Name: Nishant Sanjay Chavan  crp: 180600283
Class: BE/B  Sub: ME  Roll no: $\boxed{18}$

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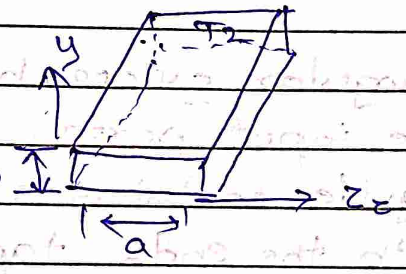
Q.1) A rectangular wave guide is hollow metallic tube with rectangular cross section. The conducting half of the waveguide center the electromagnetic field and thereby give the electromagnetic wave. Waveguide were experted of frequencies in microwave range.

The mode of rectangular waveguide,



Consequently from given Helmholtz eqn:

$$\nabla^2 H_z = \gamma^2 H_z$$

$$H_z = \left[ A_m \sin\left(\frac{m\pi x}{a}\right) + B_m \cos\left(\frac{m\pi x}{a}\right) \right] \cdot$$

$$\left[ C_n \sin\left(\frac{n\pi y}{b}\right) + D_m \cos\left(\frac{n\pi y}{b}\right) e^{-j\beta_g z} \right]$$

where $k_x = \frac{m\pi}{a}$, $k_y = \frac{n\pi}{b}$

For a ~~long~~ lossless dielectric Maxwell's cutoff eqn in frequency domain are,

$$\nabla \times E = -j\omega\mu H$$

$$\nabla \times H = j\omega\epsilon E$$



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By substituting $\frac{\partial}{\partial z} = -j\beta_g$ and $E_z = 0$

$$\beta_g E_y = -\omega \mu H_z$$

$$\beta_g E_x = \omega \mu H_y$$

$$\frac{\partial E_y}{\partial x} - \frac{\partial E_z}{\partial y} = -j\omega\mu H_z$$

$$\frac{\partial H_z}{\partial y} + j\beta_g H_y = j\omega \varepsilon E_x$$

$$-j\beta_g H_x - \frac{\partial H_z}{\partial x} = j\omega \varepsilon E_y$$

$$\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = 0$$

In rectangular waveguide

$$\frac{\partial E_x}{\partial y} - \frac{\partial E_y}{\partial z} = -j\omega\mu H_x$$

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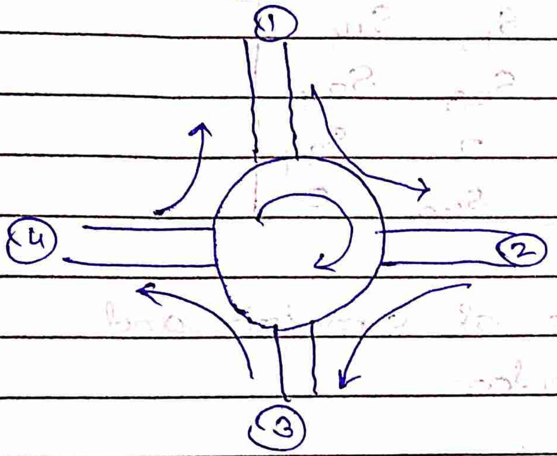
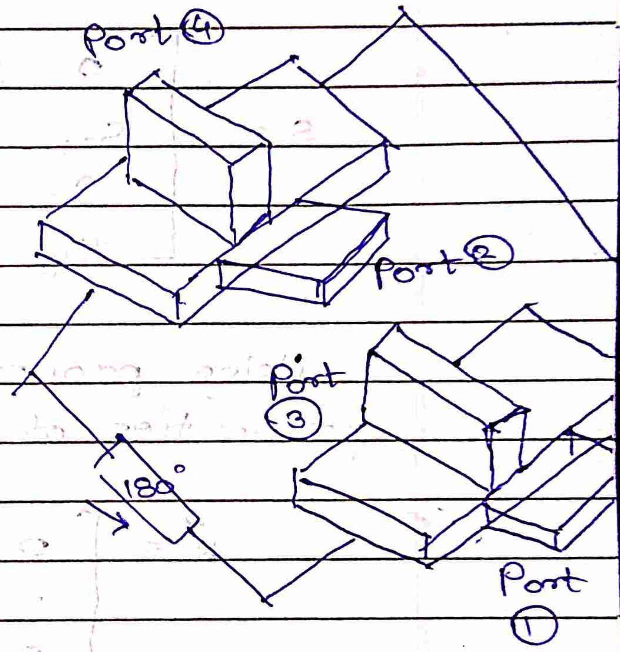
Q.2) Circulator:

A circulator is a four port microwave device which has a specific property that each terminal is connected only to ~~nex~~ next clockwise terminal. i.e. ~~P.E~~ port 1 connected to port 2 only and not to port 3 and 4 and port 2 is connected to port 3 only etc.




Construction:
1) A four port Faraday rotation circulator is shown in fig.
2) The power entering port 1 is TE10 mode and is converted to TE11 mode because of gradual rectangular to circular transition.
3) This power passes port 3 unaffected since the electric field is not significantly cut and is rotated through 45° due to ferrite passes port 4 unaffected and finally emerges out of port 2.
4) power from part 2 will have plane of polarization already titled by 45° with respect port 1.

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5) This wave gets rotated by another 45° due to ferrite rod in clockwise direction.

6) The power whose plane of polarization is tilled through 90° finds port 3 suitably aligned and emerges out of it.

7) Similarily port 3 is connected only to port 4 and port 4 to port 1.

$$S = \begin{bmatrix} 0 & S_{12} & S_{13} & S_{14} \\ S_{21} & 0 & S_{23} & S_{24} \\ S_{31} & S_{32} & 0 & S_{34} \\ S_{41} & S_{42} & S_{43} & 0 \end{bmatrix}$$

Using properties of S matrix and properties of circular

$$S = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$



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Q.3) Microwave Gyrator:

1) A gyrator/phase shifter is defined as a two-port device that has relative difference in phaseshift of 180° for transmission from port 1 to port 2 as compared the phase shift for transmission from port 2 to port 1.

2) It consists of rectangular guide with a 90° twist connected to a circular guide, which in turn connected to another rectangular guide at other end.

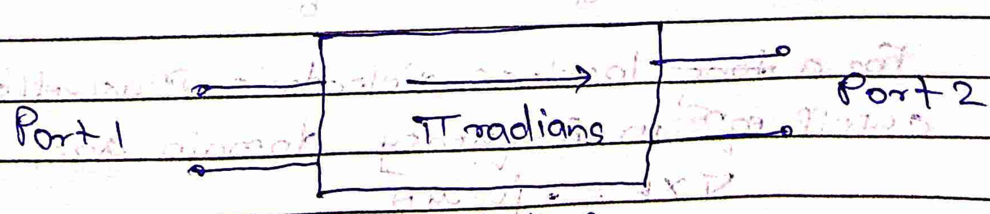
3) The two rectangular guides have the same orientation at the input ports.

4) The circular guide contains a thin cylindrical rod of ferrite with the ends tapered to reduce reflection.

5) A static axial magnetic field is applied so as to produce 90° Faraday rotation of $TE_{11}$, dominant mode in circular guide.

6) consider a wave propagation from left to right.

7) In passing through the twist the plane of polarization is rotated by 90° in a counter-clockwise direction.




Symbol of gyrator



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