

Experiment 2 : Study Of Microwave Components

Aim

To study various microwave components used in X-band waveguide systems and understand their construction, working principles, and applications.

Instruments/Equipments

1. Reflex klystron power supply
2. Gunn power supply
3. Slotted Line section
4. Microwave Test bench based on klystron and Gunn diode

Components

Reflex Klystron tube, Klystron mount, Isolator , Variable Attenuator, Frequency meter, Detector mount, E plane, H plane, Magic tee, Directional Coupler, Matched termination, PIN Modulator, Gunn diode, different types of antennas available.

Theory

Microwave components are devices used to generate, guide, control, measure, and radiate microwave energy (frequency > 1 GHz). In X-band systems (8.2-12.4 GHz), waveguides and solid-state sources like Gunn diodes or reflex-klystrons are used. Each microwave component performs a specific function, such as:

1. Generation (Gunn Oscillator / Klystron)
2. Guiding (Rectangular Waveguide)
3. Power measurement (Detector mounts, Slotted line)
4. Power division (E-plane/H-plane/Magic Tee)
5. Isolation (Circulators, Isolators)
6. Matching (Slide Screw Tuners, Movable short)
7. Radiation (Horn Antenna)

Components With Explanation

1. Waveguides

Waveguides are rectangular or circular shaped metallic tubes used to guide electromagnetic waves. In a rectangular waveguide, the electric and magnetic fields are distributed in a pattern across the cross-section of the waveguide. Each waveguide has a definite cut-off frequency below which no energy is transmitted. The dominant mode of a rectangular waveguide is given by:

$$f_c = \frac{1}{2\sqrt{\mu\epsilon}} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

where m and n correspond to modes and a and b are waveguide dimensions.

2. Waveguide Tees

Waveguide tees are used to connect waveguides to branch out the microwave signals. Commonly used microwave junctions are E-plane tee, H-plane tee, magic tee, hybrid ring, directional coupler, and circulator.

3. E-Plane Tee

E-plane tee is a T-shaped waveguide in which the side arm is parallel to the electric field of the main arm. A rectangular slot is made on the broader dimension of a waveguide and the side arm is attached as shown in the figure. Port 1 and port 2 are collinear ports and port 3 is the side arm. E-arm is also called series arm. Equal and opposite fields at the two ends of the collinear arms are obtained.

4. H-Plane Tee

The side arm of H-plane tee is parallel to the magnetic field of the main arm. All the three arms are of equal dimensions. When power is fed through the main arm, it splits into two equal parts at the two side arms. The waves leaving the two side arms have equal magnitudes and are in phase. When power is fed through one of the side arms, it divides into two waves entering the main arm and the other side arm. The outputs will be additive in magnitude and phase.

5. Magic Tee

A magic tee (hybrid tee) is a combination of E-plane tee and H-plane tee. It has a long waveguide in which two side arms are attached as shown in the figure. Port 1 and port 2 are collinear arms, port 3 is the H-arm (parallel arm), and port 4 is the E-arm (series arm). This four-port hybrid tee junction combines the properties of E-plane and H-plane tees. When power is fed through port 3 (H-arm), the field divides equally between port 1 and port 2 and the outputs are in phase. When power is fed through port 4 (E-arm), the field divides equally between port 1 and port 2 but the outputs are 180° out of phase. If equal amplitude and phase signals are applied at the two collinear arms, the energy appears only at the H-arm, while no output appears at the E-arm. The energy applied to the parallel arm gets divided equally between port 1 and port 2.

6. Directional Coupler

A directional coupler is a hybrid waveguide which couples power in an auxiliary waveguide in one direction. It is a four-port device with one port terminated in a matched load so that there is no power reflected. Directivity of the directional coupler is defined as the ratio of the power coupled in the auxiliary arm to the power coupled in the isolated arm. Ideally, directivity is infinite since the power in the uncoupled auxiliary arm is zero. The coupling is expressed in decibels (dB) as the ratio of power coupled in the auxiliary arm.

7. Slotted Waveguide Section

The slotted waveguide section is used to study the standing wave in the waveguide. A narrow longitudinal slot is cut along the centre of the broad wall of the waveguide. The slot provides smooth impedance transformation. The slot is long enough to cover several wavelengths. A probe is inserted in the holder and movable carriage on the section. A scale is attached to the slotted section to measure the distance the probe is moved.

8. Frequency Meter

A frequency meter is used to measure the frequency of the microwave signal in the waveguide. It consists of a calibrated tunable cavity. The calibration of frequency is done based on the resonance condition. Frequency Meter (Resonant Type) In one type of frequency meter, the frequency can be read directly from the scale. In another type, the frequency is determined from the chart supplied by the manufacturer.

9. Attenuators

Attenuators are used to provide suitable power level and to isolate different parts of a microwave circuit. They are calibrated to read the attenuation level in decibels (dB). A variable attenuator in a microwave test bench is an important component used to adjust the power level of a signal in a controlled manner. It allows precise control of signal attenuation, which is critical for testing and calibration in microwave systems. A variable attenuator typically consists of resistive elements or a combination of passive components that can be adjusted to change the level of attenuation in the signal path.

10. Isolator

An isolator is a device used to isolate the microwave source from the rest of the circuit. It allows transmission of waves only in one direction. This prevents reflections from reaching the source and protects the microwave generator.

11. Circulator

A circulator is a multi-port junction in which power may flow from one port to the next port only in one direction. A common application of circulators is in isolation of transmitter and receiver. Four-port circulators are commonly used.

12. Vswr Meter

A VSWR meter is an indicating voltmeter calibrated in dB. The square wave modulated output is needed to use the VSWR meter as the measuring device. Klystron Power Supply A klystron power supply is an equipment used to energize the klystron tube. It provides heater voltage and stabilized bias voltages to the electrodes of the tube. Since the variation in the bias voltage will affect the frequency of operation.

13. Tunable Probe

A tunable probe consists of a probe tip, crystal detector, and an adjustable penetration depth mechanism. It is used to pick up the electric field inside a waveguide and converts the RF (microwave) signal into a DC voltage, which can be measured using a VSWR meter or microammeter.

14. Detector Mount

A detector mount consists of a crystal diode placed inside a waveguide along with a tuning plunger. It is used to detect microwave power by converting the microwave signal into a proportional DC output, which can be measured using a VSWR meter or microammeter.

15. Klystron/Gunn Oscillator & Mount

A klystron tube or Gunn diode is mounted inside a tuned cavity to generate microwave oscillations. A movable tuning plunger is provided to adjust the operating frequency. It generates continuous wave (CW) microwave signals and serves as the basic microwave source for X-band experiments.

16. Matched Termination

The matched termination is a termination or a load for a microwave setup. Standing waves occur when ever a load doesn't completely absorb the power reaching it. In the microwave measurements, whether for power or component characteristics e.g. VSWR of slotted section, it is terminated for minimum reflection. The match termination serves this purpose. The closed end has a resistive element of suitable electrical and mechanical characteristics for providing near perfect load.

17. Pyramidal Horn Antenna

A pyramidal horn antenna is used to convert guided electromagnetic waves from a waveguide into radiated waves infreespace. It is commonly used for gain measurements, radiation pattern measurements, and other microwave radiation experiments due to its high directivity and low reflection

18. Gunn Oscillators

Gunn Oscillators are solid state microwave energy generators. These consist 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 oscillator is supplied with calibration certificate giving frequency vs micrometer reading.

19. Pin Modulators

Pin modulators are designed to modulate the continuous wave output of Gunn Oscillators. It is operated by the square pulses derived from the UHF (F) connector of the Gunn power supply. These consist of a pin diode mounted inside a section of Wave guide flanged on its both end. A fixed attenuation vane is mounted inside at the input to protect the oscillator.

20. Gunn Power Supply

Provides regulated DC bias and modulation pulses for Gunn diode & PIN modulator.

Precautions

Beam voltage should not exceed 250V , Fan should be operated to reduce the heat for reflex klystron. Carefully follow the specifications of the device and equipment.

Result

Various microwave components including waveguides, attenuators, directional couplers, tees, tuners, terminations, horn antennas, Gunn oscillators were successfully studied.



Slotted Section



Mounting Base



Matched load



Horn antenna



Detector Mount



Klystron Power Supply



Microwave test bench
-Gunn



Microwave test bench
-Klystron



Directional coupler



Isolator



E Plane



H Plane



Magic Tee