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

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

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.

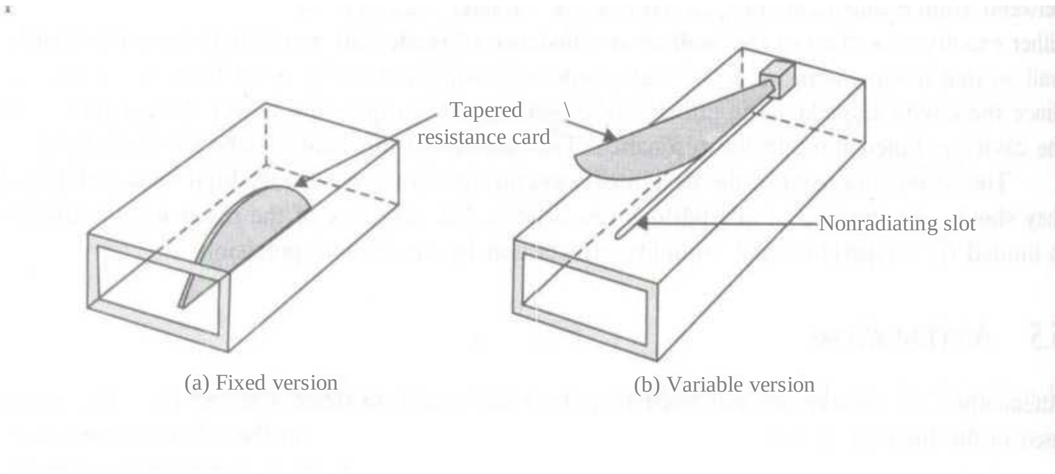

Fig 3.8: Resistive Card attenuators

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.

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 e_r>1, p_r =1 and conductivity o 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.

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.

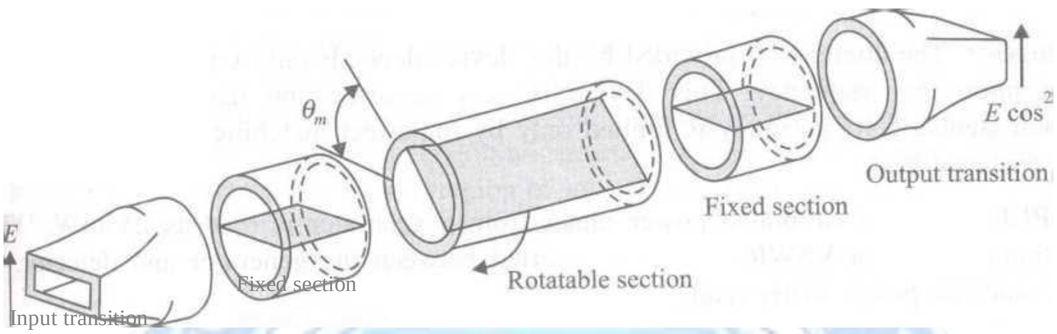

Fig3.9: Structural details of Rotary Vane Attenuator

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 $E \cos^2\theta$ Hence, the attenuation provided by the device in dB is $A = 10 \log (1/ \cos^2\theta)$.

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 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.

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 £r is given by */3l = 2MXg*, where *2 = 2/yj^ -(2/2a)*^{2} . From this relation, we can observe that the phase of the wave can be controlled either by varying £ 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 *2* 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 *2* 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.

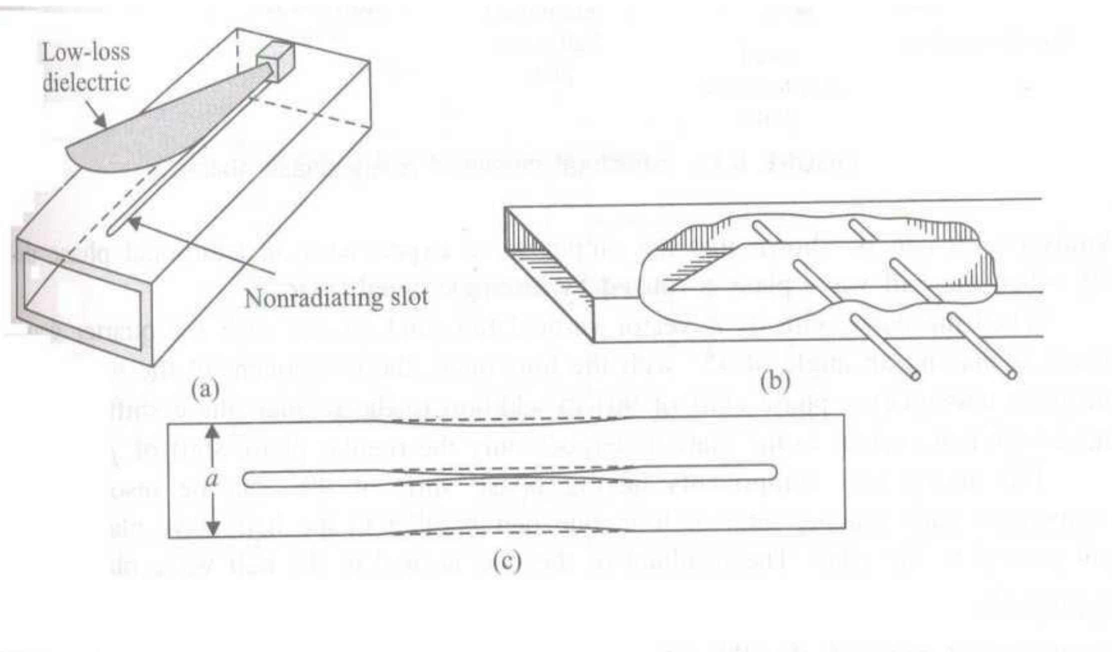

Fig 3.10 : Dielectric Phase Shifters

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 $£_r$ >1, p_r =1 and o = 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.

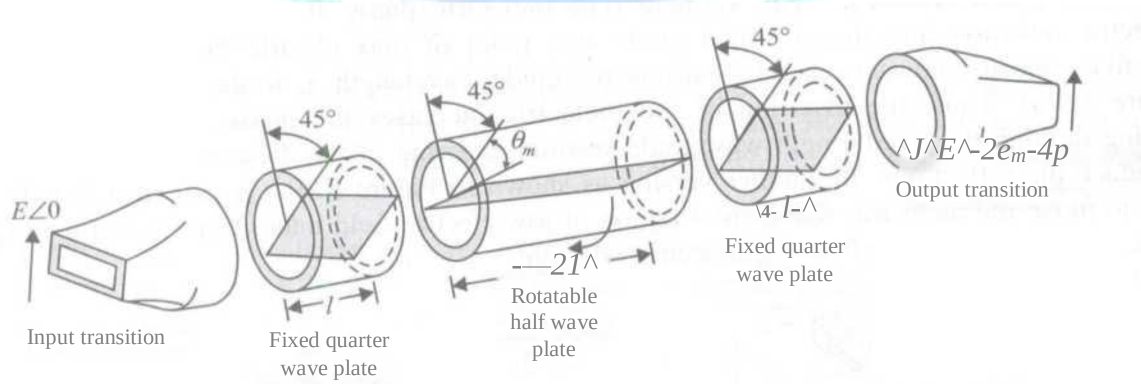

Fig 3.11: Structural details of rotary phase shifter

Analysis : It can be shown that the output wave experiences an additional phase delay of 20_{ra} when the half wave plate is rotated by an angle equal to .

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 p***l*** whereas the component normal to the plate undergoes only the regular phase shift of *p**l***

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 p***l*** $+0_{ra}$ whereas the pair parallel to the half wave plate results in a lagging phase angle of p***l*** $+90^{\circ}+\boldsymbol{0_{ra}}$.

The two components, one normal and the other parallel to the half wave plate while crossing undergoes a phase change 2 p***l*** and 2 p***l*** $+180^0$, resulting in a net phase lag of 3 p***l*** $+0_{ra}$ and 3 p***l*** $+270^{\circ}+$, 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 p***l*** $+20_{ra}$ and the other component parallel to quarter wave plate with phase lag 3 p***l*** $+270^{\circ}+2\ d_m$.

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 p***l*** and 3 p***l*** $+90^{\circ}$ resulting in a net phase lag of 4 p***l*** $+20_{ra}$ and 4 p***l*** $+36O^{\circ}+2\boldsymbol{0_{ra}}$ = 4 p***l*** $+20_{ra}$, respectively. These two equiphase components whose magnitudes are E/V2 , can be combined into one equal to Ez4 p***l*** $+20_{ra}$.

In the absence of the plates the magnitude and phase of the output would have been Ez4 p***l***. The presence of the plates makes the output to have an additional phase equal to 20_{ra} when the half wave plate is rotated by an angle equal to $\boldsymbol{Q_n}$.

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.