# KLS Vishwanathrao Deshpande Institute of Technology

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(Recognized Under Section 2(f) by UGC, New Delhi)
Udyog Vidya Nagar, Haliyal - 581 329, Dist.: Uttara Kannada
www.klsvdit.edu.in | principal@klsvdit.edu.in | hodece@klsvdit.edu.in

## DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

# University / Model Question Paper Scheme & Solution

| | | |
|---|---|---|
| Faculty Name | : | Prof. Pooja. C. Shindhe |
| Course Name | : | Microwave Engineering & Antenna Theory |
| Course Code | : | BEC701 |
| Year of Question Paper | : | Model Question Paper |
| Date of Submission | : | 03/07/2025 |

Faculty Member　　　　HoD　　　　Dean (Acad.)

Head of the Department
Dept. of Electronic & Communication Engg.
KLS VDIT, HALIYAL (U.K.)
03/07/2025

# Microwave Engineering & Antenna Theory

Time : 3 hrs Max. Marks : 100

Note: Answer any five full questions, choosing one full question from each module.

## Module-1

1 a. With the help of drift velocity graph and wave from, explain the constructional features and working of n-type GaAs diode. -10M

b. A transmission line has the following primary constants $R = 2\,\Omega/m$, $L = 8\,nH/m$, $G = 0.5\,m℧/m$, $C = 0.23\,pF/m$ and $f = 1\,GHz$ find:
(i) Characteristic impedance $Z_0$ (ii) Propagation constant $\gamma$ (iii) Wavelength $\lambda$, (iv) Phase velocity $V_p$. -10M

or

2 a. Derive the expression for the voltage of current at any point on the transmission line equation and solution starting from the fundamental. -10M

b. Explain the standing waves with neat waveforms. -10M

## Module-2

3 a. Derive scattering parameters for a multiport Network. -10M

b. The Transmission lines of characteristics impedance $Z_1$ & $Z_2$ are joined at plane PP'. Express S-parameters in terms of impedance. -10M

or

4 a. Derive S-Matrix for a Magic Tee with neat diagram and its applications. -10M

b. Explain the working of precision Dielectric Rotary Phase shifter. -10M

## Module-3

5 a. Discuss the operation of micro strip lines with its structure. Compare strip line and microstrip line. -10M

b. Explain the operation of parallel strip line along with a neat diagram. write down the expression for character impedance. -10M

or

6 a. Explain the following terms as related to antenna system.
(i) Directivity and Gain (ii) Beam Area (iii) Effective height (iv) Bandwidth -10M

b. A radio link has a 15 W transmitter connected to an antenna of $0.25\,m^2$ effective aperture at 5 GHz. The receiving antenna has an effective aperture $0.5\,m^2$ and located 15 km line of sight distance from the transmitting antenna. Assuming loss less, matched antenna, find the power delivered to the receiver. -10M

## Module-4

7a. Explain the field pattern and phase pattern with a neat diagram
b. Derive an expression and draw the field pattern for an array of two isotropic point sources situated symmetrically with respect origion with equal amplitude and phase spaced $\lambda/2$ apart. -1

OR

8 a. Derive an expression of field of a dipole in general for the case of thin linear antenna. -10
b. Find the directivity D for the source with radiation intensity -10
(i) $U = U_m \sin^2\theta, \quad 0 \le \theta \le \pi, \; 0 \le \phi \le 2\pi$
(ii) $U = U_m \cos^2\theta, \quad 0 \le \theta \le \pi/2, \; 0 \le \phi \le 2\pi$.

## Module-5

9a. Derive an expression for field strength $E_\phi$ and $H_\phi$ in case of small Loop antenna. -1
b. Derive an expression for radiation resistance of a small loop antenna -1

OR

10 a. Derive an expression for radiation resistance of a short dipole antenna -1
b. Explain the different types of horn antenna. with a diagram -1

(Prof. Pooja. C. Shindhe
KLS VDIT, Haliyal)

# Microwave Engineering & Antenna Theory.

## BEC701 (Model Question Paper)

### Module-1.

1a. With the help of drift velocity graph and wave form, explain the constructional features and working of n-type GaAs diode.

s:

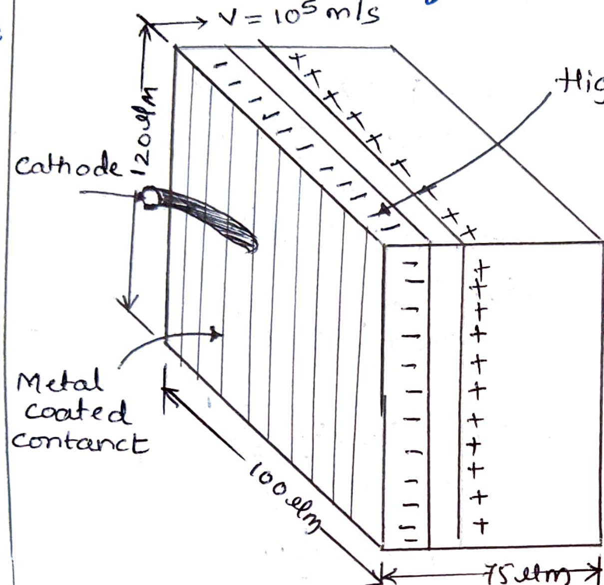
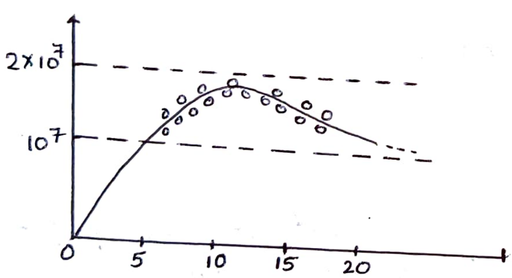
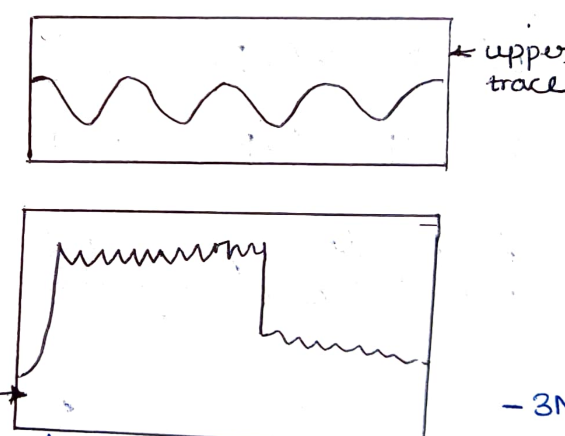



fig: n-type GaAs diode.



– 2M.




– 3M.

1. Gundiode has 3-Layers, lightly dopped N-type material is placed between two highly dopped N-type material.
2. As its made up of ony n-type material it is not a P-N junction dev.
3. Electrons are present in both lower mass and higher mass i.e. lower & higher mobility.
4. when External voltage is applied will cast low mass electrons to highmass, this cause flow of electrons in pulse form.
5. Puls are known as radio wave called microwave (higher frequency) are produced.

–5M

1b. A Transmission line has the following primary constant $R = 2\,\Omega/m$, $L = 8\,nH/m$, $G = 0.5\,m\mho/m$, $C = 0.23\,pF/m$ and $f = 1\,GHz$

Find:

(i) characteristic impedance $Z_0$.

(ii) Propagation constant $\gamma$

(iii) wavelength $\lambda$.

(iv) Phase velocity $V_p$.

Ans: (i) Characteristic impedance.

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$$

$$= \sqrt{\frac{2+j(2\pi\times10^9)\times8\times10^{-9}}{0.5\times10^{-3}+j(2\pi\times10^9)\times0.23\times10^{-12}}}$$

$$= \sqrt{\frac{50.31\angle 87.72^\circ}{15.29\times10^{-4}\angle 70.91^\circ}}$$

$$= 181.39\angle 8.40^\circ$$

$$= 179.44 + j\,26.50 \qquad -4M$$

(ii) Propagation constant ($\gamma$)

$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)}$$

$$= \sqrt{(50.31\angle 87.72^\circ)(15.29\times10^{-4}\angle 70.91^\circ)}$$

$$= \sqrt{769.24\times10^{-4}\angle 158.63^\circ}$$

$$= 0.2774\angle 79.31^\circ$$

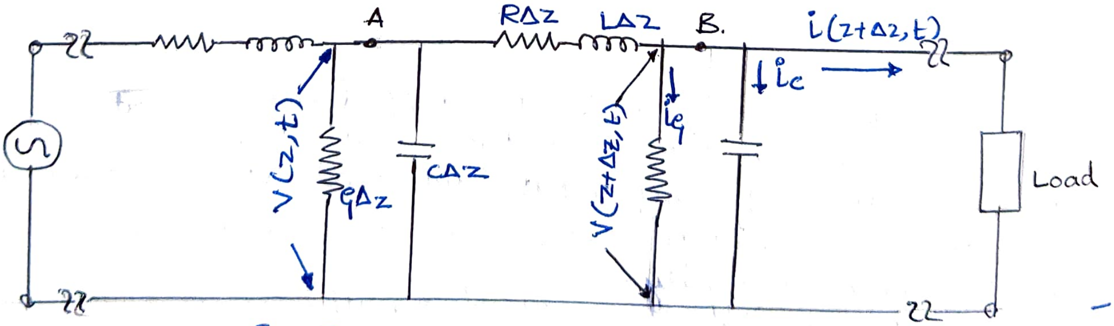
$$= 0.051 + j\,0.273 \qquad -2M$$



(iii) $\lambda = 2\pi/\beta = \dfrac{2\times\pi}{0.273} = 23.015\,km.$ $-2M$

(iv) $V_p = \omega/\beta = \dfrac{2\times\pi\times10^9}{0.273} = 23.015\,nm/sec.$ $-2M$

2a. Derive the expression for the voltage of current at any point on the transmission line equation and solution starting from the fundamental




$-2M$

Fig. Transmission line.

A Transmission line can be analysed either by the solutions of Maxwell's field equation or by the methods of distributed-circuit theory. Based on uniformally distributed-circuit theory, the schematic circuit of a conventional two-conductor transmission line with constant parameters R, L, G and C is as shown in the fig.

The parameters are expressed in their respective names per unit length. and the wave propagation is assumed in positive z-direction. By kirchoff's voltage Law, the summation of voltage drops around central loop is given by.

$$V(z,t) = i(z,t)R\Delta z + L\Delta z\frac{\partial i(z,t)}{\partial t} + V(z,t) + \frac{\partial V(z,t)}{\partial z}\Delta z$$

$$-\frac{\partial v}{\partial z} = Ri + L\frac{\partial i}{\partial t}$$

$$\frac{\partial i}{\partial z} = Gv + C\frac{\partial v}{\partial t}$$

$$V(z,t) = Re\, V(z)\, e^{j\omega t}\ ,\quad i(z,t) = Re\, I(z)\, e^{j\omega t}$$

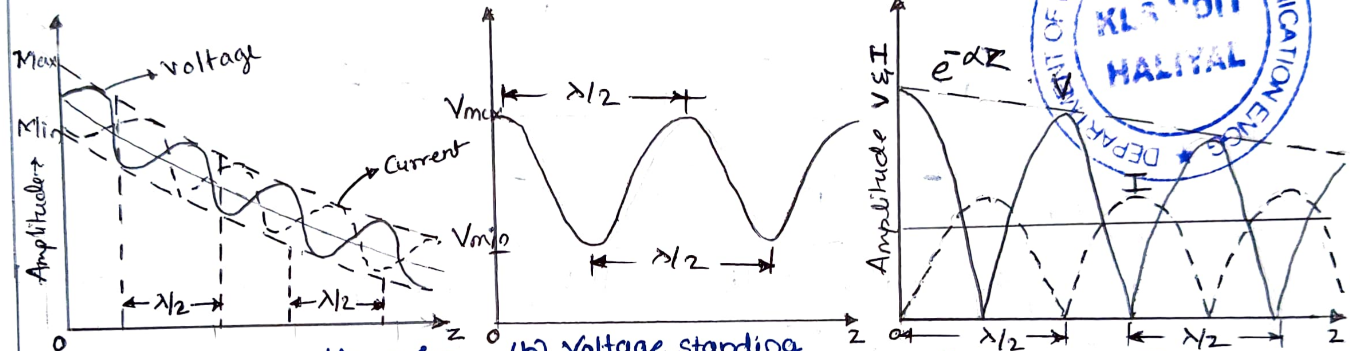
Derivation - 5M

$$\gamma = \alpha + j\beta \text{ (propagation constant)}$$

substitution of Equation.

b. Explain the standing wave with neat waveforms.

Ans.




(a) Standing-wave pattern in Lossy line

(b) Voltage standing wave pattern in Lossless Line

(c) Pure standing waves of voltage and current.



In General. $V = V_+ e^{-\alpha z} e^{-j\beta z} + V_- e^{\alpha z} e^{j\beta z}$

$$= (V_+ e^{-\alpha z} + V_- e^{\alpha z})\cos(\beta z) - j(V_+ e^{-\alpha z} - V_- e^{\alpha z})\sin(\beta z) \longrightarrow (1)$$

with no loss Eqn (1) can be written by assuming $V_+ e^{-\alpha z}$ & $V_- e^{\alpha z}$ are real,

$$V_s = V_0 e^{-j\phi} \longrightarrow (2)$$

Eqn (2) is called as Eqn of Voltage standing wave, where.

$$V_0 = \left[(V_+ e^{-\alpha z} + V_- e^{\alpha z})^2\cos^2(\beta z) + (V_+ e^{-\alpha z} - V_- e^{-\alpha z})^2\sin^2(\beta z)\right]^{1/2} \longrightarrow (3)$$

Eqn (3) is called as standing wave pattern of the voltage wave.

and.

$$\phi = \arctan\left(\frac{V_+ e^{-\alpha z} - V_- e^{\alpha z}}{V_+ e^{-\alpha z} + V_- e^{\alpha z}}\tan(\beta z)\right)$$

called phase pattern.

By differentiating Eqn (3) with respect to βz & Equating to zero, we find that.

1. Maximum value - $V_{max} = V_+ e^{-\alpha z} + V_- e^{\alpha z} = V_+ e^{-\alpha z}(1+|\Gamma|)$

2. Minimum value - $V_{min} = V_+ e^{-\alpha z} - V_- e^{\alpha z} = V_+ e^{-\alpha z}(1-|\Gamma|)$

3. The distance between two successive maxima or minima, is

One-half wave length since

$\beta z = n\pi \qquad z = \frac{n\pi}{\beta} = \frac{n\pi}{2\pi/\lambda} = n\lambda/2$

1. when $V_+ \neq 0$ & $V_- = 0$, the standing-wave becomes $V_0 = V_+ e^{-\alpha z}$
2. $V_+ = 0$ and $V_- \neq 0$, then $V_0 = V_- e^{\alpha z}$ (fig 2)
3. both are equal, $V_s = 2V_+ e^{-\alpha z} \cos(\beta z)$ and called as pure standing wave. (fig 3)

3a. Derive Scattering Parameters for a multiport network.

Ans. Incident & Reflected amplitude of microwaves at any port are used to characterise a microwave circuit. The amplitude are normalised in such a way that the square of any of these variables gives the average power in that wave in the following manner.

Input power at nth port = $P_{in} = \frac{1}{2}|a_n|^2$

Reflected Power at nth port = $P_{rn} = \frac{1}{2}|b_n|^2$

where $a_n$ & $b_n$ represent the peak amplitudes. we can exp- normalised amplitude interms of normalised voltage.

$$a_1 = \frac{V_1^+}{\sqrt{Z_0}} = \frac{V_1 - V_1^-}{\sqrt{Z_0}}, \quad a_2 = \frac{V_2^+}{\sqrt{Z_0}} = \frac{V_2 - V_2^-}{\sqrt{Z_0}}$$

$$b_1 = \frac{V_1^-}{\sqrt{Z_0}} = \frac{V_1 - V_1^+}{\sqrt{Z_0}}, \quad b_2 = \frac{V_2^-}{\sqrt{Z_0}} = \frac{V_2 - V_2^+}{\sqrt{Z_0}}$$

hence the total voltage will be some of Incident & Reffecte

$$V_1 = V_1^- + V_1^+$$
$$V_2 = V_2^- + V_2^+$$



The total Power flow in any port is given by

$$P = P_i - P_r = \frac{1}{2}(|a|^2 - |b|^2)$$

Characteristic impedance is normalised to unity, for a two-port net the relation between incident and reflected waves are expressed interms of scattering parameter

$$b_1 = S_{11} a_1 + S_{12} a_2$$
$$b_2 = S_{21} a_1 + S_{22} a_2$$

The physical significance of parameter can be discribed as follows.

$S_{11} = (b_1/a_1)_{a_2=0}$ = reflection coeffient $\tau_1$ at Port 1 / Prot 2 is off

$S_{22} = (b_2/a_2)_{a_1=0}$ = reflection coeffient $\tau_2$ at Port 2 / Port 1 is off

$S_{12} = (b_1/a_2)_{a_1=0}$ = attenuation of wave travelling from Port 2 to Po

$S_{21} = (b_2/a_1)_{a_2=0}$ = attenuation of wave travelling from Port 1 to Po

for N port it will be written as.

$$\begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_N \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1N} \\ S_{21} & S_{22} & \cdots & S_{2N} \\ \vdots & & & \\ S_{N1} & S_{N2} & \cdots & S_{NN} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_N \end{bmatrix}$$

insertion Loss (dB) $= 10 \log\left(\frac{P_i}{P_o}\right) = 10 \log\left(\frac{|a_1|^2}{|b_2|^2}\right)$
$= 20 \log\left(\frac{1}{|S_{21}|}\right) = 20 \log\left(\frac{1}{|S_{12}|}\right)$

Transmission loss(dB) $= 10 \log\left(\frac{P_i - P_r}{P_o}\right) = 10 \log\left(\frac{1-|S_{11}|^2}{|S_{12}|^2}\right)$

Reflection Loss(dB) $= 10 \log \frac{P_i}{P_i - P_r}$

Return loss (dB) $= 10 \log\left(\frac{P_i}{P_r}\right) = 20 \log \frac{1}{|\tau|} = 20 \log \frac{1}{|S_{11}|}$

The transmission lines of characteristics impedances $Z_1$ and $Z_2$ are joined at plane PP'. Express S-parameters in terms of impedances.

+ The reflection coefficient at the junction, which is $S_{11}$ and $S_{22}$, can be calculating using the formula for the reflection coefficient on transmission line terminated with a load impedance,

$$\tau = \frac{(Z_L - Z_0)}{(Z_L + Z_0)} \longrightarrow ①$$ applying to the junction.

$Z_L = Z_2$ $Z_0 = Z_1$, considering Reflection at port 1 to port 1.

$$S_{11} = \frac{Z_2 - Z_1}{Z_2 + Z_1} \longrightarrow ②$$

Similly @ port 2 to port 2

$$S_{22} = \frac{Z_1 - Z_2}{Z_1 + Z_2} \longrightarrow ③$$

* Transmission coffients $S_{21}$ and $S_{12}$ represented as, if lines are lossless and perfectly matched.

$$S_{21} = 1 + S_{11}$$
$$= 1 + \frac{Z_2 - Z_1}{Z_2 + Z_1} = \frac{Z_2 + \cancel{Z_1} + Z_2 - \cancel{Z_1}}{Z_2 + Z_1} = \frac{2Z_2}{Z_2 + Z_1} \longrightarrow ④$$

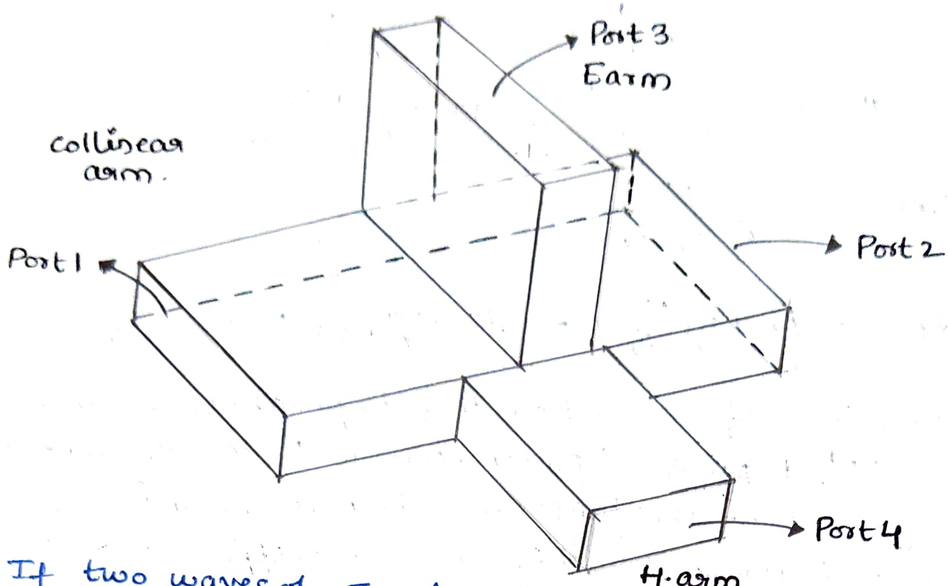
$$S_{12} = 1 + S_{22}$$
$$= 1 + \frac{Z_1 - Z_2}{Z_1 + Z_2} = \frac{Z_1 + \cancel{Z_2} + Z_1 - \cancel{Z_2}}{Z_1 + Z_2} = \frac{2Z_1}{Z_2 + Z_1} \longrightarrow ⑤$$

from Eqs ②, ③, ④ & ⑤. S-matrix will be written as.

$$[S] = \begin{bmatrix} \frac{Z_2 - Z_1}{Z_2 + Z_1} & \frac{2Z_1}{Z_2 + Z_1} \\ \frac{2Z_2}{Z_2 + Z_1} & \frac{Z_1 - Z_2}{Z_1 + Z_2} \end{bmatrix}$$

Q4a Derive S-Matrix for Magic Tee with neat diagram and applicatio. [15']

Ans:




1. If two waves of Equal Magnitude and phase are fed into Port 1 and Port 2 the output at port 3 is subtractive and become zero and total output will appear additively at the port 4.
2. wave ~~apr~~ incident at port 3 divide equally between 1 & 2 but its opposite phase. with no coupling at Port-4.
   i.e $S_{13} = -S_{23}$, $S_{43} = 0$.
3. A wave incident at Port-4 divide equally between 1 & 2 in phase with no coupling at Port-3.
   i.e $S_{14} = S_{24} \Rightarrow S_{41} = S_{42}$ and $S_{34} = 0$.
4. A wave fed into collinear arm 1 & 2 will not appear in the other collinear arm port 2 & 1 respectively.
   i.e $S_{12} = S_{21} = 0$.

Ideal lossless Magic-T $S_{33} = S_{44} = 0$.

$S_{14} = S_{41} = S_{24} = S_{42}$

$S_{13} = S_{31} = -S_{23} = -S_{32}$

i.e $[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{12} & S_{22} & -S_{13} & S_{14} \\ S_{13} & -S_{13} & 0 & 0 \\ S_{14} & S_{14} & 0 & 0 \end{bmatrix}$

applying unitary property 1 & 2, 3 and 4. } Derivation required

$$S = \begin{bmatrix} 0 & 0 & 1/\sqrt{2} & 1/\sqrt{2} \\ 0 & 0 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & 1 \\ 1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 \end{bmatrix}$$

Applications.

1. Used as microwave discriminator, Microwave bridge, Duplexer.
2. Used to isolate sensitive receiver from high power transmitter.
3. Included in controlling system pressure, regulating flow, and diverting and blending liquids.

b. Explain the working of precision Dielectric Rotary phase shifter. (4)

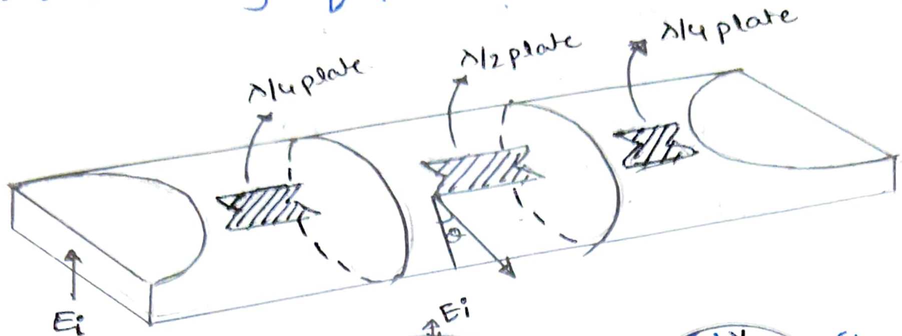
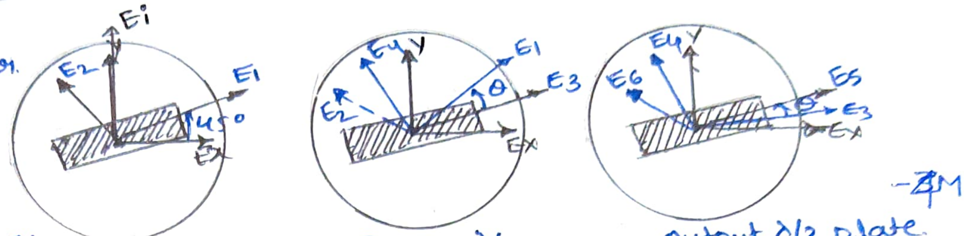



Fig. Precision phase shifter.




– 4M

$E_1 = E_i \cos 45° \, e^{-j\beta_1 l} = E_0 \, e^{-j\beta_1 l}$

$E_2 = E_i \sin 45° \, e^{-j\beta_2 l} = E_0 \, e^{-j\beta_2 l}$

where $E_0 = E_i/\sqrt{2}$, $(\beta_1 - \beta_2) l = 90°$

$E_3 = (E_1 \cos\theta - E_2 \sin\theta) e^{-j2\beta_2 l}$

$E_4 = (E_2 \cos\theta + E_1 \sin\theta) e^{-j\beta_2 l}$

$E_5 = (E_3 \cos\theta + E_4 \sin\theta) e^{-j\beta_1 l}$

$E_6 = (E_4 \cos\theta + E_3 \sin\theta) e^{-j\beta_2 l}$

{all Explination} – 6M

a. Discuss the operation of micro strip lines with its structure. Compare strip line and microstrip line.

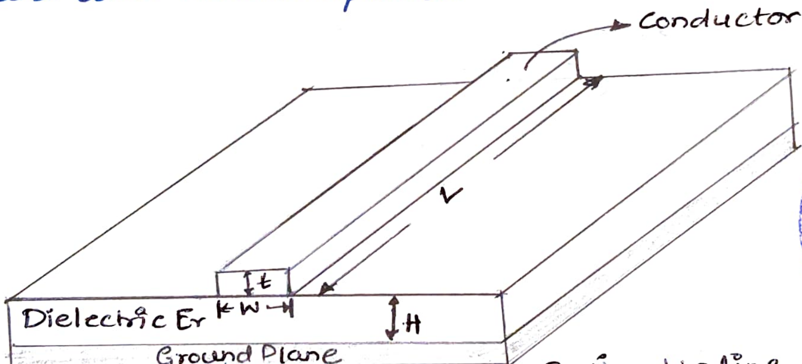



fig Microstrip line

Consists of a conductive strip on top of a dielectric substrate, with a ground plane on the other side.

Structure → Conducting strip, Dielectric Substrate, Ground Plane {Explination}

Operation:

1. Quasi-TEM Mode
2. Wave Propagation
3. Impedance.
4. Discontinuities

} Explain all

| Strip line | Microstrip line |
|---|---|
| 1. Higher dielectric loss | 1. Lower dielectric loss. |
| 2. Lower radiation Loss | 2. Higher radiation loss. |
| 3. The conductor is sandwiched b/n two dielectric layers, with ground planes on both sides of the dielectric layer. | 3. The single conductor is placed on the outer layer of PCB. with a ground plane underneath the structure. |
| 4. Slower signal propagation | 4. faster Signal propagation. |

5b. Explain the operation of parallel strip line along with a neat diagram. write down the expression for characteristics impedance

Ans: A parallel strip line is similar to a two conductor transmission line it support quasi TEM mode. it is formed by two conducting strips with one strip grounded, both being placed on the same substrate surface, for convenient connections.

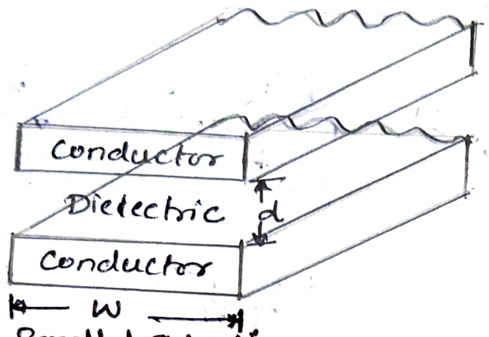


fig. Parallel strip line

Expression for character Impedance

$$Z_0 = \frac{30\pi}{\sqrt{\epsilon_r}} \frac{b}{w_e + 0.441b}$$

for $\frac{w}{b} < 0.35$ and $t/b < 0.25$

$$Z_0 = \frac{60}{\sqrt{\epsilon_r}} \ln\left(\frac{4b}{\pi d_0}\right) \text{ for } \frac{w}{b} \geq 0.35$$

6a. Explain following terms as related to antenna system.
(i) Directivity and gain (ii) Beam Area (iii) Effective height (iv) Bandwidth

Ans: (i) Directivity and gain: Directivity of an antenna is equal to the ratio of the maximum power density $P(\theta,\phi)_{max}$ (watts/m²) to its average value over a sphere as observed in the far field of an antenna,

$$D = \frac{P(\theta,\phi)_{max}}{P(\theta,\phi)_{av}}.$$

The gain G of an antenna is less than the directivity D, and ratio of the gain to the diretivity is the antenna efficiency factor.

$$G = KD.$$

(ii) Beam Area: It is the solid angle through which all of the power radiated by the antenna would stream if $P(\theta,\phi)$ maintained its maximum value over $\Omega_A$ and was zero elsewhere, thus the power radiated $P(\theta,\phi)$

$$\Omega_A = \iint_{4\pi} P_n(\theta,\phi)\, d\Omega \quad \text{--- (sr)}.$$

(iii) Effective Height: Defined as the ratio of the induced voltage to the incident field. $h = \frac{V}{E}$ also. $h_e = \frac{1}{I_0}\int_0^{h_p} I(z)\,dz = \frac{I_{av}}{I_0} h_p$. {Explination

(iv) Bandwidth:

6b. A Radio link has a 15W transmitter connected to an antenna of 2.5 m² Effective aperture at 5GHz, The receiving antenna has an Effective aperture 0.5m² and located 15km line of sight distance from the transmitting antenna. Assuming loss less, matched antenna, find the power delivered to the receiver.

Ans. Given data

$P_t = 15W$

$A_{et} = 2.5m^2$

$f = 5GHz \Rightarrow \lambda = 0.06\,m.$

$A_{er} = 0.5m^2$

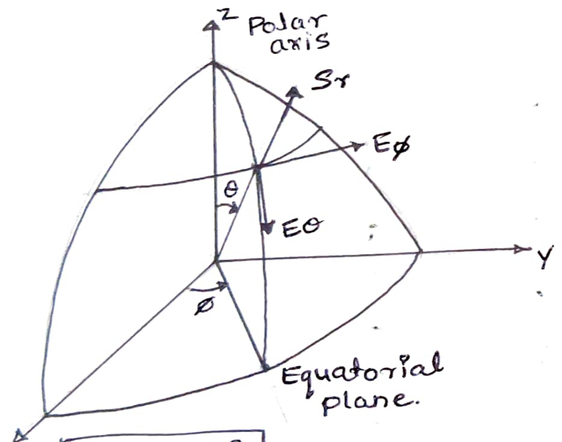
$r = 15Km.$



Soln $$P_r = \frac{P_t A_{er} A_{et}}{r^2 \lambda^2} = \frac{15 \times 2.5 \times 0.5}{15^2 \times 10^6 \times 0.06^2} = 23\,\mu W$$

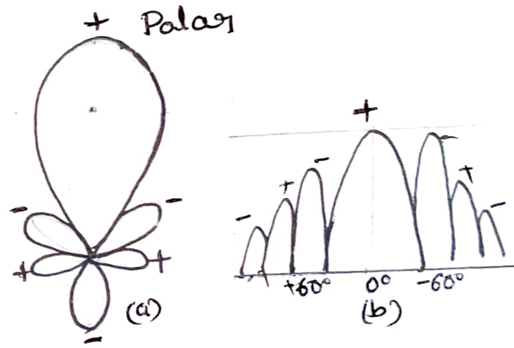
7a. Explain the field pattern and phase pattern with neat diagram.

A pattern showing the variation of electric field intensity at a constant radius r as a function of angle $(\theta, \phi)$ is called a field pattern.




$$\boxed{S_r = \frac{1}{2}\frac{E^2}{Z}}$$

fig. Field Pattern.

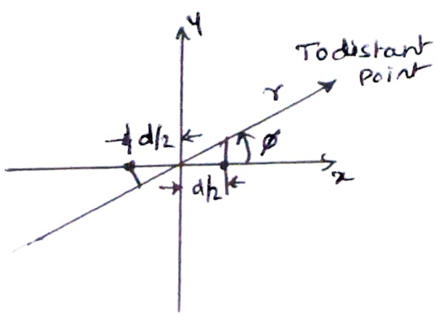


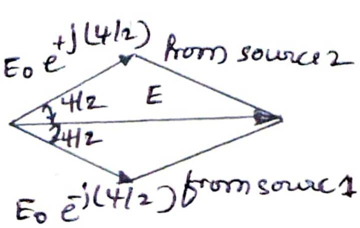

(a) Polar power pattern

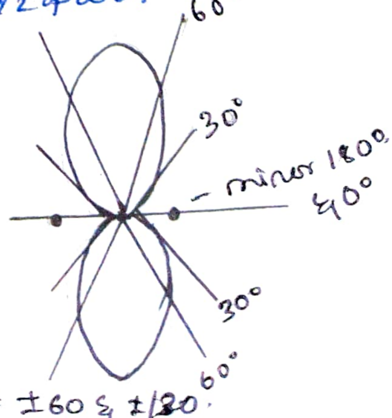
(b) Alternate phasing of pattern loss.

A Phase pattern reffers to the variation of phase values across elements in a system used to control the signal direction, shape or properties. It defines how the phase of individual components or signals changes over time, space or frequency.

7b Derive an Expression and draw the field Pattern for an array of two isotropic point sources situated symmetrical with respect to origin with equal amplitude and phase spaced $\lambda/2$ apart.




(Explain Diagram)

HPBW = ±60 & ±120.

$d_r = \frac{2\pi d}{\lambda} = \beta d.$

$E = E_0 e^{-j\psi/2} + E_0 e^{+j\psi/2}$

where $\psi = d_r \cos\phi$ amplitude of the component at distance r is given by $E_0$.

$$E = 2E_0 \frac{e^{j\psi/2} + e^{-j\psi/2}}{2}$$

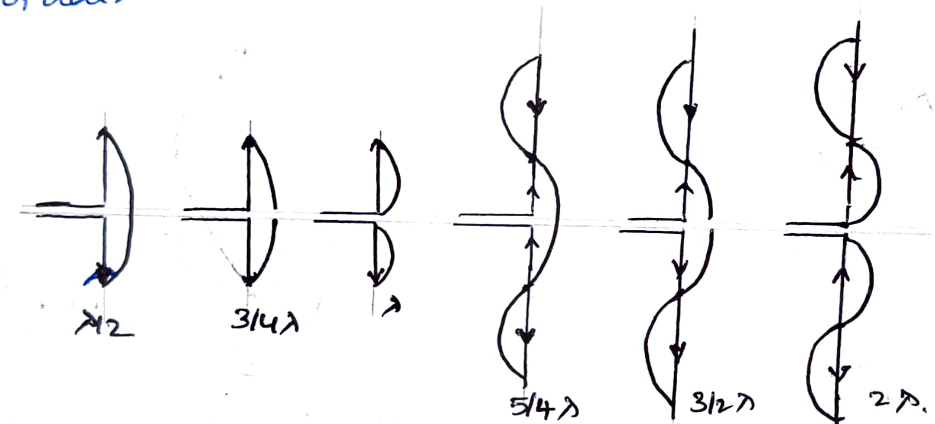
i.e $E = 2E_0 \cos \psi/2 = 2E_0 \cos\left(\frac{d_r}{2}\cos\phi\right)$. (Explain als

8a. Derive an Expression for field of a dipole in general for the case of thin linear antenna.

Ans: When the conductor diameter is less than $\lambda/100$ is called as thin Linear Antenna.

It is assumed that the antenna are symmetrically fed at the centre by a balanced two-wire transmission line. The antennas may be of any length but it is assumed that the current distribution is sinusoidal.

i.e.




far field Eqn for a thin linear antena

$$[I] = I_0 \sin\left[\frac{2\pi}{\lambda}\left(\frac{L}{2} \pm z\right)\right] e^{j\omega[t-(r/c)]}$$

$\frac{L}{2} + z$ is used when $z < 0$

$\frac{L}{2} - z$ is used when $z > 0$

$$H_\phi = \frac{j[I_0]}{2\pi r}\left[\frac{\cos[(\beta L\cos\theta)/2] - \cos(\beta L/2)}{\sin\theta}\right]$$

$$E_\theta = \frac{j60[I_0]}{r}\left[\frac{\cos[(\beta L\cos\theta)/2] - \cos(\beta L/2)}{\sin\theta}\right]$$

3b. Find the directivity D for the sources with radiation intensity.

(i) $U = U_m \sin^2\theta, 0 \le \theta \le \pi, 0 \le \phi \le 2\pi$.

(ii) $U = U_m \cos^2\theta, 0 \le \theta \le \pi/2, 0 \le \phi \le 2\pi$.

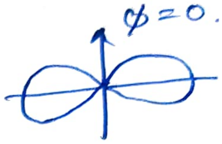
(i) $U = U_m \sin^2\theta, 0 \le \theta \le \pi, 0 \le \phi \le 2\pi$

$$P = U_m \int_0^{2\pi} \int_0^{\pi} \sin^3\theta \, d\theta \, d\phi = \frac{8}{3}\pi U_m$$

If P is the same as for the isotropic source.

$$\frac{8}{3}\pi U_m = 4\pi U_0.$$

$$\text{Directivity} = \frac{U_m}{U_0} = \frac{3}{2} = \underline{\underline{1.5}}$$



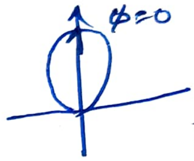

– 5M

(ii) $U = U_m \cos^2\theta, 0 \le \theta \le \pi, 0 \le \phi \le 2\pi$.

$$P = U_m \int_0^{2\pi} \int_0^{\pi/2} \cos^2\theta \sin\theta \, d\theta \, d\phi. = \frac{2}{3}\pi U_m$$

$$\frac{2}{3}\pi U_m = 4\pi U_0 \text{ and,}$$

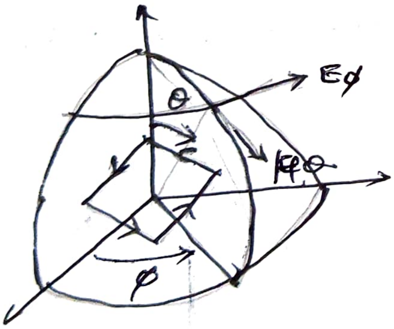
$$\text{Directivity} = \frac{U_m}{U_0} = 6$$




– 5M.

a. Derive an expression for field strength $E_\phi$ and $H_\phi$ in case of small loop antenna.

Ans: The field pattern of a small circular loop of radius a may be determined very simply by considering a square loop of the same area, that is. $d^2 = \pi a^2$. where d = side length of the small loop




$$E_\phi = -E_{\phi 0} e^{j\psi/2} + E_{\phi 0} e^{-j\psi/2}$$
$$= -E_{\phi 0} (e^{j\psi/2} - e^{-j\psi/2})$$
$$= -2j E_{\phi 0} \sin(\psi/2)$$

where $\psi = \frac{2\pi d}{\lambda} \sin\theta = d_r \sin\theta$.

$$E_\phi = -2j E_{\phi 0} \sin\left(\frac{d_r}{2} \sin\theta\right)$$ } Derivation.

$$E_\phi = \frac{120\pi^2 [I] \sin\theta}{r} \frac{A}{\lambda^2}$$ – $E_\phi$ field

$$H_\theta = \frac{E_\phi}{120\pi} = \frac{\pi [I] \sin\theta}{r} \frac{A}{\lambda^2}$$ – $H_\theta$ field

9b. Derive an Expression for radiation resistance of a small loop antenna.

Ans: To find the radiation resistance of loop antenna, the Poynting vector is integrated over a large sphere yielding the total power radiated. This power is then equated to the square of the effective current on the loop times the resistance $R_r$ (Foster-17).

$$P = \frac{I_0^2}{2} R_r \longrightarrow (1)$$

average Poynting vector of a far field

$$S_r = \frac{1}{2}|H|^2 \operatorname{Re} Z.$$

$$S_r = \frac{15\pi(\beta a I_0)^2}{r^2} J_1^2(\beta a \sin\theta)$$

$$P = \iint S_r\, ds = 15\pi(\beta a I_0)^2 \int_0^{2\pi}\int_0^{\pi} J_1^2(\beta a \sin\theta)\sin\theta\, d\theta\, d\phi$$

} derivation

$$\boxed{P = 10\beta^4 A^2 I_0^2}$$



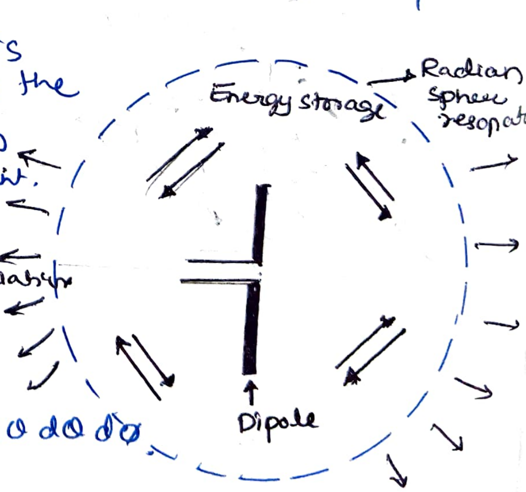
$$\frac{R_r I_0^2}{2} = 10\beta^4 A^2 I_0^2$$

Small loop $R_r = 31,171\left(\frac{A}{\lambda^2}\right)^2 = 197 C_\lambda^4$ ---- $\Omega$

for n-loop $R_r = 31,200\left(\frac{nA}{\lambda^2}\right)^2$ ---- $\Omega$

10a. Derive an Expression for Radiation Resistance of a short dipole antenna.

Ans: The poynting vector of the far field is integrated over a large sphere to obtain the total power radiated. This power is then equated to $I^2R$ where I is the rms current.




$$S = \frac{1}{2}\operatorname{Re}(E \times H^*)$$

$$S_r = \frac{1}{2}\operatorname{Re} Z H_\phi H_\phi^* = \frac{1}{2}|H_\phi|^2\sqrt{\frac{\mu}{\varepsilon}}$$

The total Power P,

$$P = \iint S_r\, ds = \frac{1}{2}\sqrt{\frac{\mu}{\varepsilon}}\iint |H_\phi|^2 r^2 \sin\theta\, d\theta\, d\phi$$

$$H_\phi = \frac{\omega I_0 L \sin\theta}{4\pi c r}$$

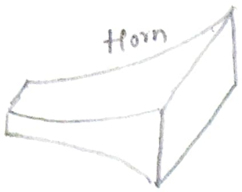
$$P = \sqrt{\frac{\mu}{\varepsilon}}\frac{\beta^2 I_0^2 L^2}{12\pi}.$$

comparing for $R_r$.

$$\sqrt{\frac{\mu}{\varepsilon}}\frac{\beta^2 I_0^2 L^2}{12\pi} = \left(\frac{I_0}{\sqrt{2}}\right)^2 R_r$$

$$R_r = \sqrt{\frac{\mu}{\varepsilon}}\ \frac{\beta^2 L^2}{6\pi}.$$

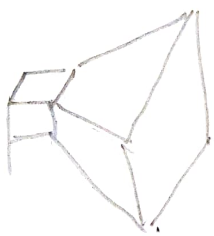
10b. Explain the different types of horn antenna with diagram.




(a) Exponential tapered pyramidal

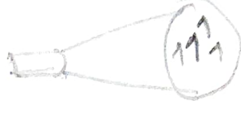
(b) Sectoral H-plane

(c) Sectoral E-plane



(d) pyramidal

(e) Exponentially tapered



(f) conical

(g) TEM biconical

(h) TE01 biconical.