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 4– TRANSVERSE ELECTROMAGNETIC WAVES

TE, TM & TEM WAVES - COMPARISION

TE	TM	TEM
• $E_z=0$ • $H_z \neq 0$	• $H_z=0$ • $E_z \neq 0$	• Both E_z & $H_z=0$

DOMINANT WAVE OR MODE

TE - Fields

$$E_y = C_1 \sin\left(\frac{m\pi}{a}x\right) e^{-j\bar{\beta}z}$$

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

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

TE_{mo} wave or mode

$m = 0$

All the fields will vanish.

$m = 1$ → fields

The lowest order mode TE_{10}

TEM WAVES - INTRODUCTION

- For TE wave lowest order mode is TE_{10}, i.e m=1
- Because m=0 makes all the fields vanish
- For TM wave for m=0, Ez=0
- But there are other two fields Ex & Hy
- For TM wave we know Hz is always zero
- So Ez & Hz =0 for m=0, so that the electromagnetic field is entirely transverse
- This special case of wave or mode is known as TEM wave or TEM mode or Principal wave
- It is the familiar type of wave propagated along all ordinary two conductor transmission lines operating in low-frequency

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.

TEM WAVES - FIELDS

$$H_z = 0$$

$$E_z = 0$$

$$E_x = \frac{\beta C_4}{\omega \varepsilon} e^{-j\bar{\beta} z}$$

$$H_y = C_4 e^{-j\bar{\beta} z}$$

TEM WAVES - CHARACTERISTICS

(i) Phase constant β

$$\beta = \sqrt{\omega^2 \mu \varepsilon - \left(\frac{m\pi}{a}\right)^2}$$

when $m = 0$

$$\beta = \sqrt{\omega^2 \mu \varepsilon - 0}$$

$$\beta = \omega \sqrt{\mu \varepsilon}$$

β varies linearly with frequency, and therefore wave propagation takes place without dispersion.

TEM WAVES - CHARACTERISTICS

(ii) Phase velocity Vph

$$V_{ph} = \frac{\omega}{\beta}$$

$$= \frac{\omega}{\sqrt{\omega^2 \mu \varepsilon - \left(\frac{m\pi}{a}\right)^2}}$$

when $m = 0$

$$= \frac{\omega}{\sqrt{\omega^2 \mu \varepsilon - 0}}$$

$$= \frac{\omega}{\omega \sqrt{\mu \varepsilon}}$$

$$= \frac{1}{\sqrt{\mu \varepsilon}}$$

$$= c \quad \text{[for air dielectric]}$$

TEM WAVES - CHARACTERISTICS

(iii) Guide Wavelength λg

$$\lambda_g = \frac{2\pi}{\beta} = \frac{2\pi}{\sqrt{\omega^2\mu\varepsilon - \left(\frac{m\pi}{a}\right)^2}}$$

when $m = 0$

$$\lambda_g = \frac{2\pi}{\sqrt{\omega^2\mu\varepsilon - 0}}$$

$$= \frac{2\pi}{\omega\sqrt{\mu\varepsilon}} \qquad \left(\frac{2\pi}{\omega} = \frac{1}{f}\right)$$

$$= \frac{c}{f} \qquad \text{[for air dielectric]}$$

TEM WAVES - CHARACTERISTICS

(iv) Cut-off frequency fc

$$f_c = \frac{m}{2a\sqrt{\mu\varepsilon}}$$

when $m = 0$

$$\boxed{f_c = 0}$$

TEM WAVES - CHARACTERISTICS

(v) Wave Impedance Z_{TEM}

$$Z_{TEM} = \frac{E_x}{H_y}$$

$$= \frac{\beta C_4}{\omega \varepsilon C_4} = \frac{\beta}{\omega \varepsilon}$$

For TEM waves $\beta = \omega\sqrt{\mu\varepsilon}$

Substituting,

$$Z_{TEM} = \frac{\omega\sqrt{\mu\varepsilon}}{\omega\varepsilon}$$

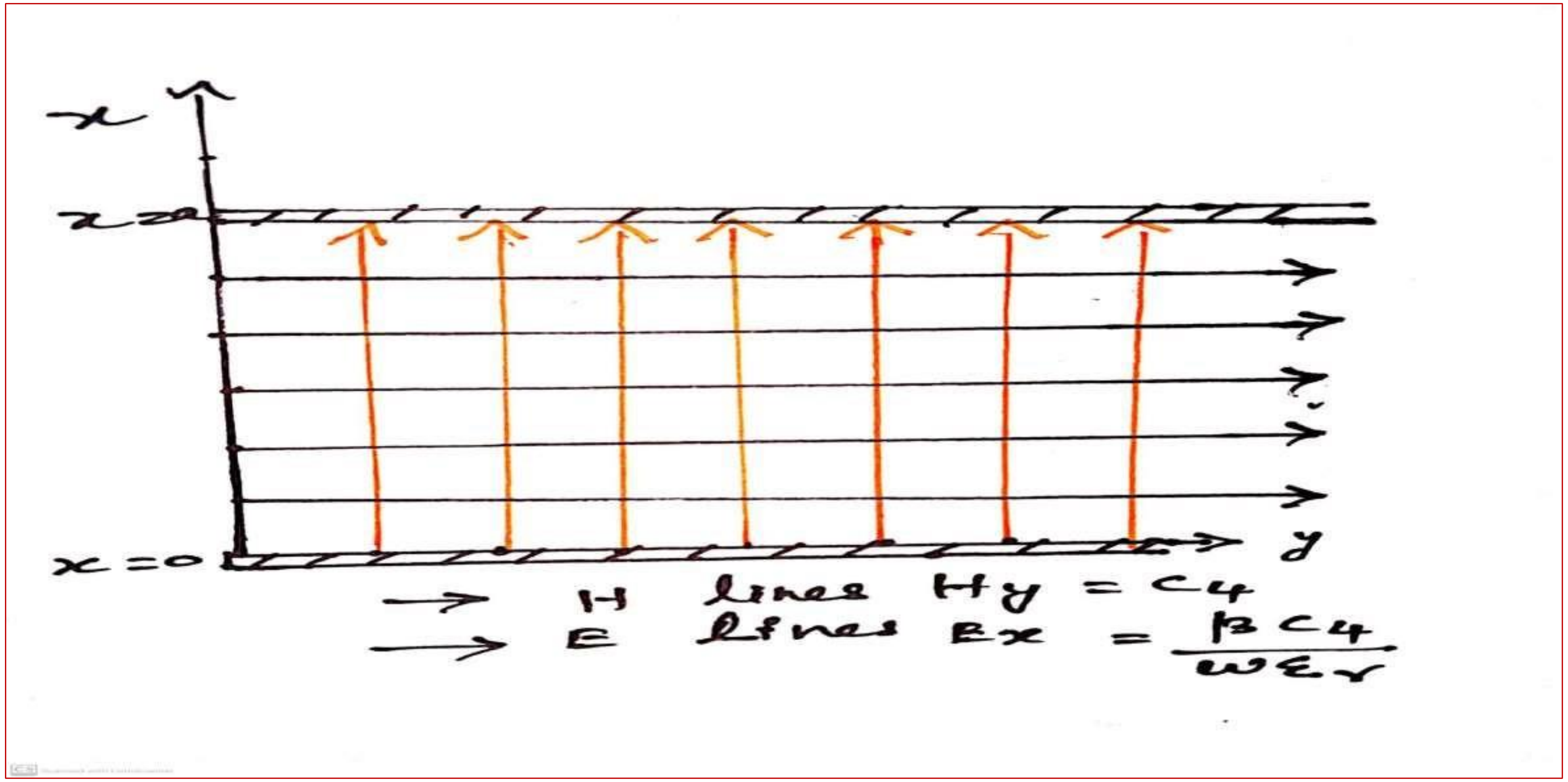
$$= \sqrt{\frac{\mu}{\varepsilon}} = \eta_0 \quad \text{[For air dielectric]}$$

$\eta_0 = 120\pi$ ohms

Intrinsic Impedance of free space

TEM WAVES – FIELD DISTRIBUTION

E & H Fields in x-y plane



TEM WAVES – FIELD DISTRIBUTION

E & H Fields in x-z plane