UNIT 3

WAVEGUIDE COMPONENTS

Syllabus

WAVEGUIDE COMPONENTS: Coupling Mechanisms – Probe, Loop, Aperture types. Waveguide Discontinuities – Waveguide Windows, Tuning Screws and Posts, Matched Loads. Waveguide Attenuators – Different Types, Resistive Card and Rotary Vane Attenuators; Waveguide Phase Shifters – Types, Dielectric and Rotary Vane Phase Shifters, Waveguide Multiport Junctions - E plane and H plane Tees. Ferrites– Composition and Characteristics, Faraday Rotation, Ferrite Components – Gyrator, Isolator

LEARNING OBJECTIVES

- Basic coupling mechanisms such as Probe, Loop, Aperture types.
- Concept of waveguide discontinuities like waveguide windows.
- Commonly used tuning screws, posts and matched loads.
- Different types and working of waveguide attenuators such as resistive card and rotary vane attenuators.
- Different types and working of waveguide phase shifters such as dielectric and rotary vane phase shifters.
- Construction and working of various waveguide multiport junctions such as E-plane, H plane and magic tees.
- Concept and characteristics of ferrite materials.
- Construction and working various ferrite components such as gyrator and isolator.

INTRODUCTION

A basic microwave circuit ordinarily consists of several microwave devices connected in some way to achieve the desired transmission of a microwave signal. The interconnection of two or more microwave devices may be regarded as a microwave junction. These are also referred as waveguide components. In this unit, we discuss about commonly used waveguide components such as probes, loops, aperture types, waveguide windows, tuning screws, posts matched loads, waveguide attenuators, waveguide phase shifters, waveguide tees as the E- plane tee, H-plane tee and magic tee..

In this unit, we will also discuss about ferrite components such as gyrator, isolator.

PART-A SHORT QUESTIONS WITH SOLUTIONS

Q1. List out the functions of various waveguide components and their applications.

Ans: Nov./Dec.-17, (R13), Q1(c)

The basic functions of waveguide components are,

1. These are responsible for absorbing microwave energy from the system
2. These components are used to match the load impedance with the source impedance.
3. These are responsible for transmitting microwave energy between the different ports while directing and reflecting energy to a port with an attached load.
4. These are used to couple power taken from the waveguide system which helps in measuring power, frequency, and other parameters to ensure proper flow of energy.

The application of waveguide components include,

1. These are as simple as a transmission line
2. These are also used to make various passive components like a filter, divider horn antennas, etc.
3. These are used to measure and regulate high power.
4. They can also work at very high frequencies.

Q2. Define,

1. **Coupling probe**
2. **Coupling loop**
3. **Aperture coupling.**

Ans:

1. **Coupling Probe**

Coupling probe is used to couple coaxial line to waveguide or resonator. The coupling of a coaxial line at the mid-point of the broader walls of the guide, where the electric field is maximum is referred as coupling probe.

2. **Coupling Loop**

Coupling loop is a metallic wire used to couple coaxial line to waveguide or resonator. This implies the placing of a loop near a point where magnetic field strength is high.

3. **Aperture Coupling**

The coupling of waveguide together using small aperture in a common wall to sample the field of main guide using another waveguide is referred as aperture coupling.

Q3. Compare probe and loop connectors. (Model Paper, Q1(c) | Dec.-19, (R16), Q1(d))

(or)

Compare probe and loop connections.

Ans: May/June-19, (R15), Q1(d)

The comparison between probe and loop connectors is shown in table.

Probe	Loop Connectors
1. Probe is connected approximately $\lambda_g/4$ distance from termination.	1. Loops are connected in the middle of the top or bottom wall of a distance of integral $\lambda_g/2$ from the shorted end.
2. For activating specific mode, probe is placed parallel to the E-field.	2. Loop is basically magnetic, so it is placed at high H-field strength.
3. Probes are specifically preferred.	3. Loops are mostly preferred.

Table

Q4. What is waveguide iris? Where it is used?

Ans:

Waveguide iris (or) window is a small section of waveguide that is commonly used for impedance matching at microwave frequencies. Using windows or irises the susceptance of a waveguide can be changed. These are of capacitive, inductive or reactive in nature.

Q5. What are tuning screw, posts and matched loads?

Ans: Model Paper, Q1(h)

Tuning Screw

Tuning screw is a metal rod which is inserted perpendicular into a rectangular waveguide in order to tune the device for impedance matching (based on its reactive nature).

Posts

Posts are thin cylindrical rods that extend completely across the narrow width of the wave guide at the centre of broad wall to provide inductive or capacitive susceptance.

Matched Loads

Matched load implies short circuiting or open circuiting the loss less line to obtain the impedance of transmission line preferably used matched load is stub.

Q6. What is post? What are the applications?

Ans: Dec.-19, (R16), Q1(c)

Post

For answer refer Unit-3, Q5, Topic: Posts.

Applications

1. The main application of posts is to provide inductive or capacitive reactance or susceptance in a waveguide for impedance matching.
2. These can be used as band pass filters by making them thicker.

Q7. What is the need of attenuator?

Ans:

Attenuators are used for complete matching of microwave power in a wave guide without any reflection and intensity of frequency. These are commonly used for measuring power gain or loss in decibels for providing isolation between instruments, for reducing the power input to a particular stage to prevent overloading and also for providing the signal generators with a means of calibrating their outputs accurately.

Q8. Why do E-plane Tee and H-plane Tee are called as series and parallel Tees?

Ans:

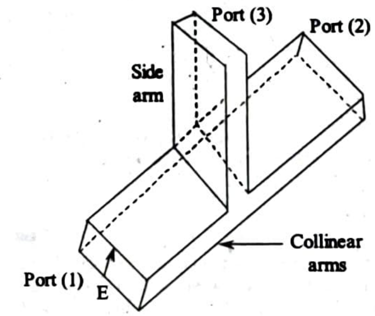
In the *E*-plane Tee, high amount of energy is delivered to an auxiliary guide connected to a transmission line, if the auxiliary guide is connected in series with the main guide at a point of low voltage and high current. Hence, *E*-plane Tee is occasionally called "series Tee".

In the *H*-plane Tee, high amount of energy is delivered to an auxiliary guide connected to a transmission line, if the auxiliary guide is connected in shunt with the main guide at a point of high voltage and low current. Hence, *H*-plane Tee is occasionally called as "parallel" or "shunt Tee".

Q9. Draw the E-plane Tee junction diagram.

Ans: April/May-18, (R13), Q1(c)

A waveguide Tee in which the axis of its side arm is parallel to the *E* field of the main guide is known as *E*-plane Tee and is shown in figure.



Figure

Q10. What magic is associated with a Magic Tee?

Ans: Nov./Dec-18, (R13), Q1(c)

The magic tee is designed in such a way that E plane and H-plane ports are simultaneously matched. Also, the other two collinear ports are matched and isolated from one another.

Q11. What is a ferrite isolator and ferrite phase shifter?

Ans:

Ferrite Isolator

Ferrite isolator is a ferrite device which allows microwave energy to pass in one direction only. Hence, it blocks the energy in the other direction in a waveguide.

Ferrite Phase Shifter

A ferrite phase shifter is an instrument that produces a change in the phase angle of the wave transmitting through it using a ferrite rod. An ideal phase shifter is perfectly matched to the input lines and output lines with zero attenuation of the wave.

PART-B ESSAY QUESTIONS WITH SOLUTIONS

3.1 COUPLING MECHANISMS – PROBE, LOOP, APERTURE TYPES

Q12. Explain coupling probes and coupling loops.

Ans: (Model Paper, Q6(a) | Nov./Dec.-16, (R13), Q4(b) | Nov.-13, (R09), Q3(a))

Coupling Probes

Coupling probes are waveguide adapters that are used to couple the electromagnetic signals from waveguide or cavity resonator to an external circuit. The phenomenon of coupling using co-axial line probe is as shown in figure (1).

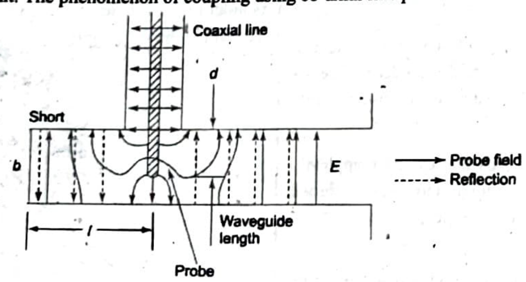


Figure (1): Probe Coupling

The coupling arrangement is in such a way that the field components must excited in parallel or perpendicular to the probe. The probe is inserted into the waveguide through broad wall and is in parallel or perpendicualr to maximum electric field for TE_{10} or dominant mode of excitation. In order to radiate field inside the waveguide depth of insertion of probes must be small.

The direction of field propagation is in one direction, when a short circuit is placed at front end of the waveguide at a distance of $\lambda/4$ from probe. For specific values of l and d, the input impedance of probe is pure resistance and is equal to the characteristic impedance of feeder coaxial line i.e., $Z_{in} = Z_0$. It can be expressed as,

$$Z_{in} = R = \frac{2\eta_o}{ab\beta_{10}k_o}\sin^2\beta_{10}l\,.\tan^2(k_o d/2)$$

Where,

η_o – Intrinsic impedance $= \sqrt{\frac{\mu_o}{\varepsilon_o}} = 120\,\pi$ or $377\ \Omega$

β_{10} – Phase constant for TE_{10} mode $= k_o\sqrt{1-(\lambda_o/2a^2)}$

a, b – Dimensions of waveguide

k_o – Propagation constant $= 2\pi/\lambda_o$.

The higher order modes that are excited at the probe are greatly attenuated due to the fields in coaxial line and at the waveguide are perpendicular to each other. By choosing proper values for l, d and small probe diameter (less than 0.15 a), the reactance in probe can be made negligible at higher order modes.

Coupling Loops

Coupling loop is a metallic wire or a single term inductor which is used to couple electromagnetic signals from waveguide or cavity resonator to an external circuit.

The coupling loops are placed between the top and bottom walls of guide with its plane perpendicular to waveguide as shown in figure (2).

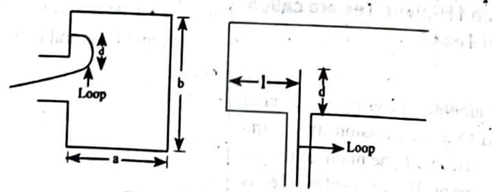


Figure (2): Loop Coupling

The coupling of loop is mainly magnetic. When a loop is placed normal to the flux lines of H-field, maximum coupling is obtained. The amount of coupling depends on size, shape and area of the loop.

Loops are generally mounted near to the shorted waveguide end wall at a distance of $\frac{n\lambda_g}{2}$ from shorted end as shown in figure (2).

To propagate field in one direction a short circuit plate is placed at distance l at front end. Then the impedance of the probe is equal to characteristic impedance (Z_o) of feeder coaxial line and it is pure resistive. It can be expressed as,

$$Z_{in} = Z_0 = R = \frac{k_0\eta_0}{2ab\beta_{10}}(\pi/a)^2(\pi d)^2\sin^2(\beta_{10}l),$$

$$d < \frac{\lambda_0}{10} \text{ and } \frac{\lambda_g}{2} < l < \frac{\lambda_g}{4}$$

Q13. Explain types of aperture coupling with neat sketches.

Ans:

The coupling of waveguides together using small aperture in a common wall is used to sample the field of main guide using another waveguide.

When the energy of the sample in main waveguide is coupled to the resonant cavity using aperture, the energy is absorbed by the cavity at the resonance which is obtained at the output of the main waveguide.

There are two types of aperture coupling based on the aperture orientation with respect to the fields as,

1. Electric or E-field coupling
2. Magnetic or M-field coupling.

1. Electric or E-field Coupling

In electric aperture coupling, when the electric dipole is transverse to the aperture plane and its dipole moment is dependent on the normal component of the electric field in the waveguide.

The normal component of the electric field lines and tangential components of magnetic field excited from the aperture as shown is figure (1).

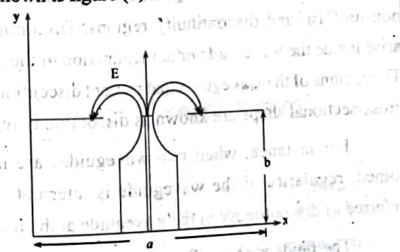


Figure (1): E-field Aperture Coupling

The electric polarizabilities for circular and rectangular apertures are given by,

$$\alpha_{e(\text{circular})} = \frac{2r_o^3}{3} \text{ and } \alpha_{e(\text{rect.})} = \frac{\pi l d^2}{16}$$

Where,

r_o – Radius of circular aperture

l – Length of rectangular aperture

d – Distance

Case (i): When the tangential electric field is zero at the conducting wall, the normal electric field lines exist as shown in figure (2).

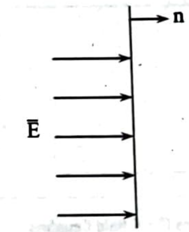


Figure (2): Normal Electric Field Near a Conducting Wall

Case (ii): When there is a small aperture the electric field lines appear near and around the aperture of conducting wall as shown in figure (3).

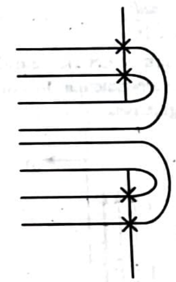


Figure (3): Electric Field Lines Around and Near the Aperture

Case (iii): When electric polarization current is infinite and normal to the conducting wall, the lines of electric field appear around it as shown in figure (4).

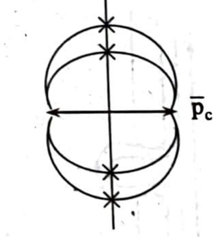


Figure (4): Electric Field Lines around Conducting Wall

2. Magnetic or M-field Coupling

In magnetic field aperture coupling, when the magnetic field is perpendicular to the aperture plane and its dipole moment is dependent on the tangential component of the magnetic field.

The tangential component of magnetic field lines are restricted through the boundaries of the aperture as shown in figure (5).

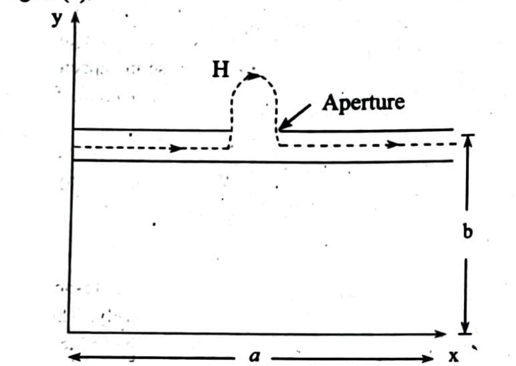


Figure (5): H-field Coupling

The magnetic polarizabilities for circular and rectangular apertures are given by,

$$\alpha_{m(circular)} = \frac{4r_o^3}{3}$$

$$\text{and } \alpha_{m(rect.)} = \frac{\pi l d^2}{16}$$

Case (i): When the normal electric field does not exist, the magnetic field lines perpendicular to conducting wall are present as shown in figure (6).

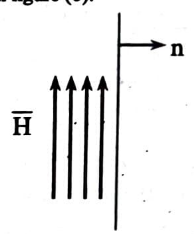


Figure (6): Magnetic Field Lines at Conducting Wall

Case (ii): When there is a small aperture the tangential magnetic field lines flows near it as shown in figure (7).

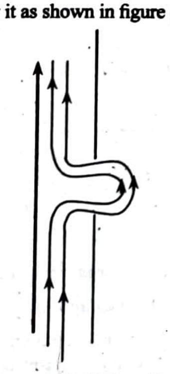


Figure (7): Magnetic Field Lines Near Aperture

Case (iii): When infinite magnetic polarization currents are parallel to the conducting walls, the magnetic field lines appear around the conducting wall as shown in figure (8).

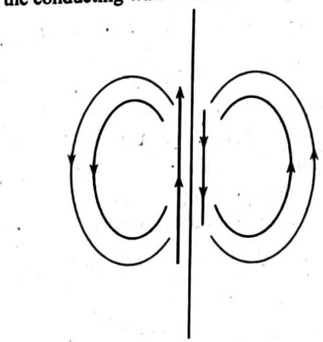


Figure (8): Magnetic Field Lines around Conducting Wall

If there exist a small circular aperture of radius $r_o << \lambda_o$ in conducting wall of rectangular waveguide operating in TE_{10} or dominant mode, then it exhibits inductive susceptance, B and is given as,

$$B = \frac{-3ab}{8r_o^3 \beta_{10} Z_{10}}$$

In dominant mode of operation, the electric dipole is excited in y - direction, the axial (z) component of magnetic dipole radiates symmetrically along z - direction and the normal (x) component of magnetic dipole radiates asymmetrically. The amount of field excitation in upper waveguide can be handled by varying the angle between waveguides or by changing the position of aperture.

3.2 Waveguides Discontinuities – Waveguides Windows

Q14. Write short notes on waveguide discontinuities.

Ans:

The structure of waveguide is a combination of uniform, non-uniform and discontinuity regions. Discontinuities can arise inside the waveguide or at the junction of the waveguide. The regions of the waveguide that present discontinuities in the cross-sectional shape are known as discontinuity regions.

For instance, when two waveguides are improperly joined, regularity of the waveguide is interrupted which is referred as discontinuity in the waveguide at the junction.

The fields within different regions of a waveguide are commonly described only by dominant propagating mode. However, to describe the fields in the discontinuous region of the waveguide, an infinite number of non-propagating modes are needed along with the dominant propagating mode.

Q15. What are the waveguide windows? How these are used in microwave circuits?

May/June-19, (R15), Q5(b)

(or)

Write short notes on "Waveguide windows (Irises)".

Nov./Dec.-16, (R13), Q1(d)

Ans:

Waveguide Windows

Waveguide windows are a small section of waveguide that are commonly used for impedance matching at microwave frequencies. Using windows or irises the susceptance of a waveguide can be changed. These are of capacitive, inductive or reactive in nature as shown in figure.

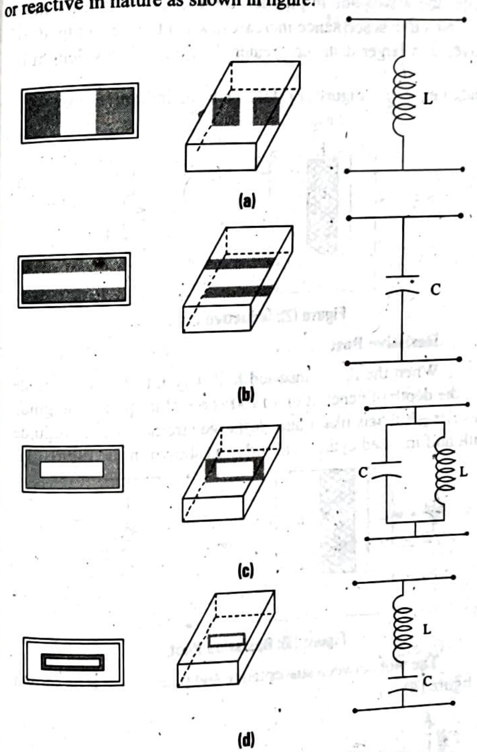


Figure: Different Types of Waveguide Windows

1. **Inductive Windows**

Inductive windows are used to increase the inductive susceptance of waveguide, which are resulted by inserting conducting diaphragm from side walls as shown in figure (a). The amount of increase in the inductive susceptance depends on depth of insertion of diaphragms. The position of window is where the magnetic field is strong. The current flowing due to a window results a magnetic field, since the plane of polarization of electric field is parallel to the plane of window. The increase in inductance takes place where the energy of magnetic field is stored.

2. **Capacitive Windows**

In order to increase capacitive susceptance of waveguide capacitive windows are used. These are resulted by inserting conducting diaphrams from top and bottom walls of waveguide as shown in figure (b). The amount of increase in capacitive susceptance depends on depth of insertion of diaphram. The position of capacitive window is in such a way that where the electric field is strong. The major drawback of using capacitive windows is that they reduce the power handling capability of waveguide.

3. **Resonant Windows**

Figure (c) and figure (d) shows the parallel resonant window and series resonant window respectively. These windows are obtained by suitably combining the inductive and capacitive windows, which produce equal reactance of capacitor and inductor. The parallel resonant window supports only dominant mode by providing a high impedance. The series resonant window contains transparent nonmetallic material and is transparent to the flow of microwave energy. For unwanted modes, the resonant window acts as a band pass filter.

3.3 Tuning Screws and Posts, Matched Loads

Q16. Write short note on tunning screws used in waveguides.

Nov.-15, (R09), Q3(c)

Ans:

Tuning Screws in Waveguide

The inductive and capacitive windows are not readily adjustable due to the imperfect contact between the diaphragm and the walls of the waveguide. By inserting a screw at the top or bottom of the waveguide, a variable susceptance value can be obtained. An effective value of the capacitive susceptance can be obtained by a screw of length less than that of quarter free-space wavelength as shown in figure (1). The capacitive susceptance value increases with depth of penetration.

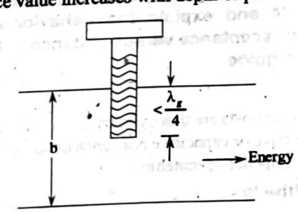


Figure (1)

When the depth of penetration is approximately a quarter-wavelength. The screw acts as a resistive circuit as shown in figure (2).

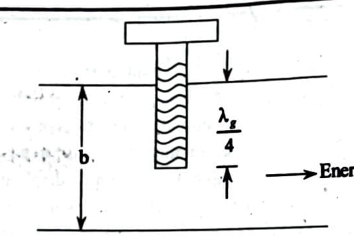


Figure (2)

An effective inductive susceptance is produced when the screw is inserted further i.e., depth of penetration is greater than that of the quarter free space wavelength as shown in figure (3).

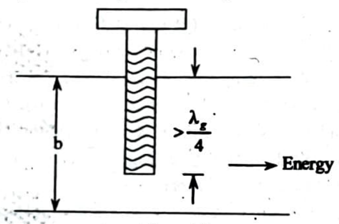


Figure (3)

The use of screws to produce a wide range of inductive susceptance is not possible since, the b dimension of waveguide is ordinarily too small.

In the direct method of impedance matching, a matching screw uses a single screw which can adjust both the length and position along the waveguide. By measuring the node position and voltage standing wave ratio, the correct position of the screw relative to the unmatched termination of the waveguide can be predicted. The adjusting position and penetration of the screw by trial and error method until the voltage standing wave ratio is within the allowable value, is the simplest method.

Usage of single screw in the impedance matching has a disadvantage that it requires a slot in the wall of the waveguide. This drawback can be overcome by using double or triple-screw units, in which two or three adjustable-depth screws are spaced at an eighth or quarter of the guide wavelength.

Q17. What are waveguide posts? Draw the equivalent circuits of waveguide posts of lengths < λ/4, = λ/4, >λ/4 and explain the behavior using a graph susceptance versus distance of the post into the guide.

Ans:

Waveguide posts are thin cylindrical rods those are used to provide inductive or capacitive reactance or susceptance in a waveguide for impedance matching.

1. **Capacitive Post**

The waveguide post acts as capacitive when it is inserted normal to the direction electric field in waveguide operating at dominant mode or TE_{10} mode. The capacitive susceptance increases with the diameter of the post. The capacitive post in a waveguide is as shown in figure (1).

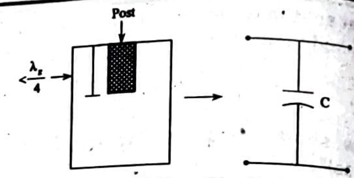


Figure (1): Capacitive Post

From figure (1), the rod is inserted or moves into a waveguide at a short distance of less than wuarter wavelength of guide i.e., $<\lambda_g/4$ in order to all in capacitive susceptance.

2. **Inductive Post**

The waveguide post acts as inductive, when it is extended across the waveguide in parallel to direction of electric field. The inductive susceptance increases, when the post extends or moves at a larger distance greater than quater wavelength of guide i.e., $>\frac{\lambda_g}{4}$. Figure (2) shows a basic inductive post.

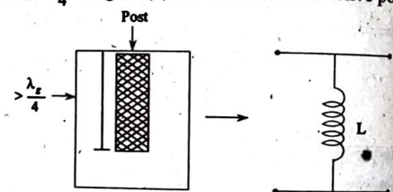


Figure (2): Inductive Post

3. **Resistive Post**

When the rod is inserted half way into the waveguide i.e., the depth of penetration of rod is equal to quater the guide wavelength it acts like a pure resistive circuit. The waveguide with half inserted cylindrical rod is as shown in the figure (3).

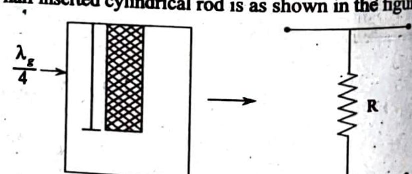


Figure (3): Resistive Post

The plot between susceptance and penetration is as shown in figure (4).

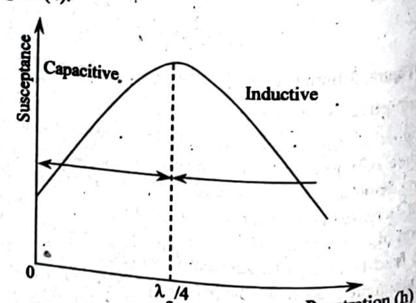


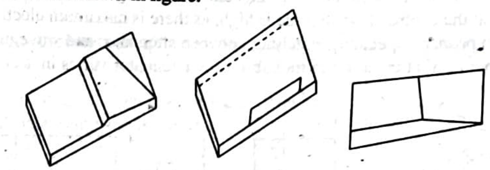
Figure (4): Susceptance versus Penetration

Q18. Write short note on matched loads in waveguide.

Ans:

Matched loads or matched terminations are impedance matching devices which are used in co-axial lines and waveguides to absorb the incident power without causing any reflections. Matched load in a waveguide is a resistive card or a graphite sand placed in parallel to the electric field. A highly absorbent resistive card must be considered with tapered front end to reduce reflections and discontinuity of the signal.

Some of the matched loads are as shown in figure.



(a) Stepped Load **(b) Tapered Load** **(c) Choped Load**

Figure: Matched Loads

Matched loads are used in test bench setups, for accurate reproducible termination for directional couplers magic tee etc.

3.4 Waveguide Attenuators – Different Types, Resistive Card and Rotary Vane Attenuators

Q19. What are the different types of waveguide attenuators? Explain their working with neat diagrams. Dec.-19, (R16), Q4(a)

(or)

Explain the functioning rotary vane attenuators. Nov./Dec.-18, (R13), Q5(a)

(Refer Only Rotary Vane Attenuators)

(or)

Write short note on rotary vane attennuator. Nov.-15, (R09), Q3(a)

(Refer Only Rotary Vane Attenuators)

Ans:

The different types of attenuators are,

1. Flap attenuators
2. Vane attenuators.

Generally, attenuators are used to measure the power gain or loss in dB.

1. **Flap Attenuators:** Flap attenuator is a variable attenuator provides continuous or step wise attenuation. Figure (1) shows a flap attenuator which includes a resistive card placed along the length of the guide. The flap (or) resistive card is seated on hinged arm in such a way that it penetrates into the waveguide. The amount of attenuation offered by the device is varied in accordance with depth of penetration of the flap.

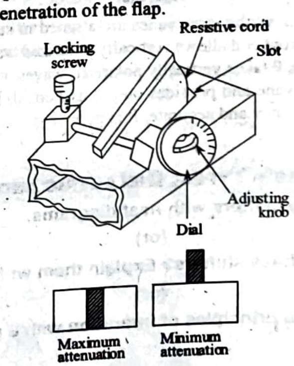


Figure (1)

Since, the flap attenuator is not a precision attenuator, the dial must be calibrated against a specific standard.

2. Vane Attenuators

Vane attenuators are classified into two types as,

(i) Movable vane attenuator

(ii) Rotary vane attenuator.

(i) Movable Vane Attenuator: Movable vane attenuators include a glass vane which is coated with aquadog or carbon. Since it is a variable attenuator, the vane mounted at the centre of waveguide is made adjustable as shown in figure (2). The amount of attenuation at the centre of waveguide is high, as there is maximum electric field and it falls if vane moves away from centre. To attain proper impedance matching between attenuator and waveguide, the ends of vane are tapered to a length of $\lambda_g/2$. The amount of attenuation in movable vane attenuator varies in accordance with frequency.

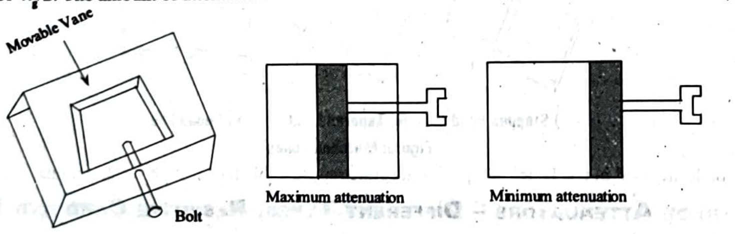


Figure (2)

Since it is not a precision attenuator, the dial must be calibrated against a standard.

(ii) Rotary Vane Attenuators: A rotary vane attenuator is a precision attenuator which provides an accuracy as ± 2.1 % of attenuation indicated within the range of frequencies. It includes three resistive cards or vanes as shown in figure (3). The tapered rotating vane is mounted in a circular waveguide at the centre. The remaining two vanes are placed in rectangular waveguides at front and back end respectively.

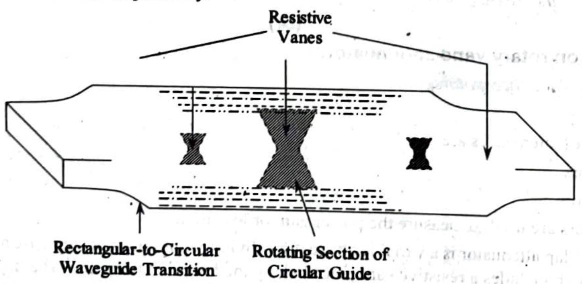


Figure (3)

The attenuation in waveguide is zero, if all the three vanes are aligned in such a way that their planes are normal to the direction of electric field. The vane at front end allows vertically polarized waves and blocks horizontal waves. The centre vane or rotary vane rotated by an angle θ takes vertically polarised waves as input and sends out $E\cos\theta$ component. The vane at output behaves same as input vane and provides output as $E\cos^2\theta$. Hence, the total attenuation occurs in rotary vane attenuator is independent of frequency and accurate. It is given by,

$$20 \log \cos^2\theta = 40 \log \cos\theta$$

3.5 Waveguide Phase Shifters – Types, Dielectric and Rotary Vane Phase Shifters

Q20. Examine about waveguide phase shifters with neat diagrams. (Model Paper, Q6(b) | Oct./Nov.-20, (R16), Q4(b))

(or)

What are the different types of Phase shifters? Explain them with neat diagrams. May/June-19, (R15), Q4(a)

(or)

What is phase shifter? Explain its principles of operation with a neat sketch. Give its applications. Nov.-13, (R09), Q3(b)

(or)

Write short note on rotary phase shifter. Nov.-15, (R09), Q3(b)

Ans:

Waveguide Phase Shifter

Phase shifter is a two-port device or component. In waveguides, phase shifters are used to introduce a change in the phase angle of the waveform transmitted through it. This phase change does not cause any attenuation in the signal and idealy this attenuation is zero.

There are two types of phase shifters i.e.,

1. **Fixed Phase Shifters**

These phase shifters are also known as binary switches, which cause a fixed change in phase of transmitted wave.

2. **Variable Phase Shifters**

These phase shifters-are also known as tunable phase shifters phase shift can achieved either by means of mechanical adjustment or by means of electronical adjustment. Electrically adjustable phase shifters find many applications due to their speedness and accuracy.

In waveguides, variable phase shifters are used to employ phase change. Dielectric and rotary (both are mechanically adjustable) phase shifters are used in rectangular and circular waveguide respectively.

Dielectric Phase Shifters

A typical dielectric phase shifter is as shown in figure (1). In dielectric phase shifter, a slab of low-loss dielectric material (i.e., polystyrene) is inserted into the waveguide. Two metal support rods are securely attached to the slab so that, it can freely move along broader dimension of the waveguide to vary the electric field intensity.

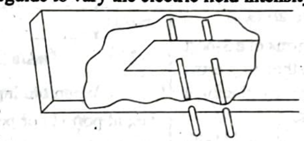


Figure (1)

The dielectric inserted into the waveguide increases the effective dielectric constant which inturn reduces the guide wavelength, λ_g. It also increases the phase shift in a wave propagating along the length of waveguide. For obtaining the minimum reflections, the spacing between supporting rods and the taper of the slab must be properly chosen. When the slab is at the centre of the guide i.e., where the electric field is strong, its maximum effect is experienced. The electrical length of the section appears to increase as the slab is moved towards the center of the waveguide since, the phase velocity in the section is reduced by the dielectric, placed in the waveguide.

Applications of Phase Shifters

1. It is used in phased array antenna system, in which the phase of large number of radiating elements are controlled to force the electromagnetic wave to add up at a particular angle to the array.
2. The high speed diode phase shifters are used in serrodyne systems where, change in phase result in nearly pure side band generation.
3. A microwave variable phase shifters of a coplanar waveguide are used to calculate the electric field.
4. The continuously variable phase shifters used for broadband, wireless local area networks, base stations, satellite communications, phased-array radar and smart antennas.
5. Phase shifters are also used in frequency-agile systems, where frequency and phase must change quickly.

Rotary Phase Shifter

A typical rotary phase shifter is as shown in figure (2). This type of phase shifter is more accurate than that of linear phase shifter. Its construction is similar to that of the rotary attenuator, it includes two fixed and one rotating waveguide sections. The centre and outer resistive cards are replaced by half-wave and quarter-wave plates respectively. The phase shift produced by the half-wave plate or rotating section is equal to twice the angle, θ through which it is rotated. A linearly polarized TE_{11} mode is converted into a circularly-polarized mode by the quarter-wave plates and similarly, it converts a circularly-polarized mode into a linearly polarized TE_{11} mode.

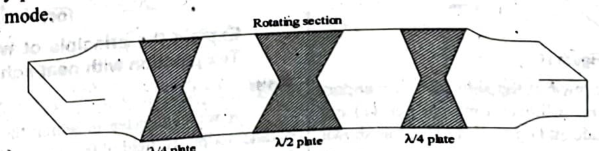


Figure (2)

The electric field components of the circularly-polarized wave i.e., x and y components are equal in magnitude but, 90° out of phase. A quarter-wave plate is constructed from a slab of dielectric material. For a TE_{11} mode propagating perpendicular to the slab, $\beta_2 > \beta_1$ (where, β_2 is the propagation constant for parallel polarization). The differential phase change must be $(\beta_2 - \beta_1)\, l = 90°$. The reflections can be reduced by tapering the ends of the dielectric slab.

3.6 Waveguide Multiport Junctions – E Plane and H Plane Tees

Q21. List out the 3 theorems associated with 3-port Tee junctions and mention their applications.

Ans:

The three theorems associated with 3-ports tee junction those describe its characteristics are,

1. A three-port tee junction can contain a short circuit in one of it's arm, only when it is placed in such a way that power can not pass through the other two arms.
2. If a junction is symmetrical to one of the arms of a 3-port tee junction, then reflections occur in other two arms during power transmission can be stopped by placing a short circuit in that symmetrical junction.
3. A 3-port tee junction having random symmetry, can never have a matched impedances in all it's 3 arms.

Applications

1. Using these theorems, 3-port tee junctions are made to function as power-dividers and adders.
2. The 3-port symmetrical tee junctions are also used as tuners by placing a short circuit in their symmetrical arm.
3. They are used in duplexer assemblies of radar installations.

Q22. Explain the construction and working of E-plane Tee.

Ans:

A waveguide Tee in which the axis of its side arm is parallel to the E field of the main guide is known as E-plane Tee and is shown in figure (1).

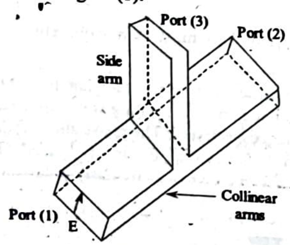


Figure (1)

When the input is applied at the side arm i.e., at port (3), the outputs obtained from collinear arms i.e., port (1) and port (2) are of equal magnitude and opposite in phase as shown in figure (2).

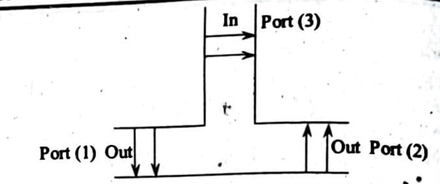


Figure (2)

When the input is applied at collinear arms i.e., at port (1) and port (2), then the output obtained from the side arm depends on the phase of the inputs applied at collinear arms. For instance, if phased inputs are applied at port (1) and port (2) then output at port (3) is zero and if a 180° phase shift is applied between port (1) and port (2) then the output at port (3) is maximum as shown in figures (3) and (4).

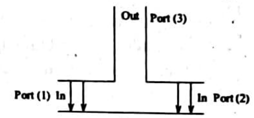


Figure (3)

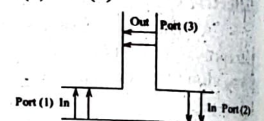


Figure (4)

When the input is applied at one of the collinear arms i.e., at port (1) or port (2), the respective outputs are obtained at port (2) or port (1) and side arm as shown in figure (5).

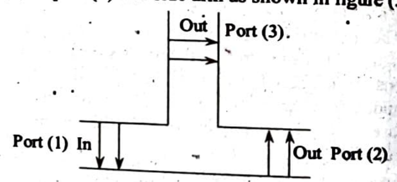


Figure (5)

In the E-plane Tee Junction, high amount of energy is delivered to an auxiliary guide connected to a transmission line, if the auxiliary guide is connected in series with the main line (at a point of low voltage and high current). Hence, E-plane Tee junction is occasionally called "Series Tee".

Q23. Draw the structure diagram of H-plane Tee and explain its characteristics.

May/June-19, (R15), Q4(b)

(or)

Describe the working of H-plane Tee and state why it is called shunt Tee.

April/May-18, (R13), Q4(a)

(or)

Explain the principle of working of a H-plane Tee junction with neat schematics.

Ans:

A waveguide tee in which the axis of its side arm is parallel to the 'H' field of the main guide is known as H-plane Tee and is shown in figure (1).

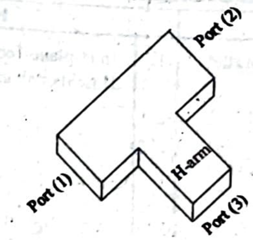


Figure (1)

When the input is applied at the side arm i.e., at port (3), the outputs of equal magnitude are obtained from collinear arms i.e., port (1) and port (2) and are of equal magnitude as shown in figure (2).

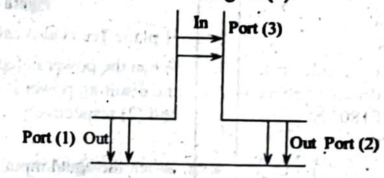


Figure (2)

When the input is applied at collinear arms i.e., at port (1) and (2), the output obtained from the side arm depends on the phase of the inputs applied at collinear arms. For instance, if phased inputs are applied at port (1) and (2) then maximum power is obtained at port (3) and if a 180° phase shift is applied between port (1) and (2) then, the output at port (3) is zero, as shown in figures (3) and (4).

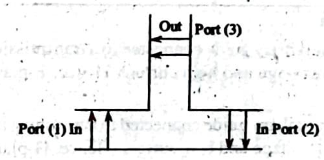


Figure (3)

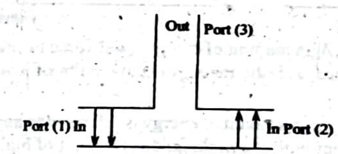


Figure (4)

When the input is applied at one of collinear arms i.e., port (1) or port (2), the respective outputs are obtained at port (2) or (1) and side arm as shown in figure (5).

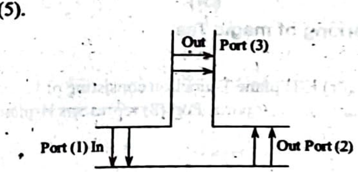


Figure (5)

In the H-plane Tee, high amount of energy is delivered to an auxiliary guide connected to a transmission line, if the auxiliary guide is connected in shunt with the main guide at a point of high voltage and low current. Hence, H-plane Tee is occasionally called "parallel" or "shunt Tee".

Q24. Explain the difference between,

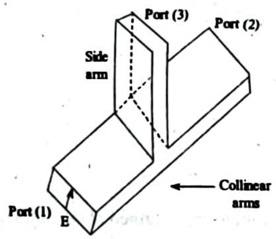
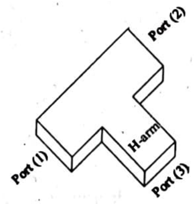
(i) E-plane Tee

(ii) H-plane Tee

Also explain clearly why do you call them series and parallel Tee respectively.

Ans:

The differences between E-plane tee and H-plane tee are mentioned in table.

	E-Plane Tee		H-Plane Tee
1.	In E-plane Tee, the axis of its side arm is parallel to the E field of the main guide.  Figure (1)	1.	In H-plane Tee, the axis of its side arm is parallel to the H field or shunting the E field of the main guide.  Figure (2)
2.	E-plane Tee is also called series Tee.	2.	H-plane Tee is also called parallel or shunt Tee.
3.	When the power is fed at port (3) i.e., at side arm, then the resulting power is equally divided between port (1) and (2) but, a phase shift of 180° is introduced between the two outputs.	3.	When the power is fed at port (3) i.e., at side arm, then the resulting power is equally divided between port (1) and (2) respectively.
4.	When the equal input power is fed at both ports (1) and (2), no output is obtained at port (3).	4.	When the equal input power is fed at both ports (1) and port (2), then maximum power i.e., addition of two inputs are obtained at port (3).
5.	When the input is applied at any one of collinear ports i.e., port (1) or port (2), the resulting powers are obtained at port (2) or port (1) and port (3).	5.	When the input is applied at any one of collinear ports i.e., port (1) or port (2), the resulting powers are obtained at port (2) or port (1) and port (3).

Table

In the E-plane Tee, high amount of energy is delivered to an auxiliary guide connected to a transmission line, if the auxiliary guide is connected in series with the main guide at a point of low voltage and high current. Hence, E-plane Tee is occasionally called "series Tee".

In the H-plane Tee, high amount of energy is delivered to an auxiliary guide connected to a transmission line, if the auxiliary guide is connected in shunt with the main guide at a point of high voltage and low current. Hence, H-plane Tee is occasionally called "parallel" or "shunt Tee".

Q25. Draw the structure of magic tee and write its characteristics. **(Model Paper, Q7(a) | Dec.-19, (R16), Q4(b))**

(or)

Explain the construction and working of magic Tee.

Ans:

Hybrid junction (or) magic-T junction (or) E-H plane T-junction consisting of four ports and the alignment of this junction is as shown in figure (1). Port (1) and port (2) are collinear ports. Port (3) represents H-plane and port (4) represents E-plane. Both ports (3) (4) are perpendicular to each other.

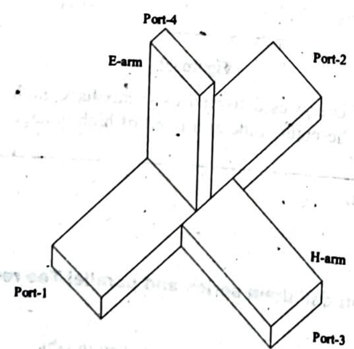


Figure (1)

The distribution of signals into the ports are illustrated in the figure (2).

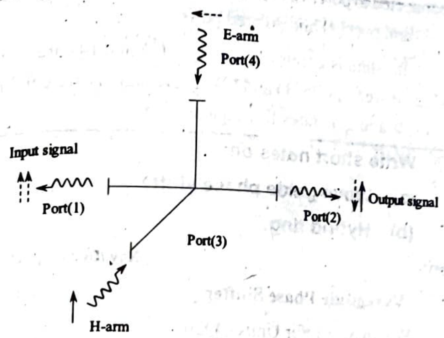


Figure (2)

The magic T-junction combines the advantages of E-plane T junction as well as H-plane T-junction.

Characteristics of Magic Tee

1. When the power is fed at port (3), the Magic Tee behaves as a *H*-plane Tee i.e., the resulting power is equally divided between port (1) and port (2). No power is obtained from port (4), i.e.,

$$a_3 \neq 0, a_1 = a_2 = a_4 = 0$$

Then, $b_1 = \dfrac{a_3}{\sqrt{2}}, b_2 = \dfrac{a_3}{\sqrt{2}}, b_3 = b_4 = 0$

2. When the power is fed at port (4), the Magic Tee behaves as an E-plane Tee i.e., the resulting power is equally divided between port (1) and port (2) but, introduces a phase shift of 180° between them. No power is obtained at port (3) i.e.,

$$a_4 \neq 0, a_1 = a_2 = a_3 = 0$$

Then, $b_1 = \dfrac{a_4}{\sqrt{2}}, b_2 = -\dfrac{a_4}{\sqrt{2}}, b_3 = b_4 = 0$

3. When the input is applied at port (1), nothing is obtained at port (2) even though they are collinear ports (Magic !!). The resulting power is equally divided between port (3) and port (4), i.e.,

$$a_1 \neq 0, a_2 = a_3 = a_4 = 0$$

Then, $b_1 = b_2 = 0, b_3 = \dfrac{a_1}{\sqrt{2}}, b_4 = \dfrac{a_1}{\sqrt{2}}$

4. When the equal powers are applied at port (3) and port (4), then maximum power is obtained at port (1) and no power at port (2) i.e.,

$$a_3 = a_4, a_1 = a_2 = 0$$

Then, $b_1 = \dfrac{a_3}{\sqrt{2}} + \dfrac{a_3}{\sqrt{2}} = 2\sqrt{a_3}, b_2 = b_3 = b_4 = 0$

5. When the unequal powers (i.e., a & $-a$) are applied at port (3) and port (4), then maximum power is obtained at port (2) and zero power at port (1) i.e.,

$$a_3 = a, a_4 = -a, a_1 = a_2 = 0$$

Then, $b_2 = \dfrac{a}{\sqrt{2}} + \dfrac{a}{\sqrt{2}} = \sqrt{2}\,a, b_1 = b_3 = b_4 = 0$

6. When equal powers are applied at port (1) and port (2) i.e., collinear ports, maximum power is obtained at port (3) and zero power at port (4) i.e.,

$$a_1 = a_2, a_3 = a_4 = 0$$

Then, $b_1 = b_2 = b_4 = 0, b_3 = \dfrac{a_1}{\sqrt{2}} + \dfrac{a_1}{\sqrt{2}} = \sqrt{2}\,a$

7. When unequal powers (i.e., a & $-a$) are applied at port (1) and port (2) i.e., collinear ports, maximum power is obtained at port (4) and zero power at port (3) i.e.,

$$a_1 = a, a_2 = -a, a_3 = a_4 = 0$$

Then, $b_1 = b_2 = b_3 = 0, b_4 = \dfrac{a}{\sqrt{2}} + \dfrac{a}{\sqrt{2}} = \sqrt{2}\,a$

Q26. Explain the application of magic Tee as an isolator using relevant diagrams.

(or)

Explain any one application of Magic Tee.

(Refer Any One Application)

Ans: **Nov./Dec.-17, (R13), Q1(d)**

The applications of magic tee are as follows,

1. **Impedance Measurement:** In this case, magic Tee is used as a bridge circuit whose arrangement is as shown in figure (1).

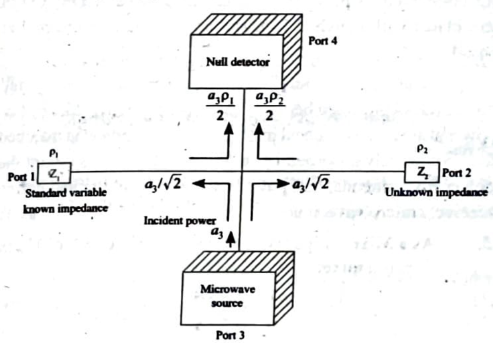


Figure (1): Impedance Measurement using Magic Tee

The unknown impedance and a standard known impedance are connected at Port (2) and Port (1) respectively. The microwave source generates power a_3 and it is distributed equally between impedances Z_1 and Z_2 at the junction.

The impedences Z_1 and Z_2 having reflection coefficients ρ_1 and ρ_2 respectively reflects the powers $\dfrac{a_3\rho_1}{2}$ and $\dfrac{a_3\rho_2}{2}$. These powers then reaches the null detection at port 4.

The net power reaching null detector,

$$\frac{a_3\rho_1}{2} - \frac{a_3\rho_2}{2} = \frac{1}{2} a_3(\rho_1 - \rho_2)$$

For perfect balancing of bridge,

$$\frac{1}{2} a_3(\rho_1 - \rho_2) = 0$$

$$\Rightarrow \quad \rho_1 = \rho_2$$

$$\Rightarrow \quad \frac{Z_1 - Z_z}{Z_1 + Z_z} = \frac{Z_2 - Z_z}{Z_2 - Z_z}$$

$$\boxed{Z_1 = Z_2}$$

Thus, the unknown impedance value can be calculated by varying the known impedance value till the bridge is said to be balanced.

2. **As a Duplexer:** Figure (2) shows the duplexer connections of a magic Tee.

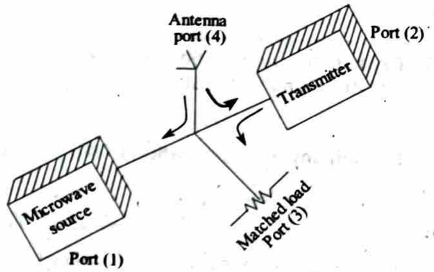


Figure (2): Magic Tee as Duplexer

The microwave source (which is receiver) and transmitter are connected to ports (1) and (2) respectively. Port (3) is terminated with matched load and an antenna is connected at port 4.

Since ports (1) and (2) are isolated ports, the transmitted power equally divided between antenna and matched load. The power at antenna is radiated into free space and power at matched load completely absorbed by it. Similarly, while receiving the power from antenna, half power reaches transmitter and half to receiver (microwave source).

3. **As a Mixer:** Figure (3) shows the connections of Magic Tee as a mixer.

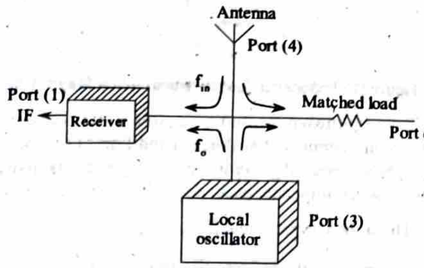


Figure (3): Magic Tee as Mixer

The antenna, receiver, local oscillator and matched load are connected to port (4), (1), (3) and port (2) respectively. Here, port (3) and port (4) are isolated ports.

- The signals coming from ports (3) and (4) are equally divided between ports (1) and (2). These signals are combined at receiver and generates IF frequency.

Q27. Write short notes on:

(a) Wave guide phase shifter

(b) Hybrid ring.

Ans: Nov./Dec.-17, (R13), Q5

(a) Waveguide Phase Shifter

For answer refer Unit-3, Q20.

(b) Hybrid Ring

Hybrid ring is also called rat race hybrid. Figure (1) shows a typical rat race hybrid junction. It is a four port junction, which is obtained by adding a fourth port to the normal three port Tee junction.

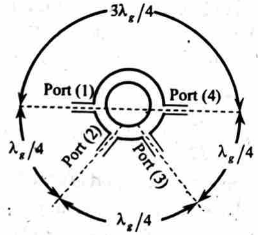


Figure (1)

Construction

The four ports are arranged as angular ring at proper intervals and are separated by proper electrical length to avoid any standing wave formation.

It should satisfy the following conditions for proper functioning,

1. The mean circumference of the total race must be $1.5\lambda_g$.
2. A separation distance of $\lambda_g/4$ must exist between each of four ports and its neighbour.

Operation

When power is applied to port (1), it is equally divided between port (2) and port (4) while the power at port (3) is zero. Since, the powers at port (2) and (4) combine in phase but, the powers at port (3) cancel each other due to a path difference of "$\lambda_g/2$". Similarly, when the power is fed at port (3), the resulting power is equally divided between port (2) and port (4) and power at port (1) is zero.

For two unequal inputs at port (1), a sum of them is obtained at port (2) and port (4) while their difference is obtained at port (3).

Q28. A matched generator with a power of one watt is connected to the H-Arm of magic tee C (port-4). The E-arm (port-3) is match terminated and the length of the coplanar arms is the same. Compute the power delivered to the termination at port 1, 2 and 3 and the power reflected at port 4 when ports 1 and 2 are match terminated.

Ans: May-10, Set-3, Q6(b)

We can obtain figure (1) based on the given characteristics of magic tee.

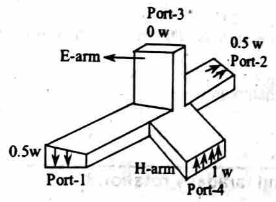


Figure (1)

We can say that, when a power of 1w is connected to H-arm, it is divided equally in port-1 and port-2, i.e., 0.5 w each and power in port-3 is zero.

When port-1 and port-2 are match terminated, then we obtain figure (2).

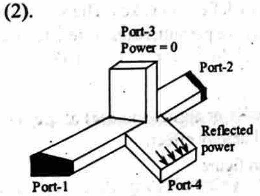


Figure (2)

As shown in the figure (2), when port-1 and port-2 are match terminated, the total power is reflected into port-4. i.e., 0.5 W + 0.5 W = 1 W.

Hence power reflected = 1 W.

Q29. A 20 mV signal is fed to the series arm of a lossless magic Tee junction. Calculate the power delivered through each port when other ports are terminated with a matched load.

Ans: Nov./Dec.-16, (R13), Q4(a)

Given that,

For a loss-less magic Tee,

Power applied at the series arm, $a_4 = 20$ mW

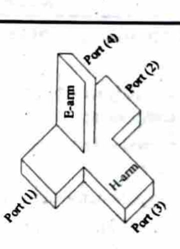
When all the remaining ports are terminated

By matched load then,

Power through port (1), $b_1 = ?$

Power through port (2), $b_2 = ?$

Power through port (3), $b_3 = ?$



Figure

For a Magic Tee shown in figure, input is applied at series arm i.e., at port (4), then it behaves as a *E*-plane Tee. Therefore, the resulting power is equally divided between port (1) and port (2) with a phase shift of 180° between them. No power is obtained at port (3) i.e., at shunt arm,

i.e., $a_4 = 20$ mW, $a_1 = a_2 = a_3 = 0$,

then, $b_1 = \frac{a_4}{\sqrt{2}} = \frac{20\text{ mW}}{\sqrt{2}}$

$= 14.142$ mW

$$\boxed{\therefore b_1 = 14.142 \text{ mW}}$$

$b_2 = -\frac{a_4}{\sqrt{2}} = -\frac{20\text{ mW}}{\sqrt{2}}$

$= -14.142$ mW

$$\boxed{\therefore b_2 = -14.142 \text{ mW}}$$

and power obtained at port (3) i.e., at shunt arm is zero.

$$\boxed{\therefore b_3 = 0}$$

3.7 Ferrites – Composition and Characteristics, Faraday Rotation, Ferrite Components – Gyrator, Isolator

Q30. List and explain the characteristics of Ferrites.

Ans: April/May-18, (R13), Q5(b)

Ferrites

A ferrite is a high resistance magnetic material, includes materials that are responsible for its magnetic properties. Ferrites are mostly used at high frequencies.

Characteristics of Ferrites

1. Ferrites possess strong magnetic properties.
2. They possess high resistivity, hence they can be used up to 100 GHz.
3. They exhibit non-reciprocal property.
4. The dielectric constant of ferrite materials is around 10 to 15.
5. They have relative permeabilities of the order of 1000.

Q31. List out the applications of ferrite components and their requirements.

Ans:

The three most widely used microwave components are circulator, isolator and gyrator. The following are the applications of these microwave components,

1. Circulators are used in radar systems to separate (isolate) transmitters and receivers from one another, that are connected to a same single antenna.
2. It is also used in parametric amplifiers (two terminal amplifiers) to isolate input from output.
3. Isolators are used to improve frequency stability of magnetrons and klystrons.
4. Gyrators are basically used to replace bulky inductors. Thereby, minimizing the cost and size of the system.
5. It is also used to carry DC part of line loop in telephonic devices. Thus, further reducing the size of the modern day telephones.

The requirements of a ferrite component are similar to that of magnetic materials. The minimum requirements for any ferromagnetic insulator to be classified as ferrite are,

1. It should have high resistivity i.e it must have 14 times more resistivity than metals.
2. A ferrite component must have high relative permeability.
3. Dielectric constant should be approximately 10 to 15 times more than metals.

Q32. What are ferrites? How they are useful in microwaves? Explain faradays rotation?

Ans:

Ferrites

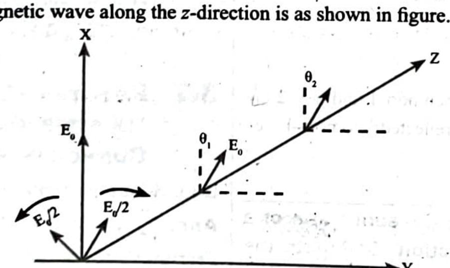
For answer refer Unit-3, Q30, Topic: Ferrites.

Ferrite material is extremely useful at microwave frequencies as the electromagnetic waves can pass through ferrites with negligible attenuation. Electromagnetic wave propagation undergoes phase shift due to ferrites, which can be influenced by the applied DC magnetic fields. The ferrites are popularly used in microwave isolators, circulators, and switches. They are used at RF frequencies in inductors as core material. They are also used in TV (cathode ray tube) deflection yokes. The specific resistivity of ferrites for use at microwave frequency is on the order of 10^{12} ohm-cm. Typical relative permittivities of ferrites lie in the range of 5-20.

Use of Faraday's Rotation

A circularly polarized wave tilts or rotates in a particular direction (clock wise or anti clockwise) along the propagation path when it allowed to pass through a ferrite rod is known as Faraday rotation or Faraday effect.

The rotation of an electromagnetic wave along the z-direction is as shown in figure.



Figure

Q33. Explain how Gyrator gives phase shift and explain it with neat diagram. Dec.-19, (R16), Q5(b)

Ans:

Gyrator is a tapered ferrite rod with two ports as shown in figure (1).

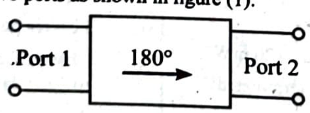


Figure (1)

Gyrator works on the principle of non-reciprocal property of Faraday rotation. The wave incident of port 1 undergoes a phase shift of 180° while transmitting through the gyrator and appears at the output port (port 2). In ideal case, during the transmission of wave from port 2 to port 1 it offers a phase shift of 0°.

Operation

Faraday rotation in a gyrator or tapered ferrite rod is as shown in figure (2).

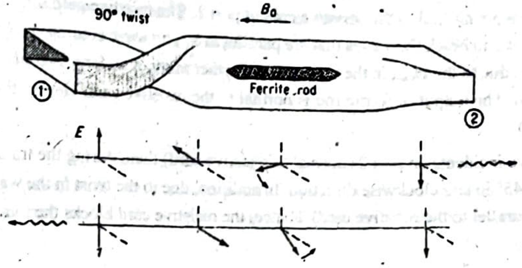


Figure (2): Faraday rotation in gyrator

From figure (2), the waveguide is twisted by a phase shift of 90° in clockwise direction. Two cases in transmitting the wave from one port to another port.

Case 1: A power wave incident on the port 1 is transmitted through the waveguide and offers a phase shift of 90°.in anti clockwise direction. Furthermore, the wave undergoes a phase change of 90° in anti clockwise direction due to the ferrite rod. Hence, the wave reacting the output port is subjected to a phase shift of 180° and it can be observed in figure (2).

Case 2: If the power wave is incident on port 2, initially, it undergoes a phase change of 90° in anti-clock wise direction due to the ferrite rod. In addition, due to the twist in the wave guide it undergoes a phase shift of 90° in clock wise direction.Hence, the relative phase difference between the input and output wave is zero. The output power wave is obtained at the port 1 as shown in figure (2).

Q34. Draw the structure of Ferrite isolator and explain its working. (Model Paper, Q7(b) | Dec.-19, (R16), Q5(a))

(or)

Explain how Ferrites are used for isolators? Explain any one of such circuit. May/June-19, (R15), Q5(a)

(or)

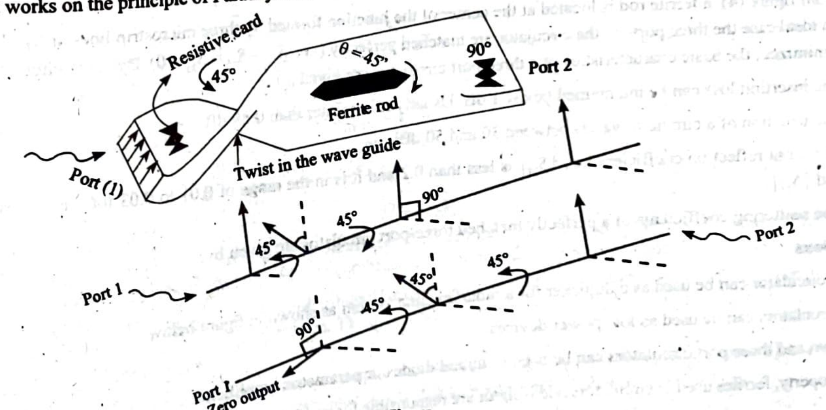
Explain the working of Faraday rotation based isolator and write its applications. Nov./Dec.-18, (R13), Q4(b)

(or)

Explain the working of Faraday rotation based isolator and write its applications.

Ans:

Ferrite isolator is a two-port ferrite device which allows the microwave power in one direction and attenuates in another direction. It works on the principle of Faraday rotation. The Faraday rotation in an isolator is as shown in figure.



Figure

Figure shows that the waveguide is twisted by an angle of 45° in anti clock wise direction. Two cases araise in the transmission of microwave power from one port to another port as follows,

Case 1: The input power incidents normal to the resistive card at port 1. The resistive card allows only the wave propagating in the direction perpendicular to it and block the waves that are parallel to it. The wave coming out of the resistive card is shifted by 45° in anti clockwise direction due to the twist in the waveguide. Further more, it undergoes more 45° phase change in clockwise direction due to the ferrite rod. The output of ferrite rod is normal to the resistive card. Hence, the total power wave is obtained at the output port (i.e., port 2).

Case 2: When the power wave incidents on port 2 (normal to resistive card) then, during the transmission through ferrite rod, it undergoes a phase change of 45° in anti clockwise direction. In addition, due to the twist in the wave guide the resultant phase of the wave becomes 90° (i.e., parallel to the resistive card). Hence, the resistive card blocks the total power and the power reaches the output port (port 1) is zero.

In general, isolators are used in high frequency matching network (i.e., in microwave circuits) to match the source and load impedances. Since, they offer less attenuation while transmitting the microwave power from port 1 to port 2.

Application of Ferrite Isolator in Microwave Circuits:

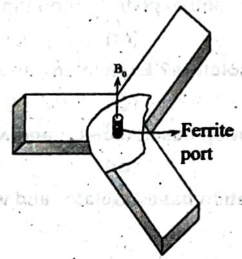
Isolator is used in several microwave circuits because it provides a very small amount of attenuation when transmitted from port (1) to port (2) and maximum amount of attenuation, when transmitted from port (2) to port (1). This feature is used in matching a source with a variable load.

Q35. With the help of diagram, explain principles and operation of a 3-port circulator.

April/May-18, (R13), Q5(a)

Ans:

A three port ferrite circulator is represented as shown in figure.



Figure

From figure (4), a ferrite rod is located at the center of the junction formed by three microstrip lines or by identical wave guides. In ideal case the three ports of the circulator are matched perfectly (i.e., $S_{11} = S_{22} = S_{33} = 0$). By using circulator the losses can be minimized, the basic characteristics of a three port circulator are given as,

(i) The insertion loss can be maintained below 1 dB. Usually it is greater than 0.89 dB.

(ii) The isolation of a circulator varies between 30 and 50 dB.

(iii) The input reflection coefficient i.e., $|S_{11}|$ is less than 0.2 and it is in the range of 0.01 to 0.03 for the values $|S_{31}|, |S_{31}|$ and $|S_{12}|$.

The scattering coefficients of a perfectly matched three-port circulator are given by,

Applications

1. A circulator can be used as a duplexer for a radar antenna system as shown in figure below.
2. Circulators can be used as low power devices.
3. Two and three port circulators can be used in tunnel diodes or parametric amplifiers.

Property, ferrites used in circulators and isolator are responsible for providing different permeability for oppositly traveling waves.

Q36. Discuss the operation and principle of isolators and circulators.

Oct./Nov.-20, (R16), Q3(b)

(or)

With the help of neat diagram explain the principle of operation of circulator.

March-21, (R16), Q3(b)

(Refer Only Circulators)

Ans:

Isolators

For answer refer Unit-3, Q34.

Circulators: A passive non-reciprocal multi-port microwave device in which the power incident on one port is obtained as output at the successive port is known as circulator. Usually circulators with three ports and four ports are used in high frequency applications.

Four-port Circulator

Each port in a circulator is linked with its neighboring ports only as shown in figure (1).

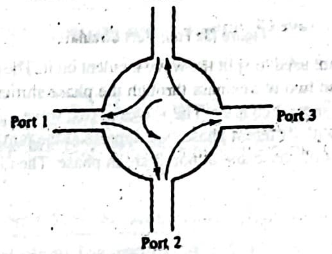


Figure (1) : Symbol of Circulator

There are two methods of designing a four port circulator.

1. Using two magic T's along with a non-reciprocal 180° phase shifter (Gyrator).
2. Using two dB side hole directional couplers and two non-reciprocal phase shifters.

1. Four-Port Circulator using Magic Tee

Figure (2) illustrates the construction of a 4-port circulator using two hybrid junctions and a gyrator (180° phase shifter). Here, the Tee junctions are used to split the incident power wave into equal magnitudes.

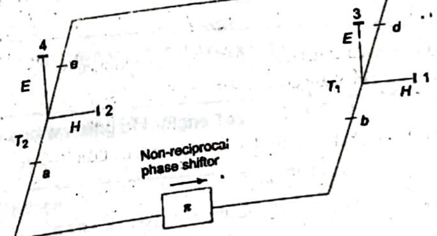


Figure (2)

(i) If power is incident on port 1, it is equally distributed between the ports 'b' and 'd' with same phase. This distributed power arrives at the ports 'a' and 'c' and gets combined at the junction and appears at port 2.

(ii) If power is incident on port 2, it is equally distributed between ports 'a' and 'c' with a phase shift of 180°. The gyrator offers a phase shift of 180° in the forward direction. The distributed power arrives at the ports 'b' and 'd' and gets combined at the junction and appears at port 3.

(iii) In the same manner, the wave incident on port 3 split into two equal magnitudes with a phase shift of 180° and arrives at arms 'a' and 'c'. These two waves gets combined at Tee junction and appears at port 4.

(iv) Similarly, the power incident on Port 4 emerges from port 1 of other hybrid Tee junction.

2. Four-Port Circulator using 3 dB Phase Shifters and Couplers

Figure (3) illustrates the design of four-port circulator using two 3 dB phase shifters and directional couplers.

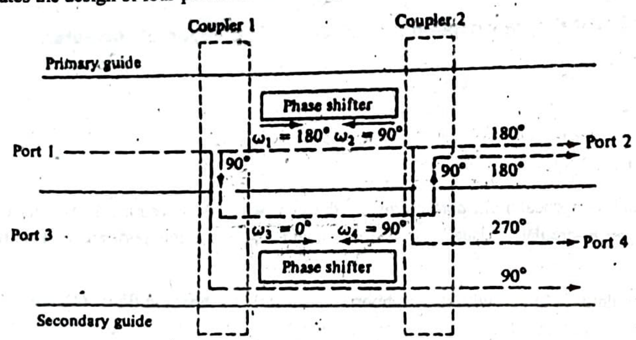


Figure (3): Four-Port Circulator

From figure (3). the two couplers are used to split the wave incident on it. The power incident on port 1 is divided into two magnitudes with 90° phase change. These two waves pass through the phase shifters which adds different phase angles based on the direction of wave and reaches the second coupler. The waves at two wave guides again splits in to two waves each with a phase changer of 90°. The four waves with different phases are appears at the ports 2 and 4 as shown in figure (3). Hence. the resultant phases of waves at port 4 are out of phase and at port 2 are in phase. The output is observed or collected at port 2.

Frequently Asked & Important Questions

Q1. Compare probe and loop connectors. REPEATED 2 TIMES

Ans: Refer Q3. (Dec.-19, (R16), Q1(d) | May/June-19, (R15), Q1(d))

Q2. Explain coupling probes and coupling loops. REPEATED 2 TIMES

Ans: Refer Q12. (Nov./Dec.-16, (R13), Q4(b) | Nov.-13, (R09), Q3(a))

Q3. What are the waveguide windows? How these are used in microwave circuits? REPEATED 2 TIMES

Ans: Refer Q15. (May/June-19, (R15), Q5(b) | Nov./Dec.-16, (R13), Q1(d))

Q4. What are the different types of waveguide attenuators? Explain their working with neat diagrams. REPEATED 2 TIMES

Ans: Refer Q19. (Dec.-19, (R16), Q4(a) | Nov./Dec.-18, (R13), Q5(a) | Nov.-15, (R09), Q3(a))

Q5. Examine about waveguide phase shifters with neat diagrams. REPEATED 2 TIMES

Ans: Refer Q20. (Oct./Nov.-20, (R16), Q4(b) | May/June-19, (R15), Q4(a) | Nov.-13, (R09), Q3(b) | Nov.-15, (R09), Q3(b))

Q6. Draw the structure diagram of H-plane Tee and explain its characteristics. REPEATED 2 TIMES

Ans: Refer Q23. (May/June-19, (R15), Q4(b) | April/May-18, (R13), Q4(a))

Q7. Draw the structure of Ferrite isolator and explain its working. REPEATED 2 TIMES

Ans: Refer Q34. (Dec.-19, (R16), Q5(a) | May/June-19, (R15), Q5(a) | Nov./Dec.-18, (R13), Q4(b))

Q8. Explain types of aperture coupling with neat sketches. Important Question

Ans: Refer Q13.

Q9. Write short note on tunning screws used in waveguides. Important Question

Ans: Refer Q16.

Q10. Explain the construction and working of E-plane Tee. Important Question

Ans: Refer Q22.

Q11. Explain the difference between,

(i) E-plane Tee

(ii) H-plane Tee

Also explain clearly why do you call them series and parallel Tee respectively. Important Question

Ans: Refer Q24.

Q12. Draw the structure of magic tee and write its characteristics. Important Question

Ans: Refer Q25.

Q13. Explain the application of magic Tee as an isolator using relevant diagrams. Important Question

Ans: Refer Q26.

Q14. List and explain the characteristics of Ferrites.

Ans: Refer Q30.

Important Question

Q15. Explain how Gyrator gives phase shift and explain it with neat diagram.

Ans: Refer Q33.

Important Question

Q16. With the help of diagram, explain principles and operation of a 3-port circulator.

Ans: Refer Q35.

Important Question

Exercise Questions

1. **The input of a coupler is connected to a 10 W source and the output is terminated on a matched load. The auxiliary output is found to be 10 mW. When 10 W is applied to the output end of the coupler and the input is terminated in a matched load the auxiliary output is found to be 10 μW. Find be the coupling and directivity.**

[**Ans:** 30 dB, 30 dB]

2. **A 20 dB coupler has a directivity of 30 dB. Calculate the value of isolation.**

[**Ans:** 50 dB]

3. **A 20 mV signal is fed to the series arm of a lossless magic tee junction. Calculate the power delivered through each port when other ports are terminated with a matched load.**

[**Ans:** 14.142 mW, –14.142 mW, 0 mW]