# KLS Vishwanathrao Deshpande Institute of Technology

(Accredited by NAAC with "A" Grade)

(Approved by AICTE, New Delhi, Affiliated to VTU, Belagavi)

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## DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING


# University / Model Question Paper

# Scheme & Solution

| | | |
|---|---|---|
| Faculty Name | : | Pooja. C. Shindhe |
| Course Name | : | Microwave Theory and Antennas. |
| Course Code | : | 21EC62 |
| Year of Question Paper | : | Model Question Paper. |
| Date of Submission | : | 20-08-24. |

Faculty Member

HoD

Head of the Department

Dept. of Electronic & Communication Engg.

KLS V.D.I.T., HALIYAL (U.K.)

Dean (Acad.)

19/8/24

21EC62

# MODEL QUESTION PAPER 1

## MICROWAVE and ANTENNAS

**TIME: 03 Hours** **Max. Marks: 100**

Note: 01. Answer any **FIVE** full questions, choosing at least **ONE** question from each **MODULE**.

| | | **Module – 1** | **Blooms Level** | **Marks** |
|---|---|---|---|---|
| **Q.1** | a. | Explain the bulk Transferred Electron effect in a semiconductor material . | L2 | 06 |
| | b. | With neat block diagram explain the typical Microwave system | L3 | 04 |
| | c. | Assume the wave equation and its solution , derive the expression for voltage and current at any point on the transmission line. | L3 | 10 |
| | | **OR** | | |
| **Q.2** | a. | A transmission line has the following parameters R=1.2Ω/m, G=28μmho/m f=1GHz, L=18 nH/m, C=0.06pF. Calculate a)the characteristic impedance b) the attenuation constant c) phase constant d) wavelength e) velocity of wave propagation. | L3 | 08 |
| | b. | List the characteristics of smith chart. | L2 | 04 |
| | c. | With the help of a functional block diagram explain construction and modes of working of a GUNN Diode. | L3 | 08 |
| | | **Module – 2** | | |
| **Q.3** | a. | Prove that impedance and admittance matrices are symmetrical for a reciprocal junction. | L3 | 06 |
| | b. | Explain different types of Attenuators. | L2 | 06 |
| | c. | Derive the S- matrix relation for E-plane. | L3 | 08 |
| | | **OR** | | |
| **Q.4** | a. | List the characteristics of magic-T when all the ports are terminated with matched load. Also derive the expression of S matrix for magic T. | L2 | 06 |
| | b. | Explain with a neat sketch construction and working of a four port Circulator. | L3 | 08 |
| | c. | Write the S-Matrix representation for multiport network | L3 | 06 |
| | | **Module – 3** | | |
| **Q.5** | a. | A lossless parallel strip line has a conducting strip width w. The substrate dielectric separating the two conducting strips has a relative dielectric constant $\varepsilon_{rd}$ of 6 and thickness d of 4mm. Calculate i) width w of the conducting strip in order to have a characteristic impedance of 50 Ω. ii) The strip line capacitance iii)Strip line inductance iv)Phase velocity. | L3 | 08 |

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| | | | | |
|---|---|---|---|---|
| | b. | Define the following terms as related to antenna system i)Directivity ii)beam area iii)Radiation pattern iv)Beam solid | L2 | 08 |
| | c. | Determine the directivity of the system if the radiation intensity is $U=U_m \cos^3 \theta$ | L3 | 04 |
| | | **OR** | | |
| **Q.6** | a. | Discuss briefly micro strip lines and its losses and also derive the expression for quality factor. | L3 | 08 |
| | b. | A radio link has a 15w transmitter connected to an antenna of $2.5m^2$ effective aperture at 5Ghz. The receiving antenna has an effective aperture of $0.5m^2$ and is located at 15km line of sight distance from the transmitting antenna. Assume lossless antennas. Find the power delivered to the receiver. | L3 | 05 |
| | c. | Calculate the directivity of the source with the pattern $U=U_m \sin\theta \sin^3\emptyset$ using i)Exact Method ii) Approximate method . $0\leq\theta\leq\Pi$ and $0\leq \emptyset \leq\Pi$ and zero elsewhere. | L3 | 07 |
| | | **Module – 4** | | |
| **Q.7** | a. | State and explain power theorem and its application to an isotropic source | L2 | 06 |
| | b. | Obtain the field pattern for two point source situated symmetrically with respect to the origin .Two sources are feed with equal amplitude and equal phase signals, Assume distance between two sources=$\lambda/2$ | L3 | 08 |
| | c. | Distinguish between end fire array and broad side array. | L2 | 06 |
| | | **OR** | | |
| **Q.8** | a. | Derive an array factor expression in case of linear array of n isotropic point sources of equal amplitude and spacing. | L3 | 08 |
| | b. | Derive the expression for radiation resistance of short dipole with uniform current | L3 | 06 |
| | c. | Starting from electric and magnetic potential , obtain the far filed components for a short dipole | L3 | 06 |
| | | **Module – 5** | | |
| **Q.9** | a. | Derive the far field expression for small loop antenna. | L3 | 06 |
| | b. | Explain the constructional details of Yagi-Uda antenna | L3 | 06 |
| | c. | Find the length L, H-plane aperture and flare angle $\theta E$ and $\theta H$ of Pyramidal Horn for which E-plane aperture is 10 $\lambda$ Horn is fed by a rectangular waveguide with TE10 mode. Assume $\delta=0.2\lambda$ in E-Plane and $0.375\lambda$ in H-Plane. Also find E-Plane, H-Plane beam widths and directivity | L3 | 08 |
| | | **OR** | | |
| **Q.10** | a. | Derive the radiation resistance of loop antenna and generalize the result for circular loop of any radius | L3 | 08 |
| | b. | Briefly explain Helical Antenna with its helical Geometry. | L2 | 06 |
| | c. | Explain different types of Horn Antennas. Explain different types of Horn Antennas. | L2 | 06 |

Module – 1.

Q1 a. Explain the bulk Transfered Electron Effect in a semiconductor material.

→ Basically the phenomenon that occurs when external voltage provided to the semiconductor material, in N-type material electrons are present in Lower mobility as well as higher mobility, by external application of voltage, lower mobility electrons cast into higher mobility, cause flow of electrons (current) in pulse form, and these are in high frequency called microwave.

When External voltage is applied electrons moves from valance band to conduction band as shown in fig.1.1. once the potential difference applied increases electrons move from conduction to higher Energy Band, continuously increase in potential voltage cause.

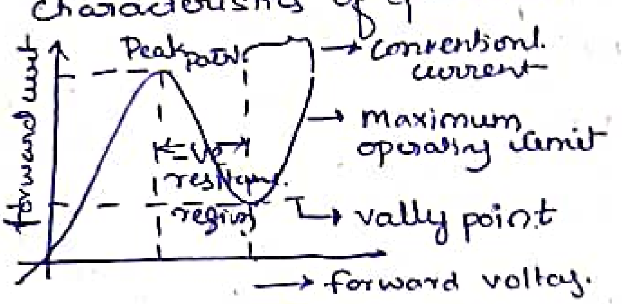
→ Electrons to attain less mobility.

→ Current starts decreasing

→ Semiconductor attains "Negative Resistance characteristics".

→ Electrons gain sufficient energy to comes back to lower Band [Conduction Band].

Characteristics of ~~[illegible]~~ TED's.



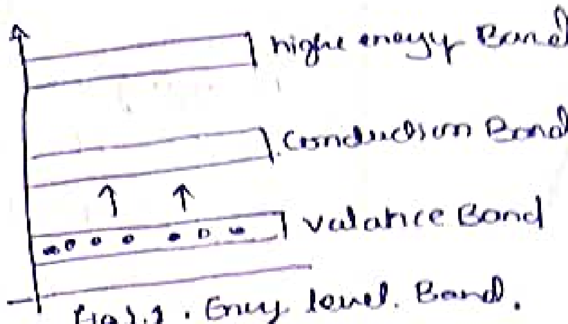
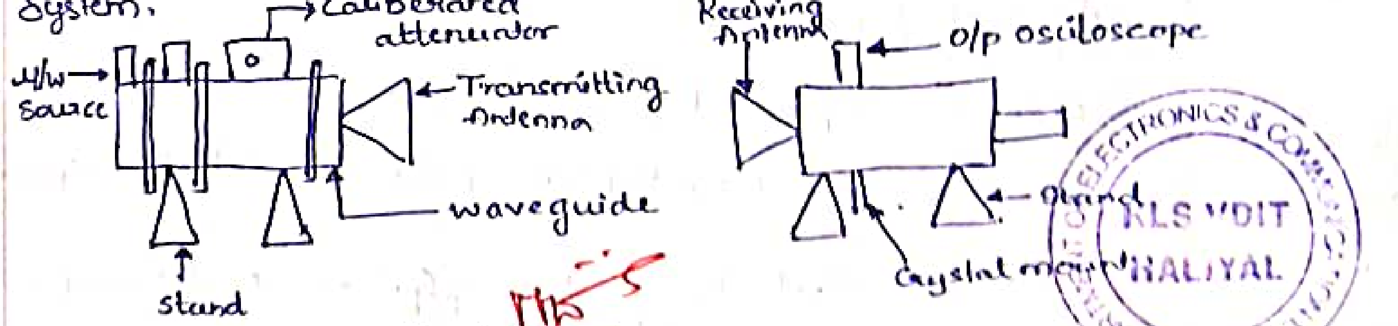




fig. 1.1. Energy level Band.

→ Once the Electrons reaches the valley point [lowest possible current]. increase in potential cause the energy to electrons and electrons moves back to higher energy band and process continues.

Q1b. With the neat Block diagram explain the typical Microwave System.

→



Microwave system includes two Subsystem.

1. Transmitting Sub system; Normaly consist of microwave oscilator which generate frequency in microwave range. with application of high potential difference, we term it as microwave source. it includes Attenuator to obtain required amount of power in sending signal. transmitting Antenna which transmit signal from guided wave to free space. wave. and wave guid which allow flow of wave's from source to Antenna.

2. Receiving Sub system: Receiving Antenna is present in the subsystem which convert freespace wave to guided, and waveguid allow to flow the signal to Receiver. A microwave amplifier is used to increes the received signal strength.

Q1. C Assume the wave equation and its solution, derive the expression for voltage and current at any point on the transmission line.

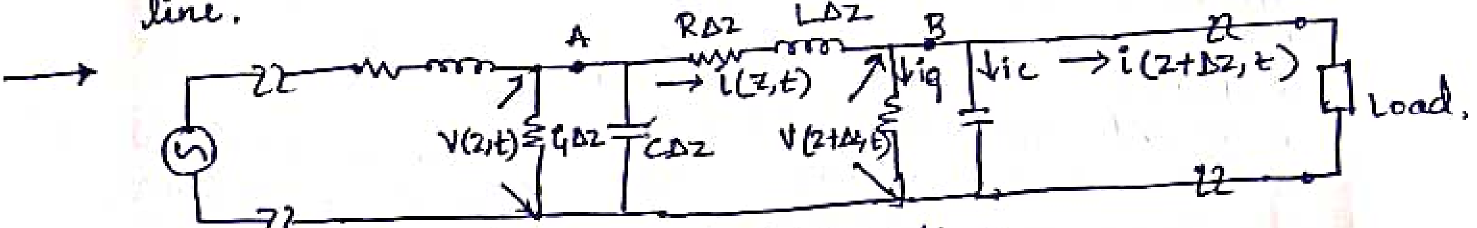



fig 1.3 Transmission line

Applying KVL, for center loop.

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

$$V(z,t) = i(z,t)\,R\Delta z + L\Delta z\frac{\partial i}{\partial t}(z,t) + V(z,t) + \frac{\partial v}{\partial z}(z,t)\,\Delta z \rightarrow ①$$

$$0 = i(z,t)\,R\Delta z + L\Delta z\frac{\partial i}{\partial t}(z,t) + \frac{\partial V}{\partial z}(z,t)\,\Delta z$$

dividing Eqn by $\Delta z$, and omitting argument $(z,t)$.

we get.

$$0 = iR + L\frac{\partial i}{\partial t} + \frac{\partial v}{\partial z}$$

$$\Rightarrow -\frac{\partial v}{\partial z} = iR + L\frac{\partial i}{\partial t} \longrightarrow ②$$

Using KCL for point B.

$$i(z,t) = i_G + i_c + i(z+\Delta z,t)$$

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

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

$$+ i(z,t) + \frac{\partial i(z,t)}{\partial z}\Delta z \longrightarrow ③$$

Rearranging Eqn (3)

$$0 = V(z,t)G\Delta z + \frac{\partial V(z,t)}{\partial z}\Delta z\, G\Delta z + C\Delta z \frac{\partial V}{\partial t}(z,t) + C\Delta z \frac{\partial}{\partial t}\left(\frac{\partial V(z,t)}{\partial z}\right)\Delta z$$
$$+ \frac{\partial i(z,t)}{\partial z}\Delta z$$

Divide Eqn by $\Delta z$

$$0 = V(z,t)G + \frac{\partial V(z,t)}{\partial z}\Delta z G + C\frac{\partial V}{\partial t}(z,t) + \frac{\partial}{\partial t}\left(\frac{\partial V(z,t)}{\partial z}\right)\Delta z + \frac{\partial i(z,t)}{\partial z}$$

Equate $\Delta z \to 0$ and omitting $(z,t)$ argument.

$$0 = VG + 0 + C\frac{\partial V}{\partial t} + \frac{\partial i}{\partial z}$$

$$\Rightarrow -\frac{\partial i}{\partial z} = VG + C\frac{\partial V}{\partial t} \to (4)$$

Differentiating Eqn (2) w.r.t. z and Eqn 4 with t. Eq (2) & (4) Becom

$$\frac{\partial^2 V}{\partial z^2} = R\frac{\partial i}{\partial z} + L\frac{\partial}{\partial z}\left(\frac{\partial i}{\partial t}\right) \to (5)$$

$$\frac{\partial}{\partial t}\left(\frac{\partial i}{\partial z}\right) = G\frac{\partial V}{\partial t} + C\frac{\partial^2 V}{\partial t^2} \to (6)$$

Substituting Eqn (4) & (6) in Eqn (5).

$$\frac{\partial^2 V}{\partial z^2} = R\left[GV + C\frac{\partial V}{\partial t}\right] + L\left[G\frac{\partial V}{\partial t} + C\frac{\partial^2 V}{\partial t^2}\right]$$

Rearrangin the Eqn, we get Transmission line Eqn for voltage. i.e

$$\boxed{\frac{\partial^2 V}{\partial z^2} = RGV + (RC+LG)\frac{\partial V}{\partial t} + LC\frac{\partial^2 V}{\partial t^2}}$$

Differentiate Eqn 2 w.r.t t and Eqn 4 with z. and get

$$\frac{\partial}{\partial t}\left(\frac{\partial V}{\partial z}\right) = R\frac{\partial i}{\partial t} + L\frac{\partial^2 i}{\partial t^2} \to (7)$$

$$\frac{\partial^2 i}{\partial z^2} = G\left(\frac{\partial V}{\partial z}\right) + C\frac{\partial}{\partial t}\left(\frac{\partial V}{\partial z}\right) \to (8)$$

Substitute Eqn (2) & (7) in Eqn (8), and we get

$$\frac{\partial^2 i}{\partial z^2} = G\left(Ri + L\frac{\partial i}{\partial t}\right) + C\left(R\frac{\partial i}{\partial t} + L\frac{\partial^2 i}{\partial t^2}\right) \to 9.$$

Rearrangin Eqn we ge current Eqn.

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

Q2. a. A transmission line has the following parameters $R = 1.2\,\Omega/m$ $G = 28\mu mho/m$, $f = 1GHz$, $L = 18\,nH/m$, $C = 0.06pF$.
Calculate a] $Z$ b] $\alpha$, c] $\beta$ d] $\lambda$ e] $V_p$

→ Given data.

$R = 1.2\,\Omega/m$

$G = 28\,\mu mho/m$

$f = 1\,GHz$

$L = 18\,nH/m$

$C = 0.06\,pF$.

soln.

$$Z = \sqrt{\frac{R + jwL}{G + jwC}}$$

$$\left.\begin{aligned} \alpha &= \frac{1}{2}\left(R\sqrt{\frac{C}{L}} + G\sqrt{\frac{L}{C}}\right) \\ \beta &= w\sqrt{LC} \end{aligned}\right\} \quad \gamma = \sqrt{(R + jwL)(G + jwC)}$$

$$V_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}}$$

$$w = 2\pi f = 2\pi \times 1GH = 2\pi \times 10^9$$

$$Z_0 = \sqrt{\frac{1.2 + j2\pi \times 10^9 \times 18\,nH}{28 \times 10^{-6} + j2\pi \times 10^9 \times 0.06 \times 10^{-12}}}$$

$$= \sqrt{\frac{1.2 + j\pi\,36}{28 \times 10^{-6} + j\,0.12\pi \times 10^{-3}}}$$

$$= \sqrt{\frac{113.10\angle 89.39}{3.78 \times 10^{-3}\angle 85.75}}$$

$$\boxed{Z_0 = 54.699\angle 1.82\ \Omega} = 54.67 + j1.737$$

$$\gamma = \sqrt{(113.10\angle 89.39)(3.78 \times 10^{-3}\angle 85.75)}$$

$$\gamma = 0.653\angle 87.57 = 0.0276 + j0.6524$$

$$\therefore \alpha = 0.0276$$

$$\beta = 0.6524$$

$$v_p = \frac{2\pi \times 10^{+9}}{3.286 \times 10^{-11}} = 1.91119 \times 10^{20}\ m/sec.$$

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Q2 b. List the characteristics of Smith chart.

1. The constant r and constant x circles all pass through of original circles in chart.
2. The constant r and x. circles all pass through the point $(Z=1, Z_q=0)$
3. The upper half of the diagram represent $+jx$.
4. The lower half of the diagram represent $-jx$.
5. for admittance the constant r circles become constant g circles and the constant x-circles becomes constant susceptance b circles.
6. The distance around the smith chart once is one-half wavelength. $(\lambda/2)$.
7. At point of $Z_{min} = 1/S$, there is a Vmin on the line.
8. At point of $Z_{max} = S$, there is a Vmax on the line.
9. The horizontal radius to the left of the chart center corresponds to Vmin, Imax, Zmin and $1/S$.
10. The Horizontal radius to the right of the chart center corresponds to Vmax, Imin, Zmax and S (SWR).
11. Since Normalized admittance Y is reciprocal of the normalized impedance Z, the corresponding quantities in the admittance chart are 180° out of phase with those in the impedance chart.
12. The normalized impedance or admittance is repeated for every half wavelength of distance.
13. The distance are given in wavelength towards the generator and also towards the load.

Q2 c. With the help of a functional block diagram explain construction and modes of working of Gun Diode.

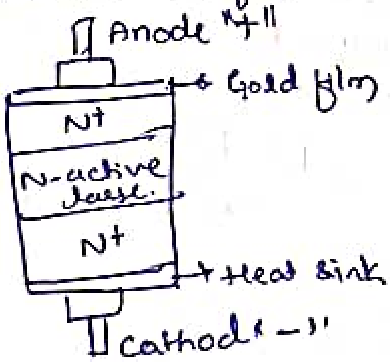


fig 2.c. functional Block of Gunn diode (GaAs).

Construction of Gunn diode.

① Gunn diode is a 3. layer device.

② It is made up of only N-type material, hence it is not a P-N-Junction device

③ A lightly dopped N-type material is placed between 2 highly dopped N-type material.

④ Gold film and Heat sink are used to prevent damage from high frequency generation in the device.

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modes of Gunn diode.

→ Gunn Oscillation Mode:

① Condition for successfull domain drift.
Transit time ($L/v_s$) > Electric Relaxation time

② frequency of oscillation = $V/L_{eff}$

③ Gunn diode a resistive circuit, which gives the oscilation,

→ Stable amplification Mode
$(f \times L) = 10^7$ cm/s and $10^{11}/cm^2 < (n \times L) \times 10^{12}/cm^2$

→ LSA Oscillation Mode.
$(f \times L) = 10^7$ cm/s and $2 \times 10^4 < (n \times L) \times 10^5/cm^2$

→ Bias - Circuit
$(f \times L)$ is small, L is very small. Current falls as gunn oscillation begins, frequence is in Basic circuit,
(1KHz to 100 MHz)

## Module - 2

Q3. a. Derive the S-Matrix representation of multiport network

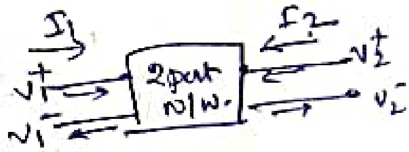
→ → Amplitude of Reflected and incident waves, at any port are used to characterise a microwave circuit.

→ Amplitude are normalized in such way that square of any of these variable gives the average power in that wave in the following

Input Power at the nth port $P_{in} = 1/2 |a_n|^2$

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

where $a_n$ & $b_n$ represent the normalized incident wave peak amplitude and normalized reflected wave peak the nth port. it is represented as.




$$a_1 = \frac{V^+}{\sqrt{Z_0}} = \frac{V_1 - V_1^-}{\sqrt{Z_0}} \qquad a_2 = \frac{V_2^+}{\sqrt{Z_0}} = \frac{V_2 - V_2^-}{\sqrt{Z}}$$

$$b_1 = \frac{V_1^-}{\sqrt{Z_0}} = \frac{V_1 - V_1^+}{\sqrt{Z_0}} \qquad b_2 = \frac{V_2^+}{\sqrt{Z_0}} = \frac{V_2 - V_2^+}{\sqrt{Z}}$$

where a - normalized amplitude of Indirect wave
b - normalized amplitude of Reflected wave,

Total voltage = $V_1 = V_1^+ + V_1^-$
$V_2 = V_2^+ + V_2^-$

The numeric suffics represent the port number. (4)

Total Power flow into any port is given by,

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

There for characteristic impedance normalized to variety the relation b/n incident and Reflected is given as.

$$b_1 = S_{11}a_1 + S_{12}a_2$$

$$b_2 = S_{21}a_1 + S_{22}a_2$$

The physical significance of S-parameter can be described as follows.

$S_{11} = (b_1/a_1)_{a_2=0}$ {Reflection coefficient $\tau_1$}

$S_{22} = (b_2/a_2)_{a_1=0}$ {Reflection coeffient $\tau_2$}

$S_{12} = (b_1/a_2)_{a_1=0}$ {Attenuation Port 2 to Port 1}

$S_{21} = (b_2/a_1)_{a_2=0}$ {Attenuation Port 1 to Port 2}.

In general for n-port networks, S-parameter are expressed as

$$\begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ \vdots \\ b_n \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & \cdots & S_{1N} \\ S_{21} & S_{22} & S_{23} & \cdots & S_{2N} \\ S_{31} & S_{32} & S_{33} & \cdots & S_{3N} \\ \vdots & & & & \\ S_{N1} & S_{N2} & S_{N3} & \cdots & S_{NN} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_N \end{bmatrix}$$

Q3 b. Explain Symmetrical Z and Y matrix for reciprocal Network

→ In a Reciprocal N/W. the impedance & Admittance are symmetrical and the junction media are characterised by scalable electrical parameters $\mu$ and $\epsilon$. for a multiport network (N. ports)

Let the incident wave amplitude is $(V_n^+)$

The reflected wave amplitude is $V_n^-$

The total voltage $V_n = V_n^+ + V_n^- = 0 \;\forall$ port $n = 1, 2, 3 \ldots N$ except the port i & j,

from Lorentz reciprocity theorem

$$\int (E_i \times H_j) - (E_j \times H_i) \cdot ds = 0.$$

Let $n \neq i \,\&\, j$ ; $V_n \neq 0$.

Illy $E_i, H_j$ & $E_j H_j \neq 0$. ∀ i & j reference plane

$$\int_{ij} (E_i \times H_j)\, ds = \int_{ij} (E_j \times H_i)\, ds$$ take port ti & tj



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i.e $\boxed{P_{ij}^{\wedge} = P_{ji}} \longrightarrow$ ①

W.K.T Admitance Y ; $I = Y.V$

$Y = \frac{I}{V}$ and $P = V.I$

Substituting in Eqn ①.

$$V_j (V_i \times Y_{ij}) = V_i (V_j Y_{ji})$$

$$\boxed{Y_{ij} = Y_{ji}}$$

hence $\boxed{Z_{ij} = Z_{ji}}$

The impedance and admittance matrices are symmetrical for a reciprocal junction.

Q3 c. Discuss the properties of S-matrix.

→ Properties of S-matrix for ports having common characteristics.
Property of S-matrix for perfect Matched Network.

[a] Zero digonal Elements for perfect Matched Network.

[b] Symmetry of [S] for a Reciprocal network.

[c] Unitary property for a lossless Junction.

[d]. Phase shift property.

[a] Zero digonal Elements ~~for ports having common characteristics~~
for an ideal N-port Network, with matched terminations on at all the ports, i.e $S_{ij} = 0 \ (i=j)$, there is no reflection from any port. Therefore under perfect matching condition the digonal elements of [S] are zero.

[b] Symmetry of [S] for Reciprocal Network.
A reciprocal Network/device has the same transmission in either direction of a pair of ports and is characterised by a symmetric scattering matrix.

$$S_{ij} = S_{ji} \ (i \neq j) \Rightarrow [S]_t = [S].$$

[c] Unitary property - for loss less network, sum of the products of each term of any one row of any column of the S matrix multiplied by its complex conjugate is unity.

$$\therefore \sum_{n=1}^{N} |S_{ni}| \cdot |S_{ni}^*| = 1$$

[d] phase shift - when reference planes shift outwards to new position by electrical phase shift $\phi_1 = \beta_1 l_1$ and $\phi_2 = \beta_2 l_2$ respectively with new S matrix $\Rightarrow [S'] = \begin{bmatrix} e^{-j\phi_1} & 0 \\ 0 & e^{-j\phi_2} \end{bmatrix} [S] \begin{bmatrix} e^{-j\phi_1} & 0 \\ 0 & e^{-j\phi_2} \end{bmatrix}$

Q4 a. what are attenuators? Explain precision type variable attenuator. (5)

→ A 2-port component used to control power levels in a microwave system by partially absorbing the transmitted microwave signal.

Precision type variable Attenuator.

* A Precision type attenuator make use of a circular waveguide section [C] containing a very thin tapered resistive card [R2]
* Both ends of section C are converted to rectangular shape through transmitting section RC1 & RC2, with resistive card R1 & R3
* Resistive card in 'C'. R2 can be rotated to 360°.
* Resistive card are placed in such a way that absorb the parallel components of E-field. i.e 'E cosθ'.
* This device is Reciprocal Device with matched impedance

i.e $S_{12} = S_{21} = E\sin^2\theta$.

$S_{11} = S_{22} = 0$.

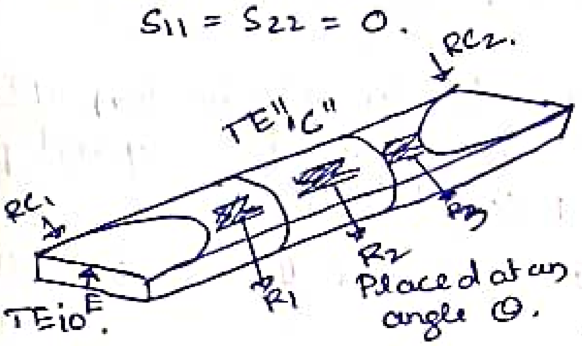



fig. 4.1 Percision variable Attenuator.

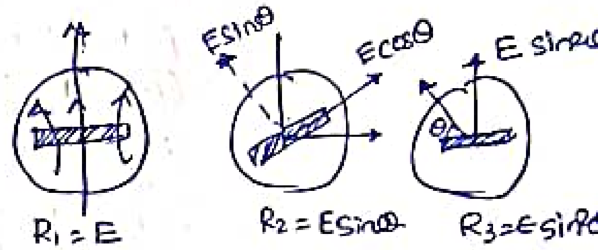


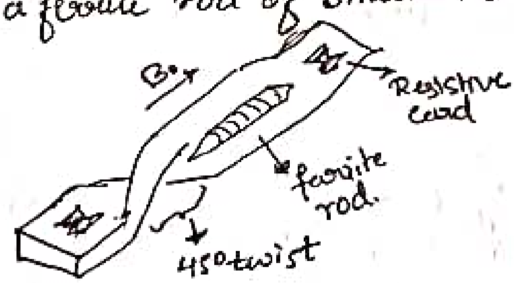

fig 4.2. field components at R1 & R2 & R3

$$[S] = \begin{bmatrix} 0 & \sin^2\theta \\ \sin^2\theta & 0 \end{bmatrix}$$ → S-matrix of a precision type variable attenuator.



Q4 b. With neat diagram explain construction and working & application of isolator.

→ A Isolator is circulator wave guide section axially loaded with a ferrite rod of smaller diameter.




The ferrite rod is subjected to steddy axial magnetic field H0, is continuously rotating.

* Resistive card R1 & R2 are place at both port 1 & port 2. which will absorb parallel component and passes perpendicular components only.

* Input feded at Port 1. experience 45° phase shift at ferrite rod. which passes through without deviation
* Output is tilted for 45° and output appear at port 2 as Ei without any changes in the wave.

when wave is feded through port 2, becaues port is placed 45° to the main axis wave attains 45° phase shift and pass through $R_2$ and attain 45° extra shift at fourth rod. Now the wave experience total 90° shift hence it made parallel, ~~now wave~~ ap. to the axis. $R_1$ place at port 1 will compeletely absorb the component giving zero output at the port 1.

Thus Isolator allowed the wave traveled from port 1 to Port 2. and restricted wave traveling from port 2 to port 1.

S-matrix of Isolator $[S] = \begin{bmatrix} 0 & 0 \\ S_{21} & 0 \end{bmatrix}$

4c. What are Coupling and isolation factors ~~of~~ in a micro strip directional coupler.

→ Micro strip directional coupler has three accessible ports where fourth port is internally terminated to provide maximum directivity.

Coupling factors → This indicates the fraction of the input power (at P1) that is delivered to the coupled port, P3.

Coupling factor $C = 10 \log (P1/P3)$

Isolation → Indicates the power delivered to the uncoupled load (P4).

Isolation $I = 10 \log (P1/P4)$

5a. lossless parallel strip line has a conducting strip width w. the substrate dielectric operating the two conducting strip has a relative dielectric contant $\epsilon_{rd}$ of 6 and thikness d. of 4 mm. Calculate,

i) width w of the conducting strip. in order to have a characteristics impedance of 50Ω.

ii) The strip line capacitance iii) Strip line inductance.

iv) Phase velocity.

Soln

a) $w = \frac{377}{\sqrt{\epsilon_{rd}}} \frac{d}{Z_0} = \frac{377}{\sqrt{6}} \frac{4 \times 10^{-3}}{50} = 12.31 \times 10^{-3} m$

b) $C = \frac{\epsilon d w}{d} = \frac{8.854 \times 10^{-12} \times 6 \times 12.31 \times 10^{-3}}{4 \times 10^{-3}} = 163.50 pF/m$

c) $L = \frac{\mu_c d}{w} = \frac{4\pi \times 10^{-7} \times 4 \times 10^{-3}}{12.31 \times 10^{-3}} = 0.414 H/m$

d) $V_p = \frac{c}{\sqrt{\epsilon_{rd}}} = \frac{3 \times 10^8}{\sqrt{6}} = 1.22 \times 10^8 m/sec$

Q5b.. Defined the following term as related to antenna (6)

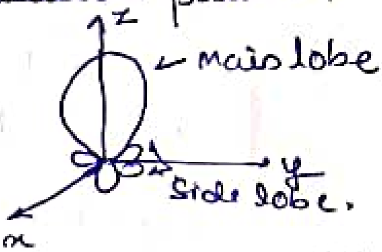
→ i) Directivity → The directivity of an antenna is equal to the ratio of maximum power density $P(\theta,\phi)_{max}$ to its average value over a sphere as observed in the far field of an antenna.

$$D = \frac{P(\theta,\phi)\,max}{P(\theta,\phi)\,avg}$$ { a dimensionless quantity ≥1 }

ii) Beam area: In polar two dimensional co-ordinators an incremental area dA on the surface of surface sphere is the product of the length $r d\theta$, in the $\theta$ direction and $r \sin\theta\, d\phi$ in the $\phi$-direction.

$$dA = r(d\theta)\,(r \sin\theta\, d\phi) = r^2 d\Omega$$

iii) Radiation Pattern: Radiation patterns are 3-D plots of field or power radiated by antenna.
Any antenna radiate maximum power in any one dirn $(\theta,\phi)$. The general structure of radiation path in 2D plane is as show.




Q5C: Determine the directivity of the system if the radiation intensity is ~~U = Um sinθ~~ $U = U_m \cos^3\theta$.

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

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

$$= U_m \left\{ \left[ -\frac{\cos^5\theta}{5} \right]_0^{\pi/2} \right\} (2\pi)$$

$$P = \frac{2\pi}{5}$$

$$\text{Directivity} = 4\pi \frac{(1)}{\left(\frac{2\pi}{5}\right)} = 10.//$$

$$\text{Directivity} = 10 \log 10 = 10 dB //.$$



2018/21

Q6. a Discuss briefly micro strip lines and its losses and also derive expression for quality factor.

→ Micro Strip lines are commonly used with the chips.

The microstrip line is also called an open-strip line.

- both MKS and English units are used in designing the microstrip line.

* Modes of microstrip lines are - quasi-transverse electric and magnetic (TEM). The Theory of TEM-coupled lines applied only approximately.

* These have better interconnection features and easier fabrication.

Losses in Microstripline.

When Dielectric Substrate of dielectric Eq is purely non-magnetic then three types of losses occurs in microstrip lines. They are →

1) Dielectric losses
2) Ohmic losses
3) Radiation losses

Dielectric losses → Dielectric material posses some conductivity '$\sigma$' but it is small such that $\sigma < \omega\epsilon$. when this conductivity is not negligible, then the displacement current density by of current density leads the conduction current density by 90°. i.e. $\alpha_d = \frac{\omega}{2}\sqrt{\mu\epsilon}\tan\theta$. nepu/cm.

Ohmic losses → It is occurred due to current flowing through strip act as finite conductor which adds Resistance to the flow.

$$R_s = \sqrt{\frac{\pi f \mu}{\sigma}} \quad \text{Surface Skin Resistor.}$$

$$\alpha_c = \frac{8.686}{Z_0 W}\sqrt{\frac{\pi f \mu}{\sigma}}$$

Radiation losses → At micro frequency. microstrip lines act as an antenna radiating small amount of power. resulting in radiation losses

$$\frac{P_{rad}}{P_t} = \frac{R_r}{Z_0} \%$$

Quality factor

$$Q_c = \frac{27.3}{\alpha_c}$$

where $\alpha_c = \frac{8.686\ R_s}{Z_0 W}$

$$Q_c = \frac{27.3\ Z_0 W}{8.686\ R_s}$$

where $Z_0 = \frac{377}{\sqrt{\epsilon_r}}\left(\frac{h}{w}\right)$ and $\sqrt{\epsilon_r} = \frac{30}{\lambda_g f_g}$.

hence $Q_c = \frac{27.3 W}{8.686\ R_s}\left[\frac{377\ \lambda_g f_g}{30}\left(\frac{h}{w}\right)\right]$

$\therefore\ R_s = 20\pi\sqrt{\frac{f_g}{\sigma}}$

$Q_c$ becomes $= 39.5\, h\, f_g \left[\frac{1}{2\pi}\sqrt{\frac{\sigma}{f_g}}\right]$

$$\therefore\ \boxed{Q_c = 0.63\, h\sqrt{\sigma f_g}}$$

Q6 b. A Radio link has a 15W transmitter connected to an antenna of 2.5 $m^2$ effective aperture at 5GHz. The receiving antenna has an effective aperture of 0.5 $m^2$ and is located at 15km line of sight distance from the transmission. Find the power delivered to the receiver.

→ Given data.

$P_t = 15W$.

$A_{et} = 2.5$

$A_{er} = 0.5$

$r = 15km$

$f = 5GHz$

$$P = P_t \frac{A_{et} A_{er}}{r^2 \lambda^2} = 15\frac{2.5 \times 0.5}{15^2 \times 10^6 \times 0.06^2}$$

$$= 234 W$$

Q 6c Calculate the directivity of the source with the pattern $U = U_m \sin\theta \sin^3\phi$.. using i) Exact method. ii) Approximate

$\rightarrow$

$$D = \frac{4\pi}{\Omega A}.$$

$$\Omega A = \iint P_n(\theta,\phi)\, d\Omega$$

$$\Omega A = \int_{\theta=0}^{\pi}\int_{\phi=0}^{\pi} (\sin\theta \cdot \sin^3\phi)\, \sin\theta \, d\theta\, d\phi.$$

$$\Omega A = \int_{\theta=0}^{\pi} \sin^2\theta \, d\theta \int_{\phi=0}^{\pi} \sin^3\phi \, d\phi.$$

$$\Omega A = \frac{\pi}{2} \times \frac{4}{3}$$

$$\Omega A = \frac{4\pi}{6} = \frac{2}{3}\pi$$

$$D = \frac{4\pi}{(\frac{2}{3}\pi)} = 6$$

$$\boxed{D = 6}$$

7Q a. State explain power theorem and its application to isotropic

$\rightarrow$ If the poynting vector is known at all points on a sphere of radius r from a point source in a lossless medium, the total power radiated by the source is the integral over the surface of the sphere of the radial component $S_r$ of the average Poynting vector. thus.

$$P = \oiint S \cdot ds = \oiint S_r\, ds.$$

for an isotropic.

$$P = \oiint S_r\, ds \Rightarrow \quad S_r \oiint ds = S_r \times 4\pi r^2$$

$$P = S_r 4\pi r^2$$

$$\Rightarrow \boxed{S_r = \frac{P}{4\pi r^2}}$$

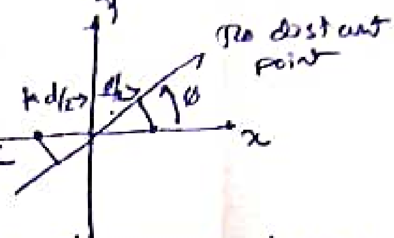
7Q b. obtain the field pattern for two point source situated symmetrically with respect to the origin. Two source are feed with equal amplitude and equal phase signals, Assume distance between two source $= \lambda/2$.

(8)

→ Two Isotropic point sources of same amplitude and same phase.

Let the two point sources 1 & 2 be separated by a distance d and d located symmetrically with respect to the origin of the co-ordinated as shown.

$\boxed{d = \lambda/2}$.




The angle $\phi$ is measured counterclockwise from positive x-axis.

Then at a distant point in the direction $\phi$, power from the source is radiated by $\frac{1}{2} d_r \cos\phi$.

where $d_r$ is distance between the source expressed as

$$d_r = \frac{2\pi d}{\lambda} \qquad d = \lambda/2$$

$$d_r = \frac{2\pi \lambda/2}{\lambda} = \pi$$

The total phase angle = $2\pi \times$ Path difference

$= d_r \cos\phi$

$$\psi = \pi \cos\phi$$

The total field is given by

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

$$E = 2E_0 \cos(\psi/2)$$

Maximum of E-field is obtained by

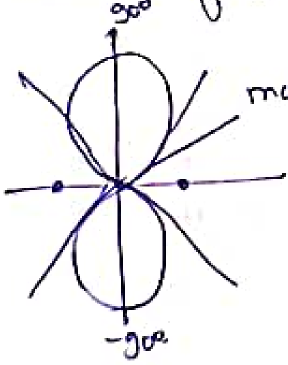
$(\psi/2) = 0$

$\pi \cos\phi = 0$

$\cos\phi = 0$

$\boxed{\phi = 90^\circ}$

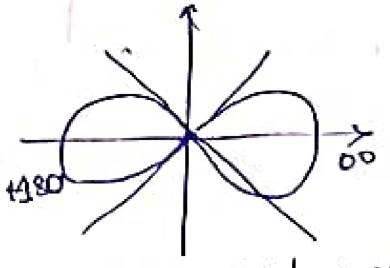
maximum field pattern occurs at $90^\circ$ & $180^\circ$.



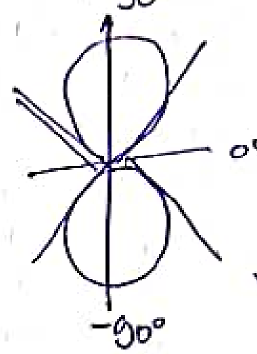
Q7 c. Distinguish between fire Array and broad Array.

→

| Fire Array | Broad Side Array |
|---|---|
| ① All Element parallel to each other, and maximum field is perpendicular to the axis of the array. | ① All Element placed parallel to each other and maximum field is perpendicular to the field. |




maximum field => 0° & 180°




maximum field ±90°

8 a. Derive an array factor expression in case of linear array of n-isotropic point source of equal amplitude and spacing.

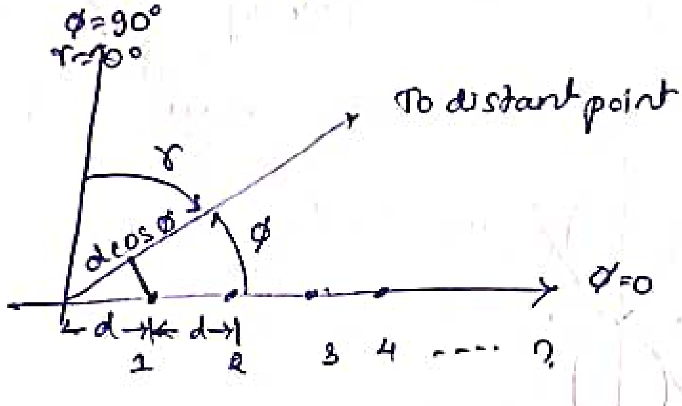
→ Consider n-isotropic point source of equal amplitude and spacing arranged as linear array. where n is any positive integer. The total field is given by

$$E = 1 + e^{j\psi} + e^{j2\psi} + e^{j3\psi} + \dots e^{j(n-1)\psi}.$$

where $\psi$ is total phase

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

where $\delta$ = phase difference of adjacent source.



$$E = e^{j\xi}\frac{(\sin n\psi/2)}{(\sin\psi/2)}$$

$\xi$ is field form source, and value is $\xi = \left(\frac{n-1}{\theta}\right)\psi$.

If the phase reffered to the centerpoint of array.

$$E = \frac{\sin(n\psi/2)}{\sin(\psi/2)}$$

hence the maximum field is given by.

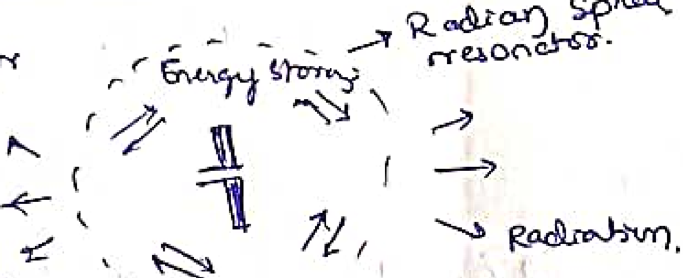
$$\boxed{E_{max} = n}$$

$$E = \frac{1}{n}\frac{\sin(n\psi/2)}{\sin(\psi/2)} \longrightarrow (1)$$

Eqn is reffered as array factor.

Q8.b. Derive the expression for radiation resistance of short dipole with uniform current.

$\longrightarrow$ To Derive the expression for Radiation Resistance of short dipole Consider the poynting vector theorem to calculate the total power radiating and Equated to the $I^2R$ where I is Rms value and R is Radiation Resistance Rr.




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

$$S_r = \frac{1}{2}Re\, E_\theta \cdot H_\phi^* \longrightarrow (2)$$

as $E_\theta = H_\phi Z = H_\phi\sqrt{\frac{\mu}{\epsilon}}$

Eqn (2) becomes

$$S_r = \frac{1}{2}Re\, Z H_\phi H_\phi^*$$

$$S_r = \frac{1}{2}|H_\phi|^2\sqrt{\frac{\mu}{\epsilon}}$$

Applying poynting therom,

$$P = \iint S_r\, ds = \frac{1}{2}\sqrt{\frac{\mu}{\epsilon}}\int_0^{2\pi}\int_0^{\pi}|H_\phi|^2 r^2 \sin\theta\, d\theta\, d\phi \longrightarrow (3)$$

$|H\phi|$ for short dipole is given as

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

Substituting in Eqn (8)

$$P = \frac{1}{32}\sqrt{\frac{\mu}{\varepsilon}} \frac{\beta^2 I_0^2 L^2}{\pi^2} \int_0^{2\pi}\int_0^{\pi} \sin^3\theta \, d\theta \, d\phi.$$

$$P = \sqrt{\frac{\mu}{\varepsilon}} \frac{\beta^2 I_0^2 L^2}{12\pi} \rightarrow (4)$$

Eqn (4) is Equated to $I_{rms}^2 \times R_r$.

i.e

$$\sqrt{\frac{\mu}{\varepsilon}} \frac{\beta^2 I_0^2 L^2}{12\pi} = I_{rms}^2 R_r$$

$$= \left(\frac{I_0}{\sqrt{2}}\right)^2 R_r$$

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

Eqn for Radiation Resistance of Short dipole antenna

Q8 c. Starting from electric and Magnetic potential, obtain the far field components for short dipole

$\Rightarrow$ consider a short dipole of length "L" placed coincident with z-axis that its center originat as in fig.

because of Retardation effect.

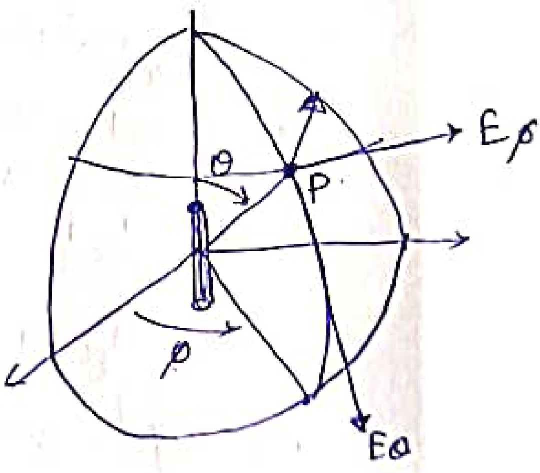
$$I = I_0 e^{j\omega t} \rightarrow (1)$$

considering propagation time

$$t = t - (r/c)$$

replacing in Eqn (1)

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



To calculate Magnetic field, need retarded vector

i.e $A_z = \frac{\mu_0}{4\pi}\int_{-L/2}^{L/2} \frac{[I]}{S}\, dz$ → ①

where $[I] = I_0\, e^{j\omega[t-(S/c)]}$ → ②

The retarded scalar potential V of a charge distribution is

$$V = \frac{1}{4\pi\varepsilon_0}\int_V \frac{[\rho]}{S}\, d\tau. \rightarrow ③$$

V can be in q form

$$V = \frac{1}{4\pi\varepsilon_0}\left\{\frac{[q]}{S_1} - \frac{[q]}{S_2}\right\}$$

$$[q] = \int [I]\, dt = I_0 \int e^{j\omega[t-(S/c)]}\, dt = \frac{[I]}{j\omega} \rightarrow ④$$

Substituting eqn ④ in ③.

$$V = \frac{1}{4\pi\varepsilon_0 j\omega}\left[\frac{e^{j\omega(t-(S_1/c))}}{S_1} - \frac{e^{j\omega[t-(S_2/c)]}}{S_2}\right]$$

$$S_1 = r - \frac{L}{2}\cos\theta$$

and

$$S_2 = r + \frac{L}{2}\cos\theta$$

In General.

$$E_r = \frac{I_0 L\cos\theta\, e^{j\omega[t-(r/c)]}}{2\pi\varepsilon_0}\left(\frac{1}{cr^2} + \frac{1}{j\omega r^3}\right)$$

and magnetic field.

$$|H| = H_\phi = \frac{I_0 L\sin\theta\, e^{j\omega[t-(r/c)]}}{4\pi}\left(\frac{j\omega}{cr} + \frac{1}{r^2}\right)$$

$H_\theta = 0.$

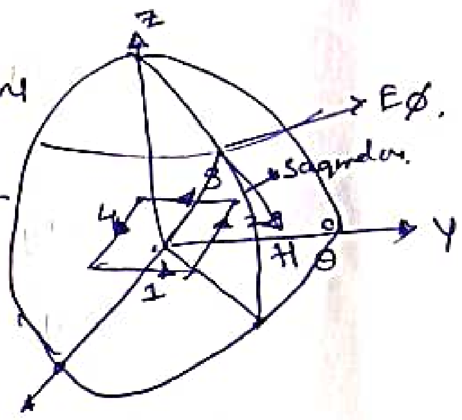
In far field $E_r$ is negligible becaus $1/r^2$ & $1/r^3$ is considerd negligible.

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

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

Q9 a. Derive the far field expression for small loop antenna.

⟹ In small loop Antenna, Square loops are considerd to find related field. In small loop size radiation pattern going to available in same form.




If the loop is oriented as shown in fig. than current / Electric field is going to has only $E_\phi$ component and $H_\theta$ component with respect magnetic field.

The total field.

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

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

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

can be written

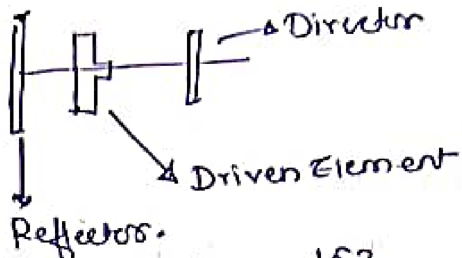
$$E_\phi = -j E_{\phi 0} d_r \sin\theta.$$

$$\boxed{E_\phi = \frac{60\pi [I] L d_r \sin\theta}{r\lambda}}$$

Q9 b. Explain the constructional details of Yagi-Uda antenna.

⇒ A basic Yagi-Uda antenna consists of 3 elements.

1) Reflector.
2) Driven Element
3) Directive.




① the length of the Reflector ⇒ $L_R = \frac{152}{f(MHz)}$

② Length of driven element $L_D = \frac{143}{f(MHz)}$

③ Length of directors. $L_{D_1} = \frac{137}{f(MHz)}$

$L_{D_2} = \frac{133}{f(MHz)}$

$L_{D_3} = \frac{130}{f(MHz)}$

$L_{D_4} = \frac{126}{f(MHz)}$

④ Spacing between driven element and director.

$$S = \frac{93}{f(MHz)}$$

Q9 c. Calculate L, H-plane aperture & $\theta_E$ and $\theta_H$. of E-plane aperture $10\lambda$ horn is fed by a rectangular waveguide of $TE_{10}$ mode. $\delta = 0.2\lambda$ in E-plane and $0.375\lambda$ in H-plane. find Beam width & directivity.

→ Given $a_E = 10\lambda$, $\delta_E = 0.2\lambda$ $\delta_H = 0.375\lambda$

$L = ?$ $a_H = ?$ $\theta_H = ?$ $\theta_E = ?$ $\theta_{HP} = ?$ $D = ?$

$L = \frac{a^2}{8\delta}$ = E-plane $a_E = 10\lambda$ $\delta_E = 0.2\lambda$

$$L = \frac{a_E^2}{8\delta_E} = \frac{(10\lambda)^2}{8(0.2\lambda)} = 62.5\lambda$$

H-plane aperture

$$L = \frac{a_H^2}{8\delta_H} \Rightarrow a_H^2 = 8L\delta_H$$

$$a_H^2 = 8 \times 62.5\lambda \times 0.375\lambda$$

$$a_H^2 = 187.5\lambda^2$$

$$\boxed{a_H = 13.693\lambda}$$

Plane analysis.

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

$$= 2\tan^{-1}\left(\frac{10\lambda}{2 \times 62.5\lambda}\right)$$

$$\boxed{\theta_E = 9.1480^\circ}$$

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

$$= 2\tan^{-1}\left(\frac{13.693\lambda}{2 \times 62.5\lambda}\right)$$

$$\boxed{\theta_H = 12.5^\circ}$$

$$(HPBD)_E = (\theta_{HP})_E = \frac{56^\circ\lambda}{a_E} = \frac{56^\circ\lambda}{10\lambda} = 5.6^\circ$$

$$\therefore (\theta_{HP})_H = \frac{67^\circ\lambda}{a_H} = \frac{67^\circ\lambda}{13.693\lambda} = 4.89^\circ$$

Directivity $\Rightarrow D = \frac{7.5 A_p}{\lambda^2}$ $\quad A_p = a_E a_H$

$$D = \frac{7.5(10\lambda)(13.693\lambda)}{\lambda^2}$$

$$\boxed{D = 1026.975}$$

$$G_P = 0.6D = \frac{4.5 A_p}{\lambda^2} = 616.185$$ (60% efficiency

Q10 a. Derive the radiation resistance of loop antenna and generlized the result for circular loop of any radius.

→ Radiation Resistance of Loop antenna.

Consider the P with the general current eqn i.e.

$$P = \frac{I_0^2}{2} R_r \rightarrow ①$$

where $R_r \rightarrow$ Radiation Resistance.

$I_0 \rightarrow$ Peak Current.

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

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

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

$$P = \frac{15}{2} \pi^2 (\beta a)^4 I_0^2 \int_0^{\pi} \sin^3\theta \, d\theta = 10\pi^2 \beta^4 a^4 I_0^2$$

since $A = \pi a^2$

$$P = 10 \beta^4 A^2 I_0^2 \longrightarrow ②$$

comparing eqn ① & ②.

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

$$R_r \simeq 31{,}200 \left(\frac{A}{\lambda^2}\right)^2$$

for n turns.

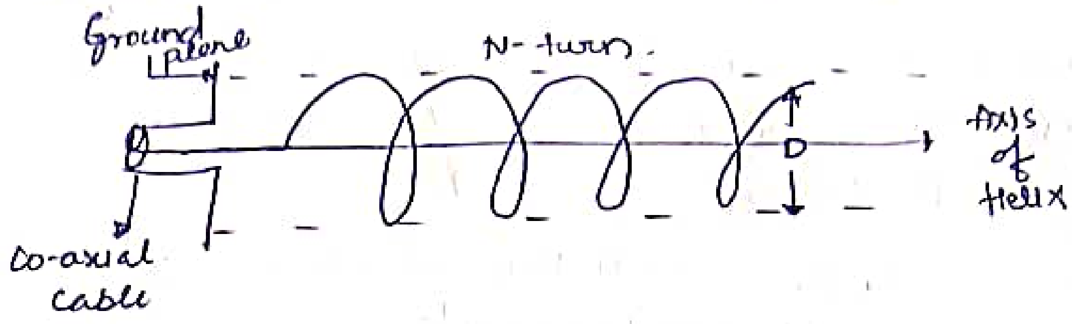
$$R_r \simeq 31{,}200 \left(\frac{nA}{\lambda^2}\right)^2$$

for Large loops.

$$R_r = 60\pi^2 C_\lambda = 3720 \frac{a}{\lambda} \,//$$

106. Helical Antenna with its helical Geometry.

→ It is an antenna in the shape of Helix.




→ It consist of N-turns along its axis.

→ The spacing of N-turns ~~along~~ between adjacent turn is 'S' m.

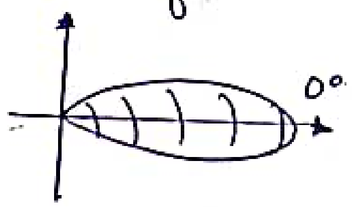
→ Axial length = N·S.

→ D- diameter of Helix,

Mode of operation. → Axial mode
→ Normal mode

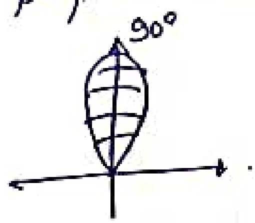
<u>Axial mode</u> → The direction of Maximum field is along the axis of Helix.

$$HPBW = \frac{52}{C}\sqrt{\frac{\lambda^3}{NS}}$$




$$R_T = \frac{140C}{\lambda}\ \Omega$$

Normal mode → The Direction of maximum field is perpendicular to the axis of Helix,




mode of operation is also called as "Broad side".

Q10c Explain different types of Horn-Antenna.

→ Types of horn antenna.

Depending upon the direction of flowing and shape the waveguide horn antennas are classified as

1. Sectoral horn
2. Circular horn

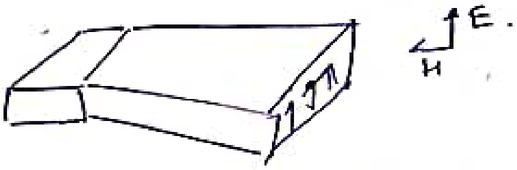
i) Sectoral horn → Depending upon direction of flaring sectoral horn are further classified into

a) H-plane Horn.

b) E-plane Horn

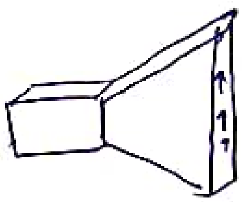
c) pyramidical Horn

a) Sectoral H-plane



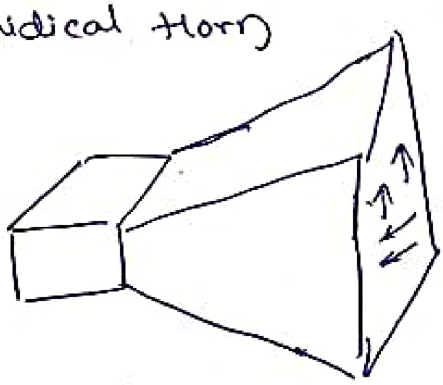

flaring is along the direction of magnetic field,

b) Sectoral E-plane



falaring is along the direction of Electric field.

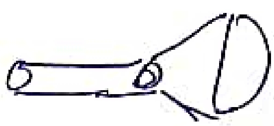
c) Pyramidical Horn



flaring is in both direction.



ii) Circular horn. → waveguide is circular and aperture is also circular. in shape. is called as conical horn.



b) Bi-conical.