Microwave Test Bench

NV9000

Learning Material

Ver 1.2

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Designed & Manufactured by:

Nvis Technologies Pvt. Ltd.

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Microwave Test Bench
NV9000
Table of Contents

Klystron Power Supply NV102

Klystron Power Supply, is a state-of the-art solid-state, regulated power supply for operating low power Klystrons such as 2K25.

It incorporates a number of proprietary features:

1. Regulated Beam Supply and Repeller Supply voltages.
2. LED Digital metering for Beam voltage, current and Repeller voltage.
3. Compact and Reliable.
4. Modular construction for easy maintenance.

In addition to AM and FM modulation of Beam current, a provision for externally modulating the Klystron supply with desired signal waveform has been provided.

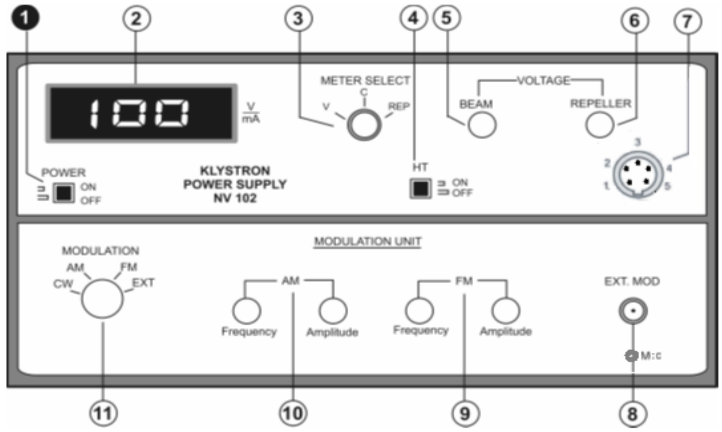
Klystron Power supply utilizes the quality components and rugged construction. A careful handling of the instrument will provide years of trouble free service. The equipment is divided in two parts one is high voltage unit and other is modulation unit. It makes it user friendly.

Technical Specifications

Beam Supply	:	**Voltage**	:	240 - 420 VDC, Variable
		Current	:	50 mA
		Regulation	:	0.5 % for 10% I/P variation
		Ripple	:	< 5m Vrms

Repeller Supply	:	-18V to -270V DC Variable	
		Regulation: 0.25%, for 10% I/P variation	
Filament Supply	:	6.3 VDC (adjustable on rear panel)	
Over-Load Trip Current	:	65mA	
Modulation	:	AM (Square)	FM (Saw-tooth)
Frequency Range		180-1450 HZ ± 5%,	72-195 Hz ± 5%
Amplitude		0-110 Vpp	0-40 Vpp
External	:	Through External Modulating Signal	
Display	:	Digital display for	
		1. Beam voltage	
		2. Beam Current	
		3. Repeller voltage	
Modulation Slector	:	FM/AM/CW/Ext	
3 ½ Digital Panel Meter	:	2V	
Meter Selector	:	Beam Voltage (V)/ Current (I)/ Rep. (Repeller)	
Connectors	:	**a.** 5-Pin connector	
		b. BNC for External Modulation	
Power Supply	:	230 V AC ± 10%, 50Hz	
Dimensions (mm)	:	345 x 283 x 153	

Front Panel Control



1. **Power:** Push button switch for supplying the power to instrument.
2. **Display:** for monitoring beam voltage (in volts), Repeller voltage and beam current (mA).

   Beam voltage: 240 V to 420 V DC

   Repeller voltage: -18 V to -270 V DC

   Beam current: 0 to 50 mA
3. **Meter Select Switch:** For selecting display mode in V – shows Beam voltage (volts), I – shows Beam current (mA) & REP – shows Repeller voltage in volts.
4. **HT:** Output ‘On’/‘Off’ switch.
5. **Beam voltage:** Adjust potentiometer, it is vary from 240 to 420 V DC.
6. **Repeller voltage:** Adjust potentiometer; it is vary from -18V to -270V DC.
7. **5-Pin connector :** Pin 1 - 5 = Beam voltage

   Pin 3 - 5 = Rep. Voltage

   Pin 2 – 4 = Heater voltage
8. **Ext. Mode:** To provide external modulating signal.
9. **FM Modulation:** Frequency potentiometer controls the frequency or the sweep modulating signal (50–150 Hz). Amplitude potentiometer controls the amplitude or sweep modulating signal (0-60Vpp)
10. **AM Modulation:** Frequency potentiometer controls the frequency or the square wave modulating signal (500 – 2000 Hz). Amplitude potentiometer controls the amplitude or square wave modulating signal (0 – 110Vpp).
11. **Modulation Selection switch:** For selecting modulation types CW mode – No modulation signal applied to the beam voltage. AM mode–A square wave modulating signal is applied to the beam voltage. FM mode–A sweep modulation is applied to the beam voltage, Ext mode–External modulating signal is accepted for modulation or beam current through BNC connector.
12. **Earphone Socket:** Here we can connect a MIC to give audio signal as a modulating signal.

Rear Panel Control

1. **Ext. /Audio:** If Ext selected then you can give any ext. modulating signal to EXT. BNC given at a front panel. If Audio is selected you can connect a microphone for giving modulating signal to Audio input socket on front panel.
2. **FM O/P**: For observing saw tooth signal which is used for FM.
3. **Heater Adjust:** After unsealing the cap we can change the heater supply.

SWR Meter NV103A

The model **NV 103A SWR meter** is a high gain low noise, tuned voltmeter operating at fixed frequency. It is designed for making standing wave measurement in conjunction with a suitable detector and slotted line or wave guide section. It may be used as null detector in bridge circuit and as fixed frequency indicator. It is calibrated to indicate directly SWR or dB when used with square law devices such as crystal diode. It is adjusted for operation at 980Hz to 1020 Hz to avoid harmonics of the line frequency.

Technical Specifications

Display	:	LCD (16 X 2)
Sensitivity	:	0.1μV for 200Ω input impedance
Noise Level	:	Less than 0.02μV
Range	:	0 – 60dB in 10dB steps
Input	:	Un-biased low and high impedance crystal biased crystal (200Ω and 200K)
Display Select	:	SWR 1 – 9
		dB 0 – 10
Modes	:	Normal
		Audio
		PC (this mode can be used only with Gunn based bench)
Gain Control	:	Adjusts the reference level, variable range 0-10dB (approximately)
Input Connector	:	BNC (F)
Input Frequency	:	1000Hz ± 10%
Power	:	230 Volts AC ± 10%, 50Hz
Dimension (mm)	:	300 × 222 × 122

Front Panel Control

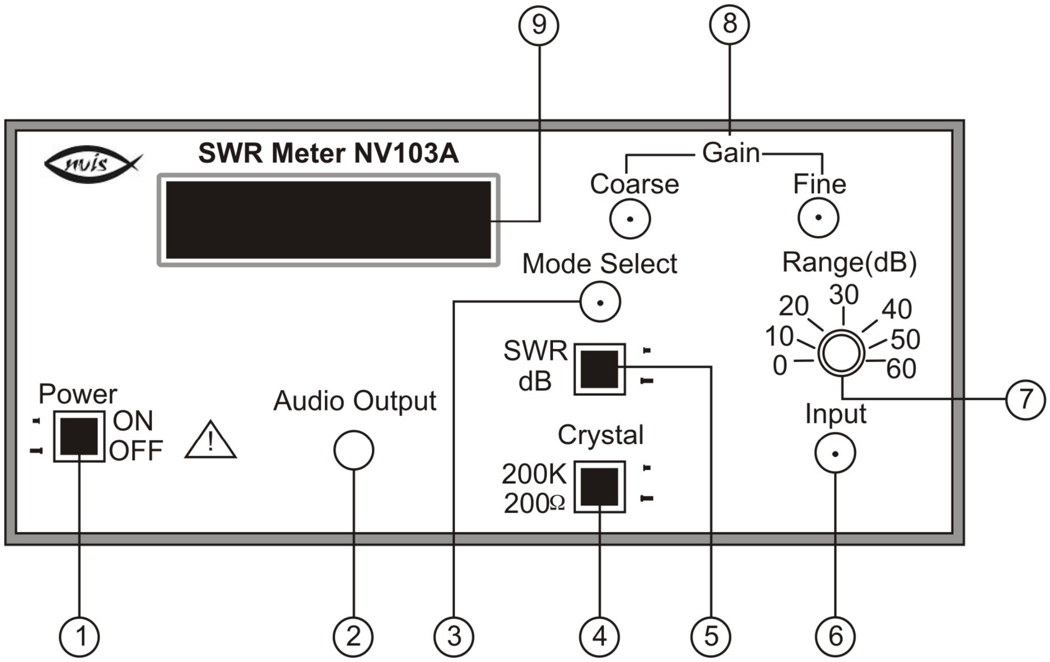


Figure 2

1. **Power:** Push button switch for supplying power to instrument.
2. **Audio Output:** This socket is provided for connecting headphone.
3. **Mode select:** This switch is given to select different modes of SWR meter.

   Modes are:

   Normal: In this mode the 1 KHz square wave detected output is given to input of SWR meter. All the measurement of gain and SWR should be measure in this mode.

   Audio: Select this mode if the input of pin modulator is an audio signal.

   PC: Select this mode if the input of PIN modulator is PC data. (This mode can be used only with Gunn based bench)
4. **Crystal:** It is an input impedance selector switch for low & high inputs i.e. High 200K- Low 200Ω.
5. **SWR/dB:** This switch provided to select display modes either it reads in dB power or SWR of device.
6. **Input:** BNC (Female) connector for connecting signal to be measured.
7. **Range Switch:** A seven position attenuator minimum in 10 dB steps.
8. **Gain Coarse:** Control for adjustments of meter or any other convenient reading.

   Gain Fine: Control for fine adjustments of meter or any other convenient reading.
9. **LCD display in SWR & dB:** LCD display, for measuring SWR and gain.

Rear Panel Control

1. **PC Interface:** This is provided for connecting RS232 cable for pc communication.
2. **Comparator Adjust:** For PC to PC communication adjusts the potentiometer such that output BNC should give the received PC signal which is transmitted from transmitter PC.
3. **Output :** Detected signal can be observed on CRO from output BNC,

Operating Theory and Instructions

Auxiliary equipment required:
For SWR measurement, following equipments is required:

1. **Signal Source :**
   The signal source should cover the desired frequency range and be amplitude modulated at operating frequency of the SWR meter. Generally square wave modulation is used which reduces to a minimum the effects of harmonic and frequency modulation. In any application, it is necessary to minimize interaction between the oscillator and the load. In these cases, an isolation device should be used.
2. **Cables or waveguides :**
   The cable or the wave guide used for connecting the source to a slotted match the source impendence over the desired frequency range.
3. **Slotted Section :**
   The slotted section should cover the desired frequency and be equipped with an accurate scale or indicator.
4. **Detector :**
   The detector should be square law (out put proportional to RF power input) device such as a Barretter or a crystal diode operated at low signal level. A Barretter is reasonable square law when used at low signal level but in general this cannot be said in all cases with crystal diode. However the sensitivity of crystal is considerably better than with Barretters so that crystals are widely used as detectors for SWR measurements.
5. **Known loads :**
   Various termination are required (i.e. a fixed and a movable short circuit) to establish reference points and to aid in calibrating the test setup.

Techniques in Measurements

Keep SWR/ dB switch at dB position.

Basically, the measurement of a standing wave ratio consists of the probe carriage at a voltage maximum position and setting the gain to obtain a reading of 0.0dB i.e. SWR=1.0. By keeping SWR/dB switch at SWR position we can read SWR directly. The probe carriage is then moves along with the slotted line to a voltage minimum or gain minimum and now note the corresponding reading at SWR position. The SWR is shown directly on the LCD display.

But there are other cases, specially in design and development, where complete knowledge of the terminating equipment is desired. This can be obtained by measuring SWR and phase in the standing wave pattern.

Generally, the impedance characteristic of the load is obtained by measuring the position of the voltage minimum. This position is compared to a shifted position of the voltage minimum which occurs when a known load replaces the load under test at reference point on the slotted line. The distance between these two minima is entered on a smith chart and the reactive component is determined. For convenience the known load usually a short circuit or shorting plate and the reference point is the load connection.

Detector probe penetration:
A general rule in slotted line work is that the penetration of a sampling probe into the line should be held to a minimum. The power extracted by the sampling probe caused distortion in the standing-wave pattern. This effect usually becomes greater as probe penetration is increased and can be explained by considering the probe as and admittance shunting the line.

Impedance in the standing-wave pattern varies along the line from maximum at a voltage maximum to a minimum at a voltage minimum. The shunt admittance introduced by the probe lowers these impedance this causing the measured SWR to be lower than the true SWR and shifting both the maxima & minima from their neutral position. The shift will be greater at a voltage maximum that at a voltage minimum.

Besides absorbing power and affecting the standing-wave pattern the probe will also cause reflections in the line. These reflections will travel towards the signal source. If the signal source is not matched, these reflection are re-fleeted towards the load and will cause additional errors in low SWR measurements.

An exception to the minimum penetration rule occurs when it is desired to examine in details a voltage minimum in a high SWR measurement. For this work, greater probe penetration can be tolerated because the voltage minimum corresponds to low impedance point in the line. However only at a voltage minimum you can tolerate substantial probe penetration.

Precaution when crystal detectors used :

With unloaded crystal, select the input impedance which gives maximum sensitivity. Usually, the XTAL 200 ohm position will give the best sensitivity. However, some crystal diodes may given higher output in the XTAL-200 K ohms position. Maximum sensitivity is desirable so probe penetration in the slotted line can be kept to a minimum.

Operation procedures:

Low SWR Measurements (10 and below):

- **a.** Turn on the instrument. For a maximum stability allow approximately 5 minutes to warm up.
- **b.** Select Normal mode with the help of Mode select.
- **c.** Set Crystal Switch for the type of detector that is to be used in our case it is 200ohm.
- **d.** Connect the detector cable to the input of the SWR meter.
- **e.** Set Gain (Coarse & Fine) controls to approximately maximum Power.
- **f.** Set range switch on 40-db or 50-db position. Adjust probe penetration to obtain maximum reading.
- **g.** Peak the meter reading by adjusting the modulation frequency of the signal source. Reduce probe penetration to keep reading on display.
- **h.** Peak the meter reading by tuning the probe detector. Reduce the gain control knob or attenuator to keep reading on display.
- **i.** Peak the meter reading by moving the probe carriage along the line. Reduce gain control knob or attenuator to keep reading on meter.
- **j.** Adjust Gain controls and /or output power from the signal source to obtain exactly 0.0dB reading i.e. SWR=1.
- **k.** Move the probe carriage along the line to obtain minimum reading in dB, without disturbing the probe or any setting.
- **l.** Now keep SWR/dB switch at SWR position.
- **m.** Read SWR, Which is directly the SWR of the load?

Note:

1. If the reading at the minimum is less than -10dB on the meter then meter displays Switch Range so we have to switch to the next higher sensitivity range(clockwise).
2. If the reading at the maximum is more than 0 dB on the meter than meter displays Over Range so we have to switch to the next appropriate range (anticlockwise).
3. However all readings on the display in dB must be added in the range selector switch position.

High SWR Measurements (Above 10):

When the SWR is high, probe coupling must be increased if a reading is to be obtained at the voltage minimum. However, at the voltage maximum, this high coupling may result in a deformation of the pattern with consequent error in reading, In addition to this error caused by probe loading there is also a danger of error resulting from the change in detector characteristics at higher R.F. levels.

Double Minimum Method:

In the double minimum method, it is necessary to establish the electrical distance between the points where the output is double the minimum.

1. Repeat steps a to i in the low SWR measurement procedure.
2. Move the probe carriage along the line to obtain minimum reading and note the probe carriage position.
3. For reference, adjust gain controls to obtain reading of 3.0dB (or any other reference can be taken).
4. Move the probe carriage along the line to obtain a reading of 0.0dB on each side of the minimum.
5. Record as d1 and d2 the probe carriage position at the two equal readings obtained in step 4.
6. Short the line and measure the distance between successive minima. Twice this distance is the guide wavelength.

The SWR can be obtained by substituting this distance into the expression.

$$SWR = \frac{\lambda g}{\pi \left(d1 - d2\right)}$$

Where λg is the guide wave length d1 and d2 are the location of the twice-minimum points.

The method overcomes the effect of probe loading since the probe is always set around a voltage minimum where larger probe loading can be tolerated however it does not overcome the effect of detector characteristics.

Calibrated attenuator Method:
Another method for measuring high SWR's is to use a calibrated variable attenuator between the signal source and the slotted line. Adjust the attenuator to keep the rectified output of the crystal diode equal at the voltage minimum and voltage maximum points. The SWR in dB is the difference in the attenuator settings.

1. Repeat steps a to i in low SWR measurements procedure.
2. Move the probe carriage along the line for a voltage minimum, adjust the attenuator to give a convenient indication on the meter, note the attenuator setting.
3. Move the probe carriage along the line to a voltage maximum, adjust the attenuator to obtain the same indication on the meter as established in step 2, and note the attenuator setting,
4. The SWR may be read directly (in dB) as the difference between the first and second readings. While this method overcomes the effect of detector variations from a square Law characteristic, the effect of probe loading still remains. Be careful; always use minimum probe penetration.

Location of voltage maximum or voltage minimum:
From the discussion on probe loading it has shown that it is more desirable to locate the voltage minimum than the voltage maximum since the effect of probe loading is less at the minimum. However, the location of voltage minimum by a single measurement, particularly on low SWR, is usually inaccurate because of its broadness, thus making the true minimum position hard to determine. An accurate method of locating the voltage minimum is to obtain the position of the probe carriage at two equal output readings on either side of the minimum and then averaging these two readings.

Working Principle of DRF Meter

The microwave signal travelling the waveguide excites the perimeter of the slot, which in turn behaves like a radiating element towards the interior of the cavity. This is constructed to resonate with high Q, and the effective size of the cavity is made variable by moving in and out a piston by means of dial knob assembly. When the resonance frequency of the cavity is equal to the frequency of the signal in the waveguide, there is a maximum energy transfer from the waveguide to the cavity.

The energy passed in the cavity does not return to the waveguide is lost as losses within the cavity. This energy drainage at a specific frequency appears as a sharp drop (dip) in the signal level at the end of the waveguide.

It is therefore possible to use the cylindrical cavity resonator with a variable short circuit termination as a frequency meter by calibrating the dial indicating the position of the piston. The various piston positions results in different cavity resonant frequencies.

Safety Precautions

This is an educational product and the microwave power used for operation is very low approximately in the range of 5-10 mW only which is totally harmless. Still we recommend the following precautions to be followed while performing the experiments:

1. Do not see directly into the energized waveguide.
2. Do not touch the Klystron tube as it carries high voltage & heats up too.
3. In antenna experiment, it is recommended to not to have any metallic reflectors near to the setup.
4. Do not touch the heat sinks on the rear panel of equipments.

Experiment 1

Objective:

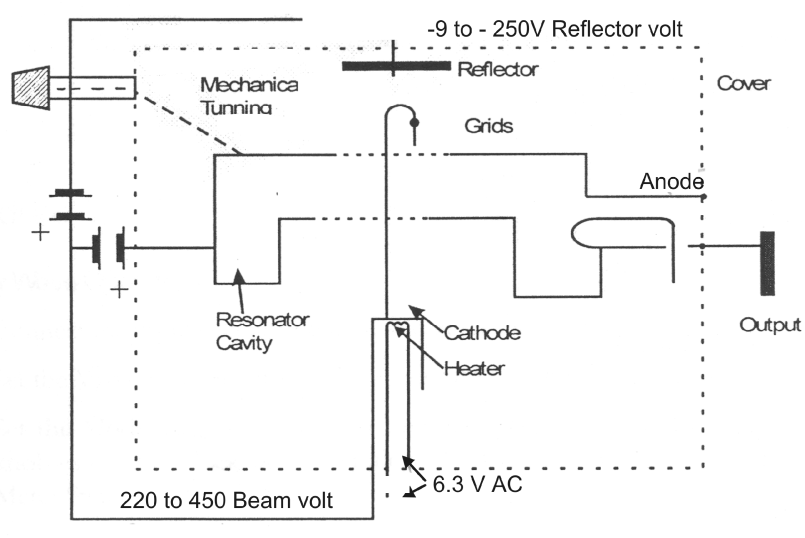
Study of characteristics of the Reflex Klystron Tube and to determine its electronic tuning range

Apparatus required:

1. Klystron power supply
2. Klystron tube with Klystron mount
3. Isolator
4. Frequency meter
5. Variable attenuator
6. Detector mount
7. Wave guide stand
8. SWR meter and Oscilloscope
9. BNC cable

Theory:

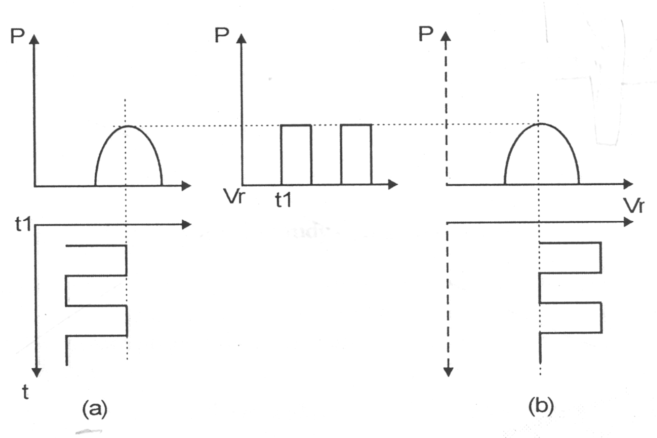
The Reflex Klystron makes the use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated & passed through the positive resonator towards negative reflector, which retards and finally, reflects the electrons and the electrons turn back through the resonator. Suppose an rf-field exists between the resonators the electrons traveling forward will be accelerated or retarded, as the voltage at the resonator changes in amplitude.



Schematics Diagram of Klystron 2K25

Figure 3

The accelerated electrons leave the resonator at an increased velocity and the retarded electrons leave at the reduced velocity. The electrons leaving the resonator will need different time to return, due to change in velocities. As a result, returning electrons group together in bunches, as the electron bunches pass through resonator, they interact with voltage at resonator grids. If the bunches pass the grid at such a time that the electrons are slowed down by the voltage then energy will be delivered to the resonator; and Klystron will oscillate. Figure 3 shows the relationship between output power, frequency and reflector voltages.



Square Wave modulation of the Klystron

Figure 4

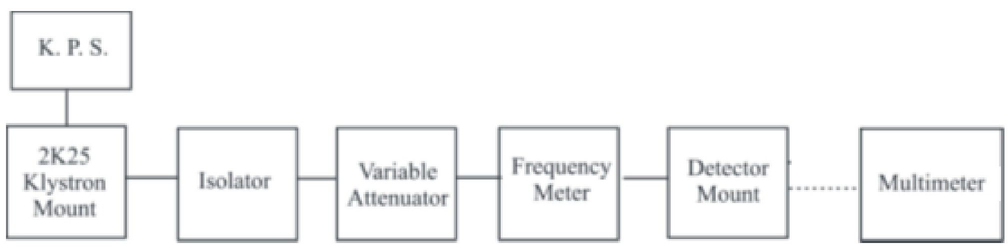
The frequency is primarily determined by the dimensions of resonant cavity. Hence, by changing the volume of resonator, mechanical tuning of klystron is possible. Also, a small frequency change can be obtained by adjusting the reflector voltage. This is called Electronic Tuning

The same result can be obtained, if the modulation voltage is applied on the reflector voltage as shown in the figure

Procedure:

Carrier Wave Operation:

1. Connect the components and equipments as shown in figure



Setup for study of klystron tube **Figure 5**

1. Set the Variable Attenuator at no attenuation position.
2. Set the mode switch of klystron power supply to CW position, beam voltage control knob to full anti-clock wise and reflector voltage control knob to fully clock wise and the meter select to Beam position.
3. Keep SWR meter at 50dB attenuation and coarse and fine potentiometers on mid position and crystal impedance at 200ohm.
4. Keep SWR/dB switch at dB position.
5. Set the multi-meter in DC microampere range.
6. Switch 'On' the klystron power supply & cooling fan for klystron tube.
7. Now in K.P.S set Mode select switch to AM- MODE position. Beam voltage control knob to fully anticlockwise position. Reflector voltage control knob to the maximum clockwise position
8. Change the reflector voltage slowly and observe the reading on the SWR meter. Set the voltage for maximum reading in the meter. If no reading is obtained, change the plunger position of klystron mount and detector mount. Select the appropriate range on SWR Meter. Now replace SWR meter to multi-meter.

9. Tune the plunger of klystron mount for the maximum output.
10. Rotate the knob of frequency meter slowly and stop at that position, when there is less output current on multi-meter. Read directly the frequency between two horizontal line and vertical line markers. If micro meter type frequency meter is used, read micrometer frequency and find the frequency from its calibration chart.

Square Wave Operation:

1. Connect the equipments and components as shown in the figure.

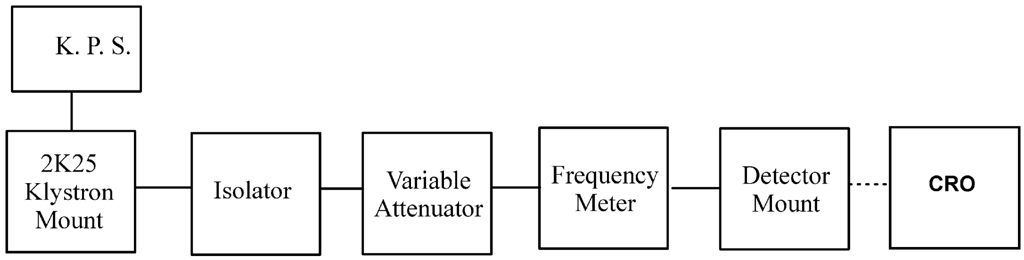


Figure 6

2. Set Micrometer of variable attenuator for no attenuation.
3. Set the range switch of SWR meter at appropriate position, crystal selector switch to 200ohm impedance position, mode select to normal position.
4. Now in KPS set Mode select switch to AM- MOD position. Beam voltage control knob to fully anticlockwise position. Reflector voltage control knob to the maximum clockwise position. .
5. Switch ‘On’ the Klystron Power Supply, SWR meter and cooling fan.
6. Change the beam voltage knob clockwise up to 300V.
7. Keep the AM amplitude knob and AM frequency knob at the mid-position.
8. Rotate the reflector voltage knob to get reading in SWR meter.
9. Rotate the AM amplitude knob to get the maximum output in SWR meter.
10. Maximize the reading by adjusting the frequency control knob of AM.
11. If necessary, change the range switch of SWR meter if the Reading in SWR meter is grater than 0.0db or less than -10dB in normal Mode respectively. Further the output can also be reduced by Variable Attenuator for setting the output for any particular position.
12. Connect oscilloscope in place of SWR Meter and observe the square wave across detector mount.

Mode Study on Oscilloscope:

1. Set up the components and equipments as shown in figure 7.
2. Set Mode selector switch to FM-Mode position with FM amplitude and FM frequency knob at mid position. Keep beam voltage control knob fully anticlockwise and reflector voltage knob to fully clockwise.

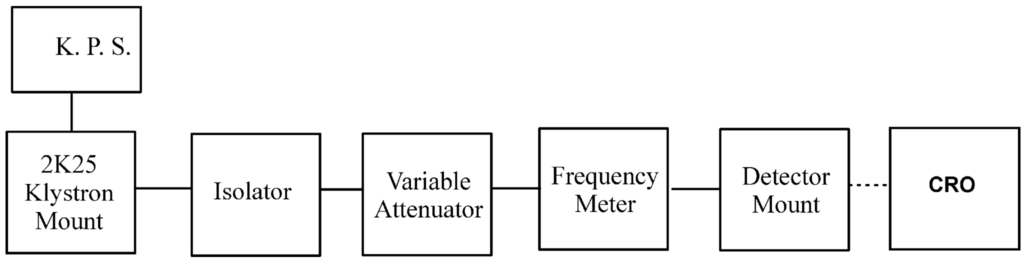
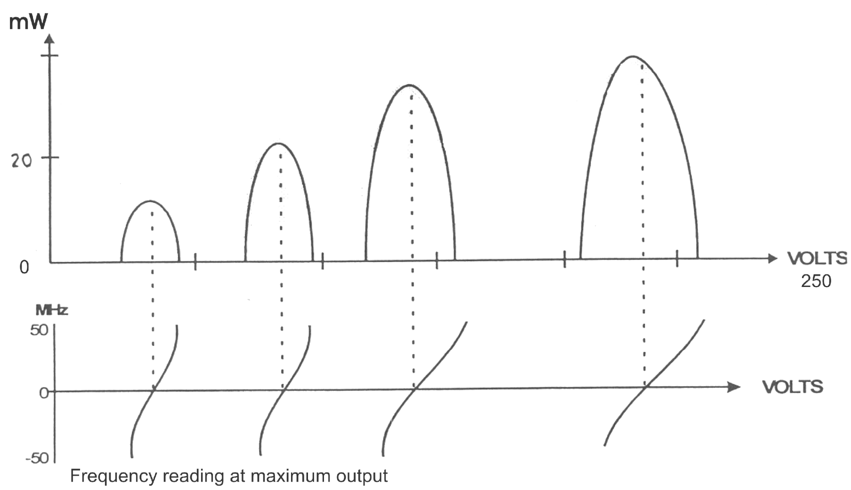


Figure 7



Modes of 2k25

Figure 8

3. Keep the time/division scale of Oscilloscope around 100Hz frequency measurement and volt/ div to lower scale.
4. Switch 'On' the klystron power supply and oscilloscope.
5. Set beam voltage to 300V by beam voltage control knob.
6. Keep amplitude knob of FM modulator to maximum position and rotate the reflector voltage anti-clockwise to get modes as shown in figure 8 on the oscilloscope. The horizontal axis represents reflector voltage axis, and vertical axis represents output power.
7. By changing the reflector voltage and amplitude of FM modulation, any mode of Klystron tube can be seen on an Oscilloscope.

Experiment 2

Objective:

To determine the frequency & wavelength in a rectangular waveguide working in TE_{10} mode

Apparatus required:

1 Klystron power supply
2 Klystron tube
3 Isolator
4 Frequency meter
5 Variable attenuator
6 Slotted section
7 Tunable probe
8 Wave guide stand
9 SWR meter
10 Matched termination.

Theory:

Mode represents in wave guides as either

$$TE\ m, n/ TM\ m,n$$

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

$$\frac{\lambda g}{2} = (d_1 - d_2)$$

Where d_1 and d_2 are the distance between two successive minima/maxima

It is having highest cut off frequency hence dominant mode.

For dominant TE_{10} mode in rectangular wave guide λo, λg and λc are related as below.

$$\frac{1}{\lambda_0} = \sqrt{\frac{1}{\lambda g^2} + \frac{1}{\lambda c^2}}$$

Where
λo is free space wave length
λg is guide wave length
λc is cutoff wave length

For TE_{10} mode, $\lambda c = \frac{2a}{m}$

Where m = 1 in TE_{10} mode and ‘a' is broad dimension of waveguide. The following relationship can be proved

$$C = f\lambda$$

Where
$c = 3 \times 10^8$ m/s is velocity of light and f is frequency.

Procedure:

1. Set up the components and equipments as shown in figure.

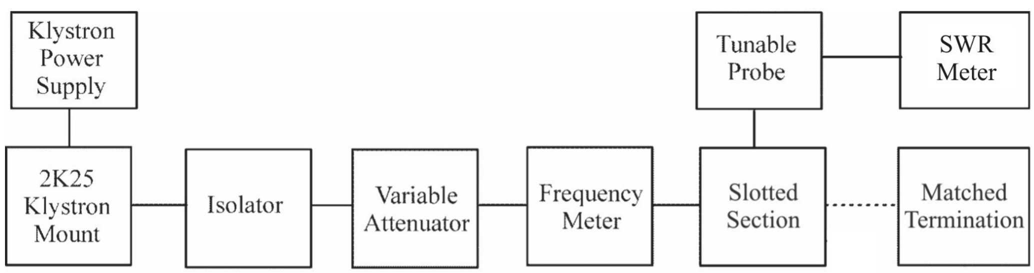
2. Set the variable attenuator at no attenuation position.

3. Keep the control knobs of SWR Meter as below :

Range dB	:	50 dB position
Crystal	:	At 200ohm Impedance
Mode select	:	Normal Position
Gain (Coarse & Fine)	:	Mid Position
SWR/dB	:	dB position

4. Keep the Control knobs of Klystron power supply as below.

Mode Select Switch	:	AM
Beam Voltage Knob	:	Fully anticlockwise
Reflector Voltage	:	Fully clockwise
AM-Amplitude Knob	:	Fully clockwise
AM-Frequency	:	Mid Position



Setup for study of frequency & wave length measurement

Figure 9

5. Switch on the klystron power supply, SWR meter and cooling fan.

6. Set beam voltage at 300V with the help of beam voltage knob, current around 15 to 20mA.

7. Adjust the reflector voltage to get some reading in SWR Meter.

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

9. Tune the plunger of klystron mount for maximum reading.

10. Tune the reflector voltage knob for maximum reading on SWR meter.

11. Tune the probe for maximum reading in SWR meter.

12. Tune the frequency meter to get a 'dip' on SWR meter and note down the frequency directly from frequency meter and detune the DRF

13. Move the tunable probe along with the slotted line to get the reading in SWR meter. Move the tunable probe to a minimum reading position. To get accurate reading, it is necessary to increase the SWR meter range dB switch to higher position, record the probe position i.e. d_1

14. Move the probe to next minimum position and record the probe position again i.e. d_2.

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

$$\lambda_g = 2(d1\text{-}d2)$$

16. Measure the wave-guide inner broad dimension 'a' which will be around 22.86 mm for X band and Calculate

$$\lambda_c = 2a \quad \text{For } TE_{10} \text{ mode}$$

17. Calculate the frequency by following equation:

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

Where
c =3 x 10^8 meter/sec. i.e. velocity of light.

18. Verify with frequency obtained by frequency meter.

19. Above experiment can be verified at different frequencies.

Experiment 3

Objective:
To determine the Standing Wave-Ratio and Reflection Coefficient

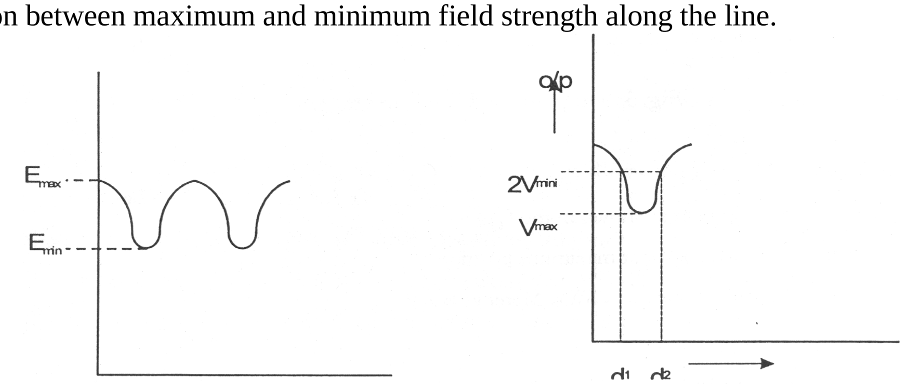
Apparatus required:

1. Klystron power supply
2. Klystron tube
3. SWR meter
4. Isolator
5. Frequency meter
6. Variable attenuator
7. Slotted line
8. Tunable probe
9. Wave guide stand
10. Matched Termination
11. BNC cable
12. S-S tuner

Theory:

It is a ratio of maximum voltage to minimum voltage along a transmission line is called SWR, as ratio of maximum to minimum current. SWR is measure of mismatch between load and line.

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



Double Minima Method

Figure 10

Hence SWR denoted by S is

$$S = \frac{E_{\max}}{E_{\min}}$$

$$= \frac{|E_I| + |E_r|}{|E_I| - |E_r|}$$

Where

E_I = Incident Voltage

E_r = Reflected Voltage

Reflection Coefficient, ρ is

$$\rho = \frac{E_r}{E_I} = \frac{Z - Z_0}{Z + Z_0}$$

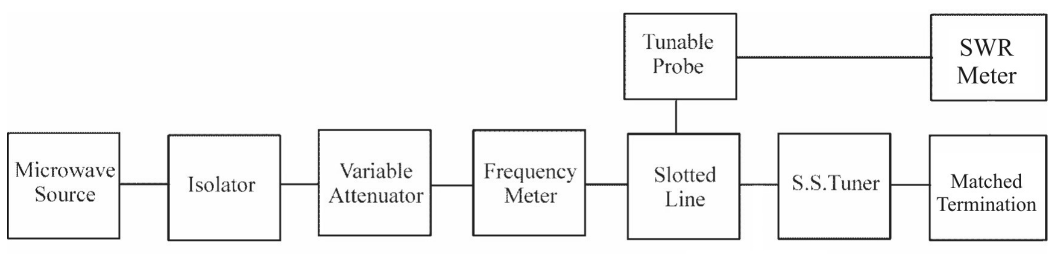
Where

Z is the impedance at a point on line,

Zo is characteristic Impedance.

The above equation gives following equation

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



Setup for SWR measurement

Figure 11

Procedure:

1. Set up the equipment as shown in the figure.

2. Keep variable attenuator at no attenuation position.

3. Keep the control knobs of SWR Meter as below :

Range dB	:	50 dB position
Crystal	:	200 ohm
Mode Switch	:	Normal Position
Gain (Coarse & Fine)	:	Mid Position
SWR/dB switch	:	dB position

4. Keep the control knobs of klystron power supply as below:

Mode Select Switch	:	AM
Beam Voltage Knob	:	Fully Anticlockwise
Reflector Voltage Knob	:	Fully clockwise
AM Frequency & amplitude Knob	:	Mid Position

5. Switch ‘On’ the klystron power supply, SWR meter and cooling fan.

6. Set the beam voltage at 300V.

7. Rotate the reflector voltage knob to get reading in SWR Meter.

8. Tune the output by tuning the reflector voltage, amplitude and frequency of AM modulation.

9. Tune for Maximum reading by tuning the plunger of Klystron Mount. Then tune for maximum reading by tuning the probe.

10. If necessary change the range dB switch, variable attenuator position and gain control knob to get reading in the SWR meter.

11. Move the probe along with slotted line, the reading will change.

a. Measurement of low and medium SWR

i. For low SWR set the S.S. tuner probe for no penetration position.

ii. Move the probe along with slotted line to get maximum reading in SWR Meter in dB.

iii. Adjust the SWR Meter gain control knob or variable attenuator until the meter indicates 0.0dB in normal modes. SWR for 0.0dB is 1.0 by keeping switch at SWR we can read it directly.

iv. Keep all the Control knobs as it is, move the probe to next minimum gain position.

v. Keep SWR /dB switch at SWR position.

vi. Read the SWR from display and record it.

vii. Repeat the above step for change of S.S. Tuner probe penetration & record the corresponding SWR.

viii. If the SWR is grater than 10dB, then you have to use the following procedure.

b. Measurement of High SWR (Double Minimum Method)

i. Set the depth of S.S. Tuner slightly more for maximum SWR.

ii. Move the probe along with Slotted line until a minimum is indicated.

iii. Adjust the SWR meter gain control knob and variable attenuator to obtain a reading of 3 dB (or any other reference) at SWR Meter.

iv. Move the probe to the left on slotted line until maximum reading is obtained i.e. '0' dB (or power should be increased by 3 dB). Note and record the probe position on slotted line. Let it be d_1.

v. Repeat the step 3 and 4 and then move the probe right along with slotted line until maximum reading is obtained in normal dB mode i.e upto 0dB. Let it be d_2.

vi. Measure the distance between two successive minima position. Twice of this distance is wave guide length λg.

$$\lambda_g = 2(d1\text{-}d2)$$

vii. Calculate SWR by following equation.

$$\text{SWR} = \frac{\lambda g}{\pi(d_1 - d_2)}$$

For different SWR, calculate the refection coefficient.

Experiment 4

Objective:

To measure an unknown Impedance with Smith chart

Apparatus required:

1. Klystron Tube 2K25
2. Klystron power supply
3. Klystron Mount
4. Isolator
5. Frequency meter
6. Variable attenuator
7. Slotted Line
8. Tunable Probe
9. SWR meter
10. Wave guide stand
11. S.S. Tuner
12. Matched Termination.

Theory:

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

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

Reflection Coefficient

$$R = \frac{Z - Z_0}{Z + Z_0}$$

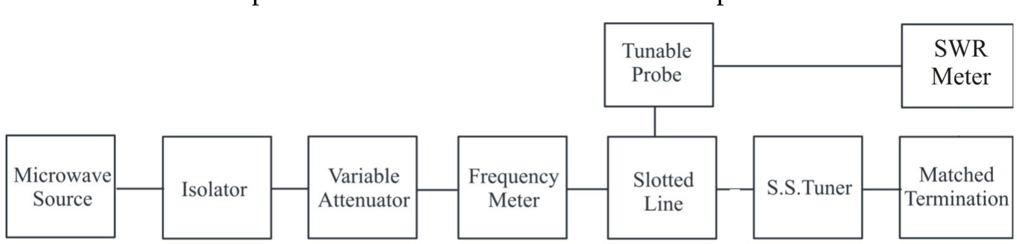
Where

Z_o = Characteristics impedance of w/g at operating frequency

Z = Load impedance at any point.

The measurement is performed in following way:

The unknown device is connected to the slotted line and the SWR = S_o and the position of one minima is determined. Then unknown device is replaced by movable short to the slotted line. Two successive minima positions are noted. The twice of the difference between minima position will be guide-wave length. 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 '1' as center; draw a circle of radius equal to So. Mark a point on circumference of chart towards load side at a distance equal to d/λg. Join the center with this point. Find the point where it cut the drawn circle. The coordination of this point this will show the normalized impedance of load.



Setup for Impedance measurement

Figure 12

Procedure:

1. Set up the equipments as shown in the figure 12.

2. Set the variable attenuator at no attenuation position.

3. Connect S.S. tuner and matched termination after slotted line.

4. Keep the control knobs of SWR Meter as below :

Range dB	:	50 dB position
Crystal	:	200 ohm
Mode Switch	:	Normal Position
Gain (Course & Fine)	:	Mid Position
SWR/dB switch	:	dB Position

5. Keep the Control knobs of Klystron power supply as below :

Mode Select Switch	:	AM
Beam Voltage Knob	:	Fully anticlockwise
Reflector Voltage	:	Fully clockwise
AM-Amplitude	:	Fully Clockwise
AM-Frequency Knob	:	Mid Position

6. Switch "On' the Klystron power supply, SWR meter and cooling Fan.

7. Set beam voltage at 300V with help of beam voltage knob.

8. Adjust the reflector voltage to get some reading in SWR Meter.

9. Tune the frequency meter knob to get dip on the SWR scale, and note down the frequency directly from frequency meter. Now you can detune the meter from dip position.

10. Measure the guide wavelength λg as previous experiment

$$\lambda g = 2\ (d_1 - d2)$$

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

12. Move the probe along with slotted line to get maximum reading.

13. Adjust SWR meter gain control knob and variable attenuator unit such that the meter indicates 1.0 on the normal upper SWR scale.

14. Move the probe to next minima point.

15. Select SWR/dB switch to SWR position. Record the SWR reading.

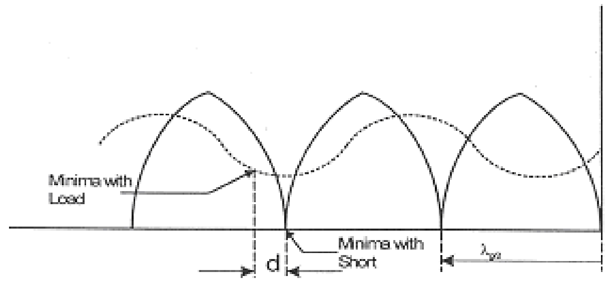
16. At this maximum position of the meter record the probe position from slotted line as $X_{1.}$

17. Replace the load by fixed short/movable short & measure the new standing wave position i.e. shift in minima. Record it as $X_{2.}$

18. Calculate X_2-X_1, it will be positive if the minima shift is towards load & negative if it has shifted towards generator.

19. Calculate shift in wavelength

$$(d) = X_2 - X_1$$



Standing waves in impedance measurement

Figure 13

20. Use normalized chart (Smith Chart) & draw a circle with radius = 1/VSWR & take center of circle = 0.00 on the smith chart.

21. Locate a point at a distance d (shift in minima) from the 0.0 moving in clockwise or anti-clockwise direction (depends on getting minima towards generator or load).

22. Join the above point to the centre of smith chart. The intersection of VSWR circle & this line gives load, reactive component or reactive circle & resistive component on real circle.

23. Normalized impedance a+ib where a & b are the real and reactive components.

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

Experiment 5

Objective:
Study of Attenuators

Apparatus required:

1 Microwave source
2 Isolator
3 Frequency meter
4 Variable attenuator
5 Slotted line
6 Tunable probe
7 Detector mount
8 Matched termination
9 SWR meter.

Theory:

The attenuators are two port bi-directional devices which attenuate power when inserted into the transmission line.

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

Where
P_1 = Power absorbed or detected by the load without the attenuator in the line.
P_2 = Power absorbed/detected by the load with attenuator in line.

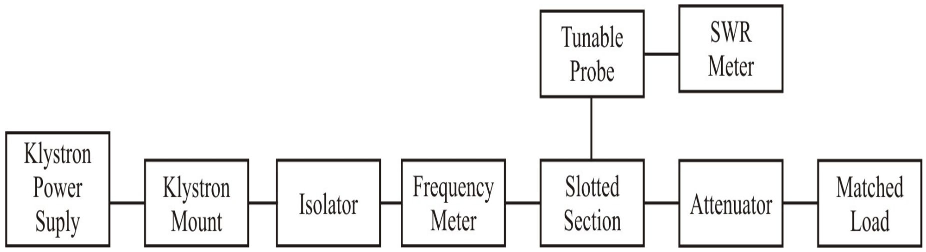
The attenuators consist of a rectangular wave guide with a resistive vane inside it to absorb microwave power according to their position with respect to side wall of the wave-guide. As electric field is maximum, at center in TE_{10} mode, the attenuation will be maximum if the vane is placed at center of the wave-guide. Moving from center toward the side wall, attenuation decreases in the fixed attenuator, the vane position is fixed where as in a variable attenuator, its position can be changed by help of micrometer or by other methods.

Following characteristics of attenuators can be studied

1. Input SWR.
2. Insertion loss (in case of variable attenuator).
3. Amount of attenuation offered into the lines.
4. Frequency sensitivity i.e. variation of attenuation at any fixed position of vane and frequency is changed.

Procedure:

1. Input SWR Measurement
   a. Connect the equipments as shown in the figure.
   b. Energize the microwave source for maximum power at any frequency of operation.
   c. Measure the SWR with the help of tunable probe, Slotted line and SWR meter as described in the experiment of measurement of low and medium SWR.
   d. Repeat the above step for other frequencies if required.



Setup for VSWR, Insertion Loss & Attenuation measurement of Attenuator

Figure 14

2. Insertion Loss /Attenuation Measurement

a. Remove the tunable probe, attenuator and matched termination from the slotted section in the above set up.

b. Connect the detector mount to the slotted line, and tune the detector mount also for maximum deflection on SWR meter (Detector mount's output should be connected to SWR meter).

c. Set any reference level on the SWR meter with the help of gain control knob of SWR meter. Let it be P_1. Now connect the attenuator in between slotted line & detector mount.

d. Set the variable attenuator to zero attenuation position and record the reading of SWR meter. Let it be P_2. Then the insertion loss of test attenuator will be P_1 - P_2 dB.

e. Now, change the micrometer reading and record the SWR meter reading in dB. Find out Attenuation value for different position of micrometer reading and record the readings to plot a graph.

f. In the same way you can test the fixed attenuator which can give you only the single attenuation value.

g. Now change the operating frequency and all the step can be repeated for finding frequency sensitivity of variable attenuator.

Note: For measuring frequency sensitivity of variable attenuator the position of micrometer reading of the variable attenuator should be same for all frequencies in operation.

Micro meter reading of variable attenuator (mm)	SWR reading (dB)

Experiment 6

Objective:

To study the substitution method for attenuation measurement and determine the attenuation due to a component under test

Equipments Required:

1. Microwave Power Source- Klystron (Gunn source can also be used)
2. Power Supply
3. Variable Standard Attenuator (Calibrated)
4. Component under test
5. Tunable Probe
6. Klystron mount with tube
7. Isolator
8. DRF
9. Matched termination
10. Slotted section
11. SWR Meter
12. Stands, Connecting Cables and Accessories

Procedure:

1. Assemble the set-up as shown in the figure:

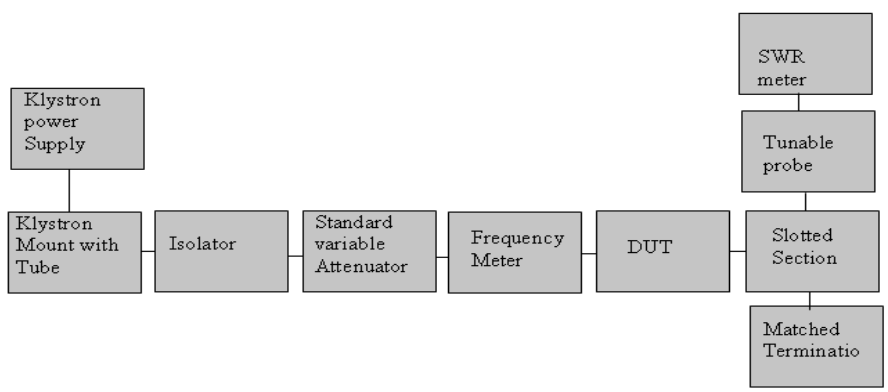


Figure 15

2. Set the variable standard attenuator (calibrated) for no attenuation position.
3. Energize the component with microwave power and thus the detector to have maximum power in the SWR meter. Here DUT may be any device under test like attenuator (Fixed or variable) or any other component.
4. Note & record the Power reading (dB) from SWR meter, Let it be P.
5. Now remove the DUT from test bench.
6. Move the standard attenuator till power P is achieved in the SWR meter.
7. Note the micrometer reading of your Standard variable attenuator.
8. From the chart of standard variable attenuator note the power value for this corresponding micrometer reading.
9. Take the difference of this reading & reading of no attenuation position from the chart.
10. This difference is the attenuation due to DUT.
11. If the Gunn Source is used then the above experiment can be performed on different frequencies also & curve can be plotted between attenuation & frequency.

Variable Attenuator Calibration Chart

Micrometer reading	Attenuation In dB	Micrometer reading	Attenuation In dB	Micrometer reading	Attenuation In dB
10 (No attenuation Position)	40	5.6	42	1.2	55.8
9.9	40	5.5	42.1	1.1	56.5
9.8	40	5.4	42.2	1	57
9.7	40	5.3	42.4	0.9	57.5
9.6	40	5.2	42.6	0.8	58
9.5	40	5.1	42.8	0.7	59
9.4	40	5	42.9	0.6	59.8
9.3	40	4.9	43.1	0.5	60
9.2	40	4.8	43.2	0.4	60.8
9.1	40	4.7	43.4	0.3	61.4
9	40	4.6	43.6	0.2	62
8.9	40	4.5	43.8	0.1	63
8.8	40	4.4	44	0	63.8
8.7	40	4.3	44.5		
8.6	40.1	4.2	44.6		
8.5	40.2	4.1	44.9		
8.4	40.2	4	45.1		
8.3	40.2	3.9	45.5		
8.2	40.2	3.8	45.8		
8.1	40.3	3.7	46		
8	40.3	3.6	46.4		
7.9	40.3	3.5	46.6		
7.8	40.4	3.4	47		
7.7	40.4	3.3	47.4		
7.6	40.4	3.2	47.5		
7.5	40.4	3.1	48		
7.4	40.5	3	48		
7.3	40.5	2.9	49		
7.2	40.6	2.8	49		
7.1	40.6	2.7	49.5		
7	40.7	2.6	50		
6.9	40.7	2.5	50		
6.8	40.8	2.4	50.5		
6.7	40.9	2.3	50.6		
6.6	41	2.2	50.8		
6.5	41	2.1	51.2		
6.4	41.1	2	51.8		
6.3	41.2	1.9	52.2		
6.2	41.3	1.8	52.6		
6.1	41.4	1.7	53.1		
6	41.6	1.6	53.6		
5.9	41.6	1.5	54		
5.8	41.8	1.4	54.6		
5.7	41.8	1.3	55		

Experiment 7

Objective:

Study of voice communication by using microwave test bench

Apparatus required:

1. Klystron based Setup
2. Variable attenuator
3. Slotted section
4. Detector mount
5. Frequency meter
6. SWR meter

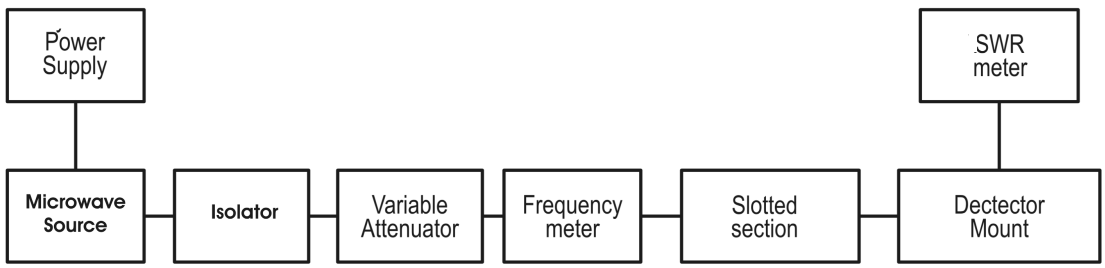


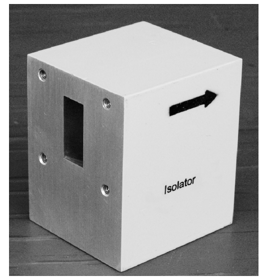
Figure 16

Procedure:

1. Setup the common structure of the bench.
2. Connect the Microphone in Audio input socket. (KPS- front panel)
3. Connect the detector output to SWR meter.
4. Keep mode select switch of SWR meter at Audio mode.
5. Connect a Headphone in given Audio output socket.
6. Tune the controls for maximum Headphone output.
7. Now you can observe the audio signals. Audio signal strength is changing by variable attenuator or the DIP arises by moving frequency meter etc.

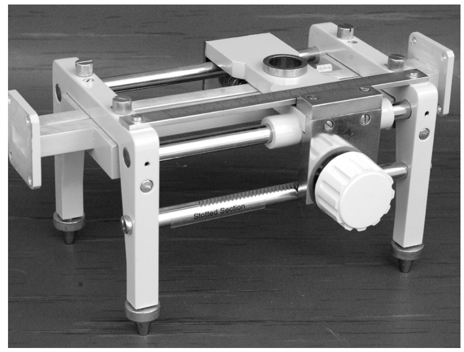
Identification of Microwave Components

Gunn Oscillator (10 MW) - NV201



Isolator – NV204

PIN Modulator – NV202



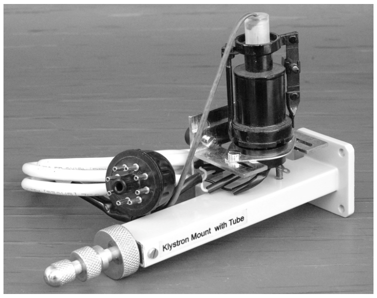
Slotted Section – NV207

Frequency Meter – NV205

Variable Attenuator – NV206

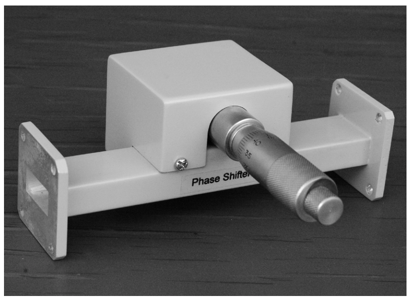
Detector Mount – NV209

Tunable Probe – NV208

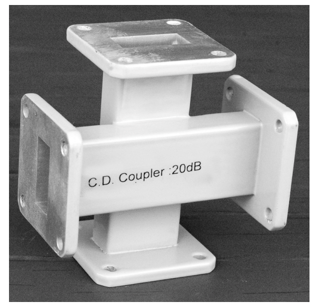


Klystron Mount – NV203

Coaxial Adapter – NV225



Phase Shifter – NV238

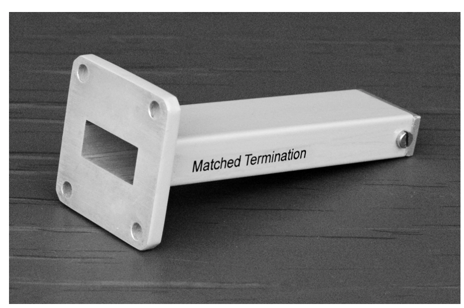


C. D. Coupler 20dB – NV229

E Plane Bend – NV232

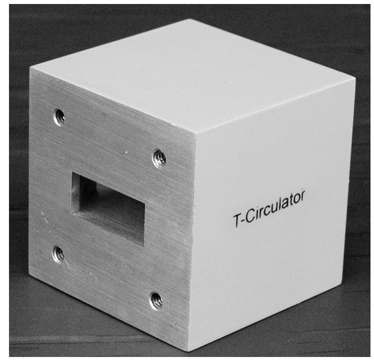
E Plane Tee – NV221

Fixed Attenuator – NV217



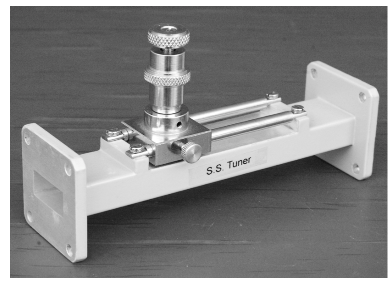
Matched Termination – NV212

Magic Tee – NV223



T-Circulator – NV230

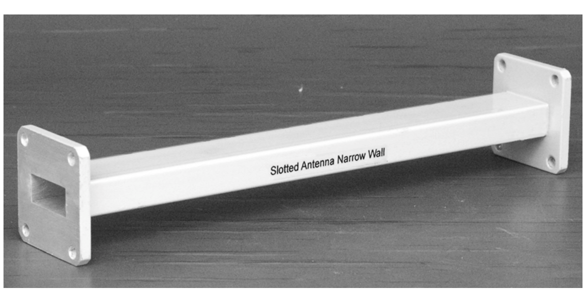
Multi hole Directional Coupler (10dB) – NV228



SS Tuner – NV220

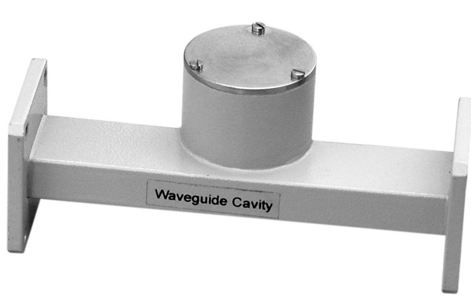
Precision movable short – NV235

Slotted Antenna Broad Wall – NV241



Slotted Antenna Narrow Wall – NV242

Parabolic Antenna – NV247



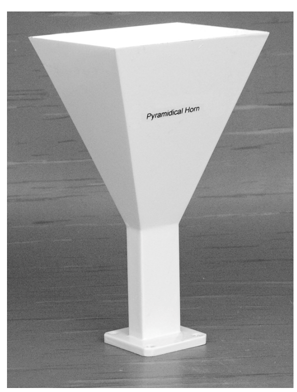
Waveguide Cavity – NV234

Waveguide Twist – NV216

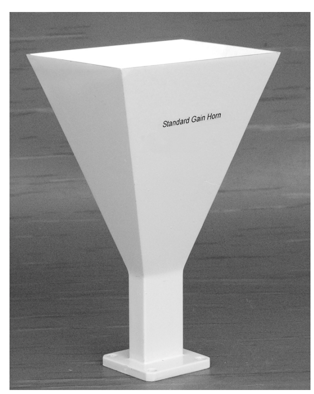
Dielectric Antenna – NV243

H Plane Sectorial Horn – NV245

Pickup Horn–NV240



Pyramidical Horn–NV246



Standard Gain Horn - (16 dB) NV239

Warranty

1. We warranty the product against all manufacturing defects for 24 months from the date of sale by us or through our dealers.
2. The warranty will become void, if
    - The product is not operated as per the instructions given in the learning material.
    - The agreed payment terms and other conditions of sale are not followed.
    - The customer resells the instrument to another party.
    - Any attempt is made to service and modify the instrument.
3. The non-working of the product is to be communicated to us immediately giving full details of the complaints and defects noticed specifically mentioning the type, serial number of the product and date of purchase etc.
4. The repair work will be carried out, provided the product is dispatched securely packed and insured. The transportation charges shall be borne by the customer.

Note: The following items are not covered in the warranty:

- Detector Diodes
- Pin Diode
- Gunn Diode
- Klystron Tube

List of Service Center

Baroda
Flat No. A/1, Mudra Complex, Behind Sudha Hotel, Ellora Park, Baroda-390023 (Gujarat)
Tel: +91-0265-3089505
Fax : +91- 0265-3089506
email : baroda@scientech.bz

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email: guwahati@scientech.bz

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List of Accessories

For One Bench:

1. BNC to BNC Cable …………………………………………………………………….2 Nos.
2. Mains Cord……………………………………………………………………………...2 Nos.
3. Learning Material +Demo CD………………………..……………………………………1 No.
4. Mini Microphone…………………………………………………………………..……..1 No.
5. Headphone……………………………………………………………………………..…1 No.