as $L \uparrow \Rightarrow m \uparrow$

$\boxed{\omega_n = \sqrt{\frac{k}{m}}}$ as $m \uparrow$ $\omega_n \downarrow$ $\Rightarrow$ larger Cavity size $\Rightarrow$ lower resonant/natural frequency.

Finally in EM terms $\cancel{\omega_n = \sqrt{\frac{k}{L}}}$ $\boxed{\omega_n = \frac{1}{\sqrt{LC}}}$

Journey of cylindrical cavity resonator

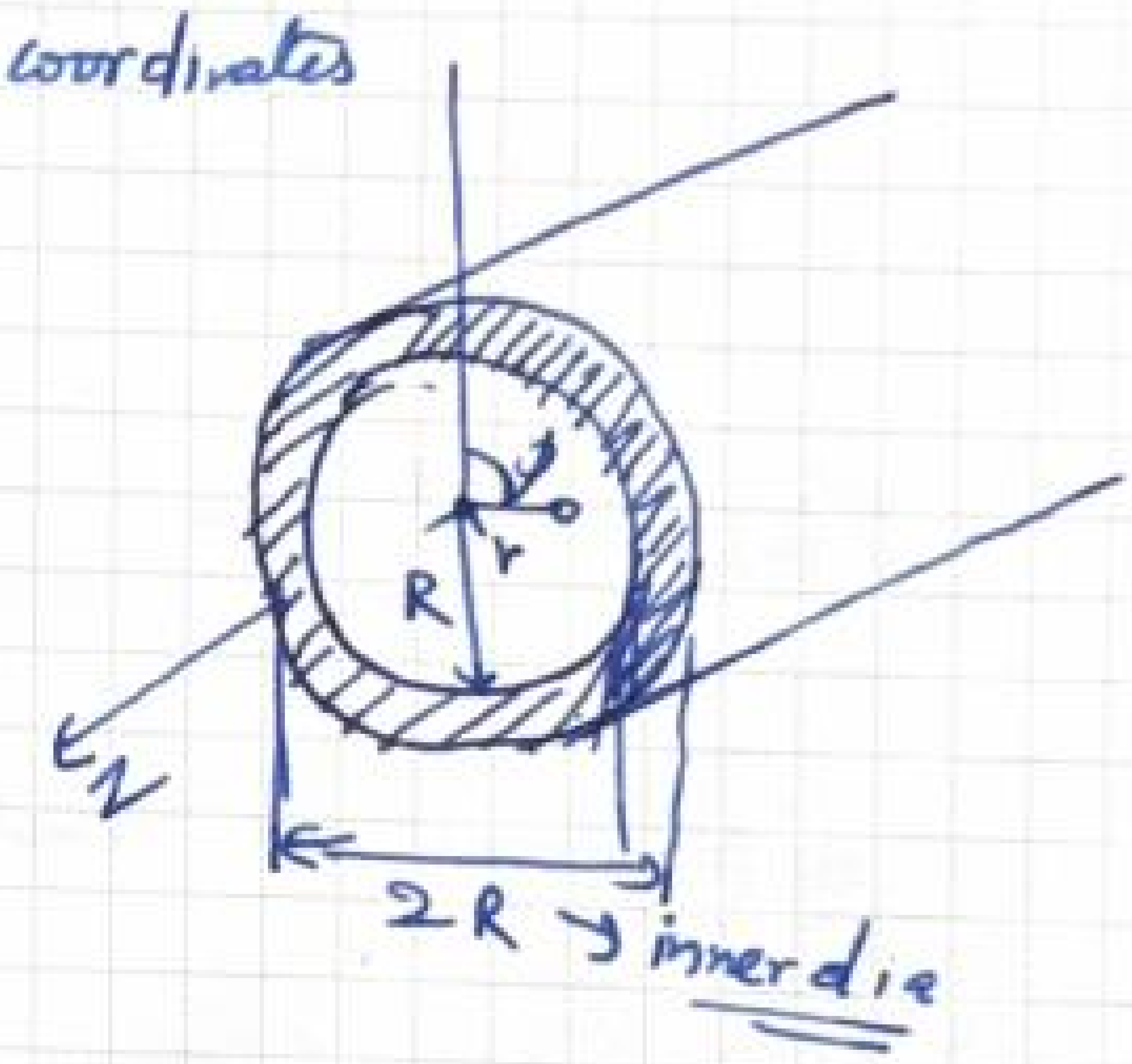
Pit stop Circular wave guide

cylindrical geometry $\Rightarrow$ cylindrical coordinates

$\phi \rightarrow$ angular component

$z \rightarrow$ axial component

$r \rightarrow$ radial component



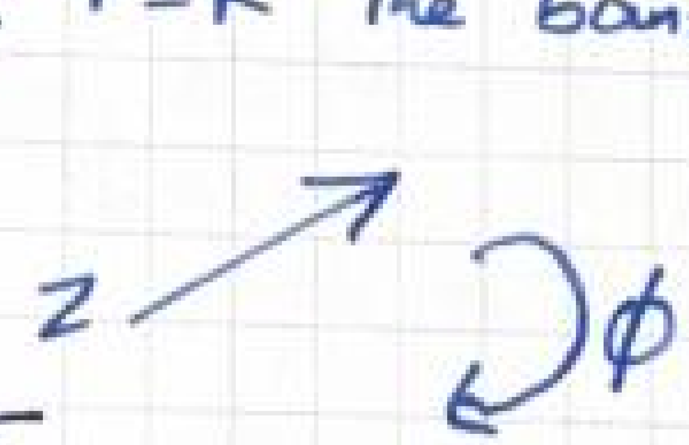
For dielec to conductor

Boundary $E_{tan} = 0$

at surface

$E_\phi = 0$ @ $r = R$. @ $r=R$ the boundary is conductor

$E_z = 0$ @ $r = R$



Both exist on surface of conductor at $r = R$

For analyzing this we need to

Calculate $\bar{E}$ & $\bar{H}$ in this geometry

Maxwell Eqns + Boundary conditions will solve this geometry's $\bar{E}$ & $\bar{H}$

No 2 conductors, same conductor for return path $\Rightarrow$ TEM doesn't exist

Circular WG has TE & TM modes only

In WG $\nabla \cdot D = 0$ $\rightarrow \rho_v = 0 \rightarrow$ No Bulk current & $\nabla \cdot B = 0$

Source free $\Rightarrow$ divergence $= 0$

only 2 Maxwell eqn needed to be solved $\rightarrow$ coz this WG is a source free homogenous region

$$\nabla \times E = -\mu \frac{dH}{dt} \qquad \nabla \times H = \varepsilon \frac{\partial E}{\partial t} + \bar{J}$$

Need to use this with cylindrical coordinates

$$\nabla \times E = \begin{vmatrix} \frac{1}{r}\hat{r} & \hat{\phi} & \frac{1}{r}\hat{z} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ E_r & rE_\phi & E_z \end{vmatrix} = \frac{1}{r}\left[\frac{\partial E_z}{\partial \phi} - r\frac{\partial E_\phi}{\partial z}\right]\hat{r}$$

$$- \left[\left(\frac{\partial E_z}{\partial r} - \frac{\partial E_r}{\partial z}\right) \cancel{\frac{\partial E_z}{\partial \phi} - r\frac{\partial E_\phi}{\partial z}}\right]$$

$$+ \frac{1}{r}\left[r\frac{\partial E_\phi}{\partial r} - \frac{\partial E_r}{\partial \phi}\right]$$

$$= -\mu \frac{d\bar{H}}{dt} \rightarrow \text{Fourier } \cancel{\text{Laplace}} \text{ transform } j\omega H$$

Separating all vectors

$$\frac{1}{r}\frac{\partial E_z}{\partial \phi} - \frac{\partial E_\phi}{\partial z} = -\mu j\omega H_r \rightarrow \hat{r} \quad -(1)$$

$$-\frac{\partial E_z}{\partial r} + \frac{\partial E_r}{\partial z} = -\mu j\omega H_\phi \rightarrow \hat{\phi} \quad -(2)$$

$$\frac{\partial E_\phi}{\partial r} - \frac{1}{r}\frac{\partial E_r}{\partial \phi} = -\mu j\omega H_z \rightarrow \hat{z} \quad -(3)$$

$$\nabla \times H = \begin{vmatrix} \frac{1}{r}\hat{r} & \hat{\phi} & \frac{1}{r}\hat{z} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ H_r & rH_\phi & H_z \end{vmatrix} = \frac{1}{r}\left[\frac{\partial H_z}{\partial \phi} - r\frac{\partial H_\phi}{\partial z}\right] - \left[\frac{\partial H_z}{\partial r} - \frac{\partial H_r}{\partial z}\right] + \frac{1}{r}\left[r\frac{\partial H_\phi}{\partial r} - \frac{\partial H_r}{\partial \phi}\right]$$

Fourier transform

$$= \varepsilon \frac{\partial \bar{E}}{\partial t} + \bar{J} \Rightarrow 0$$

~~displacement~~ current density

$J = \sigma E$ Since WG is hollow $\Rightarrow$ $\sigma \to 0$ Inside

$J = 0$

Separating all vectors

$$\frac{1}{r}\frac{\partial H_z}{\partial \phi} - \frac{\partial H_\phi}{\partial z} = \varepsilon j\omega E_r \longrightarrow \hat{r} \quad - (4)$$

$$-\frac{\partial H_z}{\partial r} + \frac{\partial H_r}{\partial z} = \varepsilon j\omega E_\phi \longrightarrow \hat{\phi} \quad - (5)$$

$$\frac{\partial H_\phi}{\partial r} - \frac{1}{r}\frac{\partial H_r}{\partial \phi} = \varepsilon j\omega E_z \longrightarrow \hat{z} \quad - (6)$$

observing 6 equations — The solution must define a propagating wave

The wave (EM wave) in the wave guide travels along 'Z' direction.

The general phasor form for travelling wave is — travelling in 'z' direction

$$\bar{E}(r,\phi,z) = \bar{E}(r,\phi)e^{-j\gamma z}$$

$$H(r,\phi,z) = H(r,\phi)e^{-j\gamma z}$$

$\gamma = \alpha + j\beta$

$\downarrow$

if lossless medium

$\alpha = 0$

Assume loss less medium

$$\bar{E}(r,\phi,z) = \bar{E}(r,\phi)e^{-j\gamma z}$$

$$H(r,\phi,z) = \bar{H}(r,\phi)e^{-j\gamma z}$$

Both $\bar{E}$ & $\bar{H}$ are functions of r, ϕ & propagate in 'Z'

$\therefore$ ~~$\nabla \times E$~~

$\left(\cancel{\frac{\partial}{\partial z} e^{-j\beta z} = -j\beta z\, e^{-j\beta z}}\right)$

$\left(\frac{\partial}{\partial x} e^{-jkx} = -kj\, e^{-jkx}\right)$ interchange, const

Comparing differential & phasor forms

we know that $\frac{\partial}{\partial x} \rightarrow e^{-jkx}\ -jk$

$\therefore \quad \frac{\partial}{\partial z} \rightarrow e^{-j\beta z}\ -j\beta$ '−' represents travelling in forward direction

Now lets replace $\frac{\partial}{\partial z}$ by $-j\beta$

Take eqn 2 & 4 pair (both are orthogonal in direction)

$$-\frac{\partial E_z}{\partial r} + \frac{\partial E_r}{\partial z} = -\mu j\omega H\phi \longrightarrow -\frac{\partial}{\partial r} E_z - j\beta E_r = -\mu j\omega H\phi \quad \text{— } (7)$$

$$\frac{1}{r}\frac{\partial}{\partial \phi} H_z + j\beta H\phi = \varepsilon j\omega E_r \quad \text{— } (8)$$

Lets find 'E' fields first ⇒ replace to eliminate 'H' terms

$$H\phi = \frac{-1}{\mu j\omega} - \frac{\partial E_z}{\partial r} + \frac{\partial E_r}{\partial z} \times \frac{1}{-\mu j\omega}$$

$$H\phi = \frac{-j}{\mu\omega}\frac{\partial E_z}{\partial r} + \frac{j}{\mu\omega}\frac{\partial E_r}{\partial z} \longleftrightarrow \text{Substitute this in}$$

eqn (8)

Confused & wrong!

$$\frac{1}{r}\frac{\partial}{\partial \phi} H_z + j\beta\left[\frac{-j}{\mu\omega}\frac{\partial E_z}{\partial r} + \frac{j}{\mu\omega}\frac{\partial E_r}{\partial z}\right] = \varepsilon j\omega E_r$$

$$\frac{1}{r}\frac{\partial}{\partial \phi} H_z + \frac{j\beta}{\mu\omega}\left[\frac{\partial E_z}{\partial r} - \frac{\partial E_r}{\partial z}\right] = \varepsilon j\omega E_r$$

$$\frac{1}{\varepsilon j\omega r}\frac{\partial}{\partial \phi} H_z + \frac{j\beta}{\mu\omega\varepsilon j\omega}\left[\frac{\partial E_z}{\partial r} - \frac{\partial E_r}{\partial z}\right] = E_r$$

$$\frac{-j}{\varepsilon\omega r}\frac{\partial}{\partial \phi} H_z + \frac{\beta}{\omega^2\mu\varepsilon}\left[\frac{\partial E_z}{\partial r} - \frac{\partial E_r}{\partial z}\right] = E_r$$

$$H_\phi = \frac{-1}{\mu j\omega}\frac{-\partial}{\partial r}E_z - \frac{j\beta E_r}{-\mu j\omega}$$ — substitute this in eqn ⑦

$$H_\phi = \frac{-j}{\omega\mu}\frac{\partial}{\partial r}E_z + \beta\frac{E_r}{\mu\omega}$$

$$\Rightarrow \frac{1}{r}\frac{\partial}{\partial\phi}H_z + j\beta\left[\frac{-j}{\omega\mu}\frac{\partial}{\partial r}E_z + \frac{\beta E_r}{\omega\mu}\right] = \varepsilon j\omega E_r$$

$$\frac{1}{r\varepsilon j\omega}\frac{\partial}{\partial\phi}H_z + \frac{j\beta}{j\omega\varepsilon}\times\frac{1}{\omega\mu}\left[-j\frac{\partial}{\partial r}E_z + \beta E_r\right] = E_r$$

$$\frac{1}{r\varepsilon j\omega}\frac{\partial}{\partial\phi}H_z + \frac{j\beta}{\omega^2\mu\varepsilon}\frac{\partial}{\partial r}E_z + \frac{\beta^2}{\mu\varepsilon\omega^2}E_r = E_r$$

$$\frac{1}{r\varepsilon j\omega}\frac{\partial}{\partial\phi}H_z - \frac{j\beta}{\omega^2\mu\varepsilon}\frac{\partial}{\partial r}E_z = \left[1 - \frac{\beta^2}{\omega^2\mu\varepsilon}\right]E_r$$

$$E_r = \frac{1}{r\varepsilon j\omega\left[1-\frac{\beta^2}{\omega^2\mu\varepsilon}\right]}\times\frac{\partial}{\partial\phi}H_z - \frac{j\beta}{\omega^2\mu\varepsilon\left[1-\frac{\beta^2}{\omega^2\mu\varepsilon}\right]}\times\frac{\partial}{\partial r}E_z$$

$$E_r = \frac{-j\,\omega^{\cancel{2}}\mu\cancel{\varepsilon}}{\cancel{j}\,r\cancel{\omega}\cancel{\varepsilon}\left[\omega^2\mu\varepsilon-\beta^2\right]}\times\frac{\partial H_z}{\partial\phi} - \frac{j\beta}{\omega^2\mu\varepsilon-\beta^2}\times\frac{\partial}{\partial r}E_z$$ $\ast L$

$$E_r = \frac{-j\omega\mu}{r\left[\omega^2\mu\varepsilon-\beta^2\right]}\frac{\partial H_z}{\partial\phi} - \frac{j\beta}{\omega^2\mu\varepsilon-\beta^2}\frac{\partial E_z}{\partial r}$$

[let $k_c^2 = \omega^2\mu\varepsilon - \beta^2$ → k_c → this is called cut off wave number

off track — Lets go into units of this

$\beta \rightarrow$ Phase constant $\rightarrow$ ~~lo~~ longitudinal wave number $\rightarrow$ Here in $\underline{z}$

How fast phase changes over distance

units rad/m

$\beta^2 \rightarrow \left(\frac{rad}{m}\right)^2$

$\mu \Rightarrow \frac{\cancel{Farad}}{m}\ \frac{Henry}{m}$ $\frac{Volt \times sec}{Amp}$ $\quad \varepsilon = \frac{Farad}{m} \rightarrow \frac{Amp \times sec}{Volt}$

$C = Q/V \quad I = \frac{Q}{t}$

Colomb x Vol

$\frac{Amp \times sec \times V}{Vol}$

$V = L \quad V = L\frac{dI}{dt} \quad \frac{V \times sec}{Amp}$

$w^2 = \frac{rad^2}{sec^2}$ $\rightarrow$ Add / sub unit should be equal

β^2

$\left(\frac{rad}{m}\right)^2 = \frac{rad^2}{sec^2} \times \frac{Henry}{m} \times \frac{Farad}{m}$ $\rightarrow w^2 \mu\varepsilon$

$\frac{rad^2}{\cancel{sec^2}} \times \frac{V \times \cancel{sec}}{Amp \times m} \times \frac{Amp \times \cancel{sec}}{\cancel{Vol} \times m}$

$\left(\frac{rad}{m}\right)^2 = \frac{rad^2}{m^2}$ unit match

k_c^2 units $\frac{rad^2}{m^2}$ $\rightarrow$ Cut off wave number

(Transverse wave number)

thats why k_c^2 we assumed not 'k_c'

$k_c \rightarrow$ termed for Transverse wave number / cut off wave number in WG

going back

$$\boxed{E_r = \frac{-j\omega\mu}{r k_c^2}\frac{\partial H_z}{\partial \phi} - \frac{j\beta}{k_c^2}\frac{\partial E_z}{\partial r}}$$

Now using Eqn 1 & 5 for E_ϕ component

$$1 \rightarrow \frac{1}{r}\frac{\partial E_z}{\partial \phi} - (-j\beta)E_\phi = -\mu j\omega H_r \quad - (9)$$

$$5 \rightarrow -\frac{\partial H_z}{\partial r} + (-j\beta)H_r = \varepsilon j\omega E_\phi \quad - (10)$$

From ①

$$H_r = \frac{-1}{rj\mu\omega}\frac{\partial E_z}{\partial \phi} \quad \frac{j\beta}{-j\mu\omega}E_\phi \cdot$$

$$H_r = \frac{j}{r\mu\omega}\frac{\partial E_z}{\partial \phi} - \frac{\beta}{\mu\omega}E_\phi$$

↳ substitute this in eqn 5

$$-\frac{\partial H_z}{\partial r} - j\beta\left[\frac{j}{r\mu\omega}\frac{\partial E_z}{\partial \phi} - \frac{\beta}{\mu\omega}E_\phi\right] = \varepsilon j\omega E_\phi$$

$$-\frac{\partial H_z}{\partial r} + \frac{\beta}{r\mu\omega}\frac{\partial E_z}{\partial \phi} \quad \frac{+j\beta^2}{\mu\omega}E_\phi = \varepsilon j\omega E_\phi$$

$$E_\phi\left[\varepsilon j\omega - \frac{j\beta^2}{\mu\omega}\right]$$

$$E_\phi = -\frac{\partial H_z}{\partial r}\left[\frac{1}{j\left[\varepsilon\omega - \frac{\beta}{\mu\omega}\right]}\right] + \frac{\beta}{jr\mu\omega\left[\varepsilon\omega - \frac{\beta^2}{\mu\omega}\right]}\frac{\partial E_z}{\partial \phi}$$

$$\cancel{\frac{\partial H_z}{\partial r}\left[\frac{j\mu\omega}{\mu\varepsilon\omega^2 - \beta}\right] - \frac{j\beta}{r\mu\omega^2\varepsilon - r\beta^2}\frac{\partial E_z}{\partial \phi}}$$

$$E_\phi = \frac{\partial H_z}{\partial r} \times \left[\frac{j\omega\mu}{\mu\varepsilon\omega^2 - \beta^2}\right] - \frac{j\beta}{r\left[\mu\omega^2\varepsilon - \beta^2\right]} \times \frac{\partial E_z}{\partial \phi}$$

again $k_c^2 = \omega^2\mu\varepsilon - \beta^2$

$$E_\phi = \frac{j\omega\mu}{k_c^2}\frac{\partial H_z}{\partial r} - \frac{j\beta}{rk_c^2}\frac{\partial E_z}{\partial \phi}$$

$$\boxed{E_\phi = \frac{-j}{k_c^2}\left[\frac{\beta}{r}\frac{\partial E_z}{\partial \phi} - \omega\mu\frac{\partial H_z}{\partial r}\right]}$$

H-Fields derivation

Let's derive 'H_ϕ'

7 — $-\frac{\partial}{\partial r}E_z - j\beta E_r = -\mu j\omega H_\phi$

8 → $\frac{1}{r}\frac{\partial}{\partial \phi}H_z + j\beta H_\phi = \varepsilon j\omega E_r$

$$-\frac{\partial}{\partial r}E_z - j\beta\left[\frac{1}{r\varepsilon j\omega}\frac{\partial}{\partial \phi}H_z + \frac{j\beta}{\varepsilon j\omega}H_\phi\right] = -\mu j\omega H_\phi$$

$$-\frac{\partial}{\partial r}E_z - \frac{j\beta}{r\varepsilon j\omega}\frac{\partial}{\partial \phi}H_z + \frac{j\beta^2}{\varepsilon j\omega}H_\phi = -\mu j\omega H_\phi$$

$$\left(-\mu j\omega + \frac{j\beta^2}{\varepsilon\omega}\right)H_\phi$$

$$\left[-\frac{\partial}{\partial r}E_z\right] - \left[\frac{\beta}{r\varepsilon\omega}\frac{\partial}{\partial \phi}H_z\right] = H_\phi\left[\frac{j\beta^2}{\varepsilon\omega} - j\omega\mu\right]$$

$$\left(\frac{-1}{\frac{j\beta^2}{\varepsilon\omega} - j\omega\mu}\right)\frac{\partial}{\partial r}E_z - \frac{\beta}{r\varepsilon\omega\left[\frac{j\beta^2}{\varepsilon\omega} - j\omega\mu\right]}\frac{\partial H_z}{\partial \phi} = H_\phi$$

$$\frac{-1}{j}\left(\frac{\varepsilon\omega}{\beta^2 - \omega^2\mu\varepsilon}\right)\frac{\partial}{\partial r}E_z - \frac{-\beta}{j(r\beta^2 - \omega^2\mu\varepsilon r)}\frac{\partial H_z}{\partial \phi} = H_\phi$$

$$\frac{-j\beta}{r k_c^2}\frac{\partial H_z}{\partial \phi} - \frac{j\varepsilon\omega}{k_c^2}\frac{\partial E_z}{\partial r} = H_\phi$$

$$\boxed{\frac{-j}{k_c^2}\left[\frac{\beta}{r}\frac{\partial H_z}{\partial \phi} + \varepsilon\omega\frac{\partial E_z}{\partial r}\right] = H_\phi}$$

<u>'H_r' derive</u>

$$\frac{1}{r}\frac{\partial E_z}{\partial \phi} - (-j\beta)E_\phi = -\mu j\omega H_r \quad -(9)$$

$$-\frac{\partial H_z}{\partial r} + (-j\beta)H_r = \varepsilon j\omega E_\phi \quad -(10)$$

From (9) $\quad H_r = \dfrac{1}{-rj\omega\mu}\dfrac{\partial E_z}{\partial \phi} + \dfrac{j\beta}{-j\omega\mu}E_\phi$

$$H_r = \frac{+j}{\omega\mu r}\frac{\partial E_z}{\partial \phi} - \frac{\beta}{\omega\mu}E_\phi$$

Confused again!

Substitute this in (10)

Redid $E\phi$

$$-\frac{\partial H_z}{\partial r} + (-j\beta)\left[\frac{j}{\omega\mu r}\frac{\partial E_z}{\partial \phi} - \frac{\beta}{\omega\mu}E_\phi\right] = \varepsilon j\omega E_\phi$$

$$-\frac{\partial H_z}{\partial r} - \left[\frac{-\beta}{\omega\mu r}\frac{\partial E_z}{\partial \phi}\right] - \left[\frac{-j\beta^2}{\omega\mu}E_\phi\right] = \varepsilon j\omega E_\phi$$

$$-\frac{\partial H_z}{\partial r} + \frac{\beta}{\omega\mu r}\frac{\partial E_z}{\partial \phi} = E_\phi\left[\varepsilon j\omega - \frac{j\beta^2}{\omega\mu}\right]$$

$$E_\phi = \frac{-1}{\left(\varepsilon j\omega - \frac{j\beta^2}{\omega\mu}\right)} + \frac{\beta}{\omega\mu r\left[\varepsilon j\omega - \frac{j\beta^2}{\omega\mu}\right]}\frac{\partial E_z}{\partial \phi}$$

$$-\frac{\partial H_z}{\partial r}\left(\frac{1}{\varepsilon j\omega}\right) + \frac{(-j\beta)}{\varepsilon j\omega} H_r = E_\phi$$

$$-\frac{\partial H_z}{\partial r}\left(\frac{-j}{\varepsilon\omega}\right) - \frac{\beta}{\varepsilon\omega} H_r = E_\phi$$

Sub this in 9

$$\frac{1}{r}\frac{\partial E_z}{\partial \phi} + j\beta\left[\frac{j}{\varepsilon\omega}\frac{\partial H_z}{\partial r} - \frac{\beta}{\varepsilon\omega} H_r\right] = -j\omega\mu H_r$$

$$\frac{1}{r}\frac{\partial E_z}{\partial \phi} - \frac{\beta}{\varepsilon\omega}\frac{\partial H_z}{\partial r} \underbrace{- \frac{j\beta^2}{\varepsilon\omega} H_r = -j\omega\mu H_r}_{H_r\left[\frac{j\beta^2}{\varepsilon\omega} - j\omega\mu\right]}$$

$$\frac{1}{r\left[\frac{j\beta^2}{\varepsilon\omega} - j\omega\mu\right]}\frac{\partial E_z}{\partial \phi} - \frac{\beta}{\varepsilon\omega\left[\frac{j\beta^2}{\varepsilon\omega} - j\omega\mu\right]}\frac{\partial H_z}{\partial r} = H_r$$

$$\frac{\varepsilon\omega}{jr\left[\beta^2 - \omega^2\mu\varepsilon\right]}\frac{\partial E_z}{\partial \phi} - \frac{\beta}{j\left[\beta^2 - \omega^2\mu\varepsilon\right]}\frac{\partial H_z}{\partial r} = H_r$$

$$\frac{j\varepsilon\omega}{r k_c^2}\frac{\partial E_z}{\partial \phi} - \frac{j\beta}{k_c^2}\frac{\partial H_z}{\partial r} = H_r$$

$$\boxed{H_r = \frac{j}{k_c^2}\left[\frac{\varepsilon\omega}{r}\frac{\partial E_z}{\partial \phi} - \beta\frac{\partial H_z}{\partial r}\right]}$$

Writing All 4 eqns E_ϕ, E_r, H_ϕ, H_r

$$\boxed{\begin{aligned}
E_r &= -\frac{j}{k_c^2}\left[\frac{\omega\mu}{r}\frac{\partial H_z}{\partial \phi} + \beta\frac{\partial E_z}{\partial r}\right] \\
E_\phi &= \frac{-j}{k_c^2}\left[\frac{\beta}{r}\frac{\partial E_z}{\partial \phi} - \omega\mu\frac{\partial H_z}{\partial r}\right] \\
H_\phi &= \frac{-j}{k_c^2}\left[\frac{\beta}{r}\frac{\partial H_z}{\partial \phi} + \varepsilon\omega\frac{\partial E_z}{\partial r}\right] \\
H_r &= \frac{-j}{k_c^2}\left[\beta\frac{\partial H_z}{\partial r} - \frac{\varepsilon\omega}{r}\frac{\partial E_z}{\partial \phi}\right]
\end{aligned}}$$

What about E_z & H_z Values?

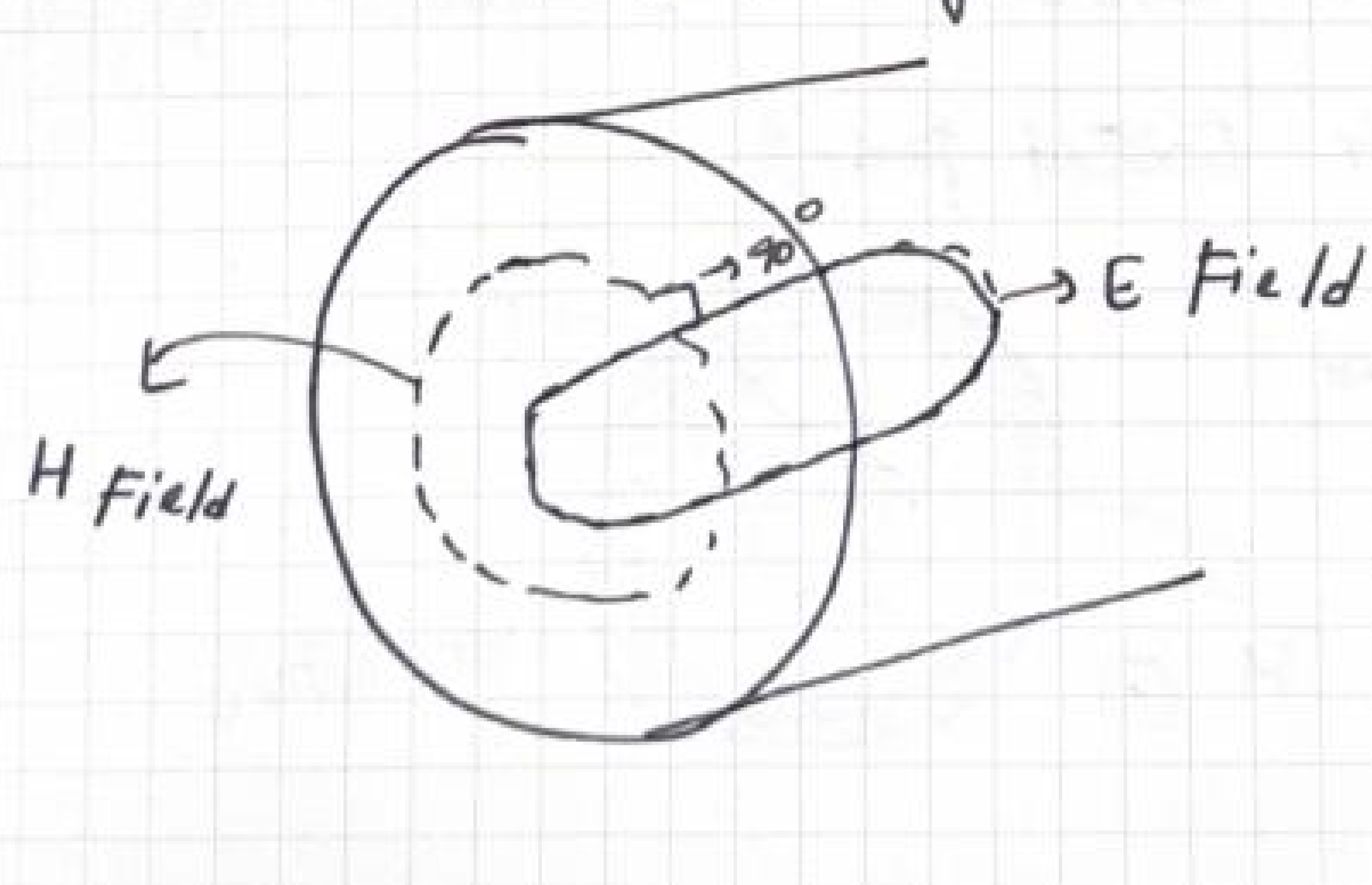
First of all let's observe one thing, How the wave propagates.

If it has to propagate in TEM then both E_z & $H_z = 0$

if this happens, the above 4 eqns $E_r, E_\phi, H_\phi, H_r \rightarrow 0$

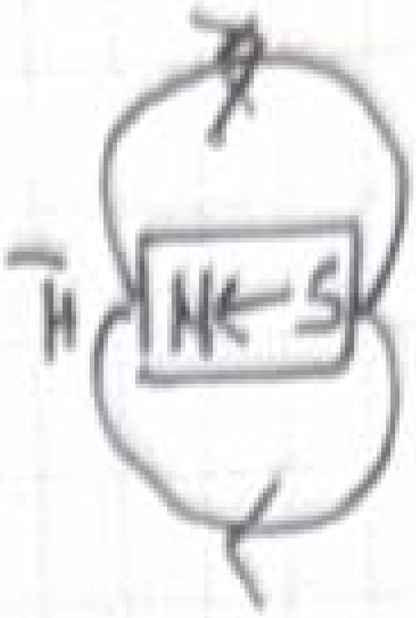
So, TEM doesn't exist - Mathematically proved!

Let's understand this physically!



Rule
$\bar{E} \perp \bar{H}$
always

we know from fundamentals $\bar{H}$ is always in Loop



$\bar{E}$ is from +ve charge to -ve charge +Q $\bar{E}$ -Q

If $\bar{H}$ is looping around the cross section of wg

then $\bar{E}$ has to be $\perp$ to $\bar{H}$

in a hollow metal tube there is no potential difference

so $\bar{E}$ has to curl & form loop no choice

The only possible $\perp$ loop $\bar{E}$ can form has to be $\perp$

Cross section $\Rightarrow$ definitly it has $\bar{Z}$ component

Z $\rightarrow$ direction of wave propagation.

So, Longitudinal component exists always.

Same way if $\bar{E}$ curls around cross section $\bar{H}$

has no choice to curl $\perp$ to it & composing of longitudinal

component.

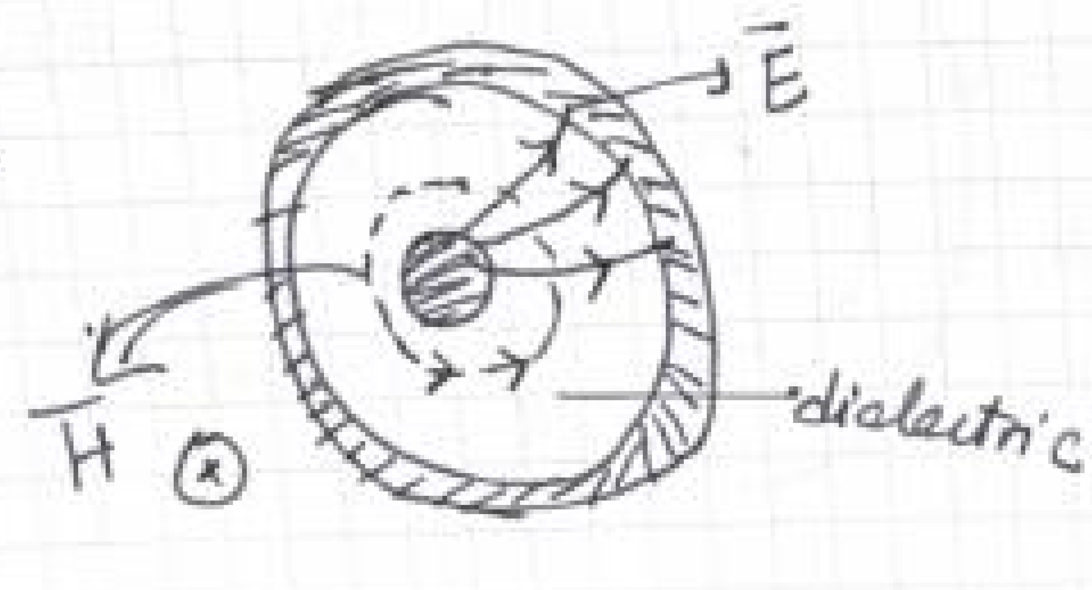
So, finally TEM cannot exist in Hollow

metallic conductor AKA Waveguide.

why TEM can exist in a 2 conductor system

like coax or twisted pair?

Lets take coax



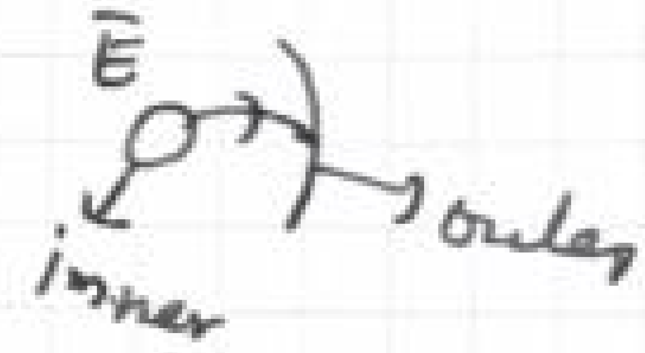
In a coax the inner & outer conductor are separated by dielectric.

The inner conductor is at a different potential compared to outer conductor forming a potential difference.

When there is potential difference, charges in the conductor flow forming a magnetic loop around center conductor. conduction curr
(No H_z component)

Since there is potential difference b/w the conductors, the charges try to attract from one conductor to another forming an $\bar{E}$ field ~~radiating~~ radially out from center to outer conductor. ~~(displacement current)~~.

$\bar{E}$ doesn't loop in itself but ~~loops~~ → no loop is actually formed. is one direction



∴ there is no longitudinal component $\bar{E}_z$ & H_z.

∴ TEM wave exists in 2 conductor system!