Maxwell's Eq^n in time domain — UNIT-I

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

Electric field int	$\nabla \times E = -\frac{\partial B}{\partial t}$	– Faraday's electromotive force law
Mag. field int	$\nabla \times H = J + \frac{\partial D}{\partial t}$	– Ampere's circuital law
E-flux density	$\nabla \cdot D = \rho_v$	Gauss law
M. flux density	$\nabla \cdot B = 0$	Gauss law

$\rho = 0$, $\sigma = 0$ — No conducting material in free space

Unit

- E → Electric field intensity V/m
- H – Mag " " Amp/m
- D – Electric flux density C/m^2
- B – Mag. flux density W/m^2

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$
$$= \sigma E + j\omega\epsilon E$$
$$= E(\cancel{\sigma_0} + j\omega\epsilon)$$
$$\boxed{\nabla \times H = j\omega\epsilon E}$$

$J = J_c + J_0$ — impressed current

$J = \sigma E$ ← Conduction current density caused by the field

Conduction current

Maxwell Eq^n in freq domain

Assume that Time varying fx in the form of $e^{j\omega t}$

$B = \mu H$

$D = \epsilon E$

$J = \sigma E$

$\epsilon = \epsilon_0 \epsilon_r$ — Electric Permittivity

$\mu = \mu_0 \mu_r$ — Mag. Permeability

$$\nabla \times E = -\frac{\partial}{\partial t}\mu H$$
$$\nabla \times E = -j\omega\mu H$$

Now curl of $\nabla \times E$

$$\nabla \times \nabla \times E = -j\omega\mu(\nabla \times H)$$
$$-\nabla^2 E + \nabla(\underbrace{\nabla \cdot E}_{0}) = -j\omega\mu(j\omega\epsilon E)$$
$$\cancel{-}\nabla^2 E = \cancel{-}(j\omega)^2 \mu\epsilon E$$
$$\boxed{\nabla^2 E = -\omega^2 \mu\epsilon E}$$

Similarly $\boxed{\nabla^2 H = -\omega^2 \mu\epsilon H}$

$\mu\epsilon = \frac{1}{c^2}$

$E = E_0 e^{j\omega t}$ — E_0 max electric field intensity

$$\frac{\partial E}{\partial t} = E_0 e^{j\omega t} \cdot j\omega$$

then $\boxed{\frac{\partial}{\partial t} = j\omega}$

$\omega = 2\pi f$, f – freq of sinusoidal variation

$\partial^2/\partial t^2 = (j\omega)^2$

$$\boxed{\frac{\partial^2}{\partial t^2} = -\omega^2}$$

γ^2

or $\nabla^2 E = j\omega\mu(\sigma + j\omega\epsilon)E$

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

Intrinsic Propagation

$\gamma = \alpha + j\beta$ — Phase constt

γ – Propagation constt.

α – Attenuation constt

$$\boxed{\nabla^2 E = \gamma^2 E}$$ or $\nabla^2 \psi = \gamma^2 \psi$

Similarly $\boxed{\nabla^2 H = \gamma^2 H}$

we know that $\mu\epsilon = \mu_0\mu_r \cdot \epsilon_0\epsilon_r$ $\qquad \left.\begin{matrix}\mu_r = \\ \epsilon_r =\end{matrix}\right\} 1$

$\mu_0 = 4\pi\times10^{-7}\ H/m \qquad \epsilon_0 = \frac{1}{36\pi}\cdot10^{-9}\ f/m$ farad/meter or $8.854\times10^{-12}\ F/m$

$$= \frac{4\pi\times10^{-7}\times10^{-9}}{36\pi\ 9\pi}$$

$$= \frac{1}{9\times10^{16}}$$

$$\mu\epsilon = \frac{1}{(3\times10^{8})^2}$$

$$\mu\epsilon = \frac{1}{c^2} \qquad c^2 = \frac{1}{\mu\epsilon}$$

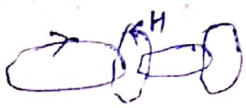
or $c = \frac{1}{\sqrt{\mu\epsilon}} \Rightarrow \boxed{3\times10^{8}\ m/sec}$

If wave propagate through other medium then velocity then air ↓es

$$v = \frac{c}{f(\sqrt{\epsilon_r})}$$

ϵ_r — dielectric constt of the medium

A changing electric field produced mag. field and changing magnetic field induced a changing electric field in the surrounding region



Mode

TEM – Both Electric and mag. fields are purely Transverse to the direction of propagation and consequently have no z directed component:

$E_z = 0 \qquad H_z = 0$

(2) TE

$E_z = 0 \qquad H_z \neq 0$

(3) TM

$E_z \neq 0 \qquad H_z = 0$

(4) HE (Hybrid) wave

$E_z \neq 0 \qquad H_z \neq 0$

UNIT - I

Microwave Engg.

[300 MHz – 300 GHz]

RF & MW Engg.
[3 KHz – 300 GHz]

(1) MW freq range is from 300 MHz – 300 GHz so that wave length (λ) may considered in microns ranges.

$\lambda = 1m$ → $1mm$

$\boxed{1\,\mu m = 10^{-6}\,m}$ (1 micron)

$1\,\text{Å}$ (angstrom) $= 10^{-10}\,m$

(2) Means that μwave also covers infrared and visible light regions.

10^{18}	Exa	E
10^{15}	Peta	P
10^{12}	tera	T
10^{9}	GHz	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	Hecto	h
10	deka	da

(3) When freq = 300 MHz.

then $\lambda = \frac{\cancel{3}\times\cancel{10^8}}{\cancel{300}\times\cancel{10^6}}$

$\boxed{\lambda = \frac{c}{f}}$

$\boxed{\lambda = 1m}$

When 300 GHz

then $\lambda = \frac{3\times\cancel{10^8}}{300\times\cancel{10^9}}$

$\lambda = \frac{\cancel{3}}{\cancel{300}_{100}\times 10} = \boxed{\frac{1}{1000}\,m}$ or $\frac{1\times 100}{1000} = \boxed{.1\,cm}$

or $.1\times 10 = \boxed{1mm}$

$\frac{1\times 10}{10}$

deci	10^{-1}	d
centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	μ

(4) IEEE freq. band

HF – 3 – 30 MHz] in AM | FM Broadcasting
VHF – 30 – 300 MHz]
UHF – 300M 1 GHz] — GSM — 900 MHz: Tr. 890 – 915, RX. 935 – 960 | 1800 MHz GSM: Tr. 1710–1785, RX – 1805 – 1880
L – 1 – 2 "]
S – 2 – 4 " ← Radar, Bluetooth, wifi, mw oven
C – 4 – 8 " — satellite
X – 8 – 12 " — Educational Purpose
KU – 12 – 18 " — DTH, VSAT, GPS.
K – 18 – 27 "] — Radar,
Ka – 27 – 40 "]
mm – 40 – 300 "] ~~Current~~ Terrestrial Purpose.
> 300 ... visible light, UV, x ray, γ, Cosmic

Advantages of MW

Pamer

(1) B.W ↑es.

Bcz freq. range of information channel will be small % of carrier freq.

Ex. consider speech signal ie 4KHz Bandwidth

when carrier

300 MHz

then no of channels. $\frac{300 \times 10^6}{4 \times 10^3} = \boxed{75000}$ no. channels

3 GHz.

$\frac{3 \times 10^9}{4 \times 10^3}$

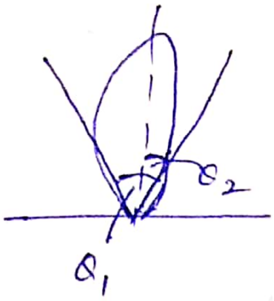
7.5 Lakhs channels.

B.W for speech – 4 KHz

music – 10-15 KHz.

TV – 5-7 MHz.

(2) As freq. ↑es Directivity ↑es Beamwidth ↓es.



$D = \frac{140 \times \lambda}{B}$

Consider 1° so that

$D = \frac{140 \times \lambda}{B}$

for Diameter of an antenna

we know that $B = \frac{140}{D/\lambda}$

Beam in degree

Diameter of an antenna in cm

wavelength in cm.

At 30 GHz.

$D = 140 \times \lambda$

$D = 140\text{cm}$

when 300 MHz.

$D = 140\text{m}$.

(3) Fading Effect and Reliability

- Due to variation in the tx medium. Fading is more effective at L freq.
- Due to LOS propagation and high freq. there is less fading effect.

Scanned with CamScanner

Power Requirement is less at Rx|Tr.

Application – 1. Industrial

2. Domestic – MW oven 2.45 GHz ($\lambda = 12$ CM)

3. Military $\qquad J = \sigma E$

4. Radar

5. Comm.

6. Mobile Comm.

7. Sat. Comm.

For wave Eqn.

Maxwell's Eqn.

$\nabla \times E = -\frac{\partial B}{\partial t}$ – Faraday's $\qquad B = \mu H$

$\qquad D = \epsilon E$

$\nabla \times H = J + \frac{\partial D}{\partial t}$ – Ampr $\qquad \epsilon = \epsilon_0 \epsilon_r$

$\mu = \mu_0 \mu_r$

$\left.\begin{array}{l} \nabla \cdot D = \rho_v \\ \nabla \cdot B = 0 \end{array}\right]$ Gauss

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

$\nabla \times H = j\omega \epsilon E$

EMT wave follow exponential form then

$E = E_0 e^{j\omega t}$

$\frac{\partial E}{\partial t} = j\omega \cdot E_0 e^{j\omega t}$

$\frac{\partial E}{\partial t} = (j\omega) \cdot E$

or $\frac{\partial^2 E}{\partial t^2} = (j\omega)^2 \cdot E$

$\boxed{\frac{\partial}{\partial t} = j\omega}$

$\frac{\partial^2}{\partial t^2} = (j\omega)^2$

$= -\omega^2$

Ques no. 1 (a) write Maxwell's Equation in Differential and in integral form.

Ans. Maxwell's Equations:

- $\oint_S E \cdot dA = \frac{q}{a_0}$ Gauss's law electric.
- $\oint_S B \cdot dA = 0$ Gauss's law magnetism
- $\int E \cdot ds = -\frac{d\phi_s}{dt}$ Faraday's law
- $\int B \cdot ds = aI + \frac{d\phi_E}{dt}$ Ampere-Maxwell law

→ In differential form:

- $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} - \vec{M_i} = -\vec{M_d} - \vec{M_i}$
- $\nabla \times \vec{H} = \vec{J_i} + \vec{J_c} + \frac{\partial \vec{D}}{\partial t} = \vec{J_i} + \vec{J_c} + \vec{J_d}$
- $\nabla \cdot \vec{D} = \rho_{ev}$
- $\nabla \cdot \vec{B} = \rho_{mv}$
- $\vec{M_d} = \frac{\partial \vec{B}}{\partial t}$, $\vec{J_d} = \frac{\partial \vec{D}}{\partial t}$

Here,
$\vec{E}$ = Electric field intensity [v/m]
$\vec{B}$ = Magnetic flux density [weber/m² = V s/m² = Tesla]
$\vec{M_i}$ = Impressed (source) magnetic current density [v/m²]
$\vec{M_d}$ = Magnetic displacement current density [v/m²]
$\vec{H}$ = Magnetic field intensity [A/M]
$\vec{J_i}$ = Impressed (source) electric current density [A/M²]

the
wave
trans-
(→

$\vec{D}$ = Electric flux density or electric displacement [C/m²]

$\vec{J_c}$ = Electric conduction current density [A/m²]

$\vec{J_d}$ = Electric displacement current density [A/m²]

ρ_{ev} = Electric charge volume density [C/m³]

ρ_{mv} = Magnetic charge volume density [weber/m³].

→ <u>In integral form:</u>

- $\iint_A \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon_0} = \frac{1}{\varepsilon_0}\iiint_V \rho\, dv$ (Gauss's law)
- $\iint_A \vec{B}\cdot d\vec{A} = 0$ (Gauss's law for magnetism)
- $\int_C \vec{E}\cdot d\vec{l} = -\frac{d\phi_B}{dt} = \frac{-d}{dt}\iint_A \vec{B}\cdot d\vec{A}$ (Faraday's law)
- $\int_C \vec{B}\cdot d\vec{l} = \mu_0 I_{encl} + \mu_0\varepsilon_0\frac{d\phi_E}{dt} = \mu_0\iint_A\left[\vec{J} + \varepsilon_0\frac{d\vec{E}}{dt}\right]\cdot d\vec{A}$

(Ampere's Law).

Ques no. 1(b) write different modes in Rectangular wave guide.

Ans. There are three type of waveguide mode in Rectangular wave guide.

1) <u>Transverse Electric (TE) mode:</u> This waveguide mode is dependent upon the transverse electric waves also sometimes called H waves, characterised by the fact that the electric vector (E) being always perpendicular to the direction of propagation.

$E_z = 0$ $\qquad H_z \neq 0$ $\qquad$ Exist in waveguide.

1) Transverse Electric (TE) mode: This waveguide mode is dependent upon the transverse electric waves also sometimes called H waves, characterised by the fact that the electric vector (E) being always perpendicular to the direction of propagation.

$E_z = 0$ $H_z \neq 0$ Exist in waveguide.

2) Transverse Magnetic (TM) Mode: Transverse magnetic waves also called (E) waves are characterised by the fact that the magnetic vector (H) is always perpendicular to the direction of propagation.

$H_z = 0$ $E_z \neq 0$ Exist in waveguide.

3) Transverse electromagnetic (TEM) Mode: The TEM waves can not be propagated within a waveguide, but is included for completeness. It is the mode that is commonly used within coaxial and open wire feeders.

The TEM wave is characterised by the fact that both the electric vector (E) and the magnetic vector (H) are perpendicular to the direction of propagation.

$E_z = 0$ $H_z = 0$ Not exist in waveguide.