29-2-24

Lec-1

Microwave Engineering
– Devid M ~~Frofar~~ Polar 4th Edition

/300 MHz and 300 GHz → Microwave
3 GHz → Book
→ Micro
↳ 10cm-1mm

$1 MHz = 10^6 Hz$
$1 GHz = 10^9 Hz$

Visible wave length (700-440 nm)
↳ Remote → Infrared

*Why are microwave frequencies of interest?
↳ Higher BandWidth
⇒ 1. Bandwidth, capacity

3 - 3400/3.4 Hz
≤ 3.4 → Normal

We need to transmit 4KHz voice signal through a wireless link. One operating at 500 MHz and second at 4 GHz, each with a 10% bandwidth around its center frequency.

500 MHz

$$\text{Number of channels} = \frac{\text{Operating frequency} * \text{percent BW}}{\text{BW per channel}}$$

$$= \frac{0.5 \text{ GHz} \times 0.1}{4 \text{ kHz}} = 12500$$

4GHz.

Number of channels $= \frac{4GH \times 0.1}{4KHz} = 100,000$

Operating frequency increases → Capacity increases
↗
BW

~~Anintena size~~

2. Antenna size

frequency বেশি → wavelength কম

1.1 table → 1st 2 page theory পড়ো

Figure - 1.1 → Approximate Band

* Current theory vs EM Field theory

Structure size smaller wavelength থেকে
↳ KCL, KVL

50 Hz → AC circuit → Maximum 60 Hz
↳ Lumped - parameter circuit components
↳ Linear, nonlinear

wavelength ছোট হলে, structure ছোট হলে,
↳ EM Field theory
↳ distributed-parameter circuit components

* Lumped, distributed parameter circuit components কোথায়, কেন ব্যবহার করব।

* Transition from Lumped to distributed
↳ tunnel doide

* General electric circuit - Transistor, FET, MOSFET

* Microwave - Doide, Tunnel doide, Variable doide

* Microwave Circuit - Insulator, Circulator, Attunnator

Klistron Oscillator → Microwave
Magnator "
TWT "

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Magnator "

TWT "

Antenna
Conversion

* Compare between electrical circuit and Microwave circuit

* Microwave heating টা কিভাবে generate করে?

transmission line / Wave line দিয়ে signal pass হয় Microwave এ

* Advantages of MW.

1. capacity / BW বেশি
2. Antenna size ছোট

⇒
1.
2.
3

* Transmission Line এর wavelength ছোট frequency বেশি হয়।

frequency, $f = 300\ MHz$

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

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

$$= 1\ m$$

Bandwidth $= 100^\circ$

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

$= 140^\circ \times \frac{1}{100^\circ}$

$= 1.4^\circ$

Second scenario,

$f = 30\,GHz$

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

$= \frac{3 \times 10^8}{30 \times 10^9} = 0.01$

$D = 140 \times \frac{0.01}{100^\circ}$

$= 0.014^\circ$

* Microwave Engineering কীভাবে signal generate করে?

* Microwave Engineering Application → বই → 3য় Page

H.W → 1-4 page

Lab 7-3-24
Lec-1

Experiment No-1:

Block diagram দিও

Study of Microwave laboratory Components

Lab report একসাথে দিবে

Microwave Test Bench Series
Nvis 9000 Series

Next experiment এর আগে আগের report জমা দিও

Lump parameter circuits

↳ Circulator, Attenuator, Isolator

প্রত্যেক Component দিয়ে কোন কাজ করা হয়?

Slot in section → স্কেল এর মতো , Supply, power, match termination
Meter, Attenuation

Report: → 20

Lab test → 30 → Experiment theory

Lab quiz → 20 → short question

Attendance → 10

Viva → 20 → Lab + theory

Front page → Ex. Name

2nd " → Objectives [আলাদা করে → point দিয়ে দিবে

3. Theory

4. Apparatus required

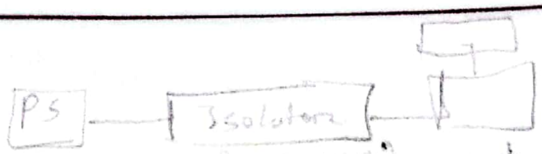
5. Experimental Setup → Diagram draw

6. " Data

7. ~~An~~ Result Analysis

→ Ex-1 এখানে না
সব Ex. এর জন্য লাগবে

change হতে পারে 3, 4 নং



8. ~~Discus~~ Discussion : Error কেন আসে

2. Objectives:

→ Preincipal operation

3. Theoretical Backround:

Microwave definition, different types frequency Bands, then compone

15. theory

1. Frequency
2. Maximum bias voltage
3. Power Output

Waveguides:

7-3-24

ME ETE 415

Sec-2

* Application of Microwaves

↳ satell. (আগের ক্লাসে)

Adv. disadv.

1. Voltage is not well defined

2. Expensive components

electricall large → starting point a voltage, অন্য point = voltage diff. ≠

" small → same "

3.

4. special wires

↳ wave guides

ME.

Maxwell's Equation → 4টা

Book -1.2

Solution of different eqn

$$\nabla \times \bar{E} = \frac{\partial \bar{B}}{\partial t} - \bar{M}$$ → electric current density = 0

$$\nabla \times \bar{H} = \frac{\partial \bar{D}}{\partial t} + \bar{J}$$

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

$$\nabla \cdot \bar{B} = 0$$

Max Eqn Adv.

↳ wave phenomena দিয়ে

$\mathcal{E}$ = Electric field $\rightarrow$ V/m

$\bar{H}$ = Magnetic field $\rightarrow$ A/m

$\bar{D}$ = Electric flux density $\rightarrow$

$\bar{B}$ = Magnetic " " $\rightarrow$

$\bar{M}$ = " " Current density $\rightarrow$

$\bar{J}$ = Electric " " $\rightarrow$

ρ = " " ~~Charg~~ Charge " $\rightarrow$

Free space,

$$\bar{B} = \mu_0 \bar{H}$$

$$\cancel{\bar{D} = \varepsilon_0 \bar{E}} \quad D = \varepsilon_0 \bar{\mathcal{E}}$$

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

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

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

*

$$\oint_c \mathcal{E} \cdot d\bar{l} = \frac{-\partial}{\partial t} \int \bar{B} \cdot d\bar{s} - \int_s \bar{M} \cdot d\bar{s}$$

eqn - 1

$$\frac{\partial}{\partial t} \rightarrow j\omega$$

time domain

Frequency

$$\nabla \times \bar{E} = -j\omega \bar{B} - \bar{M}$$
$$\nabla \times \bar{H} = j\omega \bar{D} + \bar{J}$$
$$\nabla \cdot \bar{D} = \rho$$
$$\nabla \cdot \bar{B} = 0$$

Another representation:

~~$\mathcal{E}(x,y,z,t) = \hat{x}A(x,y,z)\cdot\cos(\omega t + \phi)$~~

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

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

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

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

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

Sol: $\nabla \times E(x,y,z)] = -j\omega B(x,y,z) - M(x,y,z)$

* Importance of Max. eqn. Micro. Eng. এর প্রয়োগের
  ↳ wave এর characteristics

* Different notations of Max. eqn.

* Art. 1.2

H.W. → 1.3 Art.

14-3-24
Lab-2

~~Lab report 2~~

Ex. No - 2

Precautions!

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

Note: For Klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

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

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

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

(v) If the main supply failed in the middle of the experiment, Come to 1st condition (i.e) keep all the knobs in minimum position and switch off main switches.

(vi) Don't increase the repeller voltage more than -70V: (i.e) it should be between -70V to -270V.

Ex No- 2:

Study of the characteristics of Klystron Tube and to determine its electronic tunning range.

*Modulation হয় কোন signal সাথে যে → নির্দেশনা থাকে

Maximum to minimum!

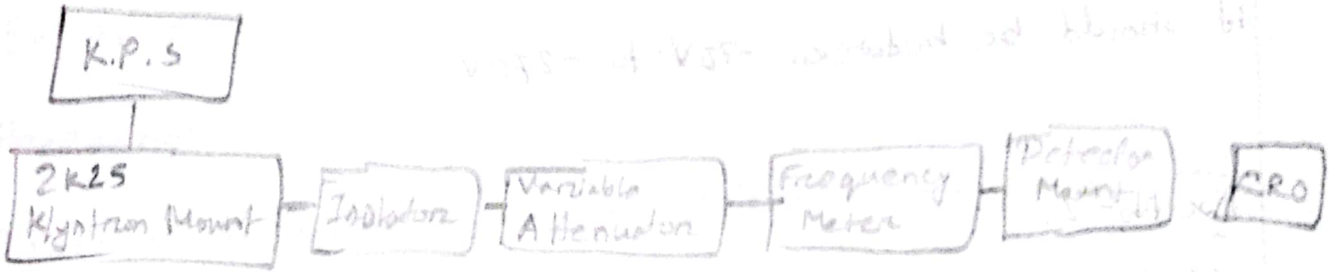
Apparatus required:

1. Klystrone power supply
2. Klystrone tube with klystrone mount
3. Isolator
4. Frequency meter
5. Variable attenuator

Theory: → Principal operation

Square wave operation → থাকে

Carrier " " → " না

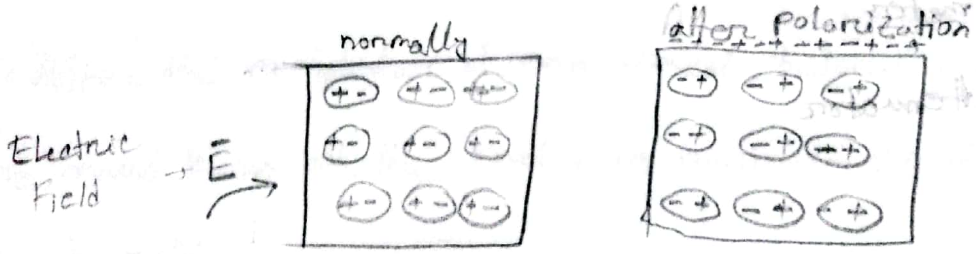


CRo → Cathod

21-3-24
Lec-3

Art. 1.3: Fields in 'media'

Piece of electronic material



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

$$D = \varepsilon . E + \bar{P}_e \quad [\because \bar{P}_e = \text{electric polarization}]$$

In linear medium, ~~P_E~~ $\bar{P}_e = \varepsilon_0 \chi_e \bar{E}$ [$\because \chi_e$ = electric susceptibility]

$$D = \varepsilon_0 \bar{E} + \varepsilon_0 \chi_e \bar{E} = \varepsilon_0 (1+\chi_e)\bar{E} = \epsilon \bar{E}$$

$$\underset{\text{Real}}{\epsilon = \epsilon'} - \underset{\text{Imaginary}}{j\epsilon''} = \epsilon_0 (1+\chi_e)$$

Imaginary part টি Dielectric loss Represent করে
↓
Dipole moment এর

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

In material with conductivity σ, a conduction current will exists..

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

From maxwell curl equation for $\bar{H}$ becomes, $\nabla \times \bar{H} = j\omega \bar{D} + \bar{J}$

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

$\varepsilon = \varepsilon' - j\epsilon''$

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

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

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

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

Where, $\tan\delta = \dfrac{\omega\epsilon'' + \sigma}{\omega\epsilon'}$ represents loss tangent

Two types of loss,

1. Conductor loss (σ)
2. Dielectric loss ($j\epsilon''$)

Conductor loss;

$$\tan \delta = \frac{\sigma}{\omega \epsilon'}$$

Anisotropic material,

The direction ~~data is~~ of polarization is not the same as in $\bar{E}$.

Ex: crystals, ionized gas

Ex ferrites: magnetic anisotropic material.

electric loss
electric anisotropic material

$\bar{P}_e, \bar{E}$ → UTTR

$\bar{P}_m, \bar{H}$

A = C

PM → Book

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,

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

Ex: Anisotropic materials

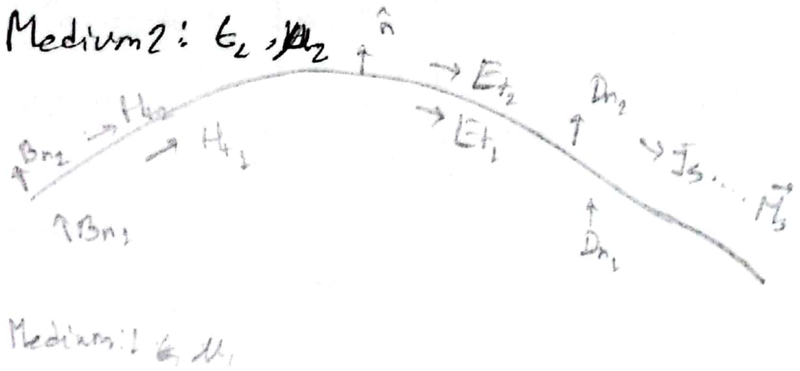
$$\epsilon = \epsilon_0 \begin{bmatrix} 1 & -2j & 0 \\ 2j & 3 & 0 \\ 0 & 0 & 4 \end{bmatrix}$$

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

$$\Rightarrow \begin{bmatrix} D_x \\ D_y \\ D_z \end{bmatrix} = \epsilon_0 \begin{bmatrix} 1 & -2j & 0 \\ 2j & 3 & 0 \\ 0 & 0 & 4 \end{bmatrix} \begin{bmatrix} 2 \\ 3 \\ 4 \end{bmatrix}$$

$$= \begin{bmatrix} 2 - 6j \\ 4j + 9 \\ 0 + 0 + 16 \end{bmatrix}$$

Boundary condition,



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

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

$$\Rightarrow (E_2 - E_1) \times \hat{n} = \bar{M}_s$$

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

Boundary conditions at a dielectric interface,

$$\rho_s = 0$$

$$J_s = 0$$

Conditions:

$$\left.\begin{array}{l} \hat{n} \cdot \bar{D}_1 = \hat{n} \cdot \bar{D}_2 \\ \hat{n} \cdot \bar{B}_1 = \hat{n} \cdot \bar{B}_2 \end{array}\right] \text{Normal flux density is continuous}$$

$$\left.\begin{array}{l} \hat{n} \times E_1 = \hat{n} \times E_2 \\ \hat{n} \times \bar{H}_1 = \hat{n} \times \bar{H}_2 \end{array}\right] \text{tangential field intensity in continuous}$$

* Air Medium ও অন্য Dielectric এর মাঝে charge থাকে না

H.W * Boundary condition at the interface with a perfect condition.

* " " " " " " magnetic wall.

H.W

21-3-24
Lec-

1.4. The wave eqn. and basic plane wave solution

The helmholtz equation:

Plane wave in alossless medium

Ex-1.1

Plane waves in a general lossy medium

Plane waves in a good conductor

Ex-1.2

EEE 4308-L1-3
Pdf

Ch-2

T-Line / Transmission Line

→ propagation delay

* কেন, কিভাবে use হয়?

Whether the simple circuit laws may be used depends on the size of our circuit in relation to the wavelength co-responding to the operating frequency.

The relation between wavelength and operating frequency

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

Lumped element description:

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

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

* Why do we need transmission line theory?

* Co-axial cable
* Parallel Plate
* Two-wire

* T-line এ current, voltage বা wave এ represent হয়,

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* T-line 'Or' currents voltage 'Or' wave a represent ব্যব,

2 waves → 1. Electric, 2. Magnetic

2.1 A

* T-line → 2 টা conductor থাকবে Always

Next class 2.2, 2.3

RLGC Model:

Conduction & displacement current

↓ 2 conductor ↓ 2 conductors

Conduction current impedence

$R' = [\Omega/m]$ → Loss component

$L' = [H/m]$

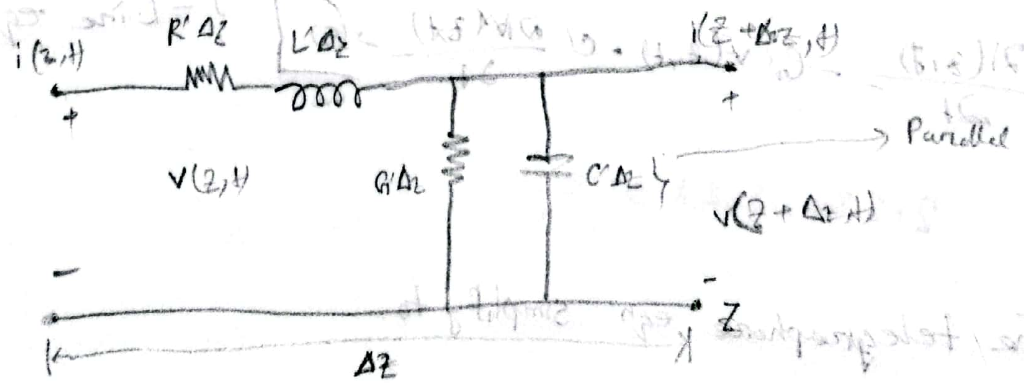
Displacement current impedence

$G' = [S/m]$

$C' = [F/m]$

R ও G circuit এর Loss কে represent করে।

Series Register, inductance



2-wire T-line

→ 4 টা parameter → V, I

T-line এর সাহায্যে V, I এর কারেন্ট বের করো:

$V(z,t), \; i(z,t) = ?$

নিচের অংশে Page 2

After applying KVL $\rightarrow V(z,t)$

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

$$\Delta V = V(z+\Delta z, t) - V(z,t) = -i(z,t) R' \Delta z - L' \Delta z \frac{\partial i(z,t)}{\partial t} \rightarrow (1a)$$

After applying KCL $\rightarrow i(z,t)$

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

$$\Delta i = i(z+\Delta z, t) - i(z,t) = -V(z+\Delta z, t) G' \Delta z - C' \Delta z \frac{\partial V(z+\Delta z, t)}{\partial t} \rightarrow (1b)$$

Divide (1a) and (1b) by Δz and taking the limit as Δz tends to 0.

$\Delta z \rightarrow 0$.

~~$V(z+\Delta z$~~

$$\left.\begin{aligned} \frac{\partial V(z,t)}{\partial t} &= -R' i(z,t) - L' \frac{\partial i(z,t)}{\partial t} \rightarrow (4) \\ \frac{\partial i(z,t)}{\partial t} &= -G' V(z,t) - C' \frac{\partial V(z,t)}{\partial t} \rightarrow (5) \end{aligned}\right]$$

Telegrapher eqn / T-Line eqn

2.23a, 2.23b → eqn

The telegraphone eqn simplify to,

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

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