Module 6 : Wave Guides

Lecture 45 : Visualization of Modal fields inside Rectangular Waveguide

Objectives

In this course you will learn the following

- Field for TE_{10} mode in Rectangular Waveguide.
- Magnetic field distribution for TE_{10} mode.

- The visualization of the modal fields is important for identifying regions from where fields can be tapped efficiently by the probes.
- The field probes are devices which can induce fields inside a waveguide or extract energy from the fields propagating inside the waveguide.
- To visualize the fields first we fix the time i.e we obtain instantaneous field distribution inside the waveguide.
- To visualize the three dimensional distribution of vector fields we follow a field vector until it either closes on itself or ends upon the walls of waveguide.
- We can see from the modal field expression that the fields are periodic over one guided wave length λ_g along the length of the waveguide.
- So essentially one has to develop a three dimensional picture of the fields only over a block of λ_g .
- The blocks can be repeated along the length of the waveguide to get the full field distribution inside the waveguide.
- Once the total instantaneous field distribution is developed the distribution can be made to move with a velocity equal to the phase velocity of the mode.
- In the following we visualize the modal fields for selective modes. (FIG)

Field for TE_{10} mode in Rectangular Waveguide

- We visualize the fields for TE_{10} mode because the TE_{10} mode is the dominant mode of rectangular waveguide and invariably people have to deal with this mode while handling rectangular waveguide.

- From general field expression for TE_{mn} mode substituting $m = 1$ & $n = 0$, we get the fields for the TE_{10} mode as follows :

$$E_y = Re\left[-j\frac{\omega\mu a}{\pi}D\sin\left(\frac{\pi x}{a}\right)e^{-j\beta z}\right] = -\frac{\omega\mu a}{\pi}\ D\sin\left(\frac{\pi x}{a}\right)\sin\left(\frac{2\pi z}{\lambda_g}\right) \quad \text{---------- (6.72)}$$

$$H_x = Re\left[\frac{j\beta a}{\pi}D\sin\left(\frac{\pi x}{a}\right)e^{-j\beta z}\right] = \frac{\beta a}{\pi}D\sin\left(\frac{\pi x}{a}\right)\sin\left(\frac{2\pi z}{\lambda_g}\right) \quad \text{---------- (6.73)}$$

$$H_z = Re\left[D\cos\left(\frac{\pi x}{a}\right)e^{-j\beta z}\right] = D\cos\left(\frac{\pi x}{a}\right)\cos\left(\frac{2\pi z}{\lambda_g}\right) \quad \text{---------- (6.74)}$$

- Let us now try to build the three dimensional picture of the electric and magnetic fields from this expressions : (FIG)

Electric Field Distribution

- Since electric field has only one component the visualization of the electric field is rather simple and straight forward.

- All the electric field vectors are oriented in y -direction. The magnitude of the electric field has sinusoidal variation in both x and z direction. The electric field is zero at $x = 0$ and $x = a$ i.e all along the vertical walls of the waveguide and maximum at $x = a/2$ i.e half way between the two vertical walls. So, we visualize the electric field vector like an arrow with length of an arrow indicating the magnitude of the field, the arrows will be vertically oriented with largest arrow at the center of the waveguide gradually, decreasing as we move towards the vertical walls and remaining constant as we move towards the horizontal walls as show in (FIG).

- Since the electric field is periodic with period λ_g in the z -direction the length of the field vector(arrow) undergoes sinusoidal variations as we travel along the z -direction.

- The total picture of the electric field then can be built up by stretching the imagination a bit and putting these entire arrows together. The electric field distribution will be as shown in the (FIG).

Magnetic field distribution for TE_{10} mode

- Visualization of magnetic fields is a little complicated compared to that of the electric field.
- The magnetic fields has two components x and z which have different special distribution.
- The important thing to note is that H_x and H_z components are shifted in space by quarter cycle in both x and z directions. This is due to the fact that H_x have a sign variation where as H_z has co-sign variation.
- Physically this means that at a location x where H_x is maximum, H_z is zero and vice-versa and at location z where H_x is maximum, H_z is zero and vice-versa.
- So, at some location say $x = 0$ and $z = 0$, H_z is maximum and H_x is zero. At $x = a/2$, H_z becomes zero and H_x is maximum. Also at $x = a$, H_z again becomes maximum with opposite direction and H_x again becomes zero.
- If we move to another plane along the length of the waveguide by distance $\lambda_g/4$, H_z is zero there and H_x is maximum. If we stretch our imagination we can see the magnetic fields as the close loops of length $\lambda_g/2$ as shown in (FIG). Since there is no variation of the field in y -direction the magnetic field would appear as a thick torrid as shown in the (FIG).
- Now repeating the block of length λ_g along the length of the waveguide we can get the total distribution of electric and magnetic fields.
- The whole field distribution is similar to a train with magnetic fields looking like compartments and the electric field appearing like the connecting rods.

Recap

In this course you have learnt the following

- Field for TE_{10} mode in Rectangular Waveguide.
- Magnetic field distribution for TE_{10} mode.