRON

AIM

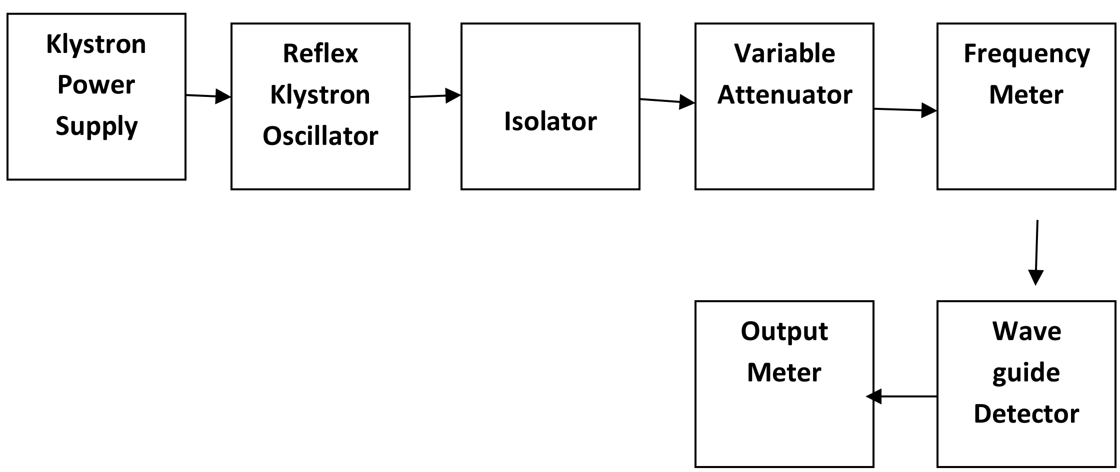
To study the Mode Characteristics of Reflex Klystron.

APPARATUS REQUIRED:

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

THEORY

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



Bench Set up Diagram

PROCEDURE

1) Assemble the components as shown in fig.
2) After following the necessary precautions, the Klystron Power Supply is switched ON.
3) To obtain peak voltage, the attenuator is positioned at it’s minimum attenuation.

4)Vary the repeller voltage from it's maximum negative value and increase it in steps on N
and record output power and frequency.
5) The frequency is measured by tuning the basic frequency meter to have a dip in the output
voltage each time.
6) The frequency meter is detuned before measuring the output power each time.
7) The mode characteristics of Reflex Klystron is plotted. (i.e. Output Voltage Vs Repeller voltage and Frequency Vs Repeller voltage)

BASIC PRECAUTIONS

1) During operation of Klystron, repeller does not carry any current and as such it may severely be damaged by electron bombardment. To protect repeller from such damage, the repeller negative voltage is always applied before anode voltage.
2). Therepeller voltage should be varied in one direction to avoid hysteres is in klystrons
3) The heater voltage should be applied first and cooling should be provided simultaneously after some time other voltages should be applied taking precaution
4) While measuring power, the frequency meter should be detained each time because there is a dip in the output power when the frequency is tuned.
5))To avoid loading of the klystron an isolator/attenuation should invariably be used between klystron and the rest of the set-up.

CALCULATIONS

(i) Knowing mode top voltages of two adjacent modes, mode numbers of the modes is computed from the equation,
N2/ N1= V2/ V1= (n+1)+3/4/n+3/4

where V1 and V2 are the values of repeller voltages required to operate the klystron in mode numbers N1 and N2.

(ii) Knowing mode number, transit time of each mode is calculated from
t 1 =(n+3/4)/f01= N1/f01

f01 → frequency of microwave operation in one mode.

(iii) ETR – Electronic tuning range i.e, the frequency band from one end of the mode to another is calculated by

ETR = f1max – f1min for N1 mode (GHz)
f1max – f1min → half power frequencies
(iv) ETS – Electronic tuning sensitivity

ETS = = f1max – f1min/V1max- V1min (MHz/V)
f1max, f1min → half power frequency
V1max, V1min→ corresponding repeller voltages for a particular mode.

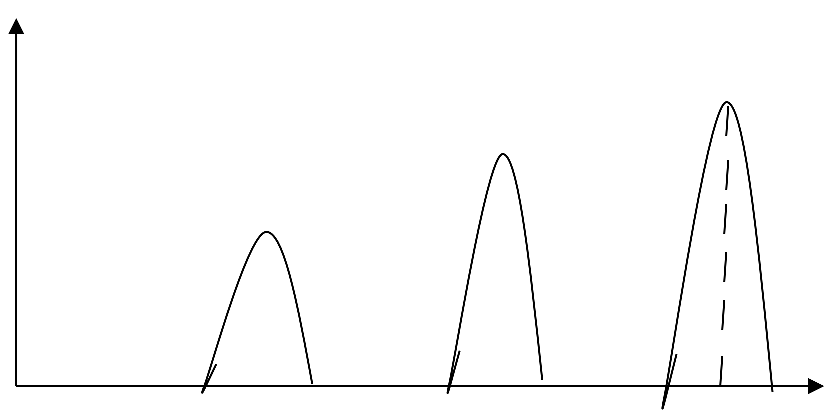
Result: The characteristics of Klystron Oscillator are verified and modes are calculated.

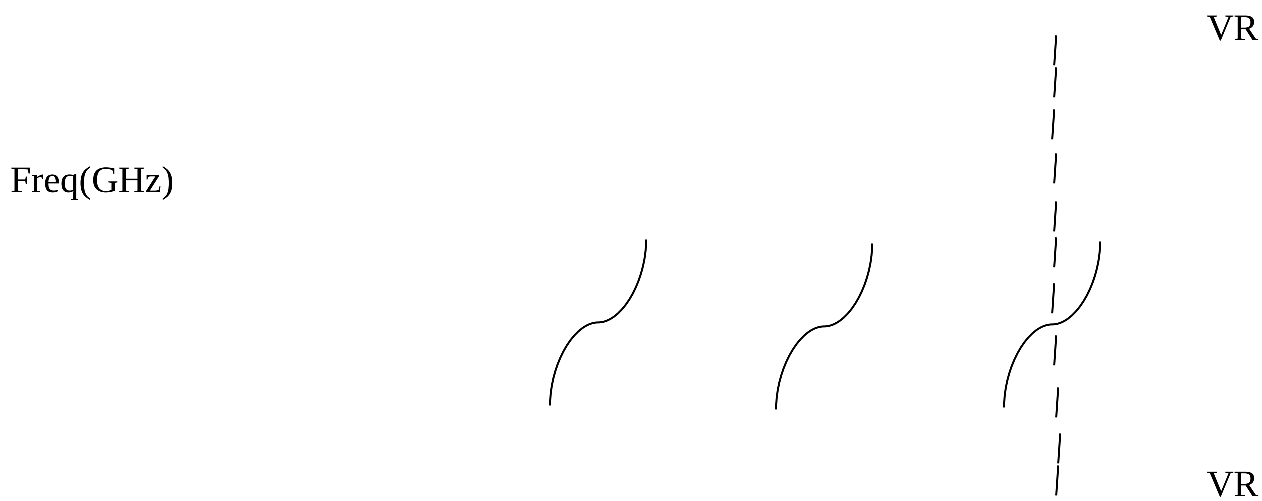
<u>Tabular column</u>

S.NO	Repeller Voltage(V)	Output (mA)	Frequency(GHz)

<u>Expected Graph:</u>

Output(mA)





REVIEW QUESTIONS

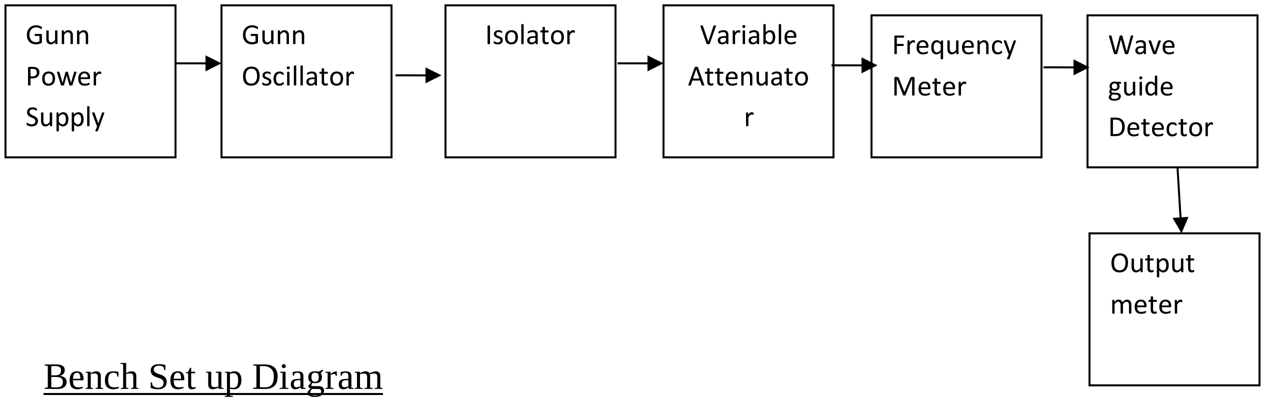
1. List two basic configuration of Klystron tubes.
2. What is velocity modulation?
3. List down the characteristic of two cavity klystron amplifier.
4. Write a note on mode of oscillations.
5. Draw the reflex klystron modes.
6. Higher order mode occur at _____________ repeller voltage.
7. When the o/p power of reflex klystron maximum?
8. List the application of reflex klystron.
9. What is transit time?
10. Which mode number is most frequently used? Why?

2. STUDY OF VI CHARACTERISTICS OF GUNN DIODE

AIM: Study of VI characteristics of Gunn diode.

APPARATUS:

X-Band Gunn Oscillator, Microwavebench, PIN modulator, Isolator, Frequency meter, Variable attenuator, Slotted section, Tunable probe, Detector Mount, Matched termination,Gunn power supply,Wave guide stand , BNC cable, Cooling fan.



Bench Set up Diagram

THEORY:

Some bulk semiconductor materials such as Gallium arsenide (GA As), Indium phosphide (InP) and Cadmium Telluride (CdTe) have two closely spaced energy bands in the conduction band. At lower electric field strengths in the material, most of the electrons will be transmitted into higher energy band. In the higher energy band the effective electron mass is longer and hence the electron mobility is lower than what it is in the lower energy band. Since the conductivity is directly proportional to the mobility there is an immediate range of electric field strengths for which the fraction of electrons that are transferred into higher energy low mobility conduction is such that the average mobility and hence conductivity decreases with an increase in the electric field strength. Thus there is a range of voltage over which the current decreases with the increasing voltage and a negative instrumental of resistance is displayed by the device. A Gunn device is also called a transferred electronic device since the negative resistance arises from the transfer of electrons from the lower to higher energy band. The oscillations that occur in the material with energy band structure noted above was discovered by J.B.GUNN. The probability of obtaining negative differential resistance had been predicted earlier by Ridley and Watkins.

PROCEDURE;

1. Turn the two knobs of the power supply fully anticlockwise.
2. Set the micrometer on the wave guide cavity gunn oscillator to approximately 10.9mm(approximate 9.5GHz)
3. Increase the voltage in (0.5V in steps up to l0V and record the corresponding current from the meter on the gunn power supply by switching alternately to current and voltage position.
4. Simultaneously note down the output current in the ammeter.

5. At each bias voltage, tune the frequency meter to observe the dip. Note the frequency reading.

6. Draw the following graphs between a) Voltage-ampere characteristics as observed in the power supply panel (b) Output current & bias voltage

(c) Frequency & bias voltage

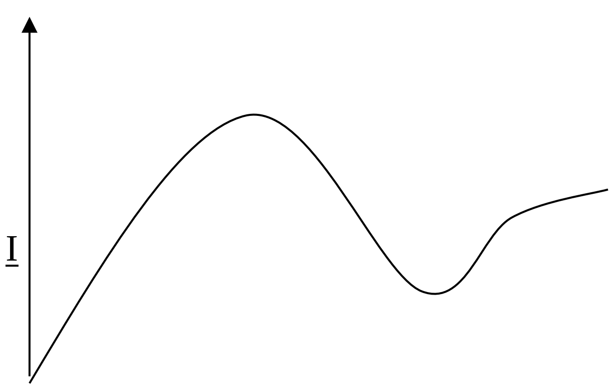
Now set the bias voltage to a value, that gives maximum output current at approximately 9.5GHz.

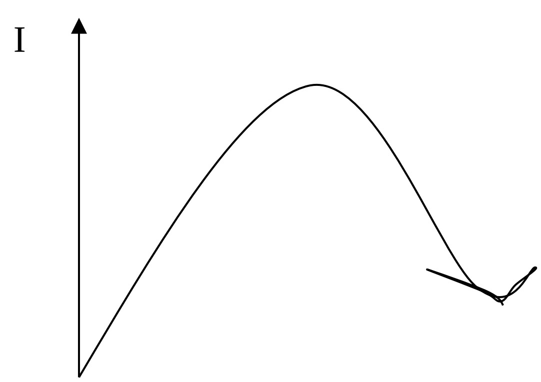
7.Vary the gunn oscillator frequency by changing the position of the micrometer reading and record corresponding current till11.5GHz(approximate).

Tabular column:

S.No	Voltage (Volts)	Current (mA)	Output (mA)	Frequency (GHz)

Expected Graphs:

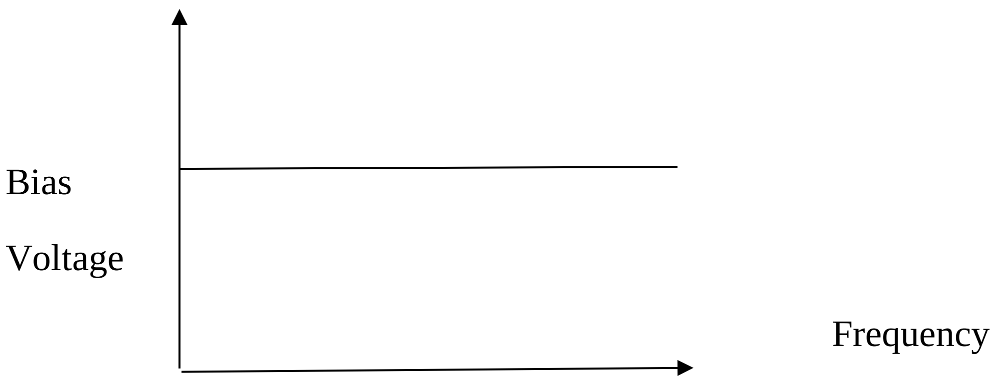




V

With Bench Setup

Without Bench Setup



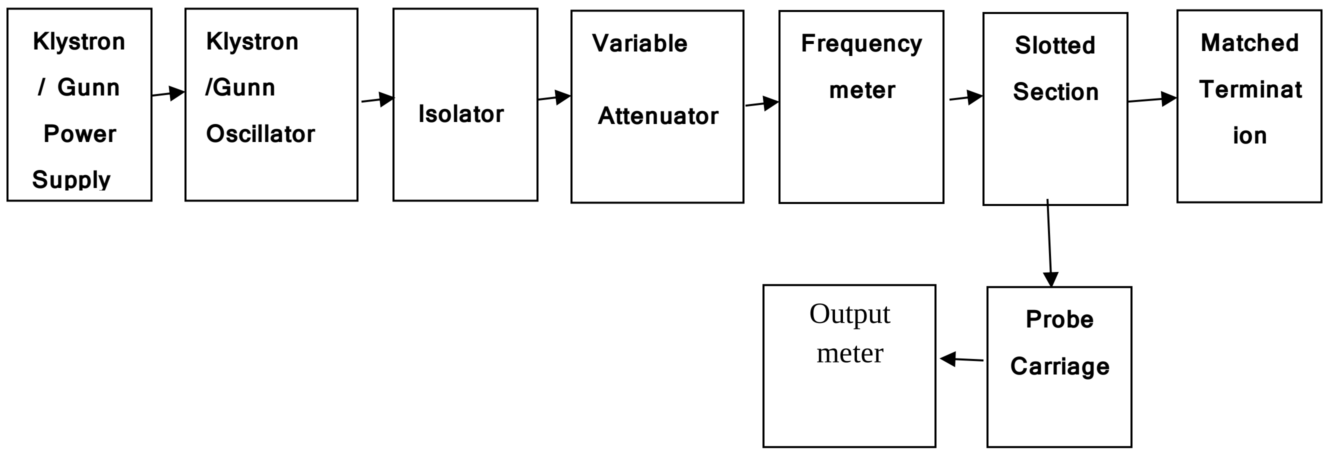
Result: The Characteristics of Gunn diode are verified and plotted

3.MEASUREMENT OF FREQUENCY AND GUIDE WAVE LENGTH

Aim: To determine the relationship between frequency and wavelength in a rectangular wave-guide.

Apparatus: Klystron power supply or Gunn Power supply, Klystron mount with klystron tube (R.K.O) or Gunn oscillator, Variable attenuator, Frequency meter, Slotted Section with Tunable Probe, wave guidedetector, Output Meter, Matched Termination

BENCH SETUP Diagram:



Theory:

For dominant mode TE10in the rectangular wave guide λo, λc, λg are related by this equation

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

Where λo is free space wave length

λg is guided wave length

λc is cutoff wave length

PROCEDURE:

1. Set up the equipment as shown in the figure

2. Set the variable attenuator at minimum.

3. Adjust the probe depth of the standing wave detector till a deflection is observed on the V.S.W.R.

4. Keep the range dB of the V.S.W.R. meter in the 40dB position.

5. Energize the klystron. Use the mode at about -160V reflector voltage module with 1khz square wave..

6. Adjust the reflector voltage to get maximum deflection on the V.S.W.R. meter.

FREQUENCY MEASUREMENT WITH THE FREQUENCY METER

1. Tune the frequency meter until a dip observed in the V.S.W.R. meter deflection. Tune the frequency meter to obtain minimum deflection.
2. Note the frequency meter setting.

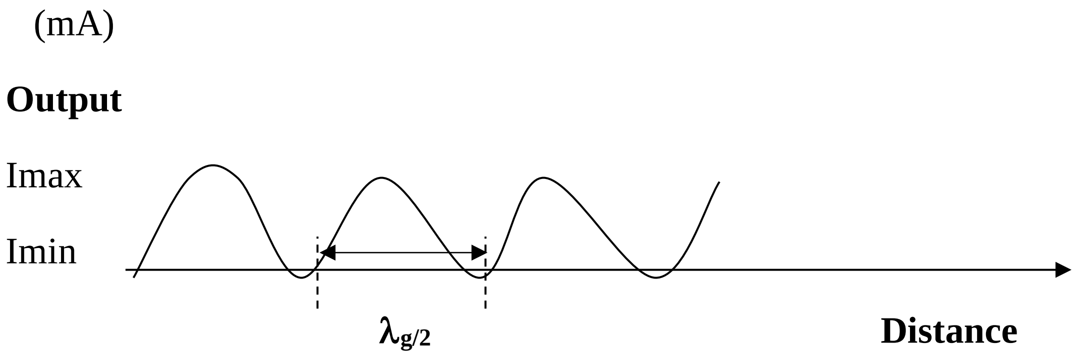
WAVE LENGTH MEASUREMENT:

1. Replace the termination with the variable short. Detune the frequency meter.
2. Move the probe along the line and watch the V.S.W.R. meter, the deflection will vary strongly.
3. Move the probe to a minimum deflection point. To get an accurate reading, it is necessary to increase the V.S.W.R. meter gain when close to a minimum.
4. Note and record the probe position.
5. Measure the wave-guide inner dimension. a = (22.860+0.046mm)or 2.29cm.
6. Calculate the frequency.

TABULAR COLUMN:

Sl. No.	$-V_R$	Output	Distance λ_g
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

<u>Graph:</u>

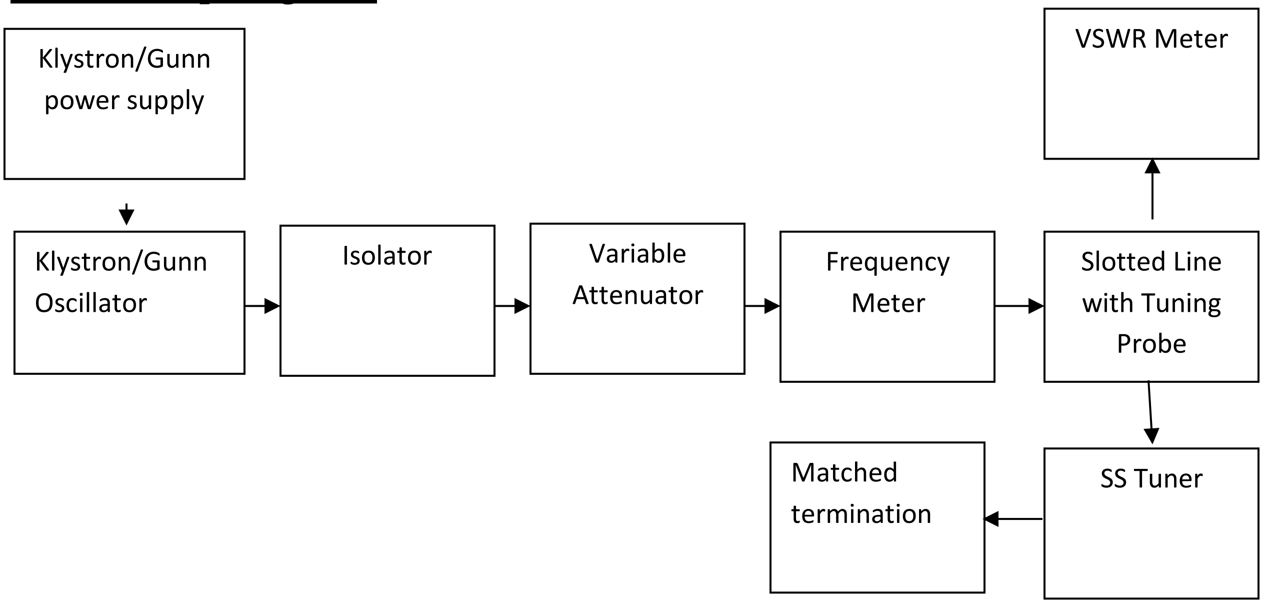


Result: The relation between waveguide parameters is verified

4.MEASUREMENT OF LOW AND HIGH VSWR

AIM: To determine the Standing-Wave Ratio and Reflection Coefficient.

Bench Set up diagram:



APPARATUS:

Klystron tube , Klystron power supply, VSWR meter , Klystron mount,Isolator(XI-621), frequency meter, Variable attenuator, Slotted line, Tunable probe, Waveguide stand, Movable short/Termination or any unknown load and BNC cable, SS tuner.

THEORY:

The electromagnetic field at any point of a transmission line (eg a wave guide) may be considered as the sum of two travelling waves. The incident wave propagates from the generator, the reflected wave propagates towards the generator .The reflected wave is set up by the reflection of the incident wave from a discontinuity on the line or from a load impedance not equal to the characteristic impedance of the line. The magnitude and phase of the reflected wave depends upon the amplitude and phase of the reflecting impedance. The magnitude also depends on the amplitude losses on the line. On a lossy line the reflected (and incident) wave will be attenuated. If the line is uniform and infinitely long there would be no reflected wave. The same applies for a line of finite length which is matched i.e. has a load equal to the characteristic impedance of the line. The presence of two travelling waves gives rise to standing wave along the line. The electrical (and mechanical) 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. Figure above shows the voltage standing wave patterns for different load impedances. The distance between two successive minima (or maxima) is half the wavelength on the transmission line. The ratio between the electrical fields of the reflected and incident wave is called the voltage reflection coefficient, being a vector, which means that is phase varies along the transmission line. The voltage standing wave ratio VSWR on a transmission line is defined as the ratio between maximum and minimum field strengths along the line.

$\rho = Er / Ei$,
$S = Emax / Emin = (Ei + Er) / (Ei - Er)$
Reflection Coefficient $=(S - 1) / (S+1)$

PROCEDURE:

1. Set up the equipment as shown in the figure.
2. Keep the variable attenuator in minimum position.
3. Keep the control knob of VSWR meter as below

Range - 40dB/50dB

I/p switch - low impedance

Meter switch - normal
Gain - mid position approximate.
4.. Keep the control knob of the Klystron power supply as below.

Beam voltage - OFF
Mod switch - AM
Beam voltage knob - fully anti-clockwise
Repeller voltage knob - fully clockwise
AM amplitude knob - around fully clockwise
AM frequency - mid position

5. Switch ON the Klystron power supply, VSWR meter and cooling fan.
6. Switch ON the beam voltage and set beam voltage at 250V.
7. Rotate the reflector voltage knob to get deflection in VSWR meter.
8. Tune the output by turning the reflector voltage, amplitude and frequency of AM modulation.
9. Tune plunger of klystron mount and probe for maximum deflection in VSWR meter.

10. If required change the range dB switch variable attenuator position and gain control knob to get deflection in the scale of VSWR meter.

A. Measurement of Low and Medium VSWR

1. Move the probe along the slotted section to get maximum deflection in VSWR meter.

2. Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates1.0 on normal VSWR scale.

3. Keep all the control knob as it is, move the probe to next minimum position. Read the VSWR on scale.

4. Repeat the above step for change of S.S tuner probe depth and record the corresponding SWR.

5. If the VSWR is between 3.2 and 10, change the range dB switch to next higher position and read SWR on second VSWR scale of 3 to 10.

B. Measurement of high VSWR (Double minimum method)

1. Get the depth of S.S tuner slightly more for maximum VSWR.

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

3. Adjust the VSWR meter gain control knob and variable attenuator to obtain a reading of 3 dB in the normal dB scale (0 to 10 dB) of VSWR meter.

4. Move the probe to the left on slotted line until full scale deflection is obtained on 0-10 dB scale. Note and record the probe position on slotted line let it be d1.

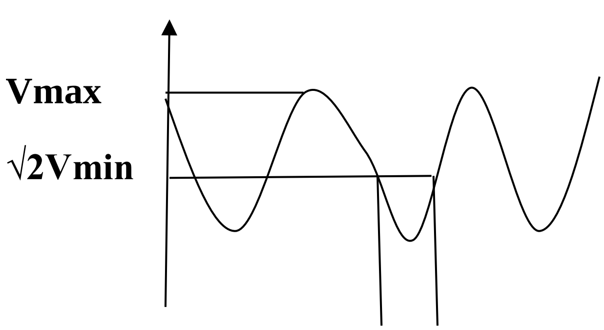
5. Repeat the step-3 and move the probe right along the slotted line until full scale deflection is obtained on 0 – 10 dB normal dB scale. Let it be d2.

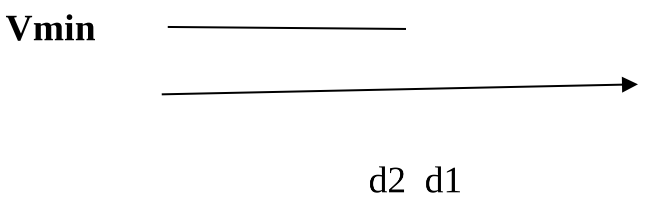
6. Repeat the S.S tuner and termination by movable short.

7. Measure the distance between two successive minima positions of the probe, twice the distance is guide wavelength λg.

8. Compute SWR from the following equation

$$\text{SWR} = \lambda g / \pi(d2 - d1)$$





OBSERVATIONS :

1. Low VSWR =
2. High VSWR =

Reflection coefficient= S-1/S+1 =

RESULT

CONCLUSION

5. IMPEDANCE MEASUREMENT

AIM: To measure unknown impedance using the Smith chart.

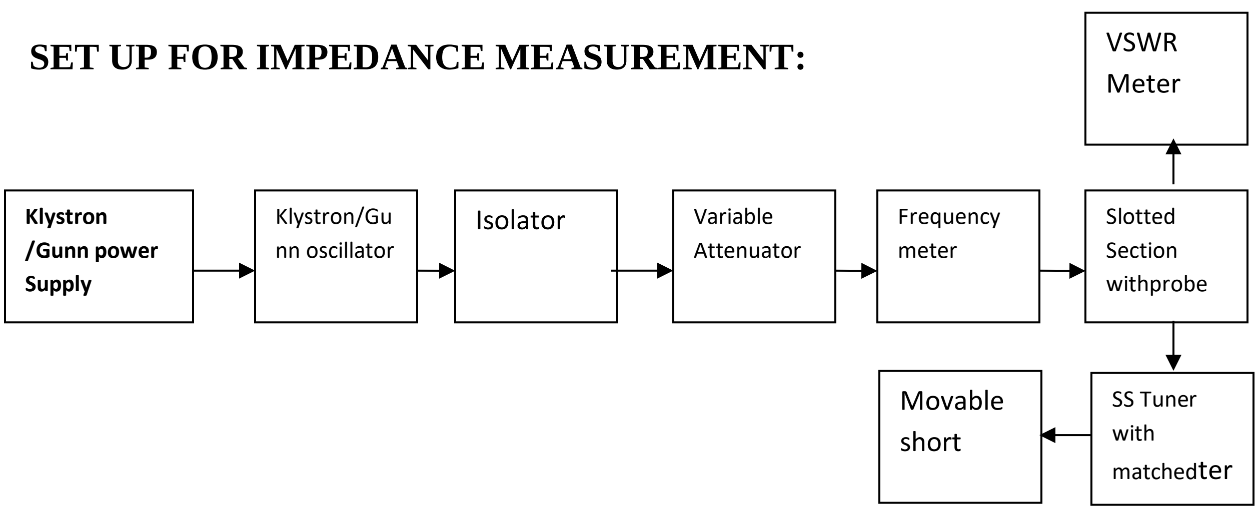
EQUIPMENT :

Klystron Tube, Klystron Power supply, Klystron Mount,Isolator, Frequency Meter, Variable Attenuator, Slotted line, VSWR Meter, Waveguide Stand, SS tuner, Movable Short/Termination

THEORY :

The impedance at any point on a transmission line can be written in the form R+jX. This SWR can be calculated S=(1+R) / (1-R)Where R is reflection coefficient = Z-Zo /Z+Zo where Z0 is the characteristic impedance of the waveguide at the operating frequency. Z is the load impedance. The unknown device is connected to the slotted section and the position of one minima is determined. The unknown device is replaced by Movable short to the slotted section. Two successive minima positions are noted. Twice the difference between the minima positions will be guide wavelength. One of the minima is used as reference for impedance measurement. Find the difference of reference minima and minima position obtained from unknown load. Let it be'd'. Take a Smith chart, taking 'l' as center; draw a circle of radius equal to 'S0'. Mark a point on circumference of Smith chart towards load side at a distance equal to d/λg. Join the center with this point. Find the point where it cuts the drawn circle. The coordinates of this point will show the normalized impedance of the load.

SET UP FOR IMPEDANCE MEASUREMENT:



PROCEDURE :

1. Set up the equipment as shown in the figure.
2. Set the variable attenuator at minimum position.
3. Keep the control knobs of VSWR Meter as below

Range - 50 dB position

Input switch - Crystal Low Impedance
Meter switch - Normal position
Gain (Coarse – fine) - Mid position
4. Keep the control knobs of Klystron power supply as below
Beam voltage switch -'OFF'
Mod switch - AM
Beam Voltage Knob - Fully anti-clockwise
Reflector voltage - Fully clockwise
AM – amplitude - Around fully clockwise
AM- Frequency Knob - Around Mid position
5. Switch 'ON' the Klystron power supply, VSWR meter and Cooling fan.

6. Switch 'ON' the Beam Voltage Switch position and set beam voltage at 300 V with the help of beam voltage knob.

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

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

9. Tune the plunger of Klystron Mount for maximum deflection.

10. Tune the reflector voltage knob for maximum deflection.

11. Tune the probe for maximum deflection in VSWR meter.

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

13. Keep the depth of the pin of SS Tuner around 3-4 mm and lock it.

14. Move the probe along the slotted section to get maximum deflection.

15. Adjust VSWR meter gain control knob and variable attenuator until the meter indicates 1.0 on the normal dB SWR scale.

16. Move the probe to next minima position and note down the SWR S0 on the scale. Also note down the probe position, let it be 'dx'.

17. Remove the SS Tuner and matched termination and place movable short at slotted section. The plunger of short should be at zero.

18. Note the position of two successive minima position. Let it be d1 and d2. Hence $\lambda g = 2(d1 - d2)$.

$d = dx - d1$

19. Calculate $d/\lambda g$.

20. Find out the normalized impedance as described in the theory section.

21. Repeat the same experiment for other frequency if required.

OBSERVATIONS :

d1 = mm.

d2 = mm

λg = 2(d1 – d2) mm.

SWR = S0 =

d =

$d/\lambda g$ =

Normalized impedance =

RESULT :

CONCLUSION

PRECAUTIONS :

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
2. While modulating repeller should never become positive with respect to cavity.
3. Cooling should be provided to Reflex klystron

6.To find parameters of Directional coupler.

AIM

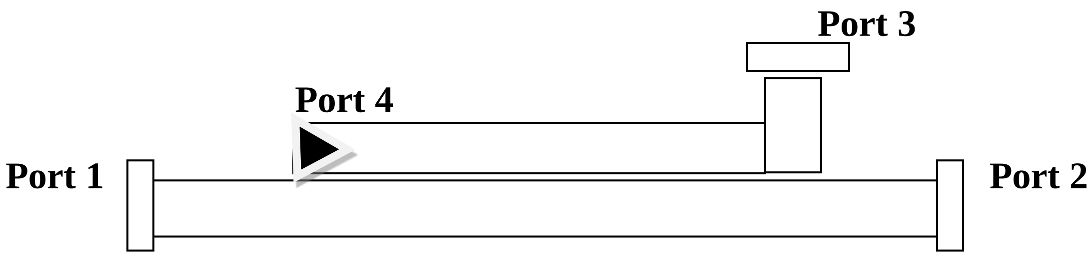
To study the function of multi hole directional coupler by measuring the following parameters.

1. Coupling factor   4 Isolation Loss
2. Insertion loss
3. Directivity

APPARATUS

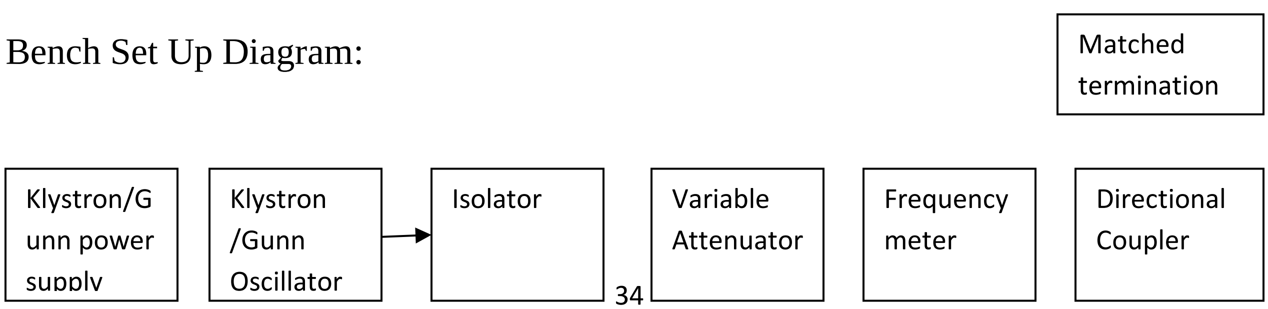
Microwave source (Klystron or Gunn diode), Isolator, Frequency meter, Variable attenuator, Slotted line, Tunable probe, Detector mount, Matched termination, MHD coupler, Waveguide Stand, Cables and Accessories, VSWR meter.

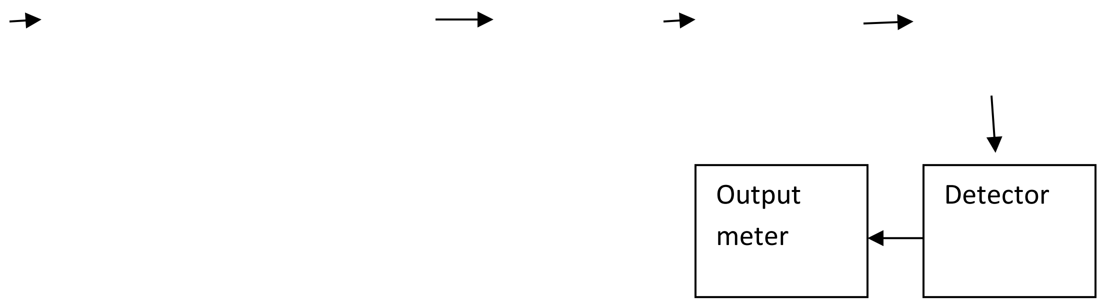
FIG.1 DIRECTIONAL COUPLER



A directional coupler is a device which is used to measure the incident and reflected wave separately. It consists of two transmission lines the main arm and the auxiliary arm. Electromagnetically coupled to each other refers to the fig. The power entering in the main arm gets divided between port 2 and 3 and almost no power comes out in port 4 power entering at port 2 is divided between port 1 and 4.
The coupling factor is defined as
Coupling (dB) = 10 log10 (P1 / P3) where port 2 is terminated.
Isolation (dB) = 10 log 10(P2 / P3) where P1 is matched with built in termination and power entering at port 1 the directivity of the coupler is a measure of separation between incident wave and the reflected wave directivity is measured indirectly as follows
Hence directivity D (dB) = 1-c = 10log10 (P2 / P1)
Main line insertion loss is the attenuation introduced in the transmission line by insertion of coupler. It is defined as
Insertion loss (dB) = 10log10 (P1 / P2).

Bench Set Up Diagram:





PROCEDURE

1. Set up the components and equipment as shown in the figure.
2. Energize the microwave source for particular frequency of operation.
3. Remove the multi hole directional coupler and connect the detector mount of the frequency meter. Tune the detector for maximum output.
4. 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 (reference level let X).
5. Insert the directional coupler as shown in second 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 measurement.
6. Note down the reading on VSWR meter on the scale with help of range – dB switch if required let it be Y.
7. Calculate coupling factor which will be X-Y = C (dB).
8. Now carefully disconnect the detector from the auxiliary port 3 and match termination from point 2 without disturbing the set up.
9. Connect the matched termination to the auxiliary port 3 and detector to port 2 and measure the reading on VSWR meter, suppose it is Z.
10. Compute the insertion loss X-Z in dB.
11. Repeat the steps from 1 to 4.
12. Connect the directional coupler in the reverse direction 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.
13. Measure and note down the reading on VSWR meter. Let it be Yd. X – Yd gives isolation.
14. Compute the directivity as Y – Yd.
15. Repeat the same for other frequencies.

OBSERVATIONS :

1. Check the condition Isolation Loss = Coupling factor + Directivity

Insertion Loss= 10 log (Pi/Pt)

Coupling factor = 10 log (Pi/Pf)

Directivity =10 log (Pf/Pb)

Isolation Loss= 10 log (Pi/Pb)

Where Pi = input power, Pt = transmitted power Pf = forward power,

Pb =backward power

7.CHARACTERISTICS OF WAVEGUIDE TEES.

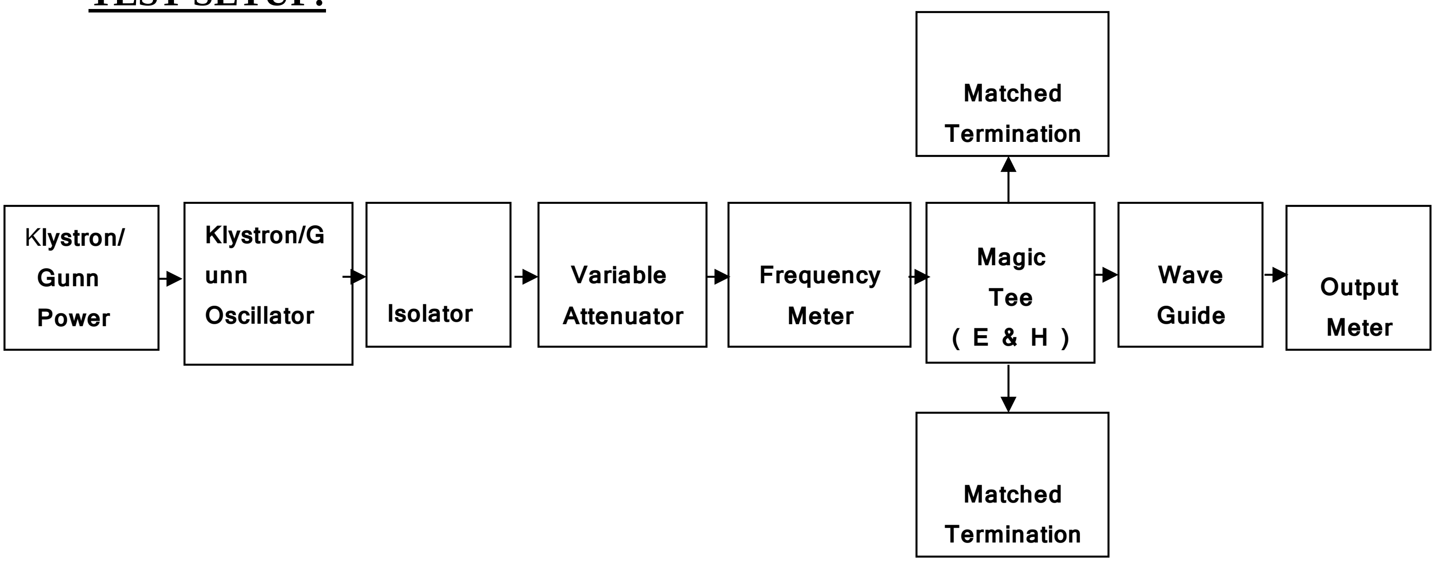
AIM: To study the characteristics of waveguide Tees.

EQUIPMENT:

1. Test set up(see previous experiment)
2. Ammeter
3. E-plane Tee

4. H-plane Tee
   &
5. Magic Tee

TEST SETUP:



PROCEDURE:

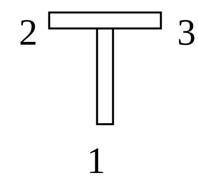
Measure the output current in the test set up and note it as I1 after adjusting the reflector voltage to the maximum output.

TEE-JUNCTION:

1. Insert the tee junction before detector mount.
2. Measure the output current at the other ports and note it as I2&I3.
3. Observe.

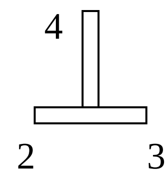
In case of E-Tee junction

I2=I3 but out of phase i.e (I2= -I3)



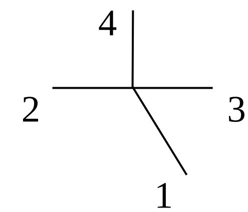
In case of H-Tee junction

(I2= I3) i.e I2=I3 in phase



In case of E H-Tee junction or Magic Tee

$$[S] = \begin{pmatrix} S11 & S12 & S13 & S14 \\ S21 & S22 & S23 & S24 \\ S31 & S32 & S33 & S34 \\ S41 & S42 & S43 & S44 \end{pmatrix}$$



(I1=I4) i.e I1=I4, I2=0 input at 3 (i.e.I3)

4. Vary the frequency of oscillation and repeat step 3.

QUESTION:

1. Make out the differences between E-Tee, H-Tee & E-H Tee.
2. Change the frequency from f1 to f6 & repeat the experiment procedure at different distance (d) & plot the pattern on polar graph paper & determine 3dB beam width & directivity.

8.CHARACTERISTICS OF THE CIRCULATOR

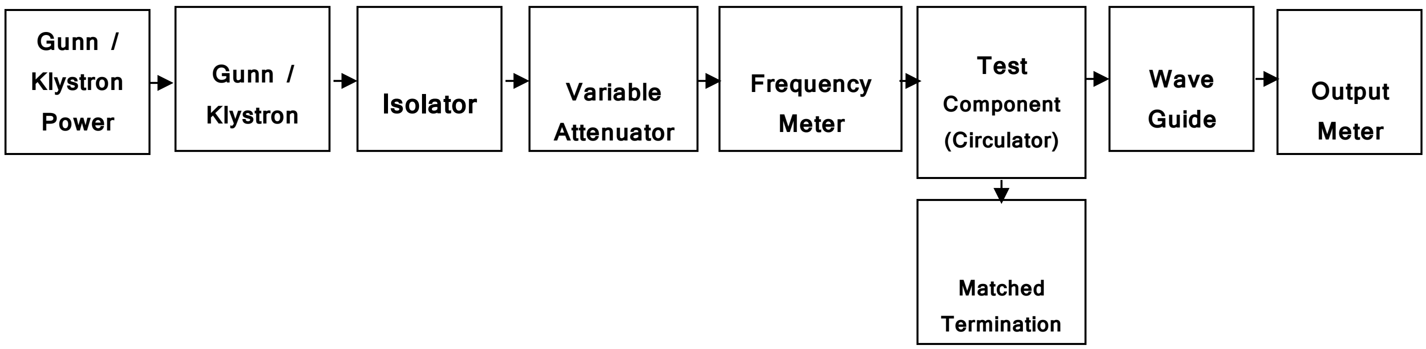
AIM: To calculate S matrix of the circulators.

EQUIPMENT:

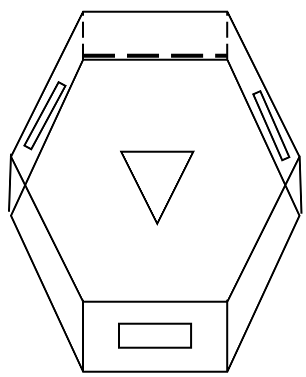
1. Test set up
2. Ammeter

3. Circulators

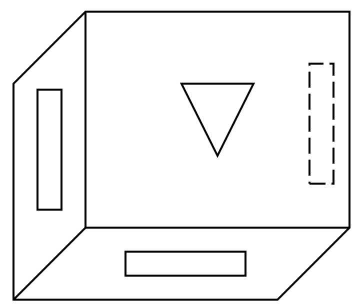
TEST SETUP:



Circulator



Y – Type



T – Type

$$[S] = \begin{pmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{pmatrix}$$

EXPERIMENTAL PROCEDURE ;

1. Switch on the KPS after keeping reflection voltage knob to maximum and beam voltage knob to minimum. .
2. Allow sufficient time & increase beam voltage to 290V or 300V.
3. Decrease the reflector voltage and the maximum current at the output. Note it as I1.

CIRCULATOR:

1. Connect the circulator before wave guide detector.
2. Measure currents at port B& port C by keeping matched termination at one port while measuring at the other port.
3. Calculate Isolation & Insertion losses.
4. By varying frequency repeat the steps 2 & 3 for at least four different values. Use calibration chart to measure frequency.

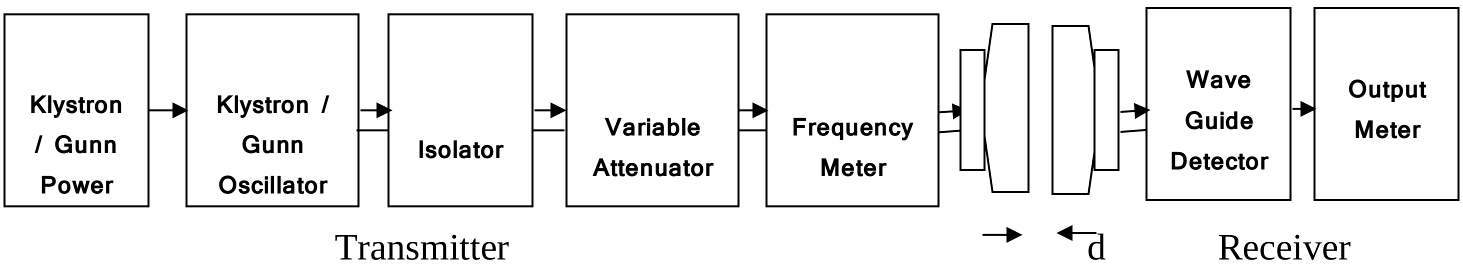
9. RADIATION PATTERN MEASUREMENT OF AN HORN ANTENNA

AIM: To determine the relationship between transmitting antenna & receiving antenna and to measure radiation pattern.

EQUIPMENT:

1. Klystron power supply.
2. Klystron mount with klystron tube (R. .K.O)
3. Isolator .
4. Frequency meter
5. Slotted section
6. Output meter
7. Crystal detector
8. Horn antennas

TEST SETUP:



THEORY

A horn antenna may be regarded as a flared out or opened out wave guide. A wave guide is capable of radiating radiation into open space provided the same is excited at one end and opened at the other end. However, the radiation is much greater through wave guide than the 2 wire transmission line. To overcome reflection and diffraction in the wave guide, the mouth of the waveguide is opened out which assumes the shape of a electromagnetic horn. If the wave guide is terminated by any type of horn, the abrupt discontinuity existed is replaced by a gradual transformation, then all the energy incident in forward direction in the waveguide will now be radiated, provided the impedance matching is proper. This improves directivity and reduces diffraction. If flaring is done only in one direction, then sectorial horn is produced. If flaring is done along both the walls, then pyramidal horn is obtained. By flaring the walls of the circular waveguide, a concial horn is formed. The fields inside the waveguide propagate in the same manner as in free space, but on reaching the mouth of the waveguide, these propagating fields continue to propagate in the same general direction but also starts spreading laterally and the wave front eventually becomes spherical. However this may be treated as transition region where the change over from the guided propagation to free space propagation occurs.

Since the waveguide impedance & free space impedance are not equal, hence to avoid standing wave ratio, flaring of walls of waveguide is done which besides matching of impedance also provide concentrated radiation pattern(ie)greater directivity and narrower beam width. It is the flared structure that is given the name electro magnetic horn radiator. The function is to produce a uniform phase front with a larger aperture in comparison to waveguide and thus directivity is greater. If flare angle is very large, the wavefront on the mouth of the horn will be curved rather than plane. This will result in non-uniform phase distribution over the aperture, resulting in increased beam width and reduced directivity, and vice versa occurs if the flare angle is very small. The directivity of the horn antenna is given as $D = 7.5\ A/\lambda 2$ where A area of horn mouth opening. Horn antennas are extensively used at microwave frequencies under the condition that power gain needed is moderate.

PROCEDURE:

1. Measure the output current in the test set up of transmitter output a frequency(f1) & note it as I1maximum output.

2. the given attenuator as in the set up and measure the output (power) current & note it as Io, for the frequency(f1) & repeat the same experimental procedure for various frequencies upto (f6)Place Connect the antenna, after the Frequency meter.
3. Connect similar antenna with W.G. detector to the receiving circuit.

4. Turn the receiving Antenna and note the reading for the Near field and also far field pattern.

Tabular column:

Near Field d_1 =

Sl No.	Angle	Output

Far Field d_2 =

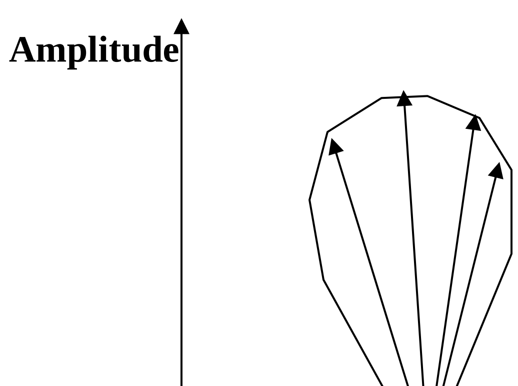
Sl No.	Angle	Output

1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

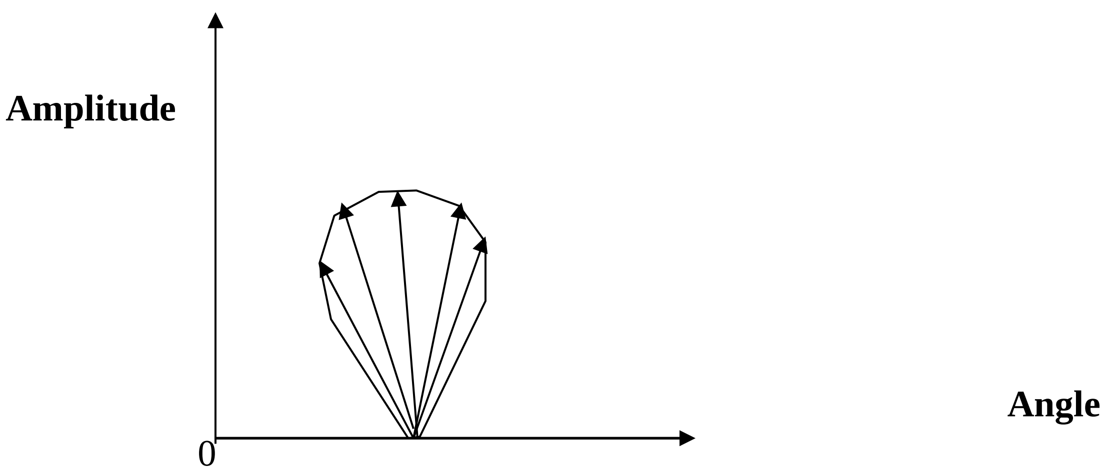
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Expected Graphs:

Near field pattern



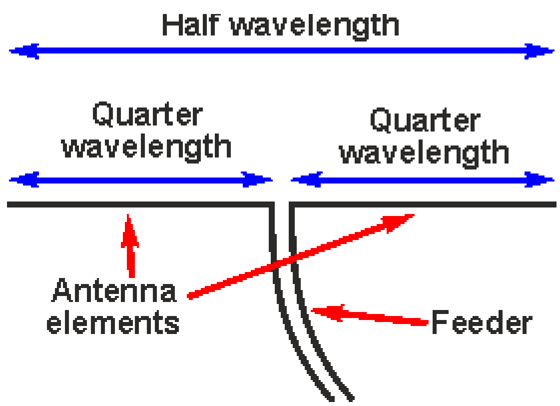
<u>Far field pattern:</u>



10. Study of various antennas like dipoles, loops, Yagi antenna, log periodic antenna and their radiation pattern.

Basic dipole antenna

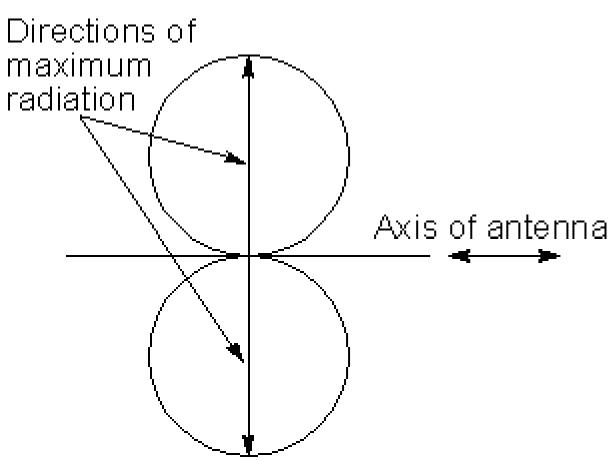
As seen the antenna consists of a radiating element that is split, normally in the centre to allow a feeder to apply power to it from a transmitter, or to take power from it to a receiver. The length of the radiating element determines many of the properties of the dipole antenna from its impedance, centre operating frequency, etc. As such this is an important feature of the antenna.Often the term dipole antenna tends to indicate a half wave dipole. This is by far the most widely used length for a dipole. It forms a resonant circuit which resonates where the electrical length is half a wavelength long - the electrical length differs from the wavelength of the signal in free space because of a number of the effects of the radiating element on the signal and it is very slightly shorter than the signal e/m wavelength in free space..



Half wave dipole antenna

Half wave dipole radiation pattern

The radiation pattern of a half wave dipole antenna that the direction of maximum sensitivity or radiation is at right angles to the axis of the RF antenna. The radiation falls to zero along the axis of the RF antenna as might be expected.



Radiation pattern of a half wave dipole antenna in free space

In a three dimensional plot, the radiation pattern envelope for points of equal radiation intensity for a doughnut type shape, with the axis of the antenna passing through the hole in the centre of the doughnut.

Small Loop Antennas

The small loop antenna is a closed loop as shown in Figure 1. These antennas have low radiation resistance and high reactance, so that their impedance is difficult to match to a transmitter. As a result, these antennas are most often used as receive antennas, where impedance mismatch loss can be tolerated.

The radius is a, and is assumed to be much smaller than a wavelength ($a \ll \lambda$). The loop lies in the x-y plane.

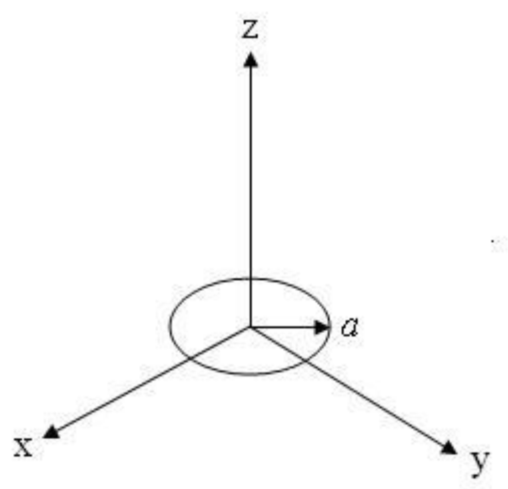


Figure 1. Small loop antenna.

Since the loop is electrically small, the current within the loop can be approximated as being constant along the loop, so that $I = I_0$.

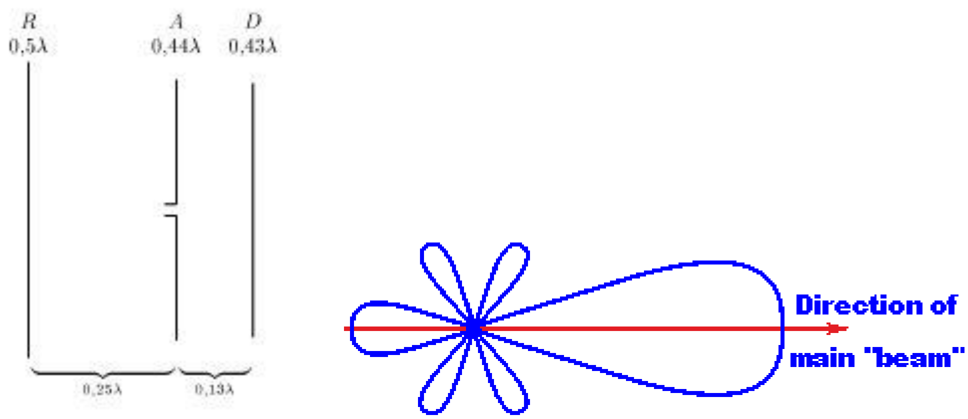
The fields from a small circular loop are given by:

$$E_\phi = \frac{\eta k^2 a^2 I_0 e^{-jkr} \sin\theta}{4r}$$

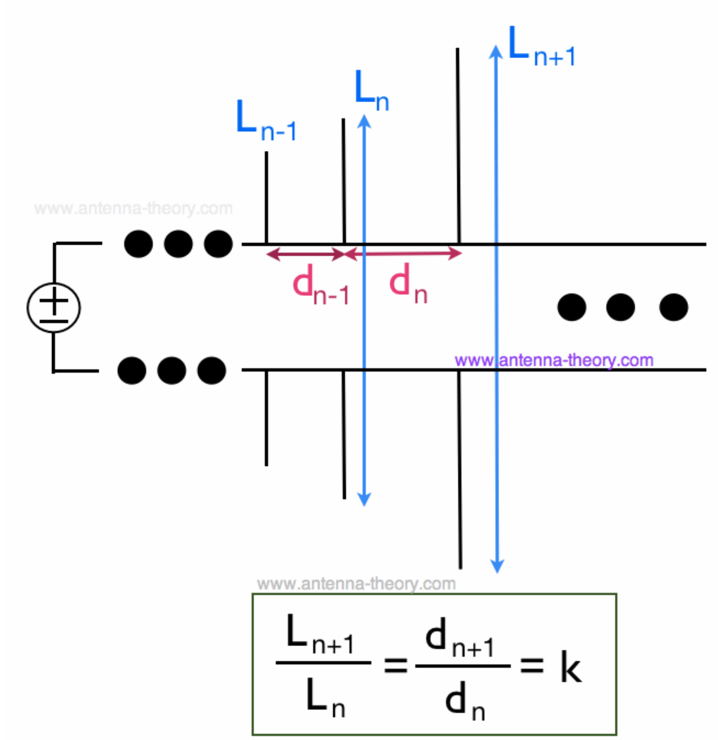
$$H_\theta = \frac{-E_\phi}{\eta}$$

Yagi-Uda Antenna

A **Yagi-Uda antenna**, commonly known simply as a **Yagi antenna**, is a directional antenna consisting of multiple parallel dipole elements in a line, usually made of metal rods. It consists of a single driven element connected to the transmitter or receiver with a transmission line, and additional parasitic elements: a so-called *reflector* and one or more *directors*. The reflector element is slightly longer than the driven dipole, whereas the directors are a little shorter.[6] This design achieves a very substantial increase in the antenna's directionality and gain compared to a simple dipole.



A **log-periodic antenna** (**LP**), also known as a **log-periodic array** or **aerial**, is a multi-element, directional, narrow-beam antenna that operates over a wide band of frequencies, a broad bandwidth. A particular form of the log-periodic design, the **log-periodic dipole array** or **LPDA**, is often used in television antennas that work in the VHF band. An LPDA antenna consists of a number of half-wave dipole driven elements of gradually increasing length, each consisting of a pair of metal rods. The dipoles are mounted close together in a line, connected in parallel to the feed line with alternating phase.


L_{n+1}
L_n
L_{n-1}
www.antenna-theory.com
d_{n-1}
d_n
www.antenna-theory.com
www.antenna-theory.com
$$\frac{L_{n+1}}{L_n} = \frac{d_{n+1}}{d_n} = k$$