



SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution



Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A++' Grade (3rd Cycle)
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

19ECT302 – TRANSMISSION LINES AND antennas

TM WAVES IN RECTANGULAR
WAVEGUIDES/19ECT302-TRANSMISSION
LINES AND
ANTENNAS/R.PRABHA/ECE/SNSCT

III YEAR/ V SEMESTER
1

UNIT 2 – GUIDED WAVES

TOPIC – TM WAVES IN RECTANGULAR WAVEGUIDES



CAN YOU RELATE THE FIGURES?





WAVEGUIDES



- A waveguide is a special form of transmission line consisting of a hollow, metal tube.
- The tube wall provides distributed inductance, while the empty space between the tube walls provide distributed capacitance.
- Waveguides are practical only for signals of extremely high frequency, where the wavelength approaches the cross-sectional dimensions of the waveguide.
- Below such frequencies, waveguides are useless as electrical transmission lines.



TYPES

Rectangular
waveguides

- Most preferred type
- Frequency difference between consecutive modes - smaller

Circular
Waveguides

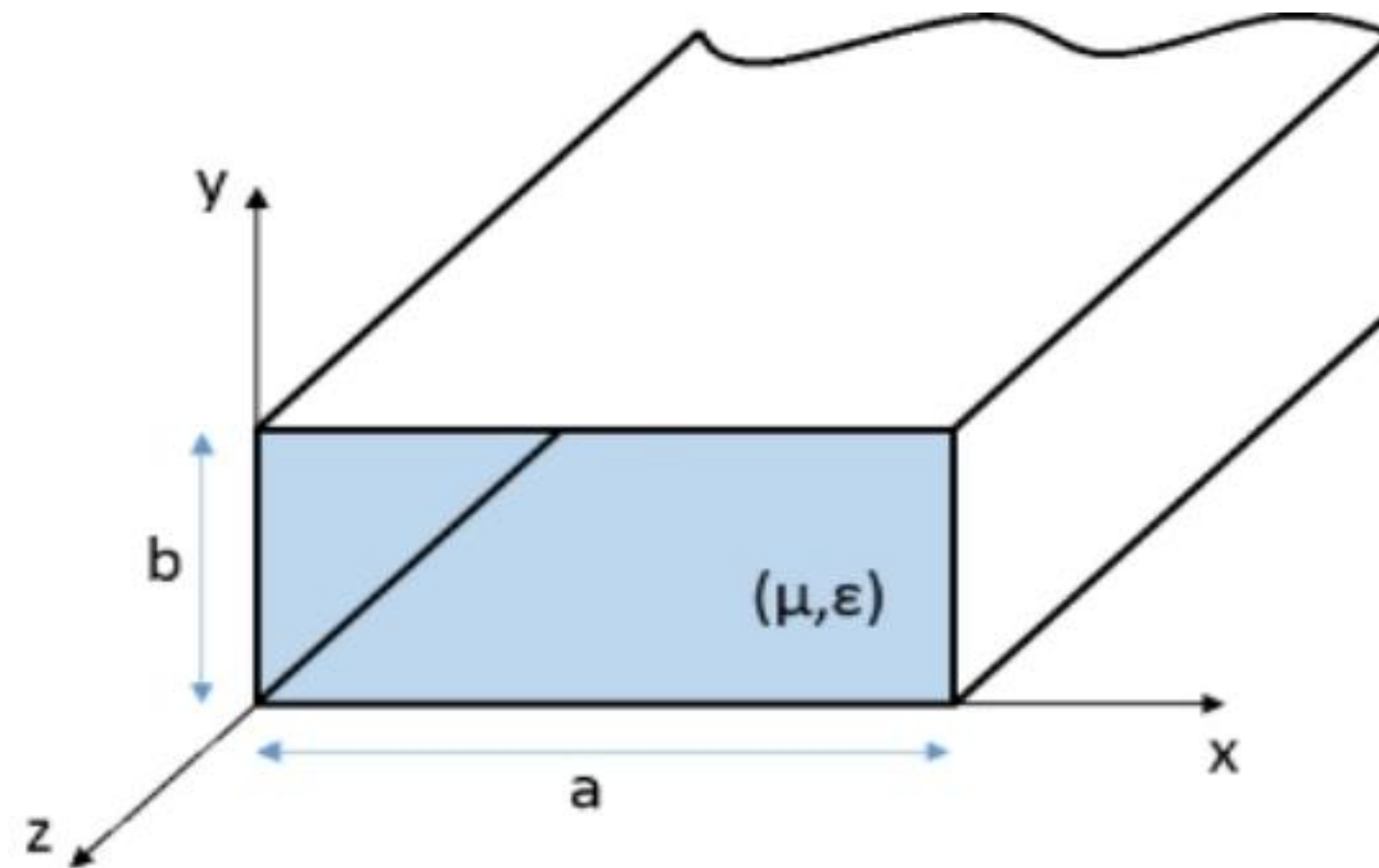
- Less Preferable
- Polarization not maintained – circular symmetry



RECTANGULAR WAVEGUIDE



- Consider a rectangular waveguide of width “a” and breath “b”.
- An EM wave is assumed to propagate in z direction as shown in fig.





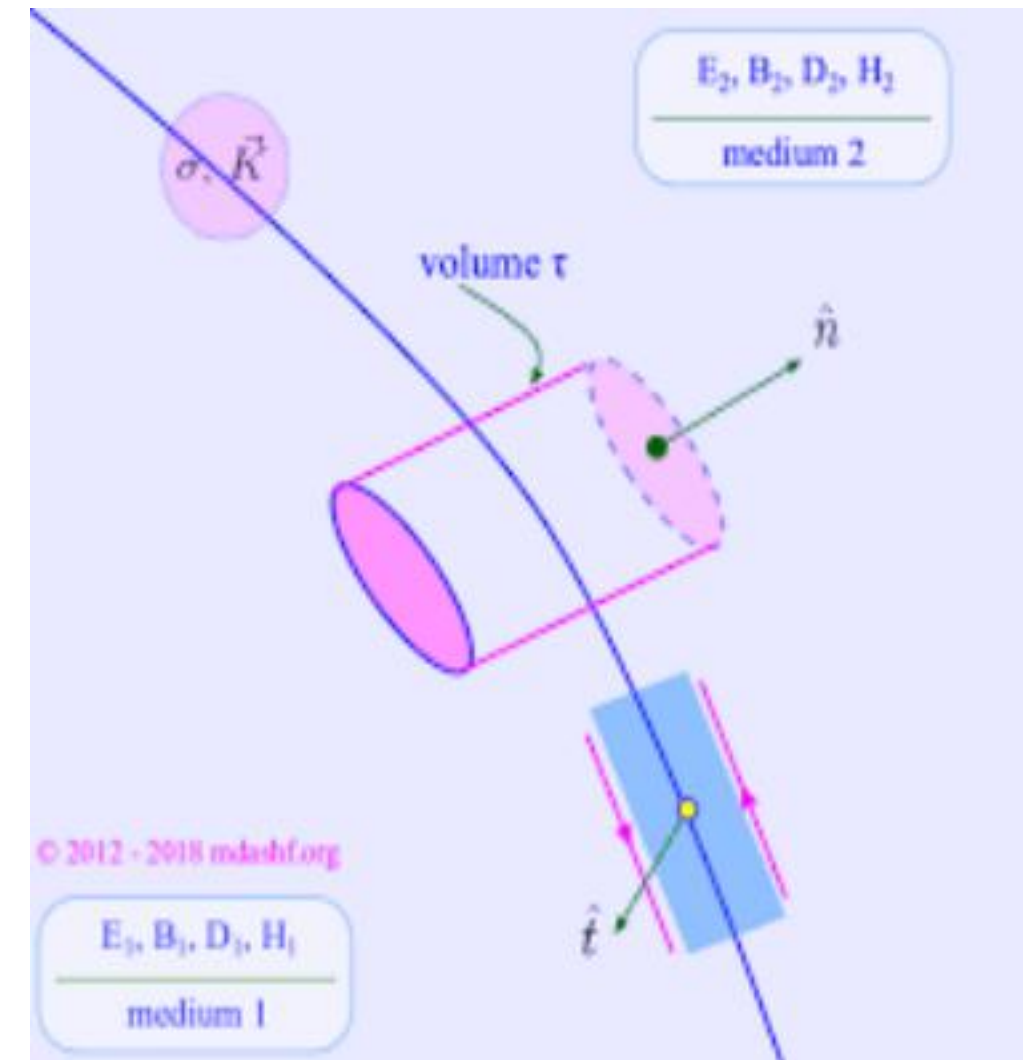
ANALYSIS



- Boundary condition

$$E_x = E_z = 0 \text{ at } y=0 \text{ and } y=b$$

$$E_y = E_z = 0 \text{ at } x=0 \text{ and } x=a$$





ANALYSIS



- Basic equations from Maxwells curl equations

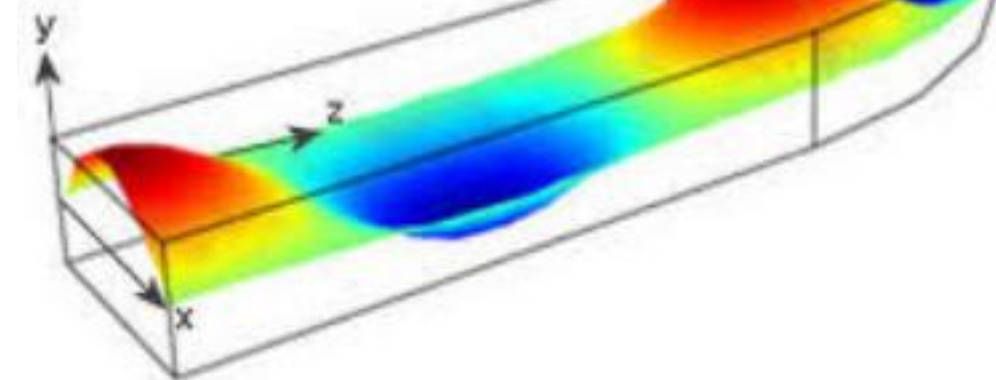
Maxwell's Equation

$$\nabla^2 \mathbf{E} + \omega^2 \mu \epsilon \mathbf{E} = 0$$

$$\nabla^2 \mathbf{H} + \omega^2 \mu \epsilon \mathbf{H} = 0$$

E_{\perp} components of the transversal electric (TE) wave in a rectangular waveguide

$$E_z = 0$$





ANALYSIS



From $\nabla \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t}$, we have

$$\frac{\partial E_z}{\partial y} - \frac{\partial E_y}{\partial z} = -\mu \frac{\partial H_x}{\partial t} \Rightarrow +j\beta_z E_y = -j\omega\mu H_x$$

$$\frac{\partial E_x}{\partial z} - \frac{\partial E_z}{\partial x} = -\mu \frac{\partial H_y}{\partial t} \Rightarrow -j\beta_z E_x = -j\omega\mu H_y$$

$$\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y} = -\mu \frac{\partial H_z}{\partial t} \Rightarrow \frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y} = -j\omega\mu H_z$$



ANALYSIS



From $\nabla \times \mathbf{H} = j\omega\epsilon\mathbf{E}$, we get

$$j\omega\epsilon\mathbf{E} = \begin{vmatrix} \hat{\mathbf{x}} & \hat{\mathbf{y}} & \hat{\mathbf{z}} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ H_x & H_y & H_z \end{vmatrix}$$



ANALYSIS



$$\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z} = j\omega\epsilon E_x \Rightarrow \frac{\partial H_z}{\partial y} + j\beta_z H_y = j\omega\epsilon E_x$$

$$\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x} = j\omega\epsilon E_y \Rightarrow -j\beta_z H_x - \frac{\partial H_z}{\partial x} = j\omega\epsilon E_y$$

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



ACTIVITY



Which number replaces the question mark?

| | | | | |
|---|---|----|----|---|
| 4 | 1 | 11 | 11 | 3 |
| 3 | 3 | 1 | 6 | 5 |
| 9 | 2 | 9 | 4 | 2 |
| 6 | 4 | 8 | 9 | 3 |
| 5 | 1 | ? | 1 | 4 |



ANALYSIS



TM WAVES ($H_z = 0$)

$$H_x \text{ \& } E_y = 0$$

E_z , E_x \& H_y will have value.

$$H_y = (c_3 \sinh hx + c_4 \cosh hx) e^{-\gamma z}$$

\rightarrow B.C can not be applied directly to evaluate c_3 \& c_4 .

\rightarrow Because tangential component of $H_y \neq 0$ at the surface of the perfect conductor.



ANALYSIS



$$E_z = \frac{1}{j\omega\epsilon} \frac{\partial H_y}{\partial x}$$
$$= \frac{1}{j\omega\epsilon} \frac{\partial}{\partial x} [C_3 \sin hx + C_4 \cosh x] e^{-\gamma z}$$

$$E_z = \frac{h}{j\omega\epsilon} [C_3 \cos hx - C_4 \sin hx] e^{-\gamma z}$$

Applying B.C I

$$C_3 = 0$$



ANALYSIS



Therefore E_z becomes

$$E_z = -\frac{c_4 h}{j\omega\epsilon} \sinh hx e^{-\bar{\gamma}z}$$

Applying B.C II

$$E_z = 0 \text{ at } x = a$$

$$E_z = -\frac{a c_4}{j\omega\epsilon} \sinh ha e^{-\bar{\gamma}z}$$

To make $E_z = 0$ at $x = a$,

$$h = \frac{m\pi}{a}$$

CS Scanned with CamScanner



ANALYSIS



Subs

$$E_z = -\frac{m\pi}{a} \frac{C_4}{j\omega\epsilon} \sin\left(\frac{m\pi}{a}x\right) e^{-\gamma z}$$

$$H_y = -\frac{j\omega\epsilon}{h^2} \frac{\partial E_z}{\partial x}$$

$$H_y = C_4 \cos\left(\frac{m\pi}{a}x\right) e^{-\gamma z}$$

|||^{ly} other fields are obtained.



ANALYSIS



subs $\bar{\gamma} = j\bar{\beta}$ for wave propagation

$$E_z = -\frac{m\pi}{a} \frac{c_4}{j\omega\epsilon} \sin\left(\frac{m\pi}{a}x\right) e^{-j\bar{\beta}z}$$

$$H_y = c_4 \cos\left(\frac{m\pi}{a}x\right) e^{-j\bar{\beta}z}$$

$$E_x = \frac{\bar{\beta}}{\omega\epsilon} c_4 \cos\left(\frac{m\pi}{a}x\right) e^{-j\bar{\beta}z}$$

The above equations are fields of TM waves between parallel planes.



THANK YOU