UNIT-III

WAVEGUIDES COMPONENTS-I

3.1 Waveguide Coupler

A signal can be fed into the waveguide in a number of ways. The most straightforward is to use what is known as a launcher. This is basically a small probe which penetrates a small distance into the centre of the waveguide itself as shown. Often this probe may be the centre conductor of the coaxial cable connected to the waveguide. The probe is orientated so that it is parallel to the lines of the electric field which is to be set up in the waveguide. An alternative method is to have a loop which is connected to the wall of the waveguide. This encompasses the magnetic field lines and sets up the electromagnetic wave in this way. However for most applications it is more convenient to use the open circuit probe. These launchers can be used for transmitting signals into the waveguide as well as receiving them from the waveguide.

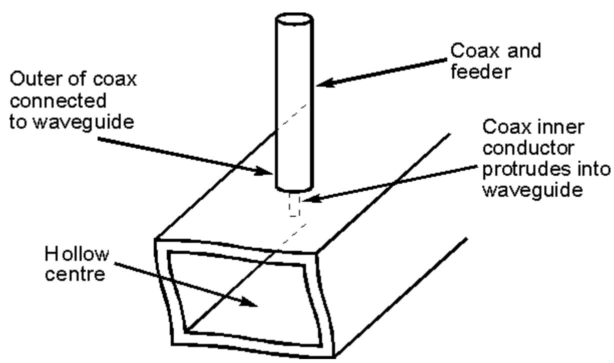


Fig 3.1: Waveguide Coupler

3.2 Coupling Probes and Loops

Probes and loops are metallic wires used to couple coaxial line to waveguide or resonator. They are also used to extract power from microwave tube oscillators and amplifiers.

Probes : They consist of an extension of the centre conductor of the coaxial line at the time mid point of one of the broader walls of the guide, where the electric field is maximum and normal to the wall.

Usually, the waveguide is terminated in a short and the probe is placed approximately $\lambda_g/4$ from the termination. To minimize the reflections at the junction, the probe must be matched to the waveguide by proper choice of the length and position of the probe relative to the closed end of the wave guide.

The centre conductor of the coaxial line may extend completely across the waveguide or it may the project an appreciable distance into the waveguide. In that case the magnetic as well as electric coupling is effective.

For matching over an appreciable frequency band one or more of the following methods may be adopted.

- The centre conductor may be flared at the point at which it enters the waveguide
- Height of the terminating section of the waveguide can be increased.
- A tapered section or some other type of impedance transformer can be used.

To excite a particular mode, the probe or probes should be placed parallel to the E-field at a position where the field has its largest value. When several probes are used, then they must be excited with appropriate phasing relation.

Loops: Loop coupling is principally magnetic, so the loop must be placed at or near a point of high H-field strength and turned in such a way that its plane is normal to the flux lines.

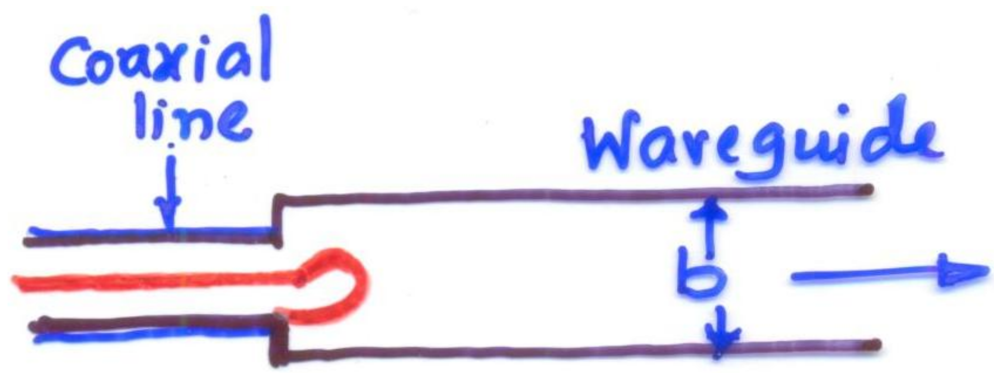


Fig 3.2: Coupling Loop

Loops can be mounted in the end wall of a shorted waveguide or in the middle of the top or bottom wall at a distance of integral $\lambda_g/2$ from the shorted end. The plane of the loop should be normal to the H-field lines for maximum coupling. The amount of coupling obtainable with the loop depends upon its size and shape in general increases with the area of the loop.

Comparison: The choice between loop and probe coupling is dictated partly by mechanical and partly by electrical considerations. The important factors are as follows.

- Likelihood of voltage breakdown in the vicinity of voltage antinode.
- Ease in adjusting the coupling
- Constancy of coupling when mechanical changes are made.
- Avoidance of interference with electron streams.

In microwave oscillators loops rather than probes are usually preferred because a probe in proper position for adequate coupling may interfere with electron movement with in the tube.

3.3 Excitation

The mode of propagation of the wave is determined by the type and location of the excitation probe. Although either probes or loops may be used as excitation sources, the probes are normally preferred for their simplicity. Different types of excitations are shown below.

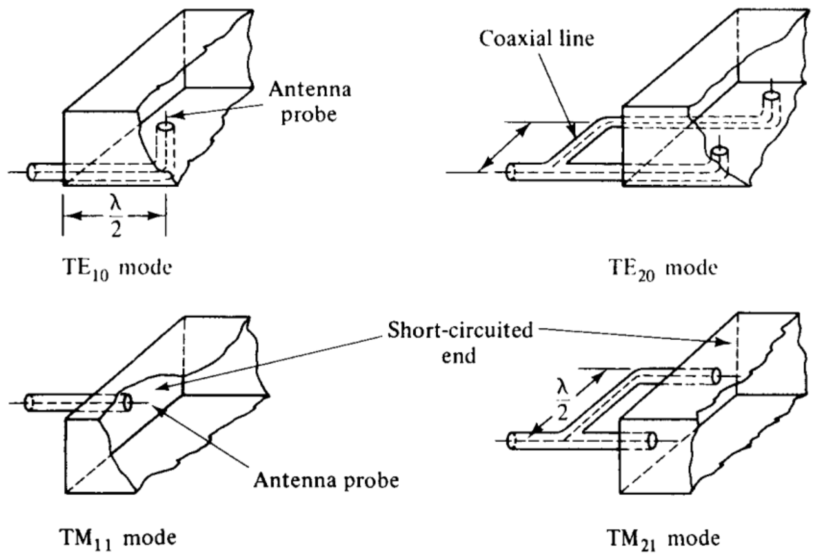


Fig 3.3: Methods of exciting various modes in rectangular waveguides.

The guide is closed at one end by a conducting wall and an appropriate exciting probe is inserted through the end or side of the guide. The end of the guide serves as a reflector and if the distance between the probe and the wall is properly adjusted, the reflected waves arrive the probe in phase with the emitted wave, and the two propagate down the guide as one wave.

The sources excite not only the desired modes but also higher order unwanted modes. Nut the choosing the guide dimensions appropriately, it is possible to have only the desired wave above cit-off frequency, the other waves then being attenuated and not propagated.

3.4 Tuning Screws and Posts

Tuning screws are also used for impedance matching purposes. Sometimes they are also used to create a large in SWR over the line like in the measurement of high SWR in the laboratory.
The drawback of not being amenable to adjustment in waveguide windows does not exist in these devices.

Screws : It is basically a metallic threaded rod and when inserted into the rectangular guide either from the top or bottom parallel to the E-field lines can give variable amount of susceptance depending upon the depth of penetration is shown in Figure 3.4.

A screw with insertion distances less than $\lambda_g/4$ produces capacitive susceptance which increases with depth of insertion or penetration. When the depth of penetration is $\lambda_g/4$ the screw is in series resonance and further insertion causes the susceptance to be inductive.

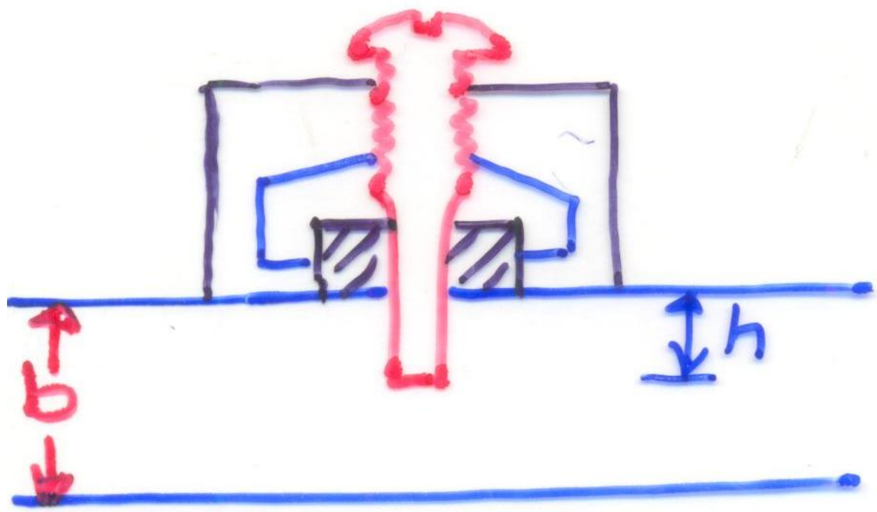


Fig 3.4: Turing Screw

The most direct method of impedance matching with a matched screw is to use a single screw adjustable both in length and position along the waveguide. But it requires a slot in the waveguide.

An Alternative arrangement is to use double or triple screw units spaced at eighth wavelength $\lambda_g/8$ or quarter wavelength $\lambda_g/4$.

Posts: A metal post or screw extending completely across the waveguide parallel to E-field adds an inductive susceptance in parallel with the waveguide.

A post extending across the waveguide at right angles to the E-field produces an effective capacitive susceptance in shunt with the waveguide at the position of the post. Variation of its susceptance with its diameter.

3.5 Wave guide Windows

Waveguide windows are made from sections of rectangular waveguide. By inserting conducting plates through the walls into the guide-section, its susceptance can be varied. This principles working of windows and they are widely used for impedance matching purpose at microwave frequencies

Inductive windows: The conducting diaphragms extending into the waveguide from either one or both of the sidewalls produce the effect of adding an inductive susceptance across the waveguide at the point at which the diaphragm is place. These are called inductive diaphragms and are depicted in figure 5.13 (a) and (b).

The amount of normalized susceptance added by the window depends upon the window insertion distance. The susceptance increases with the depth. If the insertion is from both the side walls with tow diaphragms, then the resultant window is called symmetrical one. if the insertion is from either one wall only then it is called unsymmetrical window. The choice as ease of machining and installation of pressurized windows. The dependence of their susceptance on insertion is sketched in Figure 5.14(a).

Capacitive Windows : The conducting diaphragms extending into a rectangular waveguide either from top or bottom or both walls produce the effect of adding capacitive susceptance shunted across the waveguide at that point. They are therefore called capacitive windows and shown in Figure 5.13 (c) and (d)

The amount of normalized susceptance due to the window depends upon the window insertion depth, in general increasing with the depth these are not used extensively because of the lowering of the breakdown voltage and the consequent reduction in the maximum power that can be transferred through the waveguide. The variation of susceptance with insertion is given Figure 5.14 (b).

Resonant windows : A conducting diaphragm with a rectangular opening inside gives the effect of a parallel circuit shunted across the guide at that point. This window is called resonant window and shown in Figure 5.13 (e).

If can give zero susceptance at a chosen frequency whose value depends upon the dimensions of diaphragm opening. It acts as a band-pass filter centered around this frequency. giving inductive susceptance on side and capacitive susceptance on the other side .

Obtainable Q values are of the order of 10 and decrease as the size of the aperture is increases.

Limitations : The windows suffer from two major drawbacks; one is they cannot be made readily adjustable and provide only fixed amount of susceptance and the second is the difficulty in maintaining the perfect contact between the diaphragm and walls of the waveguide.

3.6 Waveguide bends

Waveguide is normally rigid, except for flexible waveguide, and therefore it is often necessary to direct the waveguide in a particular direction. Using waveguide bends and twists it is possible to arrange the waveguide into the positions required.

When using waveguide bends and waveguide twists, it is necessary to ensure the bending and twisting is accomplished in the correct manner otherwise the electric and magnetic fields will be unduly distorted and the signal will not propagate in the manner required causing loss and reflections. Accordingly waveguide bend and waveguide twist sections are manufactured specifically to allow the waveguide direction to be altered without unduly destroying the field patterns and introducing loss.

Types of waveguide bend

There are several ways in which waveguide bends can be accomplished. They may be used according to the applications and the requirements.

- Waveguide E bend
- Waveguide H bend

Each type of bend is achieved in a way that enables the signal to propagate correctly and with the minimum of disruption to the fields and hence to the overall signal.

Ideally the waveguide should be bent very gradually, but this is normally not viable and therefore specific waveguide bends are used.

Most proprietary waveguide bends are common angles - 90° waveguide bends are the most common by far.

Waveguide E bend

This form of waveguide bend is called an E bend because it distorts or changes the electric field to enable the waveguide to be bent in the required direction.

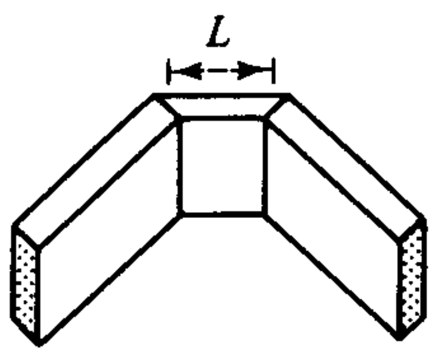


Fig 3.5 :Waveguide E bend

To prevent reflections this waveguide bend must have a radius greater than two wavelengths.

Waveguide H bend

This form of waveguide bend is very similar to the E bend, except that it distorts the H or magnetic field. It creates the bend around the thinner side of the waveguide.

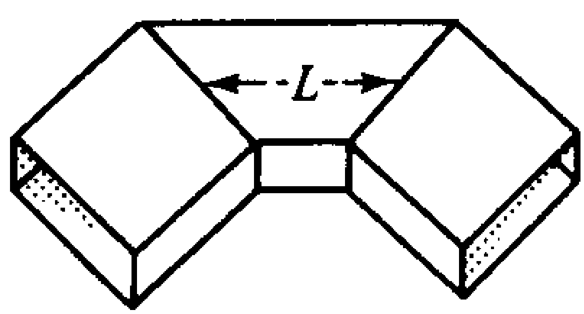


Fig 3.6 :Waveguide H bend

As with the E bend, this form of waveguide bend must also have a radius greater than 2 wavelengths to prevent undue reflections and disturbance of the field.

3.7 Waveguide twists

There are also instances where the waveguide may require twisting. This too, can be accomplished. A gradual twist in the waveguide is used to turn the polarisation of the waveguide and hence the waveform.

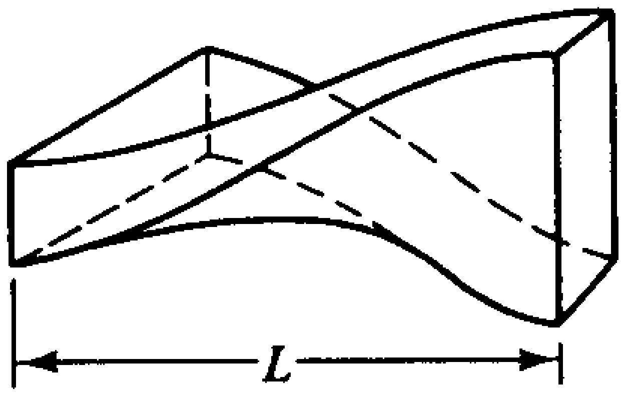


Fig3.7: Waveguide twist

In order to prevent undue distortion on the waveform a 90° twist should be undertaken over a distance greater than two wavelengths of the frequency in use. If a complete inversion is required, e.g. for phasing requirements, the overall inversion or 180° twist should be undertaken over a four wavelength distance.

Waveguide bends and waveguide twists are very useful items to have when building a waveguide system. Using waveguide E bends and waveguide H bends and their sharp bend counterparts allows the waveguide to be turned through the required angle to meet the mechanical constraints of the overall waveguide system. Waveguide twists are also useful in many applications to ensure the polarisation is correct.

3.8 Attenuators

Attenuators are passive devices used to reduce the power to desired level. They are widely used in the industry as well as in the laboratory. Their importance in the measurement can be appreciated easily from the fact that the sensitivity of most of the detector diodes depends upon the power level of the incident wave. As a result of that same amount of change in power level gives different amounts of deflection at different power levels. It leads to the requirement of maintaining the power level at various steps of measurement process a constant. Here the need of the attenuator arises by placing an attenuator after the source in the chain of the measurement system, it is possible to maintain the power level at a more or less fixed point.

Attenuation in dB of a device is ten times logarithmic ratio of power flowing into the device to the power flowing out of the device when both the input and output circuits are matched.

$$\text{Attenuation in dB} = 10\log\frac{P_i}{P_0}$$

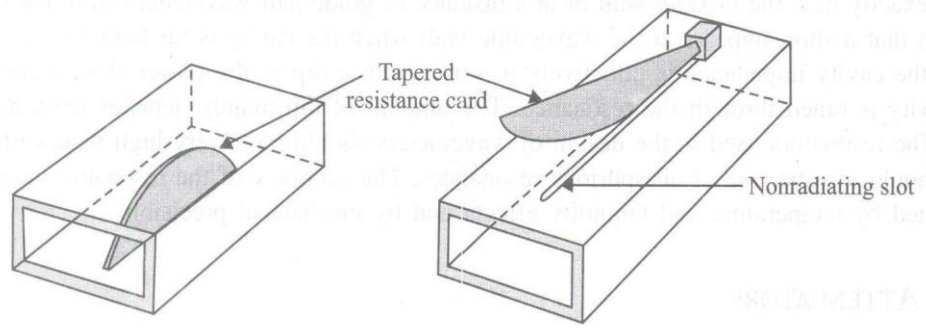
If the input circuit is not matched to the device then the P_i is equal to the power incident minus the power reflected. If the output circuit is not matched, the P_0 becomes equal to the power consumed in the output circuit plus the power reflected back into the device.

Broadly the attenuators can be divided into two groups, i.e. Resistive card attenuators which are of low cost and not very accurate and Rotary vane type attenuators which are very accurate and of frequency independent readings. We discuss a little more in detail both the devices.

3.8.1 Resistive Card Attenuator

Resistive card is basically a glass coated with carbon or Aquadag. Resistive card attenuator type has two versions, one can provide fixed amount of attenuation and the second provides variable amount of attenuation.

In the fixed version as shown in Figure 3.8(a), the resistance card tapered at both ends is bonded in place. The tapering of the card helps in maintaining low SWR at the input as well as at the output ports over the useful waveguide band. To achieve maximum attenuation per unit guide length, the card is placed parallel to the electric field and at the centre of the waveguide, where the field is maximum for the dominant mode. In this type of attenuators the amount of attenuation provided is a function of frequency, a disadvantage. It, in general, increases with frequency.



(a) Fixed version (b) Variable version

Fig 3.8: Resistive Card attenuators

In the variable version as shown in Figure 3.8(b) called Flap Attenuator, the resistance card enters into the waveguide through the slot provided in the broader wall thereby intercepting and absorbing a portion of the wave. A hinge arrangement is used to change the depth of penetration of the resistance card, there by changing the amount of attenuation from 0 dB to typically 30 dB

The biggest disadvantage with Flap Attenuators is their attenuation is frequency sensitive and also the phase of the output signal is the function of attenuation.

3.8.2 Rotary Vane Attenuator

The essential parts of rotary vane attenuator device are, two fixed and one rotary waveguide sections as shown in Figure 3.9. it also includes input and output transition sections to provide low SWR connections to rectangular waveguides.

Structure : The two fixed circular waveguide sections are identical in all respects; each attached to a transition and each consists of a piece circular waveguide with a lossy dielectric plat lying horizontal in it. In middle exists a rotatable circular waveguide section with a dielectric plate which can be placed at any angle by rotating the waveguide section. The plates are normally thing with $\varepsilon_r > 1$, $\mu_r = 1$ and conductivity σ a finite nonzero value.

The plates attenuates the wave travelling, the amount of attenuation being dependent upon the properties of the material from which the plate is cut, the dimensions of the slab and also the angle between the plane of the plate and E vector of the wave.

When E vector of the wave is normal to it, the plate does not attenuate the wave in any significant manner, where as it attenuates the wave in good amount when E vector is parallel. In the present case, the lengths of the plates are selected in such a way that after travelling past the plates with its E vector parallel, the wave amplitude becomes insignificant.

Analysts: it can be shown that the wave undergoes an amount of attenuation in dB given by

$$A = 10\log\frac{1}{\cos^4\theta_m}$$

Where θ_m is the angle of rotatable section got rotated from horizontal.

When the wave with its electric vector E vertical falls over and crosses, the input fixed section in which plate is horizontal, it does so without any attenuation.

The un-attenuated wave at the input of the rotatable section can be resolved into two components one parallel to the rotatable plate and another normal to it. The parallel component gets absorbed and attenuated almost completely by this plate whereas the normal component crosses without any significant attenuation.

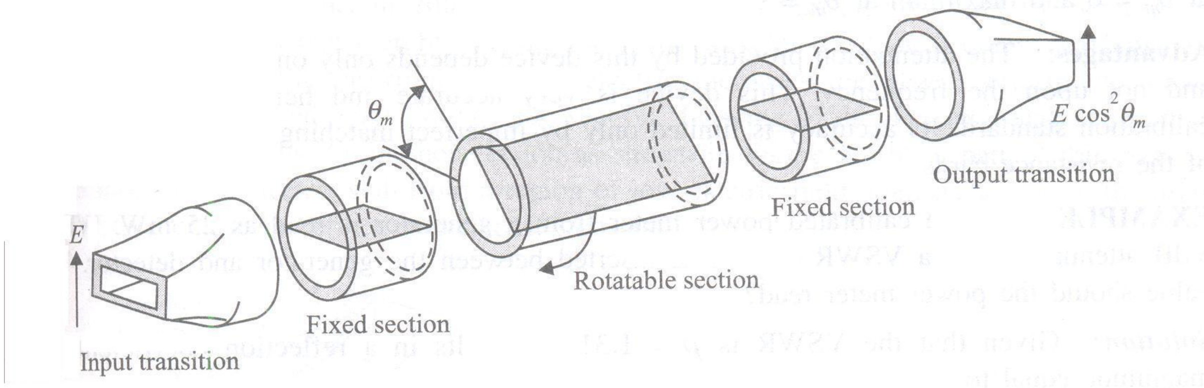


Fig3.9: Structural details of Rotary Vane Attenuator

Now it is the only normal to rotatable plate component that exists at the input of the fixed output section this component can be resolved into two, one horizontal and the other vertical. The horizontal component is parallel to the fixed section plate and hence gets absorbed whereas the vertical one comes out unattenuated which is E $\cos^2\theta_m$

If the amplitude of the input field is E, then the output field strength will be E $\cos^2\theta_m$ Hence, the attenuation provided by the device in dB is A = 10 log (1/ $\cos^2\theta_m$).

The attenuation is controlled by the rotation of the centre – section, minimum attenuation at $\theta_m = 0$ and maximum at $\theta_m = 90^0$

Advantages: the attenuation provided by this device depends only on the rotation angle θ_m and not upon the frequency. This device is very accurate and hence being used as a calibration standard. Its accuracy is limited only by imperfect matching and by misalignment of the resistance cards.

3.9 Phase Shifters

Phase shifters devices find wide applications in test and measurement systems, but most significant use is in phased array antennas, where antenna beam is steered in space by electronically controlled phase shifters. The phase shifters which use ferrites in their construction are non-reciprocal whereas others in general are reciprocal.

The phase shift that can be given to a wave of dominant mode by a waveguide section of length l and with a hollow region of non-magnetic dielectric with a dielectric constant ε_r is given by $\bar{\beta} l = 2\pi l \lambda_g$, where $\lambda_g = \lambda / \sqrt{\varepsilon_r - (\lambda / 2a)^2}$. From this relation, we can observe that the phase of the wave can be controlled either by varying ε_r or the guide width a thus changing the guide wavelength.

Several types of shifters are designed to the accuracy requirements of the application we discuss the principle of working, relative merits and demerits of the important ones here.

Dielectric phase shifters : The variable type dielectric phase shifters employ a low-loss dielectric insertion into the air filled guide at a point of max electric field to increase its effective dielectric constant thereby causing the guide wavelength λ_g to decrease as shown in Figure 3.10 (a). Thus, the insertion of the dielectric increases the phase shift in the wave passing through the fixed length waveguide section. Tapering of the dielectric slab is resorted to reduce the reflections. In another version as shown in Figure 3.10 (b), a pair of thin rods used to move the dielectric slab from a region of low electric field intensity to one of the high intensity to increase the effective dielectric constant.

Squeeze type phase shifters: it is a length of waveguide whose broader walls contain long non–radiating slots as shown in Figure 3.10 (c). A clamping arrangement is used to reduce the guide width a thus increasing the guide wavelength λ_g resulting in a decreased phase shift in the wave through the waveguide section. It is also called line stretcher.

Rotary phase shifters: The essential parts of this phase shifter are three waveguide sections, two fixed and one rotary. The fixed sections consists of quarter wave plates and the rotary section consists of half wave plate, all the plates are dielectric type.

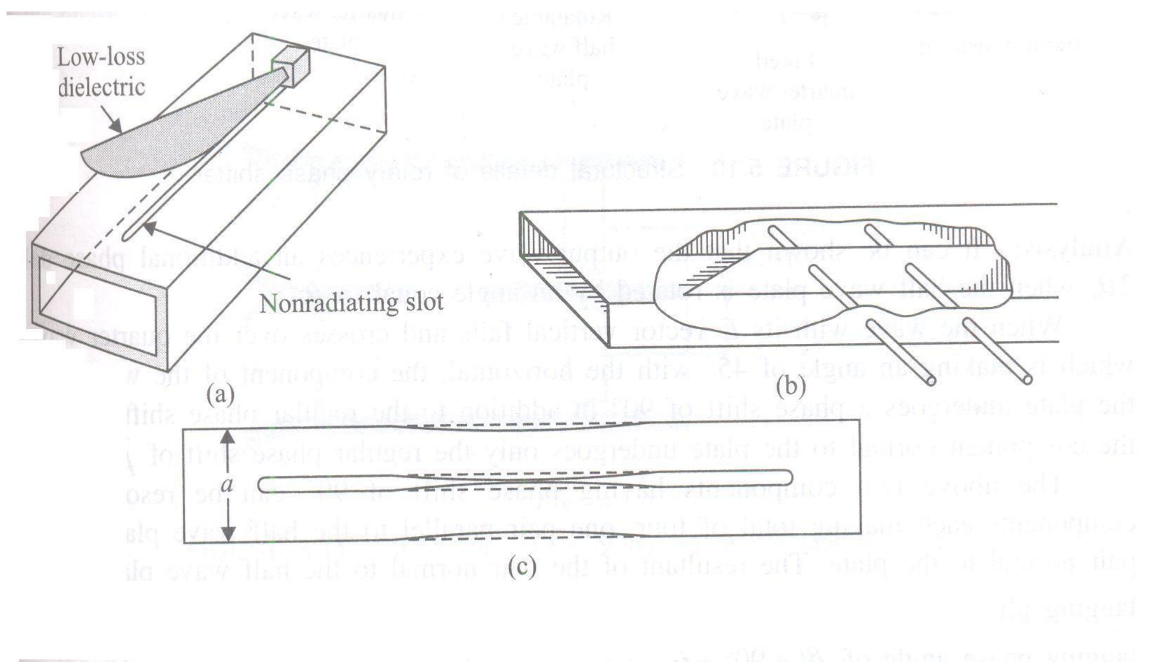


Fig 3.10 : Dielectric Phase Shifters

Structure : The two fixed quarter wave sections identical in all respects and the rotatable half wave section is just the double of a quarter wave section as shown in Figure 3.11. Each of the two fixed sections, attached to a transition, consists of a piece circular waveguide with a dielectric plate making an angle of 45^0 with the horizontal. The dielectric plate is normally thing with $\varepsilon_r > 1$, $\mu_r = 1$ and $\sigma = 0$. When E vector of the wave is normal to it, the plate does not effect the wave in any way, whereas it adds an additional phase lag when E vector parallel. The additional phase lag depends upon the properties of the material from which the slab is cut and the dimensions of the slab. The length of the plate is selected in such a way that this additional phase lag is 90^0 in case of quarter wave plate and 180^0 in case of half wave plate. As same materials are used to make half and quarter wave plates, the length of one becomes double of the other.

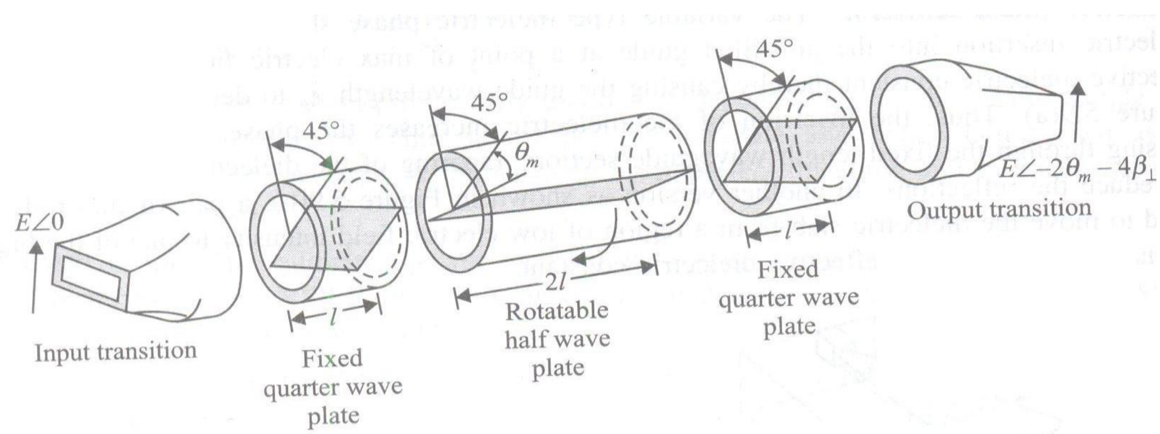


Fig 3.11: Structural details of rotary phase shifter

Analysis : It can be shown that the output wave experiences an additional phase delay of $2\theta_m$ when the half wave plate is rotated by an angle equal to θ_m.

When the wave with its E vector vertical falls and crosses over the quarter wave plate which is making an angle of 45^0 with the horizontal, the component of the wave parallel to the plate undergoes a phase shift of 90^0 in addition to the regular phase shift of $\beta\ell$ whereas the component normal to the plate undergoes only the regular phase shift of $\beta\ell$.

In each of the above two components having phase difference of 90^0 can be resolved into two components each making total of four, one pair parallel to the half wave plate and another pair normal to the plate. The resultant of the pair normal to the half wave plate will have lagging phase angle of $\beta\ell + \theta_m$ whereas the pair parallel to the half wave plate results in a lagging phase angle of $\beta\ell + 90^0 + \theta_m$.

The two components, one normal and the other parallel to the half wave plate while crossing undergoes a phase change $2\ \beta\ell$ and $2\ \beta\ell + 180^0$, resulting in a net phase lag of $3\ \beta\ell + \theta_m$ and $3\ \beta\ell + 270^0 + \theta_m$, respectively. These two components are available at the output of the half wave plate. Each of them can now be resolved into two components each, one along the quarter wave plate having a phase lag equal to $3\ \beta\ell + 2\theta_m$ and the other component parallel to quarter wave plate with phase lag $3\ \beta\ell + 270^0 + 2\theta_m$.

These two components, one is normal and the other is parallel to the quarter wave plate, while travelling through the output quarter wave plate undergoes phase delays $\beta\ell$ and $3\ \beta\ell + 90^0$ resulting in a net phase lag of $4\ \beta\ell + 2\theta_m$ and $4\ \beta\ell + 360^0 + 2\theta_m = 4\ \beta\ell + 2\theta_m$, respectively. These two equiphase components whose magnitudes are $E/\sqrt{2}$, can be combined into one equal to $E\angle 4\ \beta\ell + 2\theta_m$.

In the absence of the plates the magnitude and phase of the output would have been $E\angle 4\ \beta\ell$. The presence of the plates makes the output to have an additional phase equal to $2\theta_m$ when the half wave plate is rotated by an angle equal to θ_m.

The output remains vertically polarized, which means that the phase shifter is loss less and reflections- less for any position of the rotary section.

It is used as calibration standard because of its high accuracy.

3.10 Waveguide Tees

As noted, waveguide tees may consist of the E-plane tee, //-plane tee, magic tee, hybrid rings, corners, bends, and twists. All such waveguide components are discussed in this section.

Tee junctions. In microwave circuits a waveguide or coaxial-line junction with three independent ports is commonly referred to as a *tee junction.* From the *S*-parameter theory of a microwave junction it is evident that a tee junction should be characterized by a matrix of third order containing nine elements, six of which should be independent. The characteristics of a three-port junction can be explained by three theorems of the tee junction. These theorems are derived from the equiva*lent-circuit representation of the tee junction.* Their statements follow

1. A short circuit may always be placed in one of the arms of a three-port junction in such a way that no power can be transferred through the other two arms.
2. If the junction is symmetric about one of its arms, a short circuit can always be placed in that arm so that no reflections occur in power transmission between the other two arms. (That is, the arms present matched impedances.)
3. It is impossible for a general three-port junction of arbitrary symmetry to present matched impedances at all three arms.

E-plane Tee

An E-plane tee is a waveguide tee in which the axis of its side arm is parallel to the *E* field of the main guide (see Fig.3.12). If the collinear arms are symmetric about the side arm, there are two different transmission characteristics (see Fig.3.13). It can be seen from Fig.3.13 that if the E-plane tee is perfectly matched with the aid of screw tuners or inductive or capacitive windows at the junction, the diagonal components of the scattering matrix, S_{11}, S_{22}, and S_{33}, are zero because there will be no reflection. When the waves are fed into the side arm (port 3), the waves appearing at port 1 and port 2 of the collinear arm will be in opposite phase and in the same magnitude. Therefore

$$S_{13} = -S_{23}$$

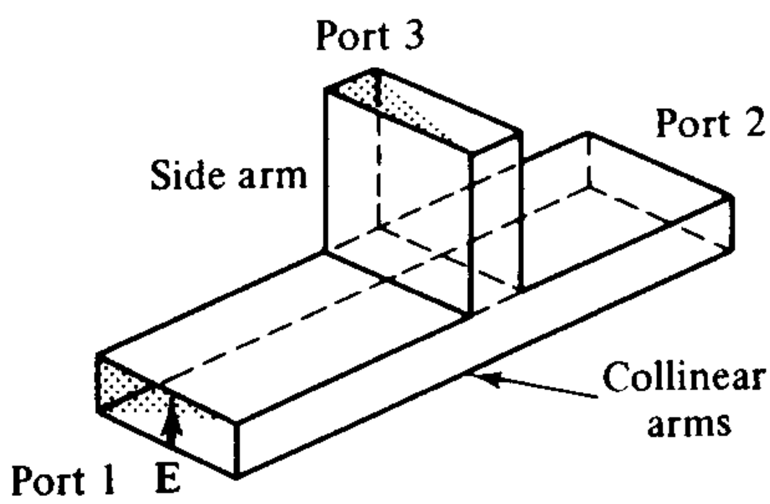


Fig 3.12 : E-Plane Tee schematic diagram

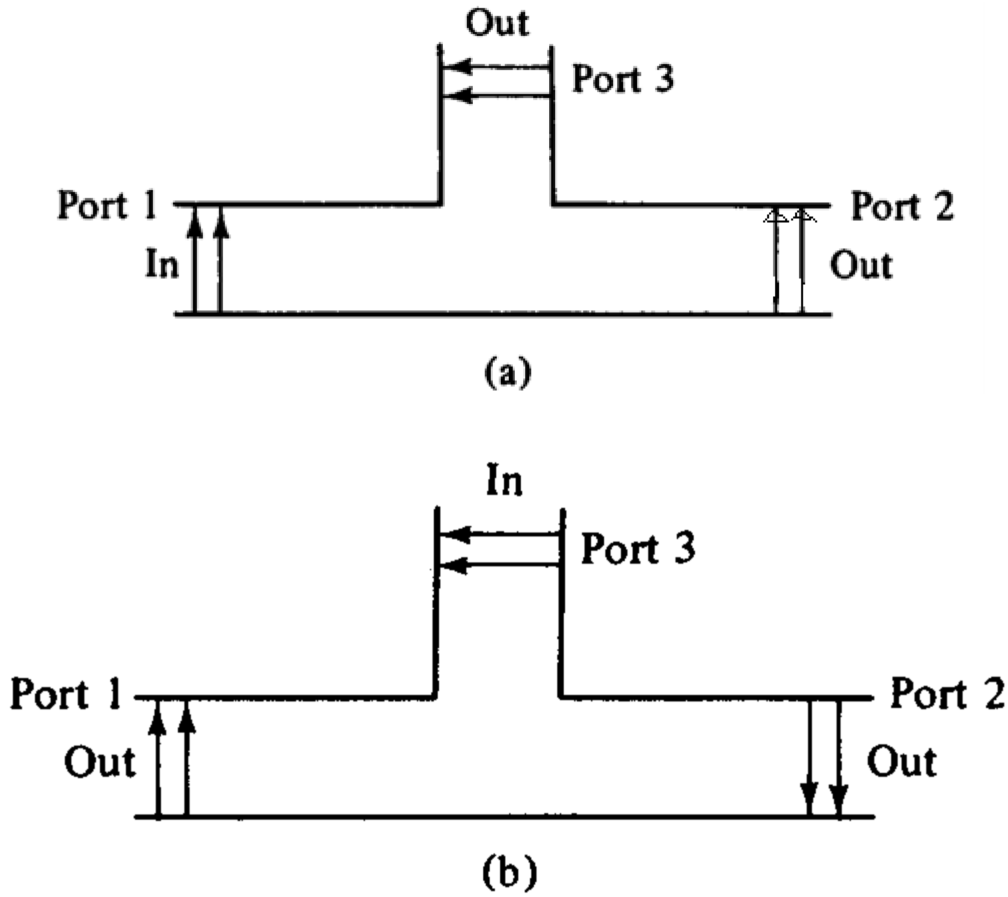


Fig3. 13 : (a) Input through main arm (b) Input through side arm.

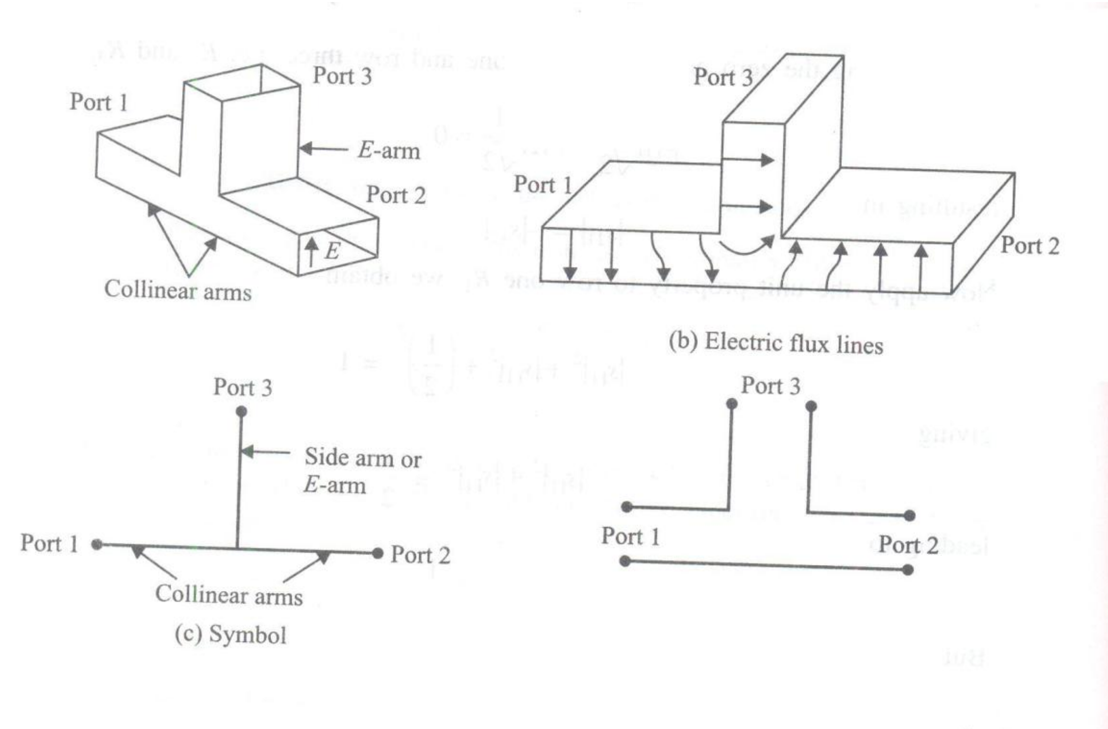


Fig 3.14: E-Plane Tee

H-Plane Tee

An H-Plane Tee has collinear arms and shunt side arm. It can be seen that if two input waves are fed into port 1 and port 2 of the collinear arm, the output wave at port 3 will be in phase and additive. On the other hand, if the input is fed into port 3, the wave will split equally into port 1 an port 2 in phase and in the same magnitude.

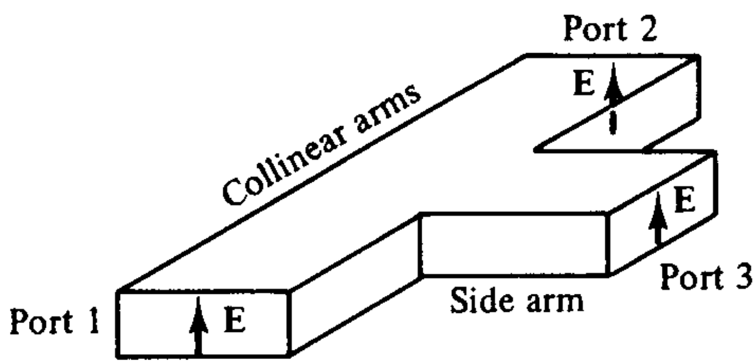


Fig 3.15: H-Plane Tee

Magic Tee

Magic Tee is an important four port, four arm junction, formed by attaching side arms to the slots cut in the narrow wall and braoad wall of apiece of wvegide. The arm connected to the slot in the broader wall is called E-arm or Difference arm and the arm connected to the slot in the narrow wall is called H-arm or Sum arm. The collinear arm ports are usaually designated as 1 and 2 and side arm ports as 3 and 4. Structurally it can be viewed as a combination of E-plane Tee and H-Plane Tee. It is also known as antisymmetric coupler, 3-dB hybrid and 3 dB coupler.

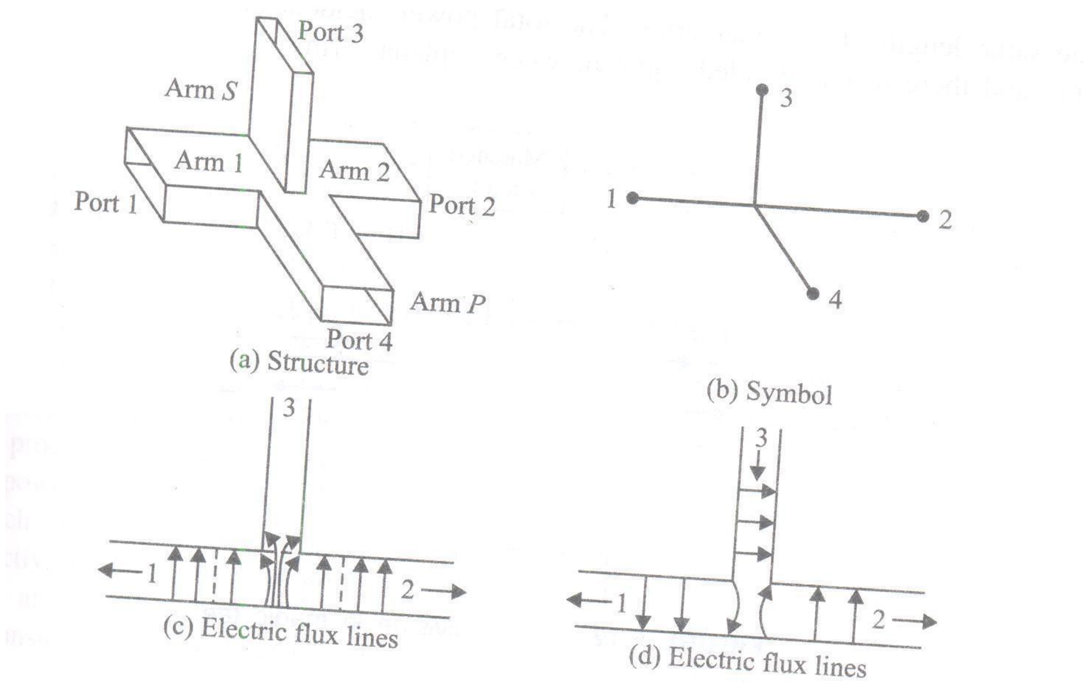


Fig 3.16: Magic Tee

Magic Tee is basically a hybrid in which the power is divided equally between the output ports. The outputs can eshibit either 0^o or 180^o phase difference. One of the main advantages of magic tee , in fact any hybrid is that the power delivered at one outputport is independent of the termination at the other ouput port provided the remaining port is match terminated.

The salient feature of Magic Tee are

- If two waves of equal amplitude and same phase are fed into port 1 and port 2, the output at port 3 is zero and additive at port 4.

- If a wave is fed into port 4, it will be divided equally between poort 1 and 2 of the main waveguide and power in port 3 will be zero. Therefore port 3 and 4 are isolated.
- The wave fed in port 3 will produce and output of eequal amplitude and opposite phase at ports 1 and 2, while the power coupled to port 4 Is zero, as port 3 and 4 are isolated.
- If wave is fed in port 1 of main waveguide, it will not be available at port 2 and vice versa, since E arm causes a phase dely while H arm causes phase advance.

Applictions of Magic Tee: The Magic / Hybrid Tee is used in

1. E-H Tuner
2. Duplexer
3. Mixer
4. Impedance measurement

3.11 Directional Coupler

Directional couplers are reciprocal, lossless and mateched 4-port network with a facilityto have protions of the forward and reverse waves on a line at two of its ports separately. Directional coupler is also called symmetric coupler and quadrature type hybrid.

The directional coupler consists of a primary waveguide 1-2 and a secondary waveguide 3-4. When all ports are terminated in their charcteristic impedances, there is free transimission of power, without reflection, between port 1 and port 2, and there is no transmission of power between port 1 and port 3 or between port 2 and port because no coupling exists between these two pairs of ports. The degree of coupling between port 1 and port 4 and between port 2 and port 3 depends on the structure of the coupler.

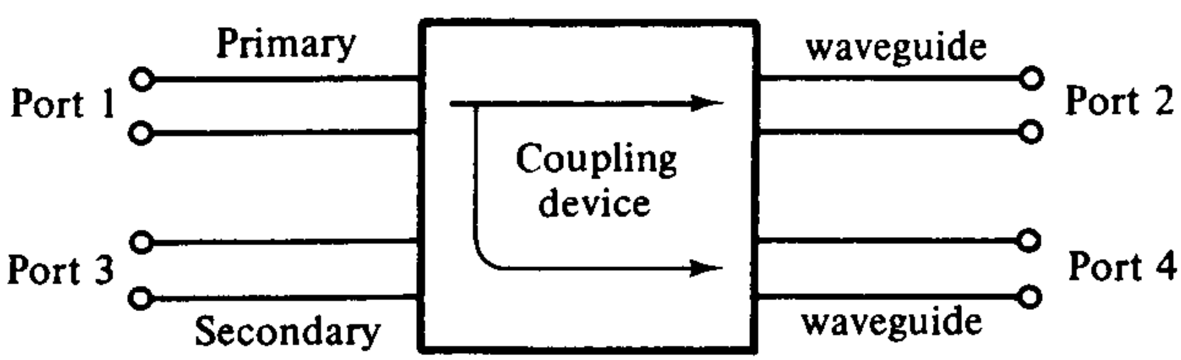


Fig 3.17: Directional Coupler

The characterics of a directional coupler can be expressed in terms of its coupling factor and its directivity. Assuming that the wave is propagating from port 1 to port 2 in the primary line, the coupling factor and the directivity are defined respectively.

$$\text{Coupling factor (dB)} = 10 \log_{10} \frac{P_1}{P_4}$$

$$\text{Directivity (dB)} = 10 \log_{10} \frac{P_4}{P_3}$$

Where
P_1= Power input to port 1
P_3 = Power output from port 3
P_4 = Power output from port 4

The coupling factor is a measurement of the ratio of power levels in the primary and secondary lines. Hence if the coupling factor is known, a fraction of power measured at port 4 may be used to determine the power input at port 1. This significance is desirable for microwave power measurements because no disturbance, which may be caused by the power measurements. The directivity is a measure of how well the forward travelling wave in the primary waveguide coupler only to a specific port of the secondary waveguide. An ideal directional coupler will have infinite directivity. Practically well designed directional coupler has directivity of 30-35 dB.

Several type of directional couplers exists, such as a two hole directional coupler, four hole directional coupler, reverse coupling directional coupler(Schwinger coupler) and Bethe hole directional coupler.

Two hole directional Coupler

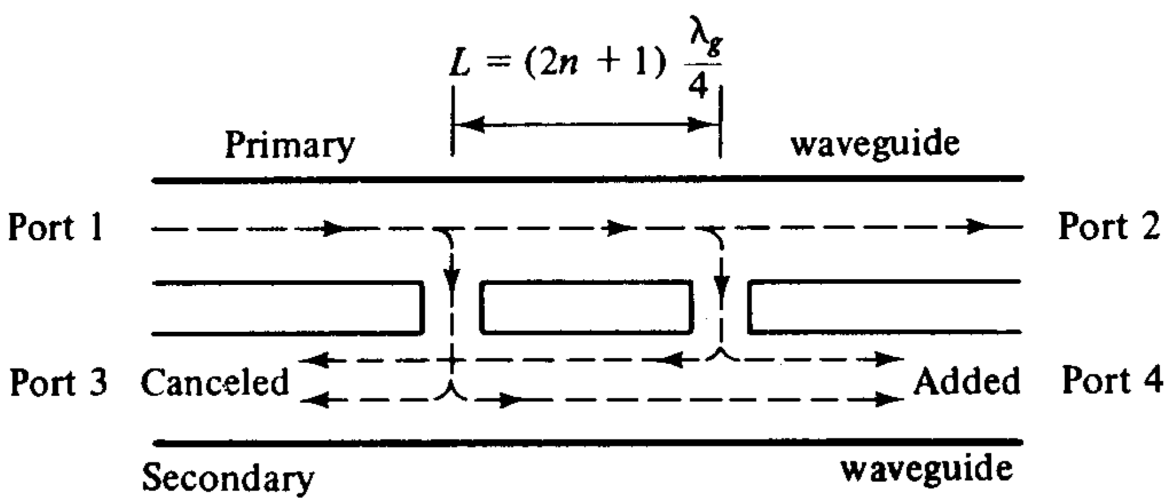


Fig3.18: A Two hole directional coupler

A two hole directional coupler with traveling wves propagating in it is illustrated in the figure above. The spacing between the centres of two holes must be

$$L = (2n + 1)\ \lambda_g/4$$

Where is n is an integer.

A fraction of the wave energy entered into port 1 passes through the holes and is radiated into the secondary guide as the h oles act as slot antennas. The forward waves in the secondary guide are in the same phase, regardless of the hole space, and are added at port 4. The backward waves in the secondary guide (waves progressing from right to left are out of phase by $(2L/\ \lambda_g)2\pi$ rad and are cancelled at port 3.

Bethe hole directional coupler

It has two versions. One is parallel guide coupler and the scond one is skewed guide coupler as shown below. In parallel guide coupler version the two gides are parallel, one lying over the broad wall of the other with a small hole aperture in the common broad wall shose offset *s* from the side wall of the guide controls the coupling.

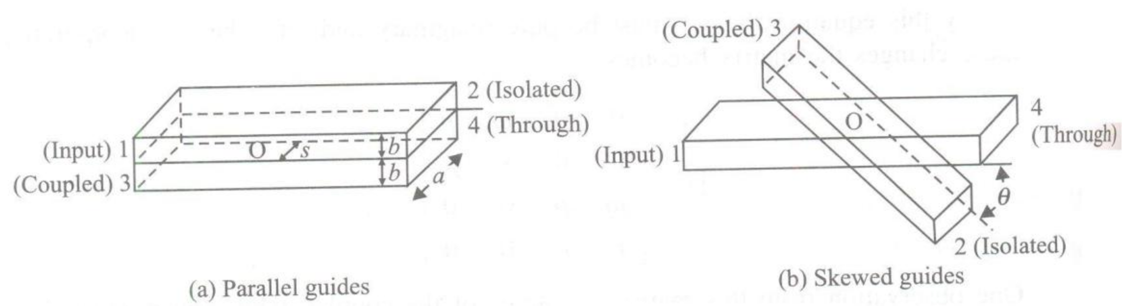


Fig 3.19: Bethe hole directional coupler

In skewed guide coupler version, one guide is over the other at an angle **θ** which controls the amplitude of the coupled waves. The geometry of the skewed Bethe hole coupler is often a disadvantage in terms of fabrication and application. Also both coupler designs operate properly only at the design frequency. Deviation from this frequency will alter the coupling level and the directivity.

In this coupler one waveguide is coupled to another through a single small hole in the common broad wall between the two guides. According to small aperture coupling theory, an aperture can be replaced with equivalent sources consisting of electric and magnetic dipole moments. The normal electric dipole moment and the axial magnetic dipole moment radiate with even symmetry in the coupled guide, while the transverse magnetic dipole moment radiates with odd symmetry. Thus by adjusting the relative strengths of these two equivalent sources, we can cancel the radiation in the direction of the isolated port, while enhanced the radiation in the direction of the coupled port.

In case of parallel guide coupler, the coupling is controlled by the aperture offset s from the side wall where as the angle **θ** between the guides controls the coupling in case of skewed waveguide coupler.

Applications: The directional coupler is used in

1. Power monitor
2. Reflecto-meter

Eg: 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.

Solution: $P_1 = 10$ W, $P_4 = 10$ mW and $P_3 = 10$ μW, *Then the coupling C in dBs is*

$$\text{Coupling factor} = 10 \log (P_1/P_4) = 10 \log (10 / 10 \times 10^{-3}) = 30 \text{ dB}$$

$$\text{Directivity} = 10 \log (P_4/P_3) = 10 \log (10 \times 10^{-3}/ 10 \times 10^{-6}) = 30 \text{ dB}$$

Eg: A 20 dB coupler has a directivity of 30 dB. Calculate the value of isolation defining all terms involved.

Isolation in dBs = Coupling in DB + Directivity in dB = 20 + 30 = 50 dB