Transverse Electromagnetic waves

For TE waves in between parallel planes, it was seen that the lowest value of m that could be used without making all the field components zero was $m = 1$.

So the lowest TE wave is TE_{10} wave.

For Transverse magnetic waves, a value of $m = 0$ does not make all the fields be zero.

TM wave fields are

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

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

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

subs $m = 0$

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

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

$$E_z = 0$$

For this special case of TM waves the component of E in the direction of propagation, that is E_z is also zero so that the electromagnetic field is entirely transverse. This wave is called the transverse electromagnetic (TEM) wave. It is also called as principal wave.

Properties

1) The fields are entirely transverse, but they are constant in amplitude across a cross section normal to the direction of propagation.

Their ratio is also constant.

For $m \neq 0$ & for air dielectric, the expressions for $\bar{\gamma}$, $\bar{E}$, $\bar{V}$ & $\bar{\lambda}$ reduced to

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

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

(2)
$$\bar{\gamma} = \gamma = j\omega\sqrt{\mu_0 \varepsilon_0}$$

$$\bar{\beta} = \beta = \omega\sqrt{\mu_0 \varepsilon_0}$$

$$\bar{V} = V = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c$$

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

$$\bar{\lambda} = \lambda = \frac{2\pi}{\omega\sqrt{\mu_0 \varepsilon_0}} = \frac{c}{f}$$

(3) Unlike TE & TM waves, the velocity of the TEM wave is independant of frequency and has a free-space value $c \approx 3 \times 10^8$ m/s. [This value is for only when the planes are perfectly conducting and the space between them is vaccum].

(4) The cut off frequency of TEM wave is

$$\boxed{f_c = 0}$$

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

This means that for TEM waves, all frequencies down to zero can propagate along the guide

(5) $\left|\frac{E_x}{H_y}\right| = \frac{\bar{E}}{\omega\varepsilon} = \sqrt{\frac{\mu_0}{\varepsilon_0}} = \eta_v = 120\pi_{377\Omega}$ (or) $\rightarrow$ intrinsic impedance of free space