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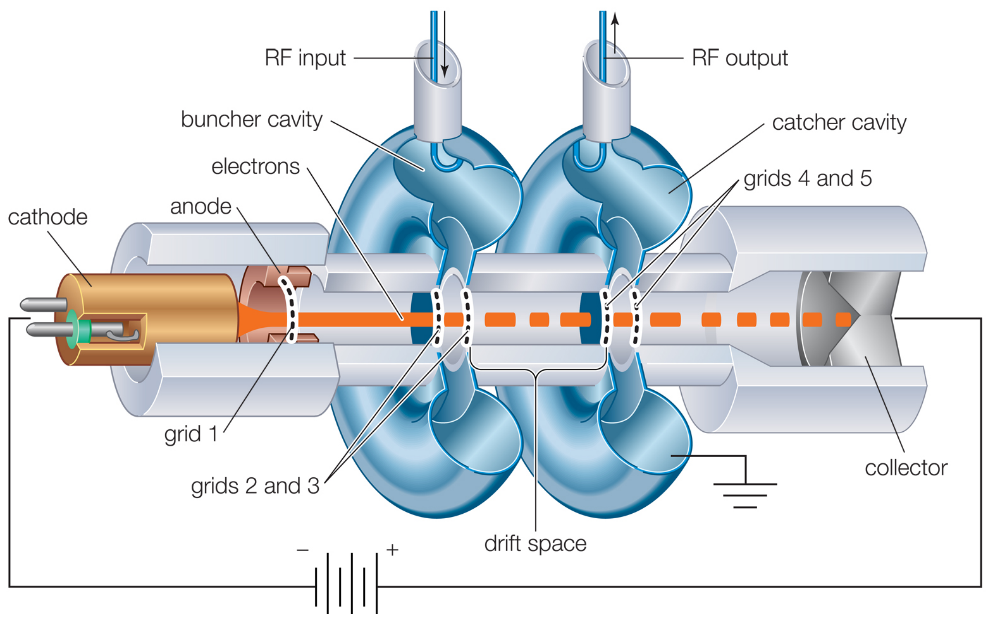
EXPERIMENT - 8

AIM - Study of different microwave components.

THEORY

1. Klystron diode

klystron, thermionic electron tube that generates or amplifies microwaves by controlling the speed of a stream of electrons. The electrons are originally accelerated to high velocity by a potential of several hundred volts and enter a narrow gap that forms part of a cavity resonator system, where they are acted upon by a radio-frequency field, which causes a bunching-up effect.



Amplitude modulation of the electrons in their bunched-up state induces a strong signal as the stream passes through the gap of a second resonator. Klystrons are used in ultrahigh-frequency (UHF) circuits, such as UHF television transmission, and for microwave radar sources, where they can produce oscillations up to 400 gigahertz, in the short microwave range.

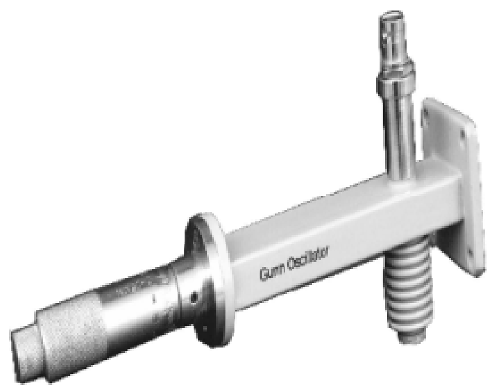
Advantages :

a) It operates at higher efficiencies.
b) In klystron, each cavity operates independently and there is no mutual coupling.

Disadvantages :

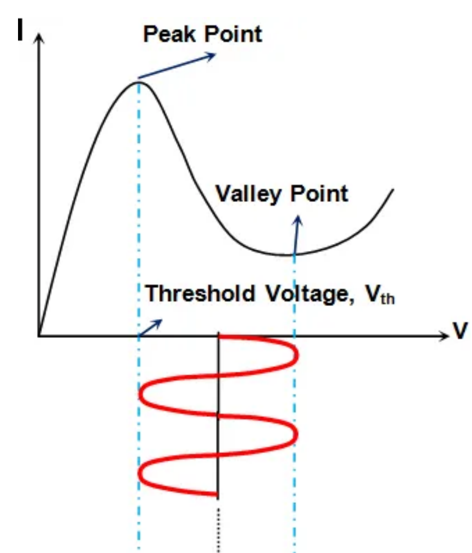
a) Two cavity klystron amplifier is not a low-noise device. Due to this fact, usually it is used in the transmitter and not in the receiver.
b) It is a narrow band device due to use of resonant cavities.

2. Gunn Oscillator



This type of diode is widely used at high frequency electronic circuits. It is also known as a transferred electron device or TED. Unlike other diodes which usually will have both N and P doped regions, Gunn diodes have only N-type of semiconductor doping material.

The applied DC bias increases, the current begins to increase at the initial stage, which continues till the threshold voltage. After this, the current continues to fall as the voltage increases until the breakdown voltage is reached. This region, which spans from the peak to the valley point, is called the negative resistance region. This property of the Gunn diode along with its timing properties cause it to behave as an oscillator provided an optimum value of current flows through it. This is because the negative resistance property of the device nullifies the effect of any real resistance existing in the circuit.



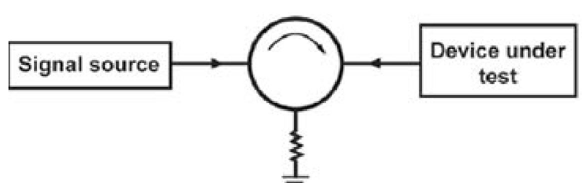
Applications :

There are several commercially available implementations of Gunn Diode oscillators. These include waveguide, microwave cavity, and yttrium-iron-garnet (YIG) sphere Gunn Diode oscillators. The frequency of oscillation of a Gunn Diode-based oscillator is controlled by a resonant structure. For waveguide and microwave cavity Gunn diode oscillators, the construction geometries and cavities of the waveguide and microwave cavity determine the resonant frequencies.

3. Isolator

An RF isolator is a two-port device which prevents RF energy from coming back to its source. It is analogous to a diode which only allows electrical current to flow in one direction, or a check valve in a fluid-flow system. Note that the RF isolator has absolutely no relationship to galvanic (ohmic) isolation used in non-RF signal and power-supply designs, and it is not galvanically isolated.
It is primarily used to protect other RF components from excessive signal reflection. For example, isolators are used in test applications to provide electrical separation between a device under test (DUT) and a sensitive signal source. This is done in the event that some of the energy at the DUT reflects back to the source.

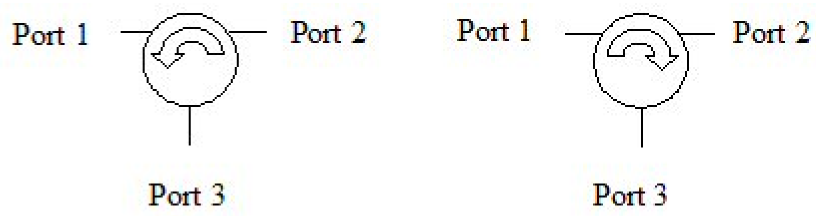
The non-reciprocity observed in these devices usually comes from the interaction between the propagating wave and the material, which can be different with respect to the direction of propagation.



It is used to shield equipment on its input side, from the effects of conditions on its output side; for example, to prevent a microwave source being detuned by a mismatched load.

4. Circulators

The circulator is a ferrite device including two or more ports. When the input signal enters into any port then the signal will transmit in a particular direction. There are different models of circulators available in the market from different manufacturing companies. These components are mainly used in different applications like radar systems, amplifier systems, transmitting or receiving from the antenna. The different models of these mainly include two port circulators; three port circulators with waveguide packages & frequency range will be up to 40 GHz, VSWR, insertion loss and isolation.



The selection of ports is arbitrary, and circulators can be made to "circulate" either clockwise (CW) or counterclockwise (CCW). A circulator's isolation is roughly equal to its return loss, and should always be specified to the same requirement. A circulator with 20 dB isolation will need to have a return loss of 20 dB. Think about it, if you terminate the third arm in a perfect 50 ohms, the clockwise isolation you will measure in a CCW circulator won't be better than the stray signal that is bouncing off the loaded port due to the reflected signal due to its mismatch to 50 ohms.

T Circulator - A circulator in which three identical rectangular waveguides are joined asymmetrically to form a T-shaped structure, with a ferrite post or wedge at its center; power entering any waveguide emerges from only one adjacent waveguide.

Y Circulator - A circulator in which rectangular waveguides are joined asymmetrically to form a Y-shaped structure to concentrate the energy on one side of the wave guide. Reversing the field or changing the direction of propagation will cause the energy to concentrate on the other side of the wave guide.

Applications of Circulators

The applications of circulators include the following

- Duplexer
- Isolator
- Reflection amplifier
- Radar systems
- Amplifier systems
- Antenna transmitting or receiving

5. Attenuator

It is a passive device that is used to reduce the strength or amplitude of a signal. At microwave frequencies, the attenuators were not only meant to do this, but also meant to maintain the characteristic impedance (Z_0) of the system. If the Z_0 of the transmission line is not maintained, the attenuator would be seen as impedance discontinuity, which causes reflections. Usually, a microwave attenuator controls the flow of microwave power by absorbing it.
Attenuation in dB of a device is ten times the logarithmic ratio of power flowing into the device (Pi) to the power flowing out of the device (P_0) when both the input and output circuits are matched.
In a microwave transmission system, the microwave power transferring from one section to another section can be controlled by a device known as microwave attenuator. These attenuators operate on the principle of interfering with electric or magnetic or both the fields. A resistive material placed in parallel to electric field lines (of field current) will induce a current in the material,which will result in I2R loss. Thus, attenuation occurs by heating of the resistive element.

Fixed - used where a fixed amount of attenuation is needed. They are also called pads. In this type of attenuator tapering is provided by placing a short section of a waveguide with an attached tapered plug of absorbing material at the end. The purpose of tapering is for the gradual transition of microwave power from the waveguide medium to the absorbing medium.

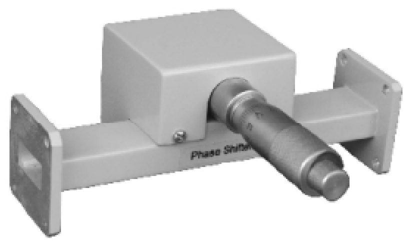
Because of the absorbing medium, reflections at the media interface will be minimized. In a fixed attenuator, plug is nothing but a dielectric slab which has a glass slab with aqua dog or a carbon film coating. The pad is placed in such a way that the plane is parallel to the electric field. For this, two thin metal rods are used.

Variable - For providing continuous or stepwise attenuation variable attenuators are used. The provided attenuation depends on the insertion depth of the absorbing plate into the waveguide. The maximum attenuation will be achieved when the pad extends totally into the waveguide. This type of variable attenuation is provided by knob and gear assembly which can be properly calibrated. The power transmitted to the load can be varied manually or electronically from nearly the full power of the source to as little as a millionth of a percent of the source power depending on the frequency of operation.
The types of variable attenuators are

1. Flap or resistive card-type attenuators
2. Slide vane attenuators
3. Rotary vane attenuators

6. Phase Shifter

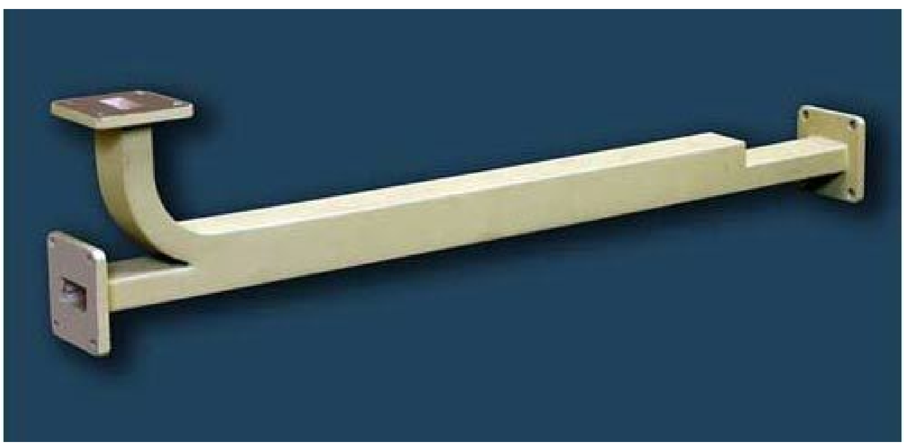
A phase shift module is a microwave network module which provides a controllable phase shift of the RF signal. Phase shifters are used in phased arrays.
Phase shifters are passive microwave devices used to change the phase angle of an RF signal. Our variable analog RF phase shifter designs have consistent amplitude across all phase states and low insertion loss, making them ideal for RF



applications. A phase shifter is used for applications such as phase modulators, frequency up-converters, testing instruments, phased array antennas, etc. and are RoHs compliant.
RF phase shifters from Radiall are designed with SMA and have broadband operating frequencies ranging between DC to 18 GHz.

7. MHD (Multi-Hole Directional Coupler)

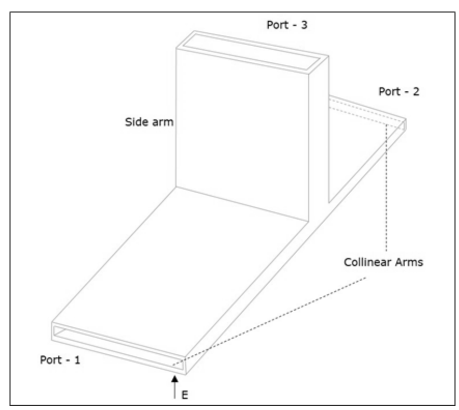
It is a four port waveguide junction consisting of primary main wavelength and a secondary auxiliary waveguide. They can Sample a small amount of microwave power for measurement purposes. They are designed to measure incident and reflected power, SWR Values, provide a signal path to a receiver or perform other desirable operations.



The coupling is done through holes on the broad side of the waveguide. The diameter in the no of holes in a row and the number of rows vary according to the coupling sector required. Scientific Microwave offers 3dB, 10dB, and 20dB couplers to its customers with minimum VSWR.

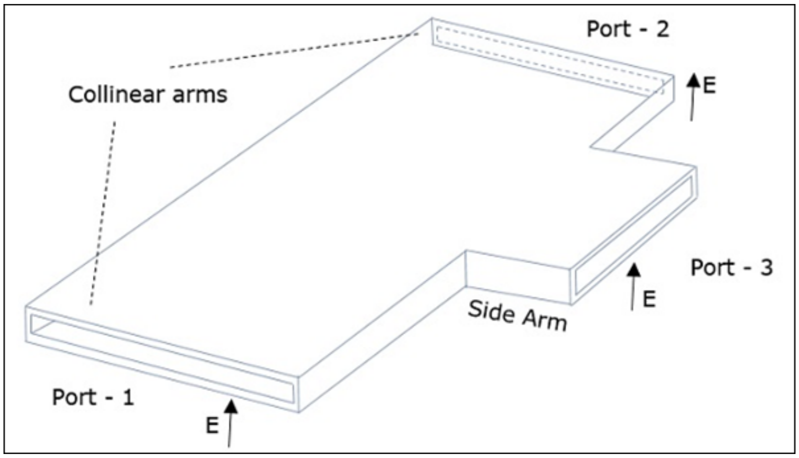
8. Magic Tee

A magic tee (or magic T or hybrid tee) is a hybrid or 3 dB coupler used in microwave systems. It is an alternative to the rat-race coupler. In contrast to the rat-race, the three-dimensional structure of the magic tee makes it less readily constructed in planar technologies such as microstrip or stripline.
The magic comes from the way it prevents signals from propagating between certain ports under specific conditions. This allows it to be used as a duplexer; for instance, it can be used to isolate the transmitter and receiver in a radar system while sharing the antenna. In practical examples, it is used to both isolate circuits and mix signals, for instance in a COHO radar.
The magic tee is a combination of E and H plane tees. Arm 3 forms an H-plane tee with arms 1 and 2. Arm 4 forms an E-plane tee with arms 1 and 2. Arms 1 and 2 are sometimes called the side or collinear arms.



E-Plane Tee - An E-Plane Tee junction is formed by attaching a simple waveguide to the broader dimension of a rectangular waveguide, which already has two ports. The arms of rectangular waveguides make two ports called collinear ports i.e., Port1 and Port2, while the new one, Port3 is called Side arm or E-arm. This E-plane Tee is also called the Series Tee.

H-Plane Tee - An H-Plane Tee junction is formed by attaching a simple waveguide to a rectangular waveguide which already has two ports. The arms of rectangular waveguides make two ports called collinear ports i.e., Port1 and Port2, while the new one, Port3 is called Side arm or H-arm. This H-plane Tee is also called Shunt Tee.



Applications of E-H Plane Tee

Some of the most common applications of E-H Plane Tee are as follows −

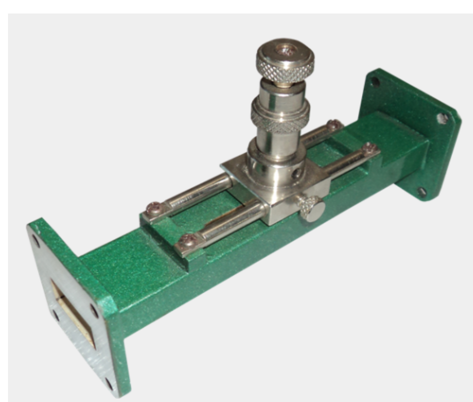
- E-H Plane junction is used to measure the impedance − A null detector is connected to E-Arm port while the Microwave source is connected to H-Arm port. The collinear ports together with these ports make a bridge and the impedance measurement is done by balancing the bridge.
- E-H Plane Tee is used as a duplexer − A duplexer is a circuit which works as both the transmitter and the receiver, using a single antenna for both purposes. Port 1 and 2 are used as receiver and transmitter where they are isolated and hence will not interfere. Antenna is connected to the E-Arm port. A matched load is connected to the H-Arm port, which provides no reflections. Now, there exists transmission or reception without any problem.
- E-H Plane Tee is used as a mixer − E-Arm port is connected with an antenna and the H-Arm port is connected with a local oscillator. Port 2 has a matched load which has no reflections and port 1 has the mixer circuit, which gets half of the signal power and half of the oscillator power to produce IF frequency.

In addition to the above applications, an E-H Plane Tee junction is also used as Microwave bridge, Microwave discriminator, etc.

9. Pin Modulators

PIN Diode modulators offer an ideal way for amplitude and the pulse modulation of microwave signals through a wide range of frequencies. These modulators utilize PIN Diodes which are mounted across the waveguide line a R.F. isolated DC bias lead passing to an external TNC (F) Connector.

The PIN Modulator is a high-speed, current-controlled absorption type attenuator. Each PIN unit includes a low-pass filter, two high-pass filters, a number of PIN diodes, and a 50-ohm strip transmission line (ridged waveguide in the higher frequency units). As an operating device, the PIN Modulator should be thought of as a variable RF attenuator whose attenuation level is controlled by DC current and voltage. By applying a +5 volt DC potential to the BIAS input connector, RF signals will be passed through the PIN Modulator with only minimum residual attenuation. The PIN diode as a microwave modulator overcomes many of the drawbacks of present modulation systems. The diode reduces reflections by absorbing power and improves spectral purity by permitting the source to operate continuously. Thus the PIN diode is the heart of a true advance in the technique of microwave modulation.



10. SS Tuner

It is used for impedance matching in the transmission lines. A tuning screw attached with a micrometer along with the carriage helps in the impedance matching. Mismatches upto 20:1 can be tuned to a VSWR of less than 1.02 at any frequency in the waveguide band.

A mechanical slide screw-tuner consists of a 50Ω slabline and a capacitive/reflective probe, referred to as a slug. Ideally, when the slug is fully retracted, the tuner presents a 50Ω impedance. As the slug is lowered into the slabline (Y-direction), it interrupts the electric field and creates a capacitance, thereby increasing the magnitude of reflection. As the slug travels along the slabline (X-direction), the phase of the reflection is rotated. It is therefore possible to re-create any and all impedances without the need of discrete components (lumped elements or transmission lines).

Applications :

Load Pull for power devices, which entails varying the impedance presented to the output of an unmatched (non 50 ohm) DUT and monitoring some parameter(s) (power, gain, efficiency...).

Source Pull for low-noise device, which entails varying the impedance presented to the input of an unmatched (non-50 ohm) DUT and determining Noise Parameters.

Stability testing / conformance testing, which entails varying the VSWR presented to an matched or completed DUT (radio, mobile phone, test board...) and monitoring degradation as a function of mismatch.

11. Movable Short

These are used to obtain a phase reference in the calibration of various experimental setup and are also used to vary the effective plane of reflection and therefore the phase of reflected wave. These are also useful in impedance measurement. It consists of a waveguide section, flanged at one end and terminated with a moveable shorting plunger on the other end, driven by a precision micrometer with L.C. of 0.01mm.

SPECIFICATION: Frequency Range 8.2 to 12.4GHz Micrometer 25 mm Micrometer LC 0.01 mm Reflection Coefficient : 0.98 Wave guide RG-52/U Flange UG-39/U

12. Matched Termination

In making measurements of waveguide components it is often desirable to absorb the power propagated down the waveguide. These are designed in such a way to absorb the maximum energy without having appreciable reflection assuring low VSWR.

In order to get maximum power at desired frequency, two different arrangements can be used, which are called terminators.

1. Matched load termination.
2. Variable Short circuit.

In matched load termination there are two types;

1. Lossy Wedge : In this, a slab of lossy material is inserted in the end of the transmission line, this absorbs all the incident power giving no way to reflect.
2. Tapered resistive card : The tapered card absorbs the power, thus matching the impedance.

13. VSWR Meter

It measures the standing wave ratio (SWR) in a transmission line. The meter indirectly measures the degree of mismatch between a transmission line and its load (usually an antenna). Electronics technicians use it to adjust radio transmitters and their antennas and feedlines to

be impedance matched so they work together properly, and evaluate the effectiveness of other impedance matching efforts.
In some instances an antenna matching / tuning unit may be used. Again for convenience these are often placed near the transmitter. It is often more convenient to place an ATU close to the transmitter as having a remote one often means getting power to it and also weather-proofing it and this adds significant cost.

Limitations :

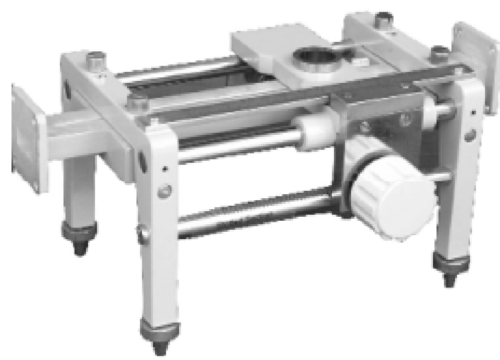
An SWR meter does not measure the actual impedance of a load (the resistance and reactance), but only the mismatch ratio. To measure the actual impedance requires an antenna analyzer or other similar RF measuring device. For accurate readings, the SWR meter itself must also match the line's impedance (typically 50 or 75 Ohms). To accommodate multiple impedances, some SWR meters have switches that select the impedance appropriate for the sense lines.
An SWR meter should connect to the line as close as possible to the antenna: All practical transmission lines have a certain amount of loss, which attenuates the reflected wave as it travels back along the line. Thus, the SWR is highest closest to the load, and only improves as the distance from the load increases, creating the false impression of a matched system.

14. Gunn Power Supply

The Gunn power supply delivers the DC and control voltages required for the operation of the Gunn oscillator and PIN modulator and enables the demodulated microwave signal to be quantitatively evaluated. Furthermore, this unit has various inputs and outputs for experiments on modulation and characteristics.
The DC voltage required for the operation of the Gunn oscillator is set to the optimum operating point of the Gunn element using the 10-turn potentiometer. The Gunn power supply can be adjusted between –10 V and 0 V and is short-circuit

proof. The Gunn voltage can be read off in alternation with the Gunn current on the measurement instrument. This permits both the point-by-point recording of the Gunn characteristic as well as control of the set operating point.
The selected measurement mode is displayed on the scale via the integrated LED. Switchover between the Gunn current IG and the Gunn voltage UG is carried out using the toggle switch. There are two sockets (labeled X, Y) for characteristic recording. The Gunn current is converted into a voltage with a conversion factor of approx. 1V/100 mA. Small Gunn current variations from Doppler signals are evaluated to the socket OUT / DOPPLER RADAR via a differential amplifier. The Gunn oscillator can be modulated externally via a supply voltage. For this, the power supply unit is equipped with a modulation input which is labeled MOD IN / GUNN EXT.

15. Slotted Section



It is the basic microwave equipment for study of VSWR Attenuation, Phase, Impedance, etc. It consists of a waveguide section in which a small longitudinal cut has been made and a carriage is affixed, which can be moved along the cut by a vernier arrangement. When a tunable detector probe is affixed on the carriage, its tip projects into the waveguide and picks up energy from the guide.
It is a section of waveguide or shielded transmission line in which the shield is slated to permit the use of a traveling probe for examination of standing waves. Also known as slotted line; slotted waveguide.
This system consists of a transmission line (Waveguide), a travelling probe carriage and facility for attaching/detecting instruments. The slot made in the center of the broad face does not radiate from any power of dominant mode. Slotted section is basically used to measure standing wave ratio (VSWR). The precession built probe carriage having centimeters scale with a vernier reading of 0.1mm least count is used to measure the position of the probe. Additionally, the slotted section can be used to measure impedance, reflection coefficient and the return loss.