Module 6 : Wave Guides

Lecture 40 : Introduction of Parallel Waveguide

Objectives

In this course you will learn the following

- Introduction of Parallel Plane Waveguide.

Introduction of Parallel Plane Waveguide

- Wave Guide is a structure which can guide Electro Magnetic Energy.
- A Wave guide is a prime component of a communication system.
- The Wave guide in structure should transport electro magnetic energy with as minimal loss as possible.
- In practice, we find two types of wave guide in structure which are as follows :

  Metallic Wave Guide : Is used in high frequency, microwaves and millimeter waves transmission. Co-axial cables and hollow rectangular or circular wave guide's fall in this category.

  Delectric Wave Guide : Is used at sub millimeter wavelenghts and optical frequencies. Optical fibres and thin film integrated optical devices fall in this category.

- The important feature of a wave guide in structure is the ' **Modal Propagation**'. The electro magnetic energy propagates inside the wave guide in the form of definite field patterns called ' **MODES** '.
- The electro magnetic fields inside a bound structure like the wave guide's can exist only in the form of MODES.
- The modal fields of a wave guide can be visualized either in the form of super position of plane waves or as a boundary value problem
- The decomposition of plane waves is possible for simple wave guide in structure like parallel plane wave guide or planer thin film wave guide's.
- For rectangular and circular wave guide one essentially has to solve the wave equation with appropriate boundary condition imposed by the wave guide walls.
- The second approach is more general where as, the first approach provides better physical understanding of the wave propagation inside the wave guide.
- A parallel wave guide is formed by two infinite parallel conducting planes. The electro magnetic energy is confined between the planes and moves in a direction parallel to the planes.
- The electro magnetic waves which can exists between the parallel planes can be of three types

  Transverse Electric Fields

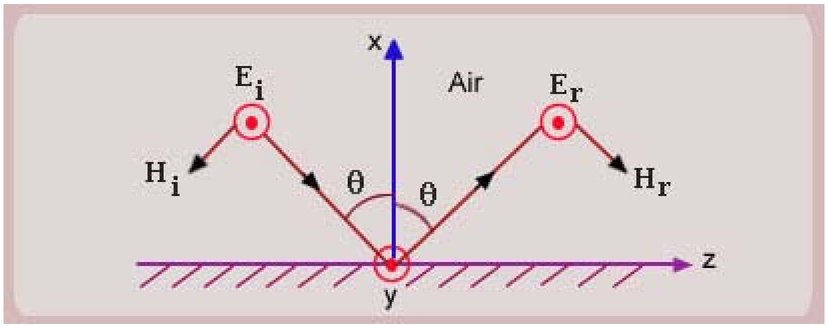
  Transverse Magnetic FIelds

  Transverse Electomagnetic Fields

- For Transverse Electric Field, the electric field is perpendicular to the direction of wave propagation. That is to say that the electric field does not have any component in the direction of wave propagation.
- For Transverse Magnetic Field, the magnetic field is transverse to the direction. of wave propagation. That is to say that the electric field does not have any component in the direction of wave propagation.
- For Transverse Electromagnetic Fields, the electric and magnetic fields both do not have a component in the direction of wave propagation.

Parallel Plane Wave Guide (contd)

- Let us try to visualize the fields inside a parallel wave guide in the form of super position plane wave.
- Let us consider a single conducting plane on which a plane wave with perpendicular polarization is incident at an angle θ as shown in the figure below



- Since the conducting plane is ideal the wave is completely reflected back and the total electric and magnetic field in the medium can be written as

$$\mathbf{E_1} = 2jE_{i0}\sin(\beta_1 x\cos\theta)e^{-j\beta_1 z\sin\theta}\hat{\mathbf{y}} \quad \text{---------- (6.1)}$$

and

$$\mathbf{H_1} = 2j\frac{E_{i0}}{\eta_1}\sin(\beta_1 x\cos\theta)e^{-j\beta_1 z\sin\theta}\cos\theta\hat{\mathbf{x}} + 2\frac{E_{i0}}{\eta_1}\cos(\beta_1 x\cos\theta)e^{-j\beta_1 z\sin\theta}\sin\theta\hat{\mathbf{z}} \quad \text{---------- (6.2)}$$

Parallel Plane Wave Guide (contd)

- The electric field which is oriented in the y-direction is parallel to the conducting plane. Naturally, the total electirc field should be zero at the conducting plane i.e at $x = 0$
- We can however note that the electric field is zero not only at $x = 0$ but at any height d which satisfies the condition

$$x = d = \frac{m\lambda_1}{2\cos\theta} \qquad m = 0, 1, 2.... \text{-------- (6.3)}$$

- What that means is the fields are unaffected if we keep another conducting plane parallel to the original conducting plane at a height given by 6.3 while the field given by 6.1 and 6.2 are not disturbed.
- The structure however has now become a bound structure wihin which the electro magnetic fields are trapped.
- Inverting equation 6.3, we get

$$\cos\theta = \frac{m\lambda_1}{2d} = \frac{m\pi}{\beta_1 d} \text{---------- (6.4)}$$

  The equation implies that for a given separation for a two conducting planes (for a given height of parallel plane wave guide, d) the plane waves can propagate only at discrete angles given by 6.4
- The plane wave cannot propagate any arbitrary angle whih does not satisfy the condition 6.4
- The characteristics of the plane wave propagation between two parallel conducting planes can then be summarized as follows:

(1) We have naturally migrated from the continuous domain of θ to the discrete domain.

(2) Since $\cos\theta$ is $\leq$ 1, there are finite number of angles θ for a given boundary separation \`d' and the frequency.

(3) For $d < \lambda_1/2, \cos\theta$ is always greater than 1 even for the smallest value of $m = 1$. This imply that no wave can be launched between the two conducting planes, if the separation between them is less than $\frac{\lambda_1}{2}$.

(4) As the separation between the boundaries increases or the wavelength decreases, the number of acceptable angles at which the wave can be launched, also increases.

Recap

In this course you have learnt the following

- Introduction of Parallel Plane Waveguide.