Staff Name: Prof. Plasin. Francis Dias.

Subject : Microwave and Antennas -

Subject code : 18EC63

Sem : 6

Max. Marks : 100

Head of the Department
Dept. of Electronic & Communication Engg.
KLS V.D.I.T., HALIYAL (U.K.)

Reference Question Paper. MWA - 18EC63

CBCS SCHEME

USN 15EC71

Seventh Semester B.E. Degree Examination, Dec.2018/Jan.2019

Microwaves and Antennas

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. 2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Derive the general transmission line equation to find voltage and current on the line interms of position 'z' and time 't'. (07 Marks)

b. Describe the different mode curve in the case of reflex klystron. (05 Marks)

c. A transmission line has a characteristic impedance of $50 + j0.01\Omega$ and terminated in a load impedance of $73 - j42.5\Omega$ calculate : i) reflection coefficient ii) SWR. (04 Marks)

OR

2 a. Define relection coefficient. Derive the equation for reflection coefficient at the load end at a distance 'd' from the load. (06 Marks)

b. Describe the mechanism of oscillation of reflex klystron. (06 Marks)

c. A transmission line has the following parameters : $R = 2\Omega/m$, $G = 0.5$mmho/m, $f = 1$GHz, $L = 8$nH/m, $C = 0.23$pF/m. Calculate : i) characteristic impedance ii) propagation constant. (04 Marks)

Module-2

3 a. State and explain the properties of S – matrix. (07 Marks)

b. With a neat diagram, explain the working of precession type variable attenuator. (06 Marks)

c. A 20mW signal is fed into one of the collinear port 1 of a lossless H-plane T junction. Calculate the power delivered through each port when other ports are terminated in matched load. (03 Marks)

OR

4 a. What is magic Tee? Derive its scattering matrix. (06 Marks)

b. Discuss different types of coaxial connectors. (04 Marks)

c. 2 transmission lines of characteristic impedance Z_1 and Z_2 are joined at plane PP'. Express S–parameters in terms of impedance when each line is matched terminated. (06 Marks)

Module-3

5 a. Explain the construction and field pattern for microstrip line. (06 Marks)

b. Explain the following terms as related to antenna system :
i) directivity ii) beam efficiency iii) effective aperture. (06 Marks)

c. The effective apertures of transmitting and receiving antennas in a communication system are $8\lambda^2$ and $12\lambda^2$ respectively. With a separation of 1.5km between them. The EM wave travelling with frequency of 6 MHz and the total input power is 25KW. Find the power received by the receiving antenna. (04 Marks)

OR

6 a. Explain co-planar strip line and shielded strip line. (06 Marks)
b. Write a note on antenna field zones. (06 Marks)
c. An antenna has a field pattern given by $E(\theta) = \cos^2\theta$ for $0 \le \theta \le \pi/2$. Find the beam area and directivity. (04 Marks)

Module-4

7 a. Derive an expression and draw the field pattern for an array of 2 isotropic point sources with same amplitude and phase spaced $\lambda/2$ apart. (06 Marks)
b. Show that the radiation resistance of $\lambda/2$ antenna is 73Ω. (06 Marks)
c. A source has a radiation –intensity power pattern given by $U = U_m \sin^2\theta$ for $0 \le \theta \le \pi$; $0 \le \phi \le 2\pi$. Find the total power and directivity. Draw pattern. (04 Marks)

OR

8 a. Derive the expressions for the far field components of short dipole. (06 Marks)
b. Explain the principle of pattern multiplication with an example. (06 Marks)
c. A source has a cosine radiation intensity pattern given by $U = U_m \cos\theta$ for $0 \le \theta \le \pi/2$ and $0 \le \phi \le 2\pi$. Find the total power and directivity. (04 Marks)

Module-5

9 a. Derive the expression for strength $E\phi$ and $H\theta$ in case of small loop. (06 Marks)
b. Explain the working and design considerations of Log-periodic antenna. (06 Marks)
c. A 16-turn helical beam antenna has a circumference of λ and turn spacing of $\lambda/4$. Find . i) HPBW ii) axial ratio iii) directivity. (04 Marks)

OR

10 a. Show that the radiation resistance of small loop is $31171\left(\frac{A}{\lambda^2}\right)^2$. (05 Marks)
b. Write a short notes on :
i) Yagi Uda array ii) parabolic reflector. (06 Marks)
c. Determine the length L, H-plane aperture and flare angles θ_E and θ_H of a pyramidal horn for which the E-plane aperture $a_E = 10\lambda$. Let $\delta = 0.2\lambda$ in the E-plane and 0.375λ in the H-plane. Also determine beam widths and directivity. (05 Marks)

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Microwaves and Antennas - 18EC63

Sem: 6

Time 3 hrs

Max. Marks 100

Note: Answer any five full questions.

Module - 1

1 (a) Derive the general transmission line equation to find voltage and current on the line interms of position z & time t (8M)

(b) Describe the different mode curve in the case of reflex klystron (6M)

(c) A transmission line has characteristic impedance of $50 + j0.01\,\Omega$ and Terminated in a load impedance of $73 - j42.5\,\Omega$. Calculate (i) reflection coefficient (ii) SWR (6M)

OR

2 (a) Define Reflection coefficient, Derive the equation for reflection coefficient at the load end and at a distance 'd' from the load. (8M)

(b) Describe the mechanism of oscillation of Reflex Klystron (8M)

(c) A transmission line has following parameters.

$R = 2\,\Omega/m$ $G = 0.5\,m\text{mho}/m$ $f = 1\,GHz$ (6M)

$L = 8\,nH/m$ $C = 0.23\,pF$

Calculate (a) the characteristic impedance

(b) Propagation constant.

(i) $Z_0 = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}} = \sqrt{\dfrac{2 + j2\pi \times 10^9 \times 8 \times 10^{-9}}{0.5 \times 10^{-3} + j2\pi \times 10^9 \times 0.23 \times 10^{-12}}}$

$= 181.39 \angle 8.40^\circ = 179.44 + j26.50.$

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

$= \sqrt{(50.31 \angle 87.72^\circ)(15.29 \times 10^{-4} \angle 70.91^\circ)}$

$= 0.2774 \angle 79.31^\circ = 0.051 + j0.273$

Module - 2

3 (a) State and explain properties of S matrix. (6M)

(b) With the neat diagram explain the working of precision type variable attenuator (8M)

(c) A 20 mW signal is fed into one of the collinear port of a lossless H plane T junction. Calculate the power delivered through each port when other ports are terminated in matched load. (6M)

OR

4 (a) What is Magic Tee? Derive its scattering matrix. (8M)

(b) Discuss different type of coaxial connectors (6M)

(c) Two transmission lines of characteristic impedance Z_1 & Z_2 are joined at plane pp'. Express S parameters in terms of impedance when each line is matched terminated. (6M)

Module -3

5 (a) Explain the construction and field pattern for microstripline (8M)

b) Explain following terms related to antenna system
(i) Directivity (ii) Beam efficiency (iii) Effective aperture (6M)

(c) The effective apertures of transmitting and receiving antennas in a communication system are $8\lambda^2$ and $12\lambda^2$ respectively. With a separation of 1.5 km between them. The EM wave travelling with frequency of 6 MHz and the total input power is 25 kW. find the power received by the receiving antenna. (6M)

OR

6 (a) Explain coplanar and shielded stripline. (8M)

(b) Write a note on antenna field zones (6M)

(c) An antenna has a field pattern given by $E(\theta) = \cos^2\theta$ for $0 \le \theta \le \pi/2$ find beam area and directivity.

Module 4

7 (a) Derive an expression & draw the field pattern for an array of 2 isotropic point sources with same amplitude and phase. (8m)

(b) Show that radiation resistance of $\lambda/2$ antenna is 73Ω

(c) A source has a radiation intensity power pattern given by $U = U_m \sin^2\theta$ for $0 \le \theta \le \pi$, $0 \le \phi \le 2\pi$ find the total power and directivity. Draw pattern.

OR

8 (a) Derive the expression for far field component of short dipole (8m)

(b) Explain principle of pattern multiplication with an example (6m)

(c) A source has cosine radiation intensity pattern given by $U = U_m \cos\theta$ for $0 \le \theta \le \pi/2$ & $0 \le \phi \le 2\pi$ find total power and directivity (06m)

Module 5

9 (a) Derive the expression for strength E_ϕ and H_θ in case of small loop. (8m)

(b) Explain Horn Antenna (6m)

(c) Find the radiation efficiency of 1m diameter loop of 10mm diameter copper wire at 1MHz (6m)

OR

(10) (a) Show that radiation resistance of small loop is $31171\left(\frac{A}{\lambda^2}\right)^2$.

(b) Write short note on (i) Yagi Uda Array
(ii) Parabolic Reflector.

(c) The radius of circular loop Antenna is 0.02λ. How many turns will give a radiation resistance of 35Ω.

18EC63. Solution Max. Marks : 100

Diagram : 03M

1 a) General Transmission line Equation to find Voltage and current on the line, interms of z & t.

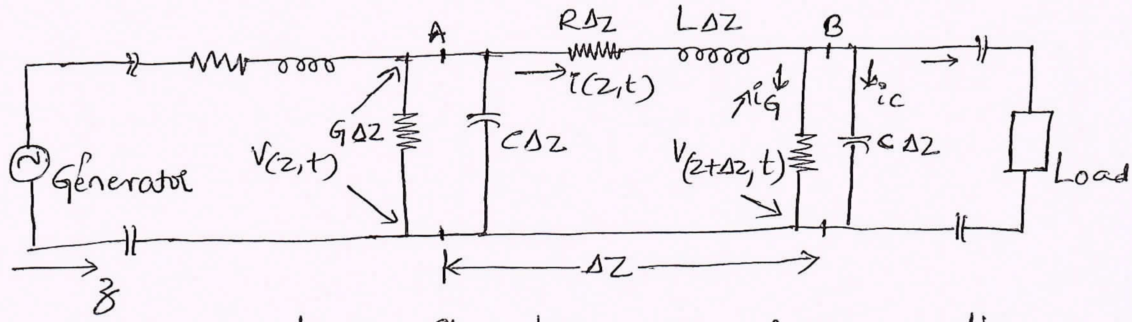


fig 1. Elementary section of transmission line

Equation : 03M

KVL

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

$\div \Delta z$

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

KCL

$$i(z,t) = v(z+\Delta z,t)G\Delta z + C\Delta z \frac{\partial v(z+\Delta z,t)}{\partial t} + i(z+\Delta z,t)$$

$$= \left[v(z,t) + \frac{\partial v(z,t)}{\partial z}\Delta z\right]G\Delta z + C\Delta z\frac{\partial}{\partial t}\left[v(z,t) + \frac{\partial v(z,t)}{\partial z}\Delta z\right] + i(z,t) + \frac{\partial i(z,t)}{\partial z}\Delta z$$

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

$$\frac{\partial^2 v}{\partial z^2} = RGv + (RC+LG)\cdot\frac{\partial v}{\partial t} + LC\frac{\partial^2 v}{\partial t^2}$$

Solution: 2M

$$\frac{\partial^2 i}{\partial z^2} = RGi + (RC+LG)\frac{\partial i}{\partial t} + LC\frac{\partial^2 i}{\partial t^2}$$

$\boxed{8M}$

$$v(z,t) = Re\ V(z)\cdot e^{j\omega t}$$

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

$$V(z) = V_+ e^{-\gamma z} + V_- e^{\gamma z}$$

$$I(z) = I_+ e^{-\gamma z} + I_- e^{\gamma z}$$

$$\gamma = \alpha + j\beta$$

1 (b) Mode curve of Reflex Klystron

Diagram : 3M
Explanation Equation : 3M
$\boxed{6M}$

$T \leftarrow$ time period at resonant frequency
$t_0 \leftarrow$ time taken by reference electron

$$t_0 = \left(n + \frac{3}{4}\right)T = NT$$

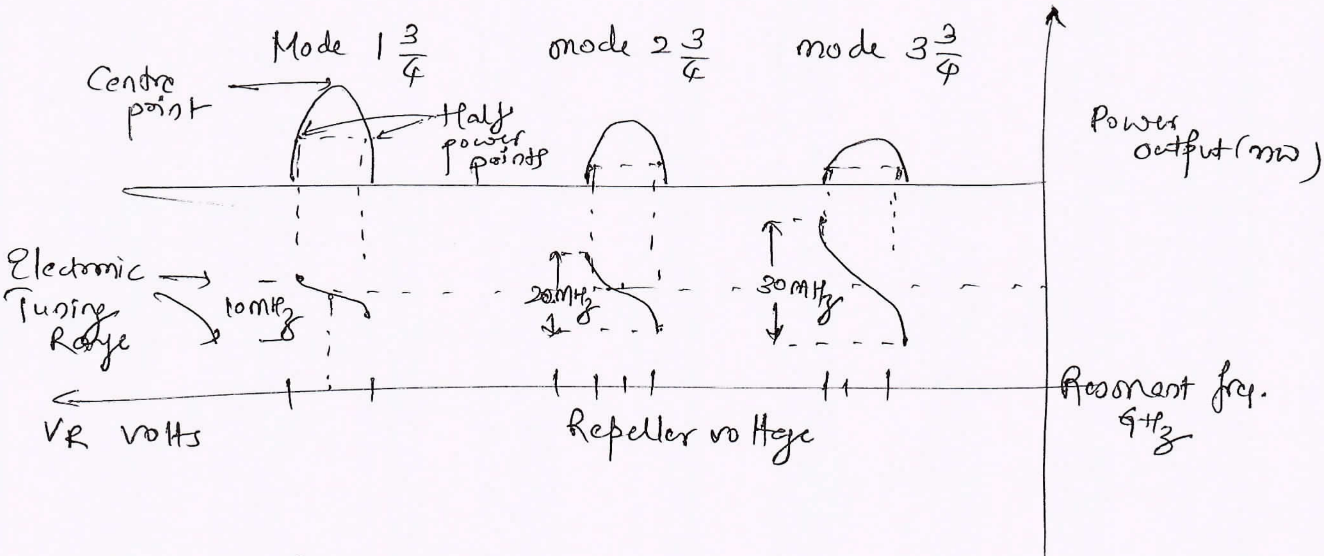
$$\boxed{N = n + \frac{3}{4}}, \quad n = 0, 1, 2, 3, 4 \ldots$$

Mode of oscillation

$$N = \frac{3}{4},\ 1\frac{3}{4},\ 2\frac{3}{4} \text{ etc}$$

for modes $n = 0, 1, 2, 3, \ldots$

Output power and frequency controlled by repeller voltage.
lowest order mode : $\frac{3}{4}$, maximum value of repeller voltage.
$t_0 \leftarrow$ minimum
Higher mode occur at lower repeller voltage



1(c) $Z_0 = 50 + j0.01\,\Omega$
$Z_L = 73 - j42.5\,\Omega$

Data : 1M
formula : 2M
Solution : 3M
$\boxed{6M}$

→ Reflection coefficient

$$\Gamma = \frac{Z_l - Z_0}{Z_l + Z_0} = \frac{73 - j42.5 - (50 + j0.001)}{73 - j42.5 + (50 + j0.01)}$$

$$= 0.377 \angle -42.7^\circ$$

→ SWR (standing wave ratio)

$$\rho = \frac{1 + |\Gamma|}{1 - |\Gamma|} = \frac{1 + 0.377}{1 - 0.377} = 2.21$$

Q (a) Reflection Coefficient

Reflection coefficient represented as Γ (gamma)

- Ratio of reflected voltage or current to the incident voltage or current

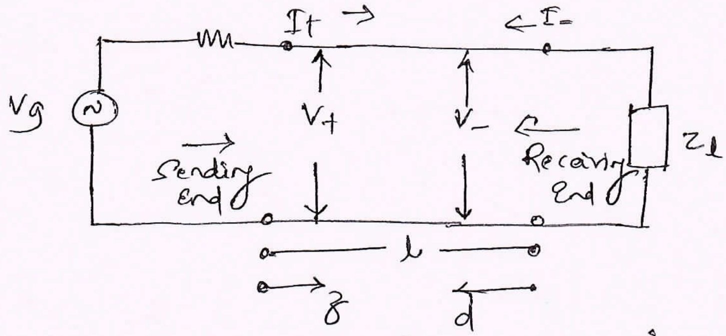
Definition : 2M

Diagram : 2M

Derivation : 4M

8M

$$\Gamma = \frac{V_{ref}}{V_{inc}} = \frac{-I_{ref}}{I_{inc}}$$



$$V = V_+ e^{-\gamma z} + V_- e^{+\gamma z}.$$

$$I = I_+ e^{-\gamma z} + I_- e^{+\gamma z}$$

$$I = \frac{V_+}{Z_0} e^{-\gamma z} - \frac{V^-}{Z_0} e^{\gamma z}$$

line length $\rightarrow l$

voltage & current at Receiving end

$$V_l = V_+ e^{-\gamma l} + V_- e^{\gamma l}$$

$$I_l = \frac{1}{Z_0}\left(V_+ e^{-\gamma l} - V_- e^{\gamma l}\right)$$

Load impedance is ratio of voltage to the current

$$Z_l = \frac{V_l}{I_l} = Z_0 \frac{V_+ e^{-\gamma l} + V_- e^{\gamma l}}{V_+ e^{-\gamma l} - V_- e^{\gamma l}}$$

Reflection Coefficient $\Gamma_l = \dfrac{V_- e^{\gamma l}}{V_+ e^{-\gamma l}} = \dfrac{Z_l - Z_0}{Z_l + Z_0}$

$$\Gamma_l = |\Gamma_l| e^{j\theta_l}.$$

$$\Gamma = \frac{V_- e^{\gamma z}}{V_+ e^{-\gamma z}}$$

- Reflection coefficient at distance 'd'.

$z = l - d$

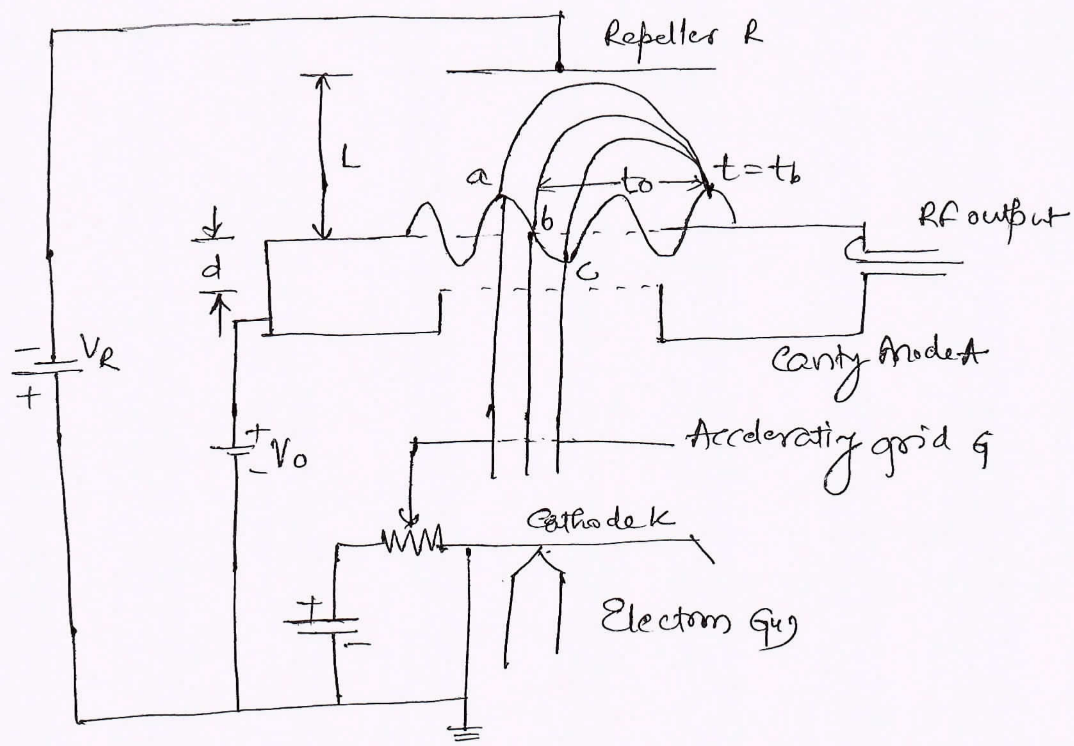
$$\Gamma_d = \frac{V_- e^{\gamma(l-d)}}{V_+ e^{-\gamma(l-d)}} = \frac{V_- e^{\gamma l}}{V_+ e^{-\gamma l}} e^{-2\gamma d}$$

2(b) Mechanism of oscillation of Reflex klystron

Diagram : 3M
Explanation : 3M

$\boxed{6M}$

- Electron through cavity gap d experiences RF field, velocity modulated.
  a ← +ve half cycle RF field, accelerated
  b ← zero RF field, unchanged velocity
  c ← -ve half cycle, retarded.



power delivered by bunched Electrons > power loss in cavity
Electromagnetic field amplitude increases, to produce Oscillation.

Data : 1M
formula : 2M
Solution : 3M.

$\boxed{6M}$

2(c) Characteristic Impedance

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} = 181.39\angle 8.40^\circ$$
$$= 179.44 + j26.50$$

γ propagation constant $= \sqrt{(R+j\omega L)(G+j\omega C)}$

$$\gamma = 0.2774\angle 79.31$$
$$= 0.051 + j0.273$$

3 (a) Properties of S matrix.

Any three

$3 \times 2M = 6M$

(i) zero diagonal elements for perfect matched network

$S_{ii} = 0$

no reflection

diagonal elements of [S] are zero.

(ii) Symmetry of [S] for reciprocal network

$S_{ij} = S_{ji} \quad (i \neq j)$ reciprocal device has same transmission characteristics.

$[S]_t = [S]$

(iii) Unitary property for a lossless junction

$$\sum_{n=1}^{N} |b_n|^2 = \sum_{n=1}^{N} |a_n|^2$$

or

$$\sum_{n=1}^{N} \left| \sum_{i=1}^{N} S_{ni} a_i \right|^2 = \sum_{n=1}^{N} |a_n|^2$$

(iv) Sum of product of each term of any row or any column of S matrix, multiplied by its complex conjugate is unity.

(iv) Phase shift property : Reference plane 1, 2

phase shift $\phi_1 = \beta_1 l_1$, $\phi_2 = \beta_2 l_2$

$$[S'] = \begin{bmatrix} e^{-j\phi_1} & 0 \\ 0 & e^{-j\phi_2} \end{bmatrix} [S] \begin{bmatrix} e^{-j\phi_1} & 0 \\ 0 & e^{-j\phi_2} \end{bmatrix}$$

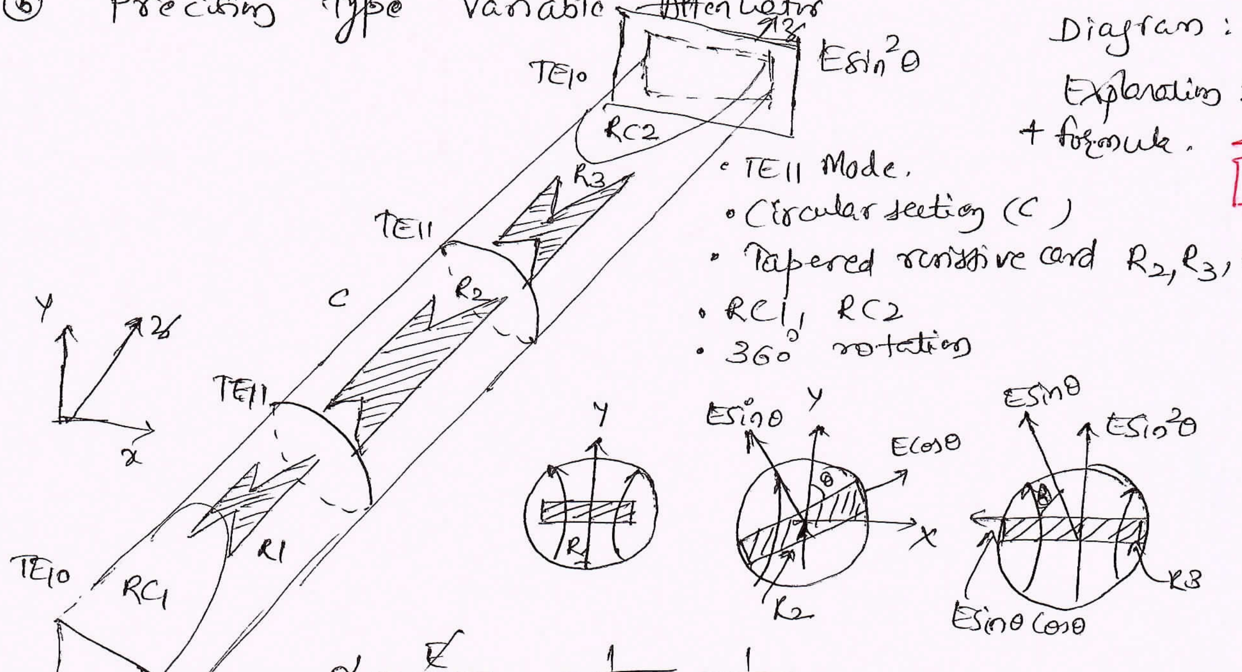
3 (b) Precision type variable Attenuator

Diagram : 3M

Explanation : 5M

+ formula.

8M



- TE11 Mode.
- Circular section (C)
- Tapered resistive card R_2, R_3, R_1
- RC1, RC2
- 360° rotation

$$\alpha = \frac{E}{E\sin^2\theta} = \frac{1}{\sin^2\theta} = \frac{1}{|S_{21}|}$$

$$\alpha_{dB} = -40\log(\sin\theta) = -20\log|S_{21}|$$

$$[S] = \begin{bmatrix} 0 & \sin^2\theta \\ \sin^2\theta & 0 \end{bmatrix}$$

(3c) H plane Tee junction problem

Port 2 & 3 are matched terminated,

$a_2 = a_3 = 0$

$|S_{11}| = 1/2$

Total effective power input to Port 1

$$P_1 = \frac{1}{2} |a_1|^2 (1 - |S_{11}|^2)$$

$$= 20(1 - 0.5^2) = 15 \text{ mW}.$$

Power transmitted to Port 3

$$P_3 = \frac{1}{2} |a_1|^2 |S_{31}|^2$$

$$= 20 * (1/\sqrt{2})^2 = 10 \text{ mW}$$

Power transmitted to Port 2

$$P_2 = \frac{1}{2} |a_1|^2 |S_{21}|^2$$

$$= 20 * (1/2)^2 = 5 \text{ mW}.$$

$$\boxed{P_1 = P_3 + P_2}$$

Data : 1M

Formula : 2M

Solution : 3M

$\boxed{6M}$

4 (a) Magic Tee & Scattering Matrix Derivation

Magic Tee → E & H plane Tee Combination

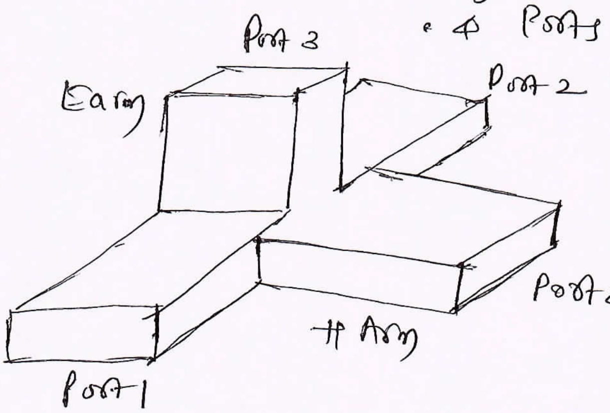
- hybrid Tee
- 4 Ports

Defn : 1M

Diagram : 3M

Derivation : 4M

$\boxed{8M}$



- characteristics 4
- difference E arm, sum H arm, & inphase waves
- E arm divides betn 1, 2, opposite phase
- H arm divides betn 1, 2, no coupling
- Wave fed to 1 or 2, not appears at 2 or 1

from 2)

$S_{13} = S_{31} = 1/\sqrt{2} = S_{24}\ S_{42}$, $S_{34} = 0$

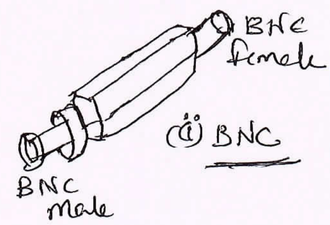
3) $S_{14} = S_{41} = 1/\sqrt{2} = S_{24} = S_{42}$, $S_{34} = 0$

(4) $S_{12} = S_{21} = 0$

4b. Coaxial Connectors.

List of connectors : 2M
Any two explanation
$2 \times 2 = 4M$
$\boxed{6M}$

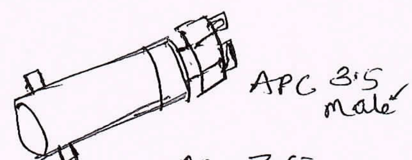
- N male / female (Navy connector)
- BNC (Male / female)
- TNC (Male / female)
- APC
- ~~SMA~~ Sub miniature A
- APC-7 Amphenol Precision connector.
- APC-3.5



(ii) BNC

(i) APC 3.5

Developed by Hewlett Packard
34 GHz operating frequency
VSWR → Low
Repeatable connection
$Z_0 = 50\,\Omega$
Male connector



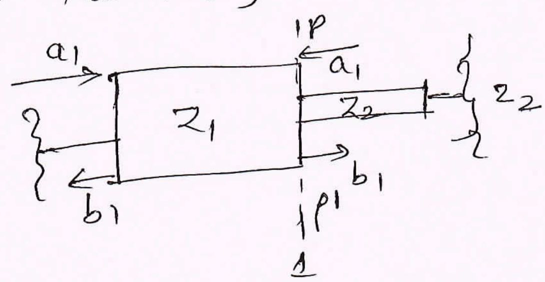
APC 3.5

(ii) BNC

Bayonet Navy connector
Developed during World War II
- 50 to 75 Ω, Z_0
- diameter 0.635 cm
- 1 GHz freq. of operation
- Upto 4 GHz usage.
- Beyond → radiating EM energy.

(4C) Two transmission line Z_1, Z_2

Diagram : 2M
Equation : 2M
Derivation : 2M
$\boxed{6M}$



$[b] = [S][a]$

(i) $S_{11} = \dfrac{Z_2 - Z_1}{Z_2 + Z_1}$

(ii) $S_{22} = \dfrac{Z_1 - Z_2}{Z_1 + Z_2} = -S_{11}$

Input line matched
$a_1 = 0, \quad b_2 = a_2 S_{22}$

(iii) $S_{12} = 2\sqrt{\dfrac{Z_1 Z_2}{Z_1 + Z_2}}$

Output line matched,
(iv) $S_{21} = \dfrac{2\sqrt{Z_2 Z_1}}{Z_2 + Z_1}$ $\quad b_1 = S_{11} a_1, \quad a_2 = 0$

$\therefore S = \begin{bmatrix} \dfrac{Z_2 - Z_1}{Z_2 + Z_1} & \dfrac{2\sqrt{Z_1}\sqrt{Z_2}}{Z_1 + Z_2} \\ 2\sqrt{Z_1 Z_2} / \ldots & Z_1 - Z_2 / Z_1 + Z_2 \end{bmatrix}$

Magic Tee,

symmetry property

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

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

$S_{34} = S_{43} = 0$, $S_{12} = S_{21} = 0$

$$\therefore [S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & -S_{13} & S_{14} \\ S_{13} & -S_{13} & 0 & 0 \\ S_{14} & S_{14} & 0 & 0 \end{bmatrix}$$

Apply unitary property row 1, 2 —— ①

$$|S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 + |S_{14}|^2 = 1$$

$$|S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2 + |S_{14}|^2 = 1$$

subtracting,

$$|S_{11}|^2 - |S_{22}|^2 = 0$$

or $|S_{11}| = |S_{22}|$

Unitary property applied to row 3, 4

$$2|S_{13}|^2 = 1 \quad \text{or} \quad |S_{13}| = 1/\sqrt{2}$$

$$2|S_{14}|^2 = 1 \quad \text{or} \quad |S_{14}| = 1/\sqrt{2}$$

Substitute in ①

$$|S_{11}|^2 + |S_{12}|^2 + 1/2 + 1/2 = 1$$

or $|S_{11}|^2 + |S_{12}|^2 = 0$

Valid if $S_{11} = S_{22} = 0$

$S_{12} = 0$

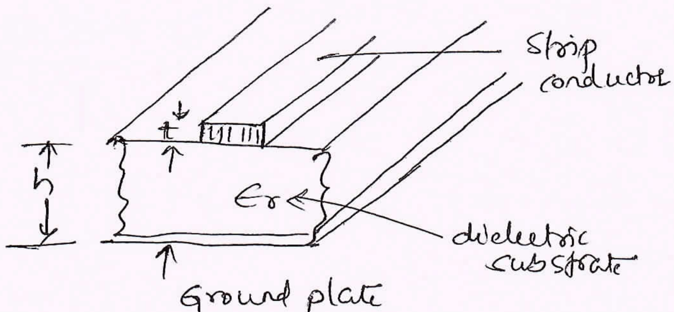
$$S = \begin{bmatrix} 0 & 0 & S_{13} & S_{13} \\ 0 & 0 & -S_{13} & S_{13} \\ S_{13} & -S_{13} & 0 & 0 \\ S_{13} & S_{13} & 0 & 0 \end{bmatrix}$$

$S_{13} = 1/\sqrt{2} = |S_{14}|$

$$\therefore [S] = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 1 & +1 \\ 0 & 0 & -1 & 1 \\ 1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 \end{bmatrix}$$

12

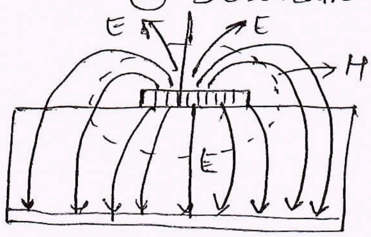
5 (a) Construction and field pattern of Microstripline



(a) Schematic Diagram

2 Diagram : 4M
Explanation : 4M
$\boxed{8M}$

- Single ground plane
- thin strip conductor
- low loss dielectric substrate
- ground plate
- Electric field lines partially in air & partially in lower dielectric substrate
- Mode of propagation Quasi TEM. or not pure TEM.
- Radiation loss $\propto$ square of frequency
- open structure, discontinuity radiates EM energy
- thin and high dielectric materials, reduces radiation loss.



(b) field Lines.

$$Z_0 = \frac{87}{\sqrt{\epsilon_r + 1.41}} \ln\left[\frac{5.98\,h}{0.8w + t}\right]$$

characteristic impedance Z_0 of the line

5 (b) (i) Directivity
(ii) Beam efficiency
(iii) Effective aperture

Defn + Explanation + Formula
$3 \times 2M = \boxed{6M}$
Each

→ (i) Directivity is ratio of radiation intensity in the direction of maximum from the antenna to the radiation intensity averaged overall direction

$$D = \frac{U_{max}}{U_{avg}} \qquad \boxed{D = \frac{4\pi}{\Omega_A}}$$

$$U_{avg} = \frac{\text{Total power radiated by antenna}}{4\pi}$$

→ (ii) Beam efficiency $\epsilon_M = \Omega_M / \Omega_A$

ratio of main beam area to the total beam area.

$\Omega_A = \Omega_M + \Omega_m$, Ω_A consists of main beam area Ω_M plus minor lobe area Ω_m

→ (iii) Effective Aperture

- Aperture of Antenna is area through which power is radiated or received.

$\lambda^2 = A_e \Omega_A$

$D = 4\pi/\lambda^2 \cdot A_e$

- describes power capturing capability
- Higher A_e, more power delivery

5 (c) $A_{et} = 8\lambda^2$

$A_{er} = 12\lambda^2$

$R = 1.5\, km$

$f = 6\, MHz$

$P_t = 25\, kW$

$P_r = ?$

$\lambda = \frac{c}{f} = \frac{3\times 10^8}{6 * 10^6}$

$= 50$

Date: 1M
Formula: 2M
Solution: 3M

$\boxed{6M.}$

$$\frac{P_r}{P_t} = \frac{A_{er}\, A_{et}}{R^2 \lambda^2}$$

$$\therefore P_r = \frac{P_t \cdot A_{er}\, A_{et}}{R^2\lambda^2}$$

$$= \frac{25 * 10^3 * 8\lambda^2 * 12\lambda^2}{(1.5 * 10^3)^2 (50)^2}$$

$$= \frac{2400\lambda^2 * 10^3 * \lambda^2}{5625 * 10^6}$$

$$= 0.4266 * 10^{3}\, \lambda^2 \cdot \lambda^2$$

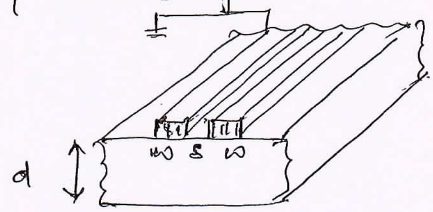
$= \underline{\underline{2.666}}$ watts $= 2.66$ kW //

6 (a) Coplanar stripline and shielded striplines

Diagram : 4M
Explanation : 4M

$\boxed{8M}$

(i) Coplanar stripline



- 2 conducting strips
- One substrate
- One strip grounded
- Convenient connections.
- reliability increased.

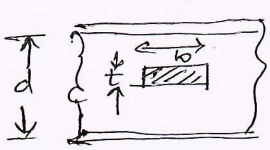
$$Z_0 = \frac{2 P_{avg}}{I_0^2}$$

$I_0 \leftarrow$ total peak current

$P_{avg} \leftarrow$ average power flow

$$P_{avg} = \frac{1}{2} Re \iint (E \times H^*) \cdot u_z \cdot dx \cdot dy$$

(ii) Shielded striplines



- stripconductor embedded in dielectric medium
- top & ground planes have no connection.

$$Z_0 = \frac{94.15}{\sqrt{\epsilon_r}} \left(\frac{w}{d} K + \frac{C_f}{8.854\epsilon_r} \right)$$

$$K = \frac{1}{1 - t/d}$$

$t \leftarrow$ strip thickness

$d \leftarrow$ distance between planes

$$C_f = \frac{8.854\epsilon_r}{\pi} \left[2K \ln (K+1) - (K-1) \ln (K^2 - 1) \right],$$

fringe capacitance pF/m.

6 (b) Antenna field Zones

Explanation
3 × 2 m = $\boxed{6m}$
zones

- space surrounding antenna is divided into 3 regions, according to field behaviour
- Boundaries between regions are not distinct
- field behaviour changes gradually

(i) Reactive near field region
- region immediate surrounding antenna
- reactive field dominates
- region is sphere, with antenna at its centre

(ii) Radiating near field (fresnel region)
- Intermediate region between near field region and far field region
- radiation field significant

(iii) far field (fraunhofer Region)

$r \lambda >> D$, $r >> \lambda$

- angular field distribution
- not depend on the distance
- pattern well established.

6 (c) Antenna field pattern $E(\theta) = \cos^2\theta$, $0 \leq \theta \leq \pi/2$

(i) Beam Area
(ii) Directivity

Data: 1M
formula: 2M
Solution: 3M
$\boxed{6M.}$

(i) $$\Omega_A = \int_0^{2\pi}\int_0^{\pi} P_n(\theta,\phi)\cdot d\Omega$$

$E(\theta) = \cos^2\theta$

$0 \leq \theta \leq \pi/2$

$$\therefore \Omega_A = \int_0^{2\pi}\int_0^{\pi} \cos^4\theta \cdot \sin\theta . d\theta . d\phi$$

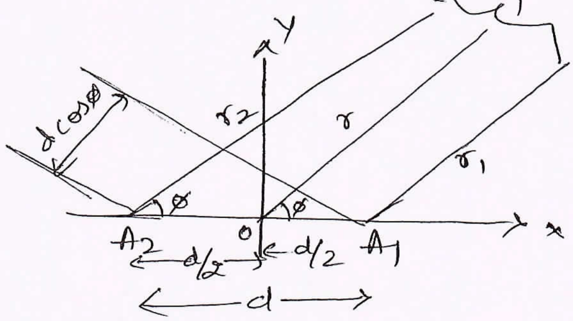
$$= -2\pi\left[\frac{1}{25}\cos^5\theta\right]_0^{\pi/2} = \frac{2\pi}{5} = 1.26 \text{ Sr.}$$

(ii) $$D = \frac{4\pi}{\Omega_A} = \frac{4\pi}{1.26} = 9.97$$

7 (a) Array of 2 isotropic point source with same amplitude & phase.

Diagram : 02
Formula : 02
Vector Diagram : 02
pattern : 02

$\boxed{8m}$



Path Difference: $Pd = d\cos\phi$

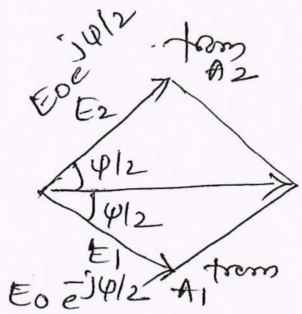
$Pd = \frac{d\cos\phi}{\lambda}$

Phase difference $\psi = 2\pi Pd$

$\psi = \frac{2\pi d\cos\phi}{\lambda}$

$\psi = \beta d\cos\phi$

$\psi = d_r\cos\phi$



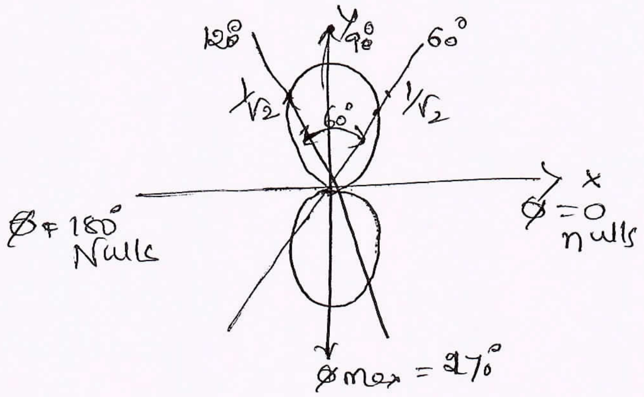
$* E_n = \cos\left(\frac{\pi\cos\phi}{2}\right)$

$\phi_{max}: 90°, 270°$ $\quad \cos\left(\pi\frac{\cos\phi}{2}\right) = \pm 1$

$\phi_{null}: 0, 180°$ $\quad \cos\left(\pi\frac{\cos\phi}{2}\right) = 0$

$\phi_{HPBW}: \pm 60°, \pm 120°$

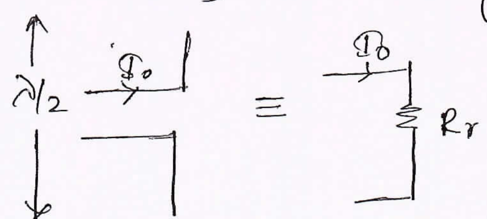
$\cos\left(\frac{\pi}{2}\cos\phi\right) = \frac{1}{\sqrt{2}}$



(b) Radiation resistance of $\lambda/2$ antenna

Diagram : 02
Formula : 02
Derivation : 02

$\boxed{6m}$



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

Average Poynting Vector

$S = \frac{1}{2} Re\{|H_\phi|^2 120\pi\}$

$|H_\phi|^2 = \frac{I_0^2}{(2\pi r)^2} = \frac{\cos^2(\pi/2\cos\theta)}{\sin^2\theta}$

$S = \frac{1}{2}\frac{I_0^2}{4\pi^2 r^2}\frac{\cos^2(\pi/2\cos\theta)}{\sin^2\theta} \times 120\pi$

$S = \frac{I_0^2}{\pi r^2}\frac{\cos^2(\pi/2\cos\theta)}{\sin^2\theta} \cdot 15$

Total Power radiated :

$$P = \iint S\, ds$$

$$P = \int_0^{2\pi}\int_0^{\pi} S r^2 \sin\theta \cdot d\theta \cdot d\phi$$

$$P = \frac{I_0^2\, 15 \times 2\pi}{\pi} \int_0^{\pi} \frac{\cos^2(\pi/2 \cos\theta)}{\sin\theta} \cdot d\theta.$$

$$P = I_0^2 \times 30 \int_0^{\pi} \frac{\cos^2(\pi/2 \cos\theta)}{\sin\theta} \cdot d\theta.$$

$$P = 30 I_0^2 (1.218)$$

$$P = 36.54\, I_0^2 \quad \text{——— (1)}$$

$$P = \frac{1}{2} I_0^2 R_r \quad \text{——— (2)}$$

Equate (1) & (2)

$$30 I_0^2 (1.218) = \frac{1}{2} I_0^2 R_r$$

$$\therefore R_r = 73.08\,\Omega$$

$$\cong 73\,\Omega$$

7 (c)

$$U = U_m \sin^2\theta \cdot d\theta \cdot d\phi$$

$$0 \le \theta \le \pi, \quad 0 \le \phi \le 2\pi$$

Data : 1m
Formula : 2m
Solution : 3m
(pattern)
$\boxed{6m}$

Sol? $P = ?$ Total Power radiated = ?

$D = ?$

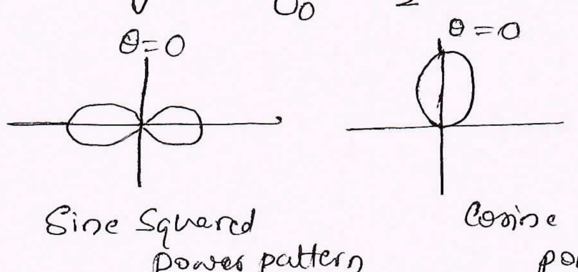
$$P = U_m \int_0^{2\pi}\int_0^{\pi} \sin^3\theta \, d\theta \cdot d\phi$$

$$= \frac{8}{3}\pi U_m$$

For isotropic source

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

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



Sine Squared power pattern   Cosine squared power pattern.

8 @ Short Dipole :

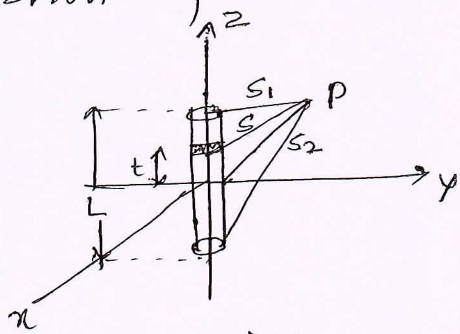


Diagram : 02

Basic formula : 02

Derivation : 04

$\boxed{08\ M}$

$I = I_0 e^{j\omega t}$

$I = I_0 e^{j\omega (t - r/c)}$

$$A_z = \frac{\mu_0}{4\pi} \int_{-L/2}^{L/2} \frac{[I] \cdot dz}{s}$$

$S_1 = r - L/2 \cos\theta$

$S_2 = r + L/2 \cos\theta$

$$A_z = \frac{\mu_0}{4\pi} \int_{-L/2}^{L/2} I_0 \frac{e^{j\omega(t - r/c)}}{r} \cdot dz$$

$$E_r = \frac{I_0 L \cos\theta\, e^{j\omega(t-(r/c))}}{2\pi \epsilon_0} \left(\frac{1}{cr^2} + \frac{1}{j\omega r^3} \right)$$

$$E_\theta = \frac{I_0 L \sin\theta\, e^{j\omega(t - r/c)}}{4\pi \epsilon_0} \left(\frac{j\omega}{c^2 r} + \frac{1}{cr^2} + \frac{1}{j\omega r^3} \right)$$

General case.

far field

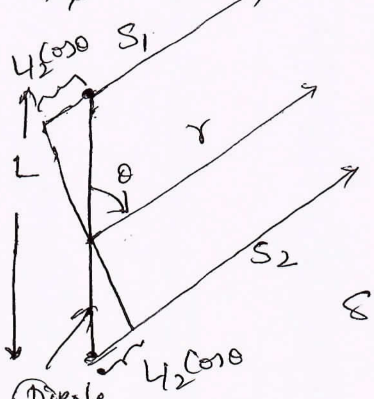
$$E_\theta = j\omega I_0 L \frac{\sin\theta\, e^{j\omega(t - (r/c))}}{4\pi \epsilon_0 c^2 r}$$

$$= j\frac{I_0 \beta L}{4\pi \epsilon_0 c r} \sin\theta\, e^{j\omega(t - (r/c))}$$

$$H_\phi = j\omega I_0 L \frac{\sin\theta\, e^{j\omega(t - (r/c))}}{4\pi c r}$$

$$= j\frac{I_0 \beta L}{4\pi r} \sin\theta\, e^{j\omega(t - (r/c))}$$

$$\frac{E_\theta}{H_\phi} = \frac{1}{\epsilon_0 c} = \sqrt{\frac{\mu_0}{\epsilon_0}} = 376.7\ \Omega$$



Short Dipole when $r \gg L$

⑧ (b) Pattern multiplication

Diagram : 3
+ Explanation: 3
$\boxed{6m}$

Total field pattern of array of non isotropic but similar sources is product of individual source pattern and pattern of array of isotropic point sources each located at the phase centre of individual source & having same relative amplitude and phase, while total phase pattern is the sum of phase pattern of individual source and the array of isotropic point source.

$$E = \underbrace{f(\theta,\phi)\, F(\theta,\phi)}_{\text{field pattern}} \left[\underbrace{f_p(\theta,\phi) + F_p(\theta,\phi)}_{\text{phase pattern}} \right.$$

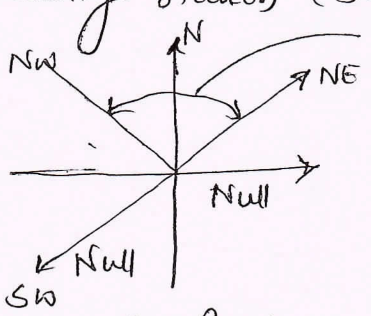
$f(\theta,\phi) \rightarrow$ field pattern of individual source

$f_p(\theta,\phi) \rightarrow$ phase pattern of individual source

$F(\theta,\phi) \rightarrow$ field pattern of array of isotropic sources

$F_p(\theta,\phi) \rightarrow$ Phase pattern of array of isotropic sources.

Ex: Broadcasting station (500 - 1500 KHz)



(a) Requirement

(b) Idealized pattern.

8 (c) $U = U_m \cos\theta$

Data : 01
Formula : 02
Solution : 03
$\boxed{6m}$

$0 \leq \theta \leq \pi/2$

$0 \leq \phi \leq 2\pi$

$P =$ Total Power $= ?$

$D = ?$

$$P = \int_0^{2\pi}\int_0^{\pi} U_m \cos\theta \cdot \sin\theta . d\theta . d\phi$$

$$= \pi U_m$$

for isotropic source

$$\pi U_m = 4\pi U_0$$

$$D = \frac{U_m}{U_0} = 4 = D$$

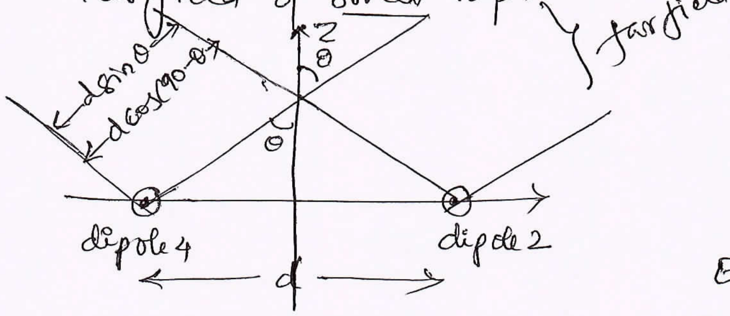
(9) (a) Small Loop:

- Loop dimensions are small compared to wavelength
- field pattern of circular loop and square loop are same.

Defn : 1m
Diagram : 03
Derivation : 04

$\boxed{8m}$

far field of small loop.



$$E_\phi = E_{\phi_0} \sin(\psi/2)\,(-2j)$$

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

$$E_\theta = j\frac{60\pi[I]\sin\theta}{\lambda}\cdot\frac{L}{r}$$

$$E_{\phi_0} = j\frac{60\pi[I]}{\lambda}\cdot\frac{L}{r}$$

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

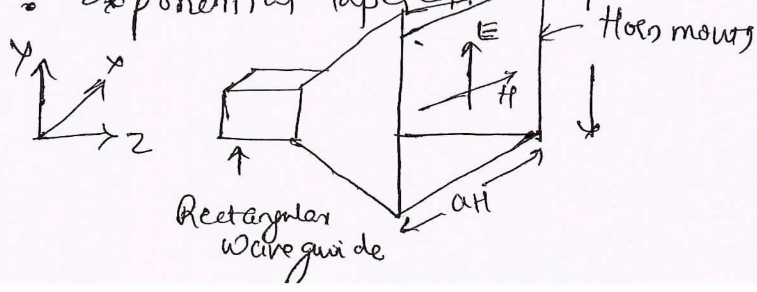
$$H_\theta = \frac{E_\phi}{120\pi} = \frac{\pi[I]\sin\theta}{r}\,\frac{A}{\lambda^2}$$

9 (b) Horn Antenna

- flared out or opened out waveguide structure
- Produces uniform phase, large aperture
- greater directivity

Diagram
+ Explanation
=> 2+4 = 6m

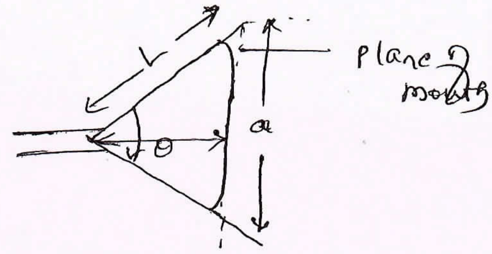
Types
- Rectangular Horn Antenna
- E plane sectorial horn Antenna
- H plane sectorial horn Antenna
- Pyramidal
- Exponential tapered.



Design Equation of Horn Antenna

$$\theta = \tan^{-1}\left(\frac{a}{2L}\right)$$

$$\theta = 2\cos^{-1}\left(\frac{L}{L+\delta}\right)$$



horn Dimension

$$\delta_0 = \frac{L}{\cos(\theta/2)} - L \rightarrow \text{optimum } \delta$$

$$L = \frac{\delta_0 \cos(\theta/2)}{1-\cos(\theta/2)} \rightarrow \text{optimum length.}$$

$$D \cong \frac{7.5 A_p}{\lambda^2}$$

9 ⓒ For small loop

Data : 1m
Formula : 2m
Solution : 3m
$\boxed{6m}$

$$\frac{R_L}{R_r} = \frac{3430}{C^3 f_{MHz}^{3.5} d}$$

$f = 1$ MHz

$C = \pi d = \pi$

$d = 10 * 10^{-3}$

$$\frac{R_L}{R_r} = \frac{3430}{(\pi)^3 * 10 * 10^{-3} * (1 * 10^6)^{3.5}}$$

$$\simeq 11000$$

$$K = \frac{1}{1 + R_L/R_r}$$

$K = 9 * 10^{-5}$ (-40.5 dB)

For loop n turns, R_r increases by $\propto n^2$
R_L increases by $\propto n$

$$\frac{R_L}{R_r} = \frac{3430}{C^3 f_{MHz}^{3.5} \cdot d}$$

if $\frac{R_L}{R_r} >> 1$

K increases $\propto n$

10 (a) Radiation resistance of small loop

Basic formula: 3M
Derivation: 5M
$\boxed{8M}$

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

far field E_ϕ, H_θ

$$S_r = \frac{1}{2} Re \{ E_\phi H_\theta^* \}$$

far field $\frac{E_\phi}{H_\theta} = 120\pi$

$$E_\phi = 120\pi H_\theta = Z_0 \cdot H_\theta$$

$$S_r = \frac{1}{2} Re \{ Z_0 H_\theta \cdot H_\theta^* \}$$

$$S_r = \frac{1}{2} |H_\theta|^2 120\pi$$

$$|H_\theta| = \frac{I_0 \beta a}{2r} J_1 (\beta a \sin\theta)$$

$$|H_\theta|^2 = \left(\frac{I_0 \beta a}{2r}\right)^2 J_1^2 (\beta a \sin\theta)$$

$$S_r = \frac{1}{2} \left(\frac{I_0 \beta a}{4r^2}\right) J_1^2 (\beta a \sin\theta) \times 120\pi$$

Total Power

$$P = \int_0^{2\pi} \int_0^{\pi} S_r \, r^2 \sin\theta \cdot d\theta \cdot d\phi$$

$$P = 2\pi \int_0^{\pi} \frac{(I_0 \beta a)^2}{4 \cancel{r^2}} J_1^2 (\beta a \sin\theta) \cdot \cancel{1}60\pi \sin\theta . d\theta.$$

$$P = 30\pi^2 (I_0 \beta a) \int_0^{\pi} J_1^2 (\beta a \sin\theta) . \sin\theta . d\theta ,$$

for small loop:

$$J_1^2 (x) = \left(\frac{x}{2}\right)^2 = \frac{x^2}{4}$$

$$P = 30\pi^2 (I_0 \beta a)^2 . \frac{\beta a^2}{4} \int_0^{\pi} \sin^3\theta . d\theta$$

$$= \frac{30\pi^2 I_0^2 (\beta a)^4}{\cancel{4}} \times \frac{\cancel{4}}{3}$$

$$P = 10\pi^2 I_0^2 (\beta a)^4 \text{ ——— } (1)$$

Equate ① & ②

$$\frac{1}{2} I_0^2 R_r = 10\pi^2 I_0^2 (\beta a)^4$$

$$R_r = 20\pi^2 (\beta a)^4$$

$$R_r = 197 \left(\frac{C}{\lambda}\right)^2$$

$$R_r = 20\pi^2 \left(\frac{2\pi}{\lambda}\right)^4 a^4$$

$$R_r \simeq 31171 \left(\frac{A}{\lambda^2}\right)^2$$

$$R_r = 31200 \left(A/\lambda^2\right)^2 //$$

10 ⓑ i) Yagi Uda Array:

(ii) Parabolic Reflector

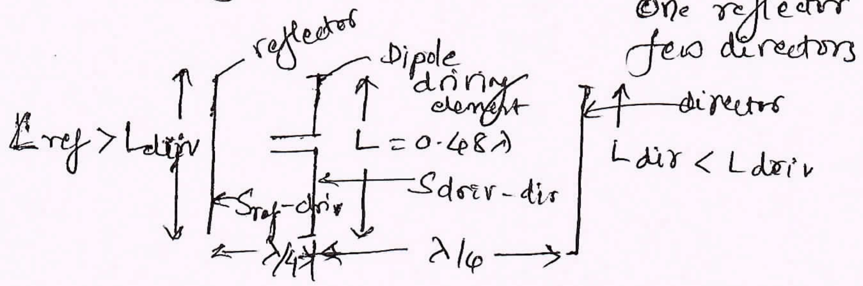
Diagram : 3m

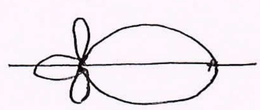
Explanation : 3m.

6M

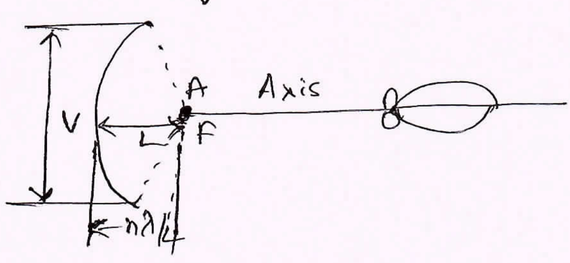
(i) Yagi Uda : One active element - folded dipole, $\lambda/2$ impedance ← resistive

few Parasitic element - One reflector, few directors



Radiation pattern: 

(ii) Parabolic Reflector :



$L = n\lambda/4$

- Distance L between the focus & vertex of the paraboloid is even number of $\lambda/4$

10 ©   circular loop Antenna:

Data : 1M
Formula: 2M
Solution: 3M
$\boxed{6M}$

$$R_r = 31200\left(\frac{nA}{\lambda^2}\right)^2$$

$$A = \pi a^2$$

$$A = \pi(0.02\lambda)^2$$

$$35 = \frac{31200\, n^2 \pi^2 (0.02)^4 \lambda^4}{\lambda^4}$$

$$\frac{35}{31200 * \pi^2 * (0.02)^4} = n^2$$

$$n = 27 \,//$$