EEC 603
MICROWAVE ENGINEERING

UNIT-1

Applications of circular waveguide

- Rotating joints in radars to connect the horn antenna feeding a parabolic reflector (which must rotate for tracking)

- TE_{01} mode suitable for long distance waveguide transmission above 10 GHz.

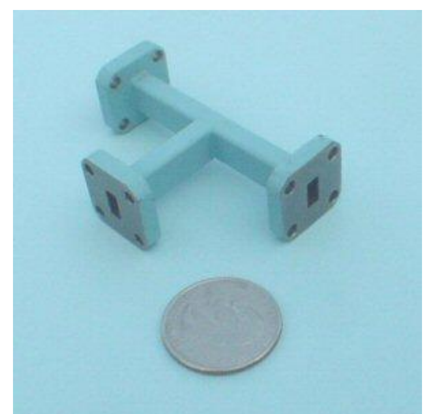
- Short and medium distance broad band communication (could replace / share coaxial and microwave links)

Waveguide components

Rectangular waveguide

Waveguide to coax adapter

Waveguide bends



E-tee

Figures from: www.microwaves101.com/encyclopedia/waveguide.cfm

Uses

- To reduce attenuation loss
  - High frequencies
  - High power
- Can operate only above certain frequencies
  - Acts as a High-pass filter
- Normally circular or rectangular
  - We will assume lossless rectangular

Modes of propagation

From these equations we can conclude:

- TEM (E_z=H_z=0) can't propagate.
- TE (E_z=0) transverse electric
  - In TE mode, the electric lines of flux are perpendicular to the axis of the waveguide
- TM (H_z=0) transverse magnetic, E_z exists
  - In TM mode, the magnetic lines of flux are perpendicular to the axis of the waveguide.
- HE hybrid modes in which all components exists

Dominant Mode

- The dominant mode is the mode with lowest cutoff frequency.
- It's always TE_{10}
- The order of the next modes change depending on the dimensions of the guide.

Group velocity, u_g

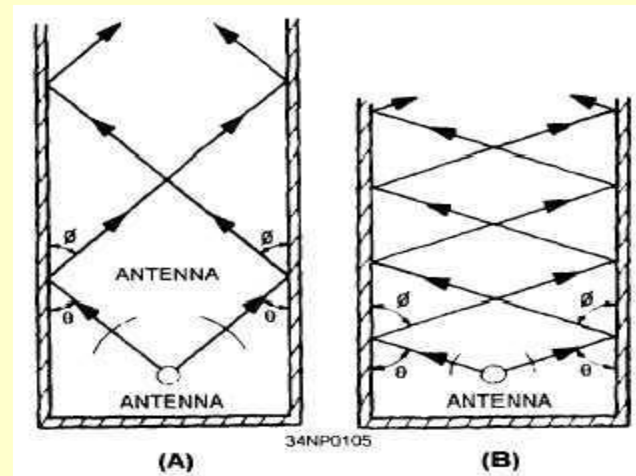
- As frequency is increased, the group velocity increases.

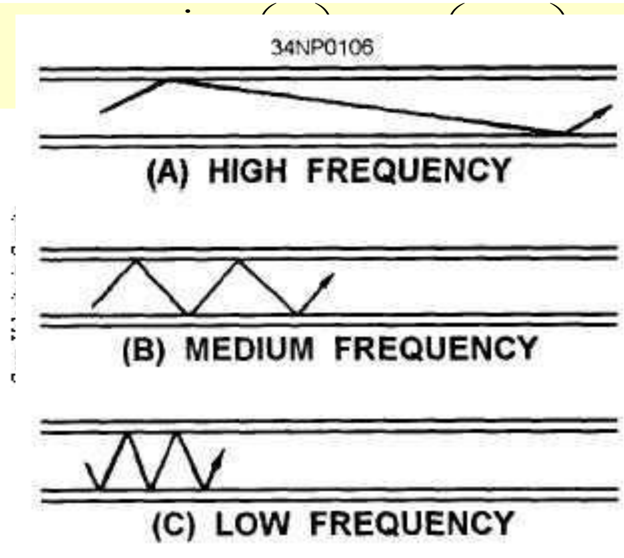
- Is the velocity at which the energy travels.

$$u_g = \frac{1}{\partial\beta / \partial\omega} = u'\sqrt{1-\left[\frac{f_c}{f}\right]^2} \quad \left[\frac{\text{rad/s}}{\text{rad/m}}\right] = \left[\frac{m}{s}\right]$$

- It is always less than u'

$$\boxed{u_p u_g = (u')^2}$$





Power transmission

- The average Poynting vector for the waveguide fields is

$$P_{ave} = \frac{1}{2}\mathrm{Re}\left[E \times H^*\right] = \frac{1}{2}\mathrm{Re}\left[E_x H_y^* - E_y H_x^*\right]$$

$$= \frac{\left|E_x\right|^2 + \left|E_y\right|^2}{2\eta}\hat{z} \qquad [\mathrm{W/m^2}]$$

- where $\eta = \eta_{TE}$ or η_{TM} depending on the mode

$$P_{ave} = \int P_{ave} \cdot dS = \int_{x=0}^{a}\int_{y=0}^{b} \frac{\left|E_x\right|^2 + \left|E_y\right|^2}{2\eta} dy dx \qquad [\mathrm{W}]$$

Attenuation in Lossy waveguide

- When dielectric inside guide is lossy, and walls are not perfect conductors, power is lost as it travels along guide.

$$P_{ave} = P_o e^{-2\alpha z}$$

- The loss power is $$P_L = -\frac{dP_{ave}}{dz} = 2\alpha P_{ave}$$

- Where $\alpha = \alpha_c + \alpha_d$ are the attenuation due to ohmic (conduction) and dielectric losses
- Usually $\alpha_c >> \alpha_d$

Attenuation for TE$_{10}$

- Dielectric attenuation, Np/m

$$\alpha_d = -\frac{\sigma\eta'}{2\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

Dielectric conductivity!

- Conductor attenuation, Np/m

$$\alpha_c = -\frac{2R_s}{b\eta'\sqrt{1-\left(\frac{f_{c,10}}{f}\right)^2}}\left(0.5+\frac{b}{a}\left(\frac{f_{c,10}}{f}\right)^2\right)$$