SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

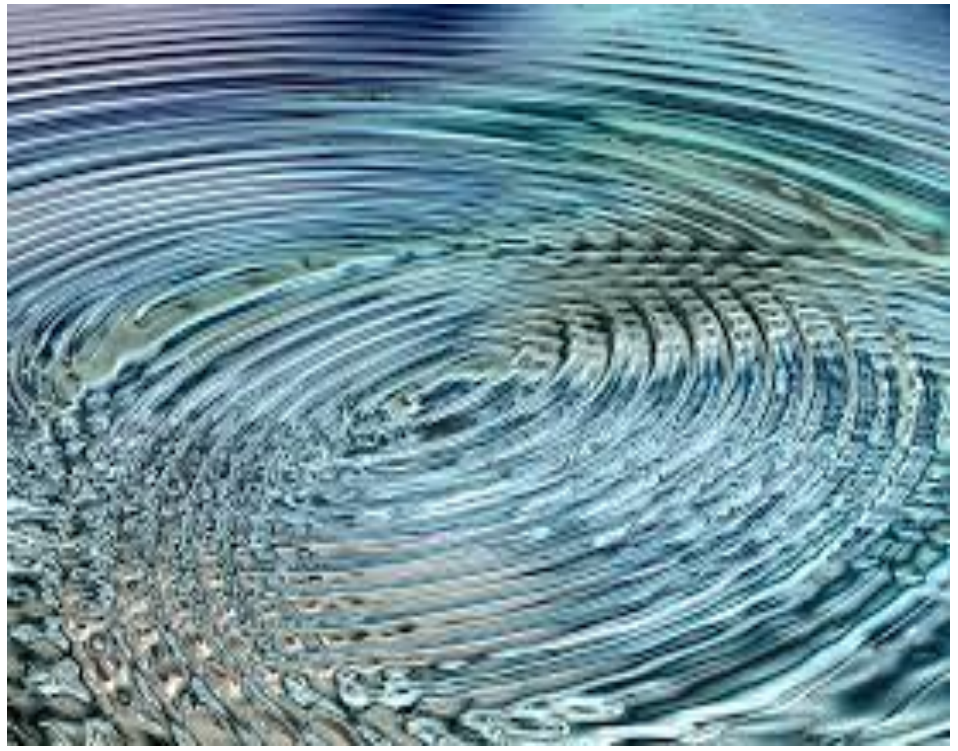
19ECT302 – TRANSMISSION LINES AND ANTENNAS

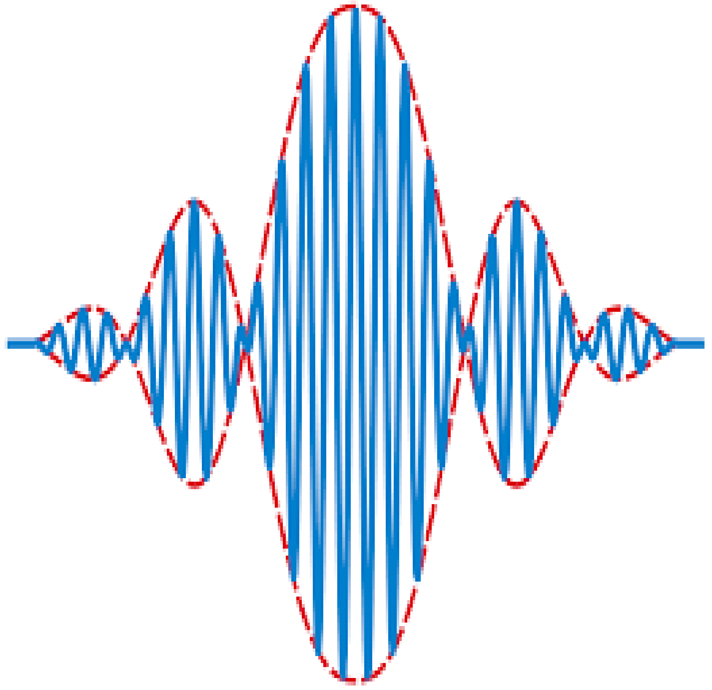
III YEAR/ V SEMESTER

UNIT 2 – GUIDED WAVES

TOPIC 1– WAVES BETWEEN PARALLEL PLANES

WHAT DO YOU RELATE FROM THIS ?





WAVES

A wave is a disturbance (change from equilibrium) of one or more fields such that the field values oscillate repeatedly about a stable equilibrium

TWO TYPES

Mechanical Waves

Electromagnetic Waves

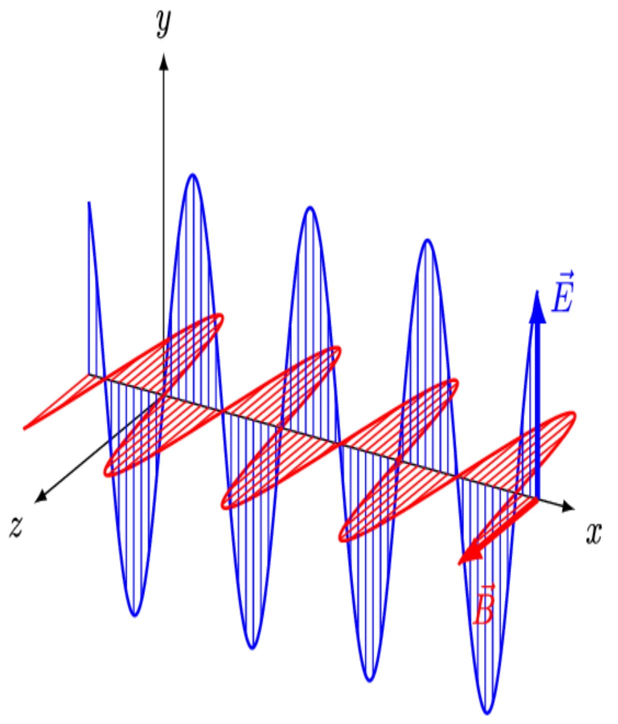
ELECTROMAGNETIC WAVES

- Electromagnetic waves are also known as EM waves

- Produced when an electric field comes in contact with the magnetic field

- They are the composition of oscillating electric and magnetic fields

- They are solutions of Maxwell's equations which are the fundamental equations of electrodynamics



EM WAVE PROPAGATION BETWEEN PARALLEL PLANES

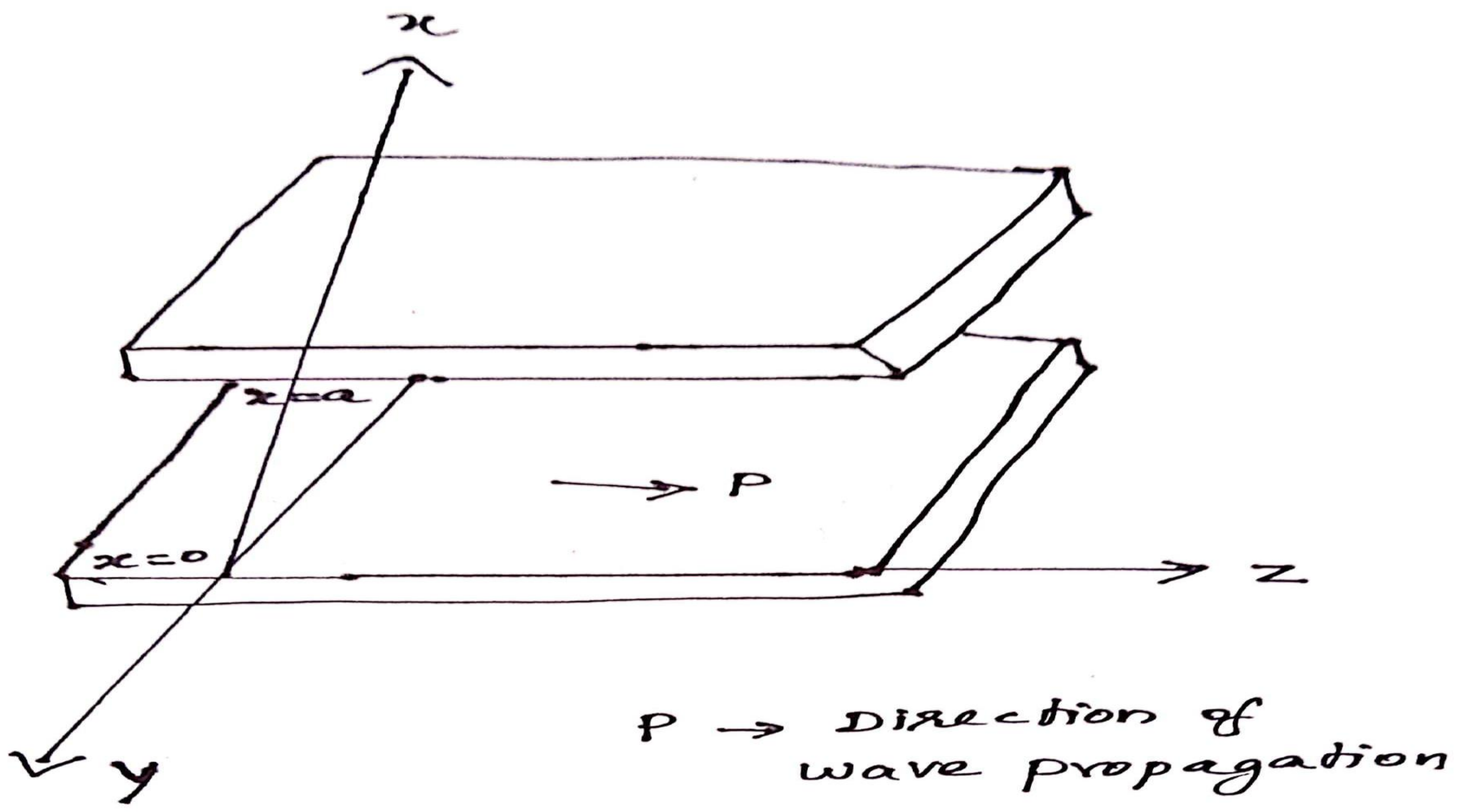


Fig (i) parallel conducting planes

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

In order to determine the EM field configuration in the region between the planes

→ Maxwell's equations will be solved

→ subject to appropriate boundary conditions.

Maxwell's Equations

$\nabla \times H = \sigma + j\omega \varepsilon E$

($\sigma = 0$, since medium between the plane is air)

$\therefore \nabla \times H = j\omega \varepsilon E$

$\nabla \times E = -j\omega \mu H$

Boundary conditions for perfectly conducting planes

$E_{tan} = 0$

$H_{nor} = 0$

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

Wave equations

$$\nabla^2 E = \gamma^2 E$$

$$\nabla^2 H = \gamma^2 H$$

$$\gamma = \sqrt{(\sigma + j\omega\varepsilon)(j\omega\mu)}$$

$$\sigma = 0$$

$$\therefore \gamma = \sqrt{j\omega\varepsilon \times j\omega\mu} = j\omega\sqrt{\mu\varepsilon}$$

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

In rectangular co-ordinates & free non-conducting region $\boxed{\nabla \times H = -j\omega\varepsilon E}$ ..

$$\begin{vmatrix} \vec{a_x} & \vec{a_y} & \vec{a_z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ H_x & H_y & H_z \end{vmatrix} = -j\omega\varepsilon \left[E_x \vec{a_x} + E_y \vec{a_y} + E_z \vec{a_z}\right]$$

By equating, we get three equations.

$$\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z} = j\omega\varepsilon E_x \rightarrow (1)$$

$$-\left[\frac{\partial H_z}{\partial y} - \frac{\partial H_x}{\partial z}\right] = j\omega\varepsilon E_y \rightarrow (2)$$

$$\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = j\omega\varepsilon E_z \rightarrow (3)$$

ACTIVITY

Answer the logical puzzle

There are three boxes in a table. One of the box contains Gold and the other two are empty. A printed message contains in each box. One of the message is true and the other two are lies. The first box says 'The Gold is not here'. The Second box says 'The Gold is not here'. The Third box says 'The Gold is in the Second box'. Which box has the Gold?

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

III^{ly} for $\boxed{\nabla \times E = -j\omega\mu H}$

$$\frac{\partial E_z}{\partial y} - \frac{\partial E_y}{\partial z} = -j\omega\mu H_x \rightarrow (4)$$

$$-\left[\frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z}\right] = -j\omega\mu H_y \rightarrow (5)$$

$$\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y} = -j\omega\mu H_z \rightarrow (6)$$

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

Propagation constant

$$\bar{\gamma} = \bar{\alpha} + j\bar{\beta}$$

* If $\bar{\gamma} \rightarrow$ real, α have value, $\beta = 0$

→ represents there is no wave motion, but only an exponential decrease in Amplitude.

* If $\bar{\gamma} \rightarrow$ imaginary, $\bar{\alpha} = 0$, $\bar{\beta}$ have value

→ represents a wave propagation, but no attenuation.

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

Important Assumptions

* In y-direction → the field is uniform and constant.

$$\therefore \frac{\partial}{\partial y} = 0$$

* In x-direction → Certain boundary must met.

so $\frac{\partial}{\partial x}$ → no change

* In z-direction → The wave is assumed to propagate

$$\therefore \frac{\partial}{\partial z} = -\bar{\gamma}$$

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

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

After substituting assumptions → eqns (1) to (6) becomes,

$$\bar{\gamma} H_y = j\omega\varepsilon E_x \rightarrow (7)$$

$$-\bar{\gamma} H_x - \frac{\partial H_z}{\partial x} = j\omega\varepsilon E_y \rightarrow (8)$$

$$\frac{\partial H_y}{\partial x} = j\omega\varepsilon E_z \rightarrow (9)$$

$$\bar{\gamma} E_y = -j\omega\mu H_x \rightarrow (10)$$

$$-\bar{\gamma} E_x - \frac{\partial E_z}{\partial x} = -j\omega\mu H_y \rightarrow (11)$$

$$\frac{\partial E_y}{\partial x} = -j\omega\mu H_x \rightarrow (12)$$

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

Solving Equns. (7), (8), (10) & (11) simultaneously, we get

$$E_x = \frac{-\gamma}{h^2} \frac{\partial E_z}{\partial x} \quad \rightarrow (12)$$

$$H_y = \frac{-j\omega\varepsilon}{h^2} \frac{\partial E_z}{\partial x} \quad \rightarrow (13)$$

$$E_y = \frac{j\omega\mu}{h^2} \frac{\partial H_z}{\partial x} \quad \rightarrow (14)$$

$$H_x = -\frac{\gamma}{h^2} \frac{\partial H_z}{\partial x} \quad \rightarrow (15)$$

where $h^2 = \gamma^2 + \omega^2\mu\varepsilon$

CONCLUSION

- In equations 12 &13 there is a component of electric field in the direction of propagation (Ez), but no component of magnetic field (Hz)
- These waves are known as E waves or Transverse Magnetic(TM) waves
- In equations 14 &15 there is a component of magnetic field in the direction of propagation (Hz), but no component of electric field (Hz)
- These waves are known as H waves or Transverse Electric (TE) waves

ASSESSMENT

Derive the EM fields of an EM wave assumed to propagate in y-direction.

REFERENCES

- E.C. Jordan and K.G.Balmain "Electro Magnetic Waves and Radiating System, PHI,New Delhi, 2003
- John D Kraus and Daniel A Fleisch, "Electromagnetics with Applications", Mc Graw Hill Book Co, 2005.

THANK YOU