SNS COLLEGE OF ENGINEERING
(Autonomous)
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

19EC502 – TRANSMISSION LINES AND WAVE GUIDES

III YEAR/ V SEMESTER

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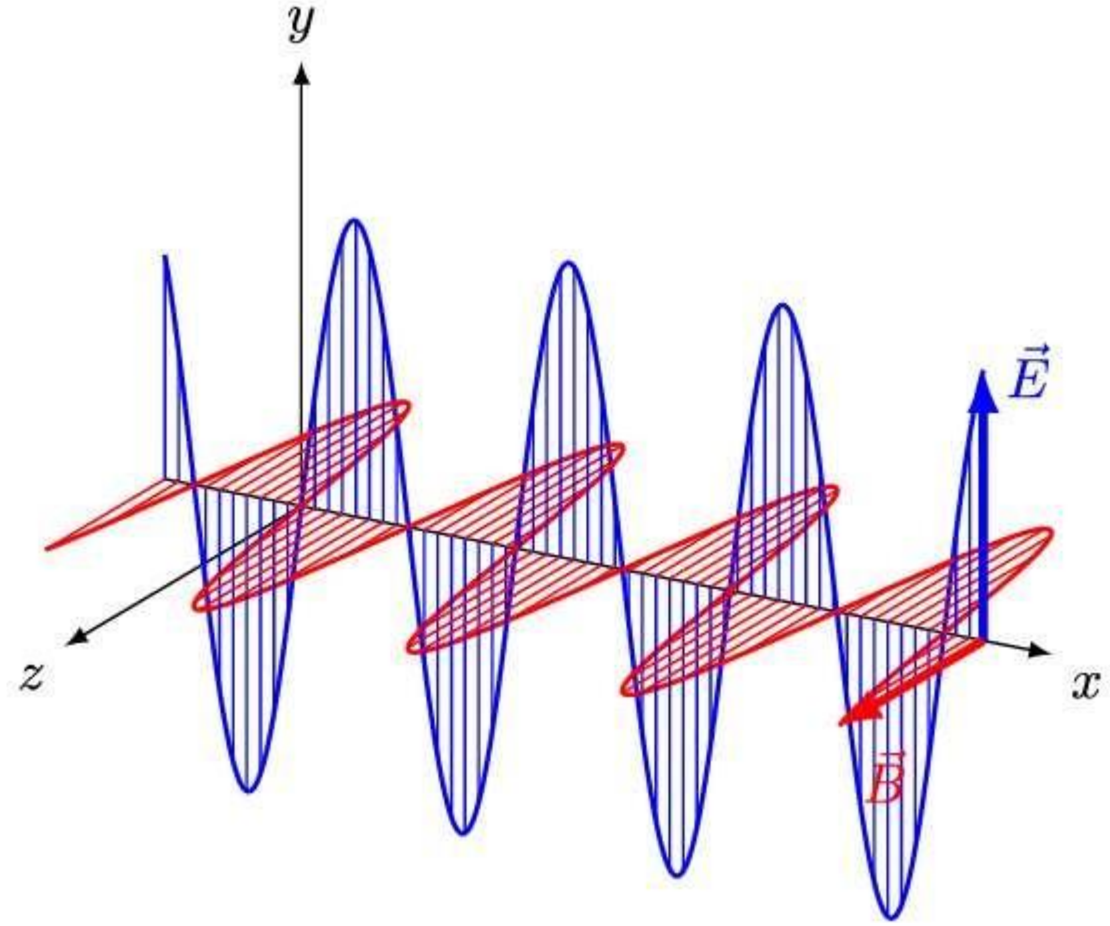
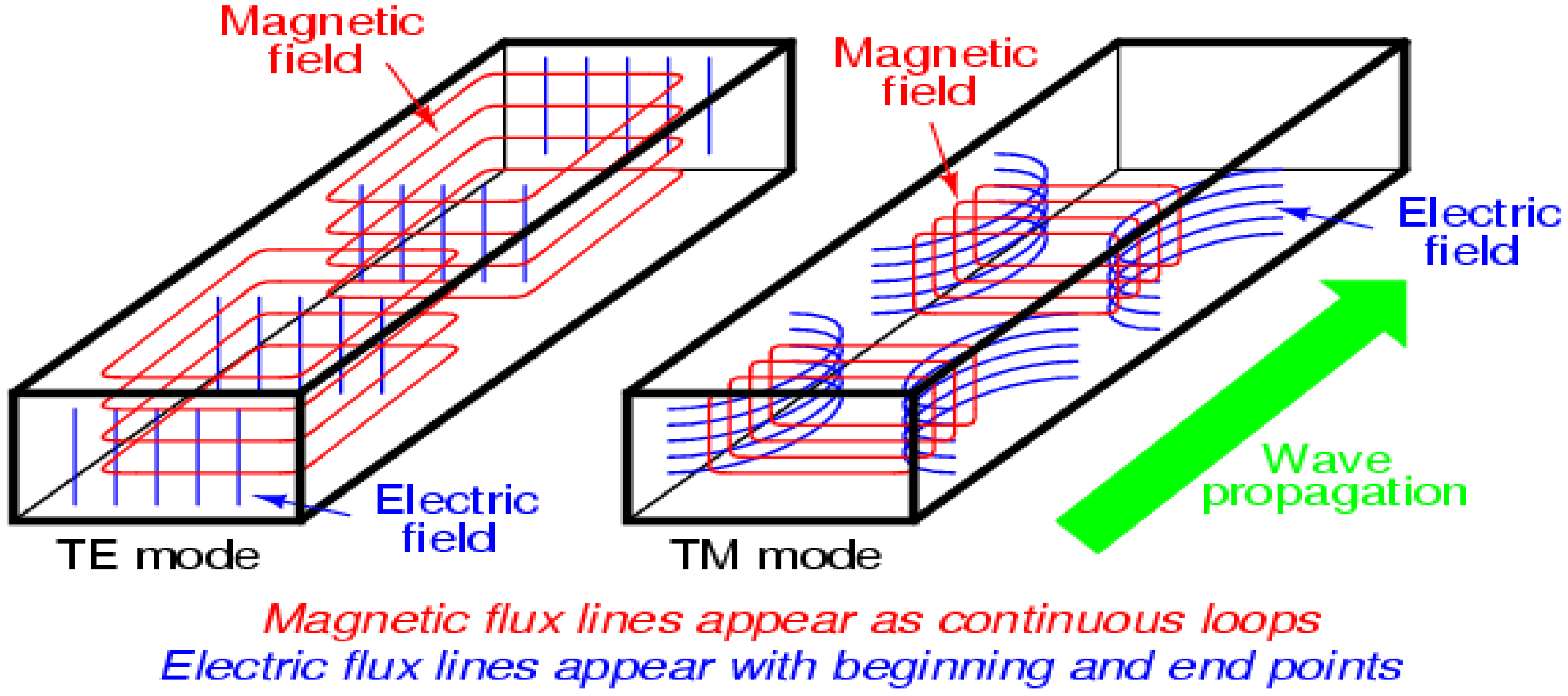
UNIT 2 – GUIDED WAVES

TOPIC 2 – TRANSVERSE ELECTRIC AND TRANSVERSE MAGNETIC WAVES

WHAT DO YOU RELATE FROM THIS ?





EM WAVES - CLASSIFICATION

- EM waves are classified based on the type of field present in the direction of wave propagation

TWO TYPES

1. TE WAVES

2. TM WAVES

TE WAVES

TE WAVES ($E_z = 0$)

If $E_z = 0$, but $H_z \neq 0$ [$\therefore H_y$ & $E_x = 0$]

$$E_y = \frac{j\omega\mu}{h^2}\frac{\partial H_z}{\partial x}$$

$$H_x = \frac{-\bar{\gamma}}{h^2}\frac{\partial H_z}{\partial x}$$

The wave equation

$$\frac{\partial^2 E_y}{\partial x^2} + \underbrace{\cancel{\frac{\partial^2 E_y}{\partial y^2}}}_{0} + \frac{\partial^2 E_y}{\partial z^2} = -\omega^2\mu\varepsilon E_y \rightarrow (1)$$

$$\& \quad \frac{\partial^2}{\partial z^2} = \bar{\gamma}^2$$

TE WAVES - ANALYSIS

Eq (1) becomes,

$$\frac{\partial^2 E_y}{\partial x^2} + \bar{\gamma}^2 E_y = -\omega^2 \mu \varepsilon E_y$$

$$\frac{\partial^2 E_y}{\partial x^2} + h^2 E_y = 0 \qquad [\because h^2 = \bar{\gamma}^2 + \omega^2 \mu \varepsilon]$$

Since $E_y = E_y^0 e^{-\bar{\gamma} z}$ the above eqn, becomes

$$\frac{\partial^2 E_y^0}{\partial x^2} + h^2 E_y^0 = 0 \rightarrow (2)$$

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

Eq ② is a differential Eqn/, & the solution is

$$E_y^0 = C_1 \sin hx + C_2 \cos hx \rightarrow ③$$

where C_1, C_2 are arbitrary constants.

Showing the variation in z direction

$$E_y = E_y^0 e^{-\bar{\gamma} z} = (C_1 \sin hx + C_2 \cos hx) e^{-\bar{\gamma} z}.$$

C_1 & C_2 determined from boundary conditions.

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

Boundary condition

$E_{tan} = 0$ at the surface of the perfect conductors for all values of z and time.

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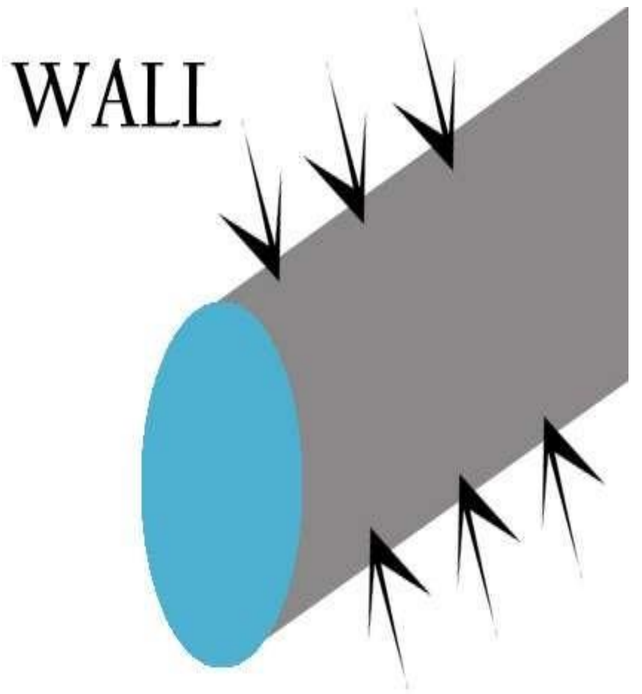
$E_y = 0$ at $x = 0$

$E_y = 0$ at $x = a$

for all values of z.



TE WAVES - ANALYSIS

Applying B.C (i)

$E_y = 0$ at $x = 0$

$E_y^\circ = c_1 \sin 0 + c_2 \cos 0$

$E_y = c_2$

$\therefore$ c_2 must be zero to make $E_y = 0$ at $x = 0$

Then Eqn. 3 becomes,

$$E_y^\circ = c_1 \sin hx \rightarrow (4)$$

TE WAVES - ANALYSIS

Applying B.C (ii)

subs $E_y = 0$ at $x = a$ in eq (4)

$$E_y^{\circ} = C_1 \sin h x$$

To make $E_y = 0$, h must be equal to $\frac{m\pi}{a}$

$$\therefore h = \frac{m\pi}{a} \quad \text{for } m = 1, 2, 3 \ldots$$

$$\therefore E_y^{\circ} = C_1 \sin h \left(\frac{m\pi}{a}\right)$$

$$E_y = C_1 \sin h \left(\frac{m\pi}{a}\right) x \, e^{-\bar{\gamma} z} \longrightarrow (5)$$

TE WAVES - ANALYSIS

Other Fields Determination

$$\bar{\gamma} E_y = -j\omega\mu H_x$$

$$H_x = \frac{-\bar{\gamma}}{j\omega\mu} C_1 \sin\left(\frac{m\pi}{a}\right)x \, e^{-\bar{\gamma} z} \rightarrow (6)$$

TE WAVES - ANALYSIS

$$H_z = -\frac{1}{j\omega\mu}\frac{\partial E_y}{\partial x}$$

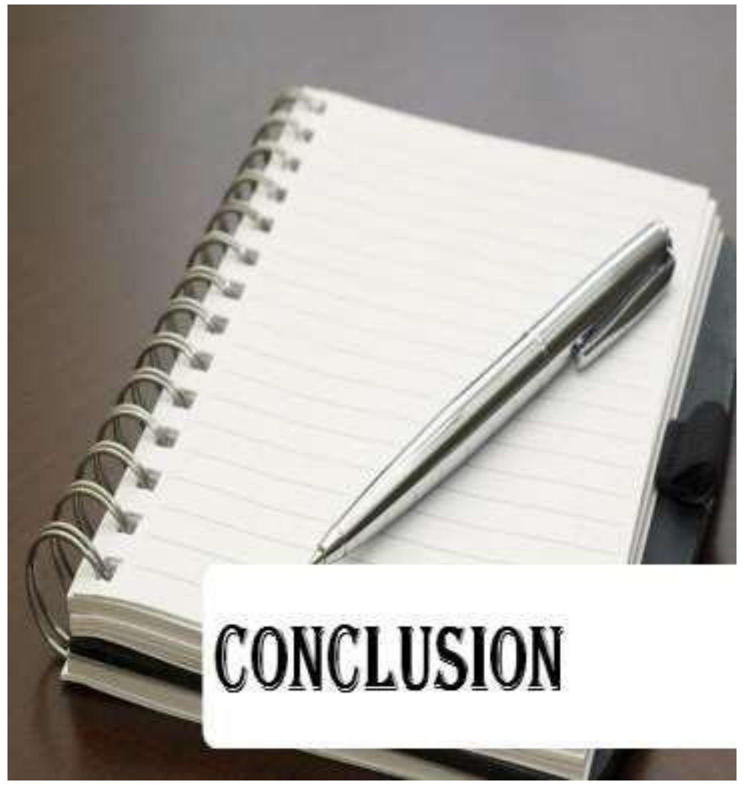
$$H_z = -\frac{m\pi}{j\omega\mu a} C_1 \cos\left(\frac{m\pi}{a}\right)x \, e^{-\gamma z} \rightarrow (7)$$

TE_{m0} wave (or) mode

In eqns (5), (6) & (7)

→ Each value of m specifies a particular field configuration (or) mode.

→ The associated wave is known as TE_{m0} wave (or) TE_{m0} mode.



TEmo MODE

$$H_z = -\frac{1}{j\omega\mu}\frac{\partial E_y}{\partial x}$$

$$H_z = \frac{-m\pi}{j\omega\mu a} C_1 \cos\left(\frac{m\pi}{a}\right)x\, e^{-\bar{\gamma} z} \rightarrow (7)$$

TEmo wave (or) mode

In eqn (5), (6) & (7)

→ Each value of m specifies a particular field configuration (or) mode.

→ The associated wave is known as TEmo wave (or) TEmo mode.

TM WAVES - ANALYSIS

- For TM waves Hz=0
- Therefore Hx &Ey = 0 in the basic field equations
- Ez, Ex & Hy will have value

$$Hy = (C3 \sinh x + C4 \cosh x)$$

- The boundary condition can not be applied directly to Hy to evaluate C3 & C4
- Because Htan is not equal to zero at the perfect conductor surface
- Therefore Ez is obtained in terms of Hy and then the boundary condition is applied to Ez

TM WAVES - ANALYSIS

- Boundary conditions are
  Ez=0 at x=0 and x=a
  Ez=0 at y=0 and y=b

- After applying the B.C as for TE waves, we get
  C3=0 & $h=m\pi/a$

TM WAVES - FIELDS

TM WAVE FIELDS

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

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

$$E_x = \frac{\bar{\gamma}}{j\omega\varepsilon}C_4\cos\left(\frac{m\pi}{a}\right)x\, e^{-\bar{\gamma}z}$$

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