Microwave
Lec-2

07-03-2024

1. Several Application of microwave engineering
Difficulties / Disadvantage:
Microwave engineering characteristics:
Maxwell equation

(1) Defn (2) Necessary (3) Article 1.2.

The solution and different ~~equation~~ representation of Max well equation:

Advantages of Maxwell Equation:

(1) $\nabla \times \vec{\mathcal{E}} = \frac{-\delta B}{\delta t} - \overline{M}$ —— (1.1 a) F

(2) $\nabla \times \vec{H} = \frac{\delta D}{\delta t} + \overline{J}$ A

(3) $\nabla \cdot \overline{D} = \rho(\vec{r})$

(4) $\nabla \cdot B = 0$ (F) G. Law for

$\mathcal{E}$ is the electric field. (V/m)

H is the magnetic field. (A/m)

D is the flux density in colums per meter (C/m^2)

$\overline{B}$ is the magnetic flux density. (Wb/m^2)

M is the magnetic current density (V/m^2)

J is the electric current density (A/m^2)

ρ is the electric charge density (C/m^3)

permeability vs permitivity.

(1) –

$$\nabla \cdot \nabla \times \vec{\mathcal{E}} = 0 = -\frac{\delta}{\delta t}(\nabla \cdot \overline{B}) - \nabla \cdot \overline{M}$$

$$\nabla \cdot J + \frac{\delta \rho}{\delta t} = 0.$$

Equation 2 :

$$\nabla \cdot \nabla \times \bar{H} = \frac{\delta}{\delta t}(\nabla \cdot D) + \nabla \cdot J$$

$$0 = \frac{\delta \rho}{\delta t} + \nabla \cdot J$$

$$\nabla \cdot J + \frac{\delta \rho}{\delta t} = 0$$

$$\oint_c \bar{E} \cdot d\bar{l} = -\frac{\delta}{\delta t}\int_S \bar{B} \cdot d\bar{s} - \int_S \bar{M} \cdot d\bar{s}$$

$\frac{\delta}{\delta t} = j\omega \leftarrow$ Frequency

time domain

$$\nabla \times \vec{E} = -j\omega \bar{B} - \bar{M}$$

$$\nabla \times \bar{H} = j\omega \bar{D} + \bar{J}$$

$$\nabla \cdot \bar{D} = \rho$$

$$\nabla \cdot B = 0$$

$$\mathcal{E}(x, y, z, t) = Re\left[\bar{E}(x, y, z)e^{j\omega t}\right]$$

Example :

$$\nabla \times \bar{\mathcal{E}} = -\frac{\delta \bar{B}}{\delta t} - \bar{M}$$

$$\nabla \times \mathcal{E}(x, y, z, t) = -\frac{\delta \bar{B}}{\delta t}(x, y, z, t) - M(x, y, z, t)$$

$$\nabla \times E(x, y, z)e^{j\omega t} = -\frac{\delta B}{\delta t}(x, y, z)e^{j\omega t} - \bar{M}(x, y, z)e^{j\omega t}$$

$$e^{j\omega t}\left[\nabla \times E(x, y, z)\right] = -B(x, y, z)(j\omega e^{j\omega t}) - \bar{M}(x, y, z)e^{j\omega t}$$

$$\nabla \times \bar{E}(x, y, z) = -j\omega B(x, y, z) - M(x, y, z)$$

This will be the solution of above equation.

Home work: Importance of Maxwell equation.

Different notation of Maxwell equation.

Article → 1.2

~~phase and~~ 1.3 field in media and boundary condn

1.4 Wave equation

Microwave Lab 2

14.03.24

Precaution:

(1) Keep all the knobs in minimum position before going ~~on~~ to switch 'ON' the power supply of VSWR/Kryston power supplies.

Kryston power supply 'HT' should be off before switching on the main supply.

• Note: For kryston power supply 'HT' should be off before switching on the main supply.

(2) Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.

(3) Switch on the main supply and give some warm up to get current / accurate reading.

(4) After the completion of experiment, before going to switch off the mains keep all the knobs in minimum positions as those are rule 1.

5) If the main supply failed in the middle of the experiment, comes to 1st condition keep all the knobs in minimum position and switch off main switches.

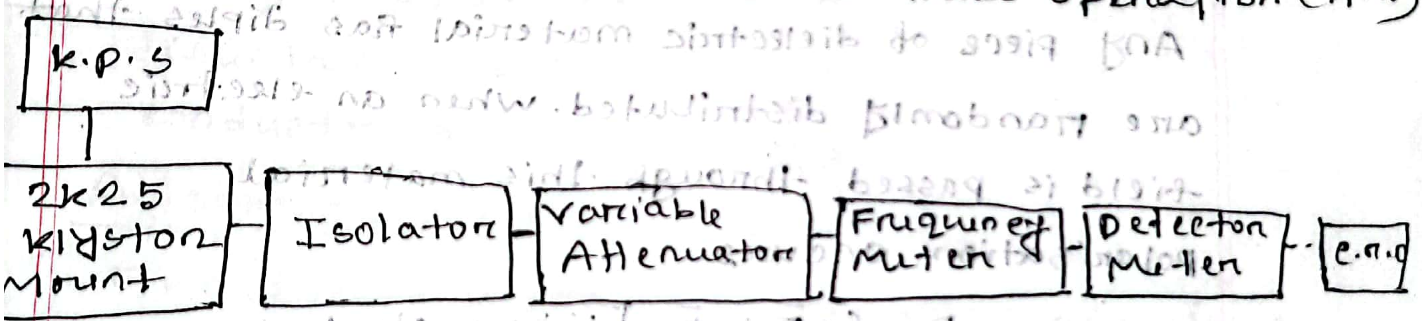
6) Don't increase the repeller voltage more than -70V it should be between -70V to -270V.

Ex-2 : Study of the characteristics of klystron Tube and to determine its electronic tuning range.

Apparatus Required:

(1) Klystron power supply (2) Klystron Tube with klystron mode (3) Isolator (4) Frequency meter. (5) Variable attenuator (6) Detector mount (7) Wave guide stand. (8) SWR meter & oscilloscope (9) BNC cable.

Theory of the operation square wave operation (H.W)



(1) Variable Attenuator 20dB NVS
(2) slotted section
(3) Mount navis
(4) Frequency Meter.

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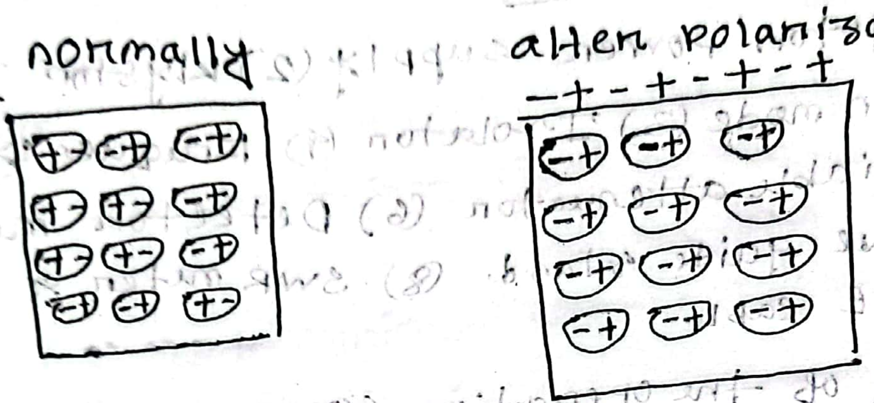
Art: 1.3 Fields in media:

Piece of dielectric material



Any piece of dielectric material has diples that are randomly distributed. When an electric field is passed through this material polarisation occurs.

$$D = \epsilon_0 \bar{E} + \bar{P_e} \left[\because \bar{P_e} = \text{electric polarisation}\right].$$

In linear medium

$$\bar{P_e} = \epsilon_0 \chi_0 \bar{E} \left[\because \chi_0 = \text{electric susceptibility}\right].$$

$$D = \epsilon_0 \bar{E} + \epsilon_0 \chi_e \bar{E} = \epsilon_0 (1+\chi_e)\vec{E} = \epsilon \bar{E}$$

$$\epsilon = \epsilon' - j\epsilon'' = \epsilon_0 (1+\chi_e)$$

The imaginary part ($j\epsilon''$) represents loss in the medium due to damping of the vibrating dipole moments.

In material with conductivity σ, a conduction current will exists

$$\bar{J} = \sigma \bar{E}$$

The form maxwell curl equation for $\bar{H}$ becomes

$$\nabla \times \bar{H} = j\omega \bar{D} + \bar{J}$$

$$= j\omega \bar{D} + \sigma \bar{E} = j\omega \epsilon \bar{E} + \sigma \bar{E}$$

$$= j\omega \epsilon' \bar{E} + (\omega \epsilon'' + \sigma) \bar{E}$$

$$= j\omega (\epsilon' - j\epsilon'' - j\frac{\sigma}{\omega}) \bar{E}$$

$$= j\omega \epsilon_0 \epsilon_r (1 - j\tan\delta) \bar{E}$$ conductor loss

where $\tan\delta = \frac{\omega\epsilon'' + \sigma}{\omega\epsilon'}$ represent loss tangent.

Two types of loss (σ)

dielectric loss ($j\epsilon''$)

conductor loss $\tan\delta = \frac{\sigma}{\omega\epsilon}$

Anisotropic material:

The direction of polarisation is not the same as E. ex crystals.

ionized gases } ferrites - magnetic anisotrophic material

electric anisotrophic material.

যে সমস্ত polarisation এর material এ একই দিকে থাকে isotropic material.

Pm = magnetic Polarisation. $P_m, \bar{E}$

Pe = electric Polarisation. $P_e, \bar{H}$

Electric $\begin{bmatrix} D_x \\ D_y \\ D_z \end{bmatrix} = \begin{bmatrix} \epsilon_{xx} & \epsilon_{xy} & \epsilon_{xz} \\ \epsilon_{yx} & \epsilon_{yy} & \epsilon_{yz} \\ \epsilon_{zx} & \epsilon_{zy} & \epsilon_{zz} \end{bmatrix} = \begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix} = [\epsilon] \begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix}$

Similarly,

Magnetic $\begin{bmatrix} B_x \\ B_y \\ B_z \end{bmatrix} = \begin{bmatrix} \mu_{xx} & \mu_{xy} & \mu_{xz} \\ \mu_{yx} & \mu_{yy} & \mu_{yz} \\ \mu_{zx} & \mu_{zy} & \mu_{zz} \end{bmatrix} \begin{bmatrix} H_x \\ H_y \\ H_z \end{bmatrix} = [\mu] \begin{bmatrix} H_x \\ H_y \\ H_z \end{bmatrix}$

$D = \epsilon E$ (For ~~magnetic~~ electric)

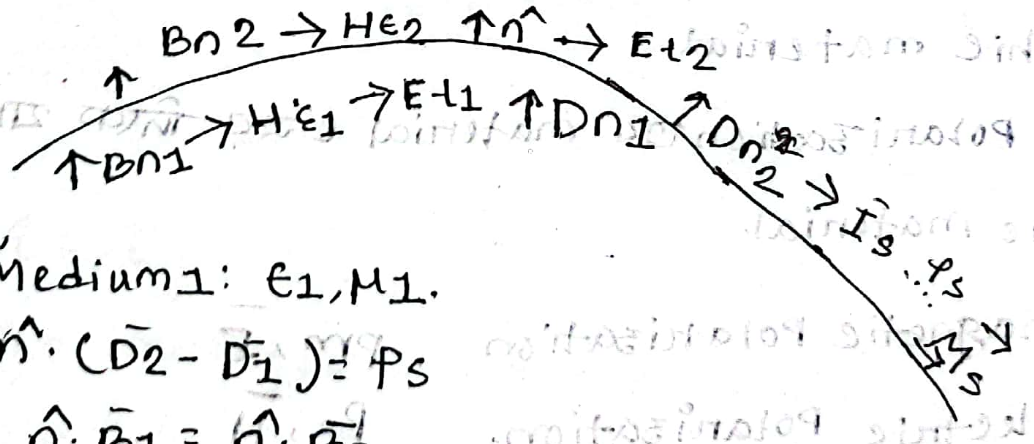
$B = \mu H$ (For magnetic)

Ex- Anisotropic material

$$\epsilon = \epsilon_0 \begin{bmatrix} 1 & -2j & 0 \\ 2j & 3 & 0 \\ 0 & 0 & 4 \end{bmatrix}$$

$\bar{E} = 2\hat{x} + 3\hat{y} + 4\hat{z}$ what is $\bar{D} = ?$

Boundary condition:



Medium 1: ϵ_1, μ_1.

$\hat{n} \cdot (\bar{D}_2 - \bar{D}_1) = \rho_s$

$\hat{n} \cdot \bar{B}_1 = \hat{n} \cdot \bar{B}_2$

$(\bar{E}_2 - \bar{E}_1) \times \hat{n} = \bar{M}_s$

$\hat{n} \times (\bar{H}_2 - \bar{H}_1) = \bar{J}_s$

Boundary condition at a dielectric interface

$\rho_s = 0$

Conditions:

$\hat{n} \cdot D_1 = \hat{n} \cdot \bar{D_2}$
$\hat{n} \cdot B_1 = \hat{n} \cdot \bar{B_2}$] normally flux density is continuos

$\hat{n} \times \bar{E_1} = \hat{n} \times \bar{E_2}$
$\hat{n} \times \bar{H_1} = \hat{n} \times \bar{H_2}$] tangential field intensity is continuos.

Boundary conditions at the interface with a perfect conductor.

Boundary conditions at the interface with a magnetic wall.

1.4. The wave eqn and basic plane wave solution

The Helmholtz equation

plane wave in a lossless medium.

Ex-1.1

Plane waves in a general lossy medium.

Plane waves in a good conductor.

Ex-1.2

Chapter-2

Transmission line Theory

~~why we use transmission lines?~~

Chapter-2 → 1st introduction.

Whether the simple circuit laws may be used depends on the size of our circuit in relation to the wavelength corresponding to the operating frequency

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

The relation between wavelength and the operating frequency.

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

If the size of the circuit in question is much smaller ~~than~~ that the operating wavelength ($\sim\lambda/100$ or smaller), the simple circuits laws apply. In such ~~in~~ as case, we say that the elements of the circuit are lumped elements.

If the size of the circuit in question is comparab to that of the operating wavelength ($\sim\lambda/10$ to $\sim\lambda$) the simple circuits laws do not apply. In such as case, we say that the elements of the circuits are "distributed" elements.

Article - 2.1.

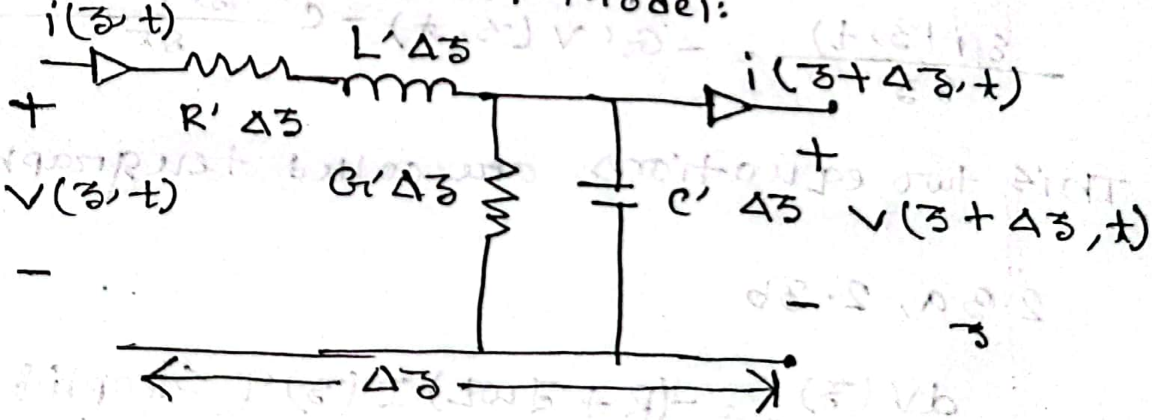
R and L → conduction current
G and C → Displacement

There is conduction current in the two conductors and a displacement current between these two conductors where the electric field E is varying with time.

R' (Ω/m)
L' (H/m)
G' (S/m)
C' (F/m)

R and G represent loss of circuit.

General Equivalent circuit Model:



After apply (KVL) V(z, t)

$$V(z+\Delta z, t) + i(z,t) R' \Delta z + L' \Delta z \frac{\delta i(z,t)}{\delta t}$$

$$\Delta V = V(z+\Delta z, t) - V(z,t) = -i(z,t) R' \Delta z - L' \Delta z \frac{\delta i(z,t)}{\delta t} \quad \text{I(a)}$$

~~Before~~ after apply KCL V(z, t)

$$V(z,t) = i(z+\Delta z, t) + V(z+\Delta z, t) G' \Delta z + C' \Delta z \frac{\delta V(z+\Delta z, t)}{\delta t}$$

$$\Delta i = i(z+\Delta z, t) - i(z,t) = -v(z+\Delta z, t)\, G' \Delta z - C' \Delta z \frac{\delta v(z+\Delta z, t)}{\delta t}$$

Divide 1(a) and 1(b) by Δz and taking the limit $\Delta z \to 0$

$$\frac{v(z+\Delta z, t) - v(z,t)}{\Delta z} = -R' i(z,t) - L' \frac{\delta i(z,t)}{\delta t}$$

$$\frac{i(z+\Delta z, t) - i(z,t)}{\Delta z} = -G' v(z+\Delta z, t) - C' \frac{\delta v(z+\Delta z, t)}{\delta t}$$

$$\frac{\delta v(z,t)}{\delta z} = -R' i(z,t) - L' \frac{\delta i(z,t)}{\delta t}$$

$$\frac{\delta i(z,t)}{\delta z} = -G' v(z,t) - C \frac{\delta v(z,t)}{\delta t}$$

This two equations are called telegrapher equation

2.3a, 2.3b

$$\frac{dV(z)}{dz} = -(R + j\omega L)\, I(z)$$

$$\frac{dI(z)}{dz} = -(G + j\omega C)\, V(z)$$

simplify teliographer equation

Transmission line থেকে primary parameter বের করতে বললে এতটুকু লেখতে হবে.
এর সমাপ্ত.

Article

2.1, 2.2, 2.3.

24-04.24.

γ = propagation constant

α = attenuation "

β = function of Frequency

Defn of propagation constant — eqn-2.5

wave propagation of transmission line:

— direction.

অবশেষে transmission line এর e ipidence line, current বের করতে হবে

Another transmission line as a lossless line.

$R = G = 0$

$\gamma = j\omega\sqrt{LC}$

Eqn → 2.13.

γ

lossless transmission এর জন্য attenuation constant and phase constant এর মান.

condition 1:

Low loss condition line

Another:

Distortion less line.

Article → 2.7 → lossy transmission line

কোন ব্যবহার করব.

Distortion line.

2.82 → Eqn 2.84

Example - 2.6

কেমন distortion line হবে

1st: explain

Article-No: 2.2, 2.3 Ex - 2.1 (Table পর্যন্ত পড়তে হবে)

Telegrapher eqn জানতে হবে.

Microwave

24-04-24

What is the telegrapher eqn?

Figure-2.2

Transmission line voltage and current represtation.

2.18, 2.20 - eqn

Fig-2.3

Ex-2.1 : Table-2.1.

How to calculate the transmission line of the co-axial cable.

Art - 2.3 (Fig-2.4)

Eqn → 2.35.

Standing wave.

Matched condn - $\Gamma = 0$ up and down

Eqn - 237 কিছুই থাকে না constant

Return Loss: যখন সম্পূর্ণ Power এর কিছু অংশ ফিরে— আসবে। Eqn-2.38.

Standing wave: max voltage → min voltage
current min → current max

eqn → 2.39

Eqn → 2.41 → SWR.

Total reflin - $\gamma = 1$. ꝑ to 0

SWR → 1 to ∞ vari

SWR বেশি থাকলে ভালো না কম থাকলে ভালো or
γ এর মান 1 " " or 0 " "

Two successive voltage max] diff - ~~2.35~~ 2.39
" " " min]

2.42 eqn → 2.44.