Modified

CBCS SCHEME

USN | | | | | | | | | | |

18EC63

Sixth Semester B.E. Degree Examination, July/August 2022
Microwave and Antennas

Time: 3 hrs.

Max. Marks: 100

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

Module-1

1 a. Making use of functional block diagram explain the working of reflex Klystron oscillator. Also discuss modes of oscillation. **(10 Marks)**

b. A transmission line has the following parameters, $R = 2\Omega$, $G = 0.5$mho/m, $f = 1$GHz, $L = 8$nH/m, $C = 0.23$PF.
Calculate :
i) Characteristic impedance
ii) Propagation constant. **(04 Marks)**

c. List the characteristics of smith chart. **(06 Marks)**

OR

2 a. A reflex Klystron is to be operated at frequency of 10GHz, with DC beam voltage 300V, repeller space 0.1cm for 1 mode, calculate P_{RFMax} and corresponding repeller voltage for a beam current of 20mA. **(04 Marks)**

b. Derive the equation of transmission line with possible solution. **(10 Marks)**

c. A certain transmission line has the characteristics impedance of $75 + j0.01\Omega$ and is terminated in a load impedance of $70 + j50\Omega$.
Compute :
i) The reflection coefficient
ii) Transmission coefficient
iii) Standing wave ratio. **(06 Marks)**

Module-2

3 a. Prove that impedance and admittance matrices are symmetrical for a reciprocal junction. **(05 Marks)**

b. 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. **(10 Marks)**

c. In a H-plane T junction compute power delivered to the loads of 40Ω and 60Ω connected to arms 1 and 2 when a 10mW power is delivered to the matched port 3. **(05 Marks)**

OR

4 a. Derive the S-matrix representation for multiport network. Also define the losses interms of S-parameters. **(08 Marks)**

b. Explain briefly precision type variable attenuator. **(05 Marks)**

c. What are waveguide tees? Explain its basic types with neat diagram. **(07 Marks)**

Module-3

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 of 6(beryllium oxide) and thickness 'd' of 4 meter. Calculate :

i) The required width 'w' of the conducting strip in order to have a characteristic impedance of 50Ω.

ii) Strip line capacitance

iii) Strip line inductance

iv) Phase velocity. **(08 Marks)**

b. Explain the following terms related to antenna system :

i) Directivity

ii) Beam area

iii) Radiation pattern. **(06 Marks)**

c. Determine the directivity of the system if radiation intensity is given by $U = U_m \sin\theta \sin^2\phi$ using Exact method. Given that $0 \le \theta \le \pi$ and $0 \le \phi \le \pi$. **(06 Marks)**

OR

6 a. A microwave relay link is to be designed such a way that the transmitting and receiving antennas are separated to 30 statute miles. The directive gains of both the antennas are equal to 45db. Assuming both antennas are lossless and matched at 3GHz. Find what power is transmitted by the transmitter to have received power of 1MW. **(06 Marks)**

b. Explain briefly losses in micro–strip line. **(06 Marks)**

c. Calculate the directivity of the source with pattern $U = U_m \sin\theta^2 \sin^3\phi$ using :

i) Exact method

ii) Approximate method, where $0 \le \theta \le \pi$ and $0 \le \phi \le \pi$. **(08 Marks)**

Module-4

7 a. 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 is $\frac{\lambda}{2}$. **(10 Marks)**

b. Make use of poynthing theorem derive the expression for radiation resistance of short dipole with uniform current. **(10 Marks)**

OR

8 a. Derive an array factor expression in case of linear array of 'n' isotropic point sources of equal amplitude and spacing. **(10 Marks)**

b. Starting from electric and magnetic potential, obtain the far field components for short dipole. **(10 Marks)**

Module-5

9 a. Derive the far field expression for small loop antenna. **(08 Marks)**

b. Explain the constructional details for following antenna :

i) Yogi – uda array

ii) Parabolic reflector. **(12 Marks)**

OR

10 a. Derive the expression for radiation resistance of loop antenna. **(10 Marks)**

b. Find the length L, H-plane aperture and flare angle θ_E and θ_H of pyramidal horn for which E –plane operators is 10λ horn is fed by a rectangular waveguide with TE_{10} mode. Assume $\delta = 0.2\lambda$ in E – plane and 0.375λ in H – plane. Also find E – plane, H – plane beam widths are directivity. **(10 Marks)**

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Sir, regarding Modification of Scheme and Solutions of ECE/ETE board

"Manjunatha P" <manjup.jnnce@gmail.com>

To: boe@vtu.ac.in

August 23, 2022 10:46 AM

Comments from BoE of ECE Board for the following subjects towards Scheme and solution

Dear Sir,

Subject Name: Microwave and Antennas: 18EC63

After discussion with BoE members of ECE board, there are no issues in this subject.

Hence the same may be considered for the further process

With regards

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" APPROVED "

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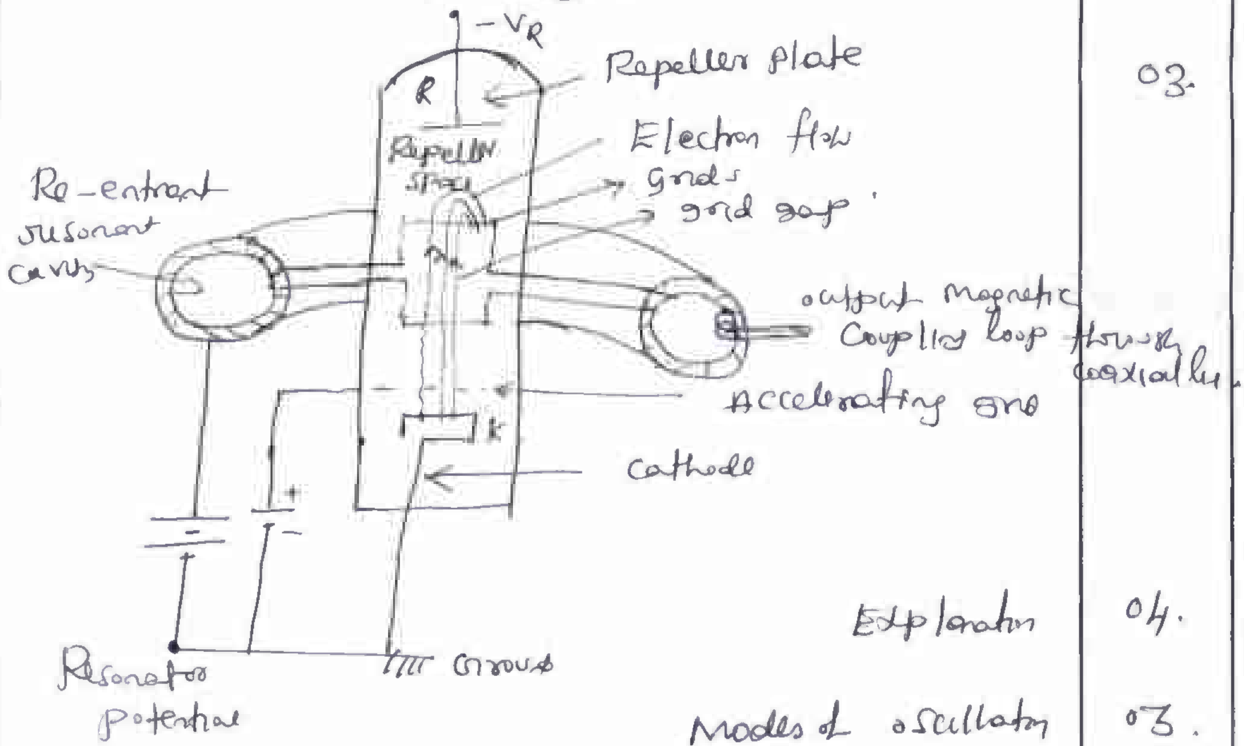
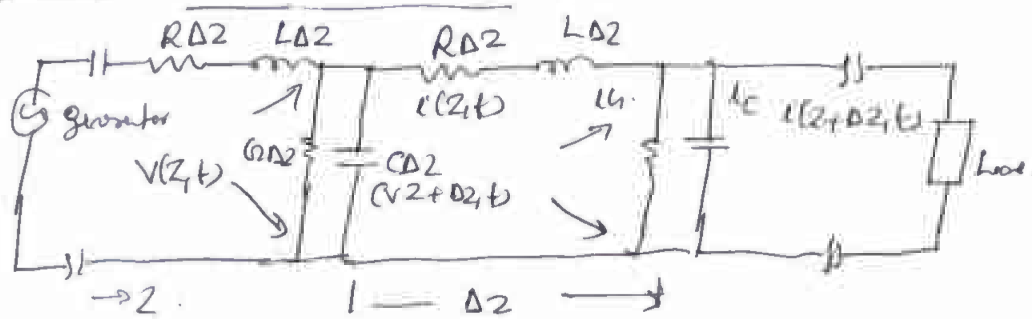
Scheme & Solutions

Signature of Scrutinizer

Subject Title : Microwave and Antennas. **Subject Code :** 18EC63

Question Number	Solution	Marks Allocated
	Module-1	
1 a)	Functional block diagram 	03.
	Explanation	04.
	Modes of oscillation	03.
b)	(i) $Z_0 = \sqrt{(R+j\omega L)/(G+j\omega C)}$ $= 181.3 \angle 8.4^\circ \Rightarrow 179.5 + j\,0.2648$	02
	(ii) $\gamma = \sqrt{(R+j\omega L)(G+j\omega C)}$ $= 0.0514 + j\,0.2725$	02.
c)	Characteristics of Smith Chart ① The constant r and constant x loci form two families of orthogonal circles in the chart. ② upper half represent $+jx$ and lower half represent $-jx$ ③ the point $z_{min} = 1/e$	

Subject Title : **Subject Code :**

Question Number	Solution	Marks Allocated
(4)	At point $Z_{max} = e$ there is V_{max} on the line.	
(5)	The normalized impedance or admittance is repeated for every half wavelength of distance	06.
6)	the distance around the Smith Chart once is one half of wavelength	
2a)	$P_{Rmax} = (0.398 V_0 I_0)/N$	
	$= \dfrac{0.398 \times 300 \times 20 \times 10^{-3}}{1\frac{3}{4}}$	03
	$= \underline{\underline{1.365 \text{ Watts}}}$.	
	$\lvert V_R \rvert = (6.74 \times 10^{-6} \times f_{Hz} \times L_m \times \sqrt{V_0/N}) - V_0$	03
	$L_m = 10^{-3} m$ $\quad N = 1\frac{3}{4} = 1.75$	
	$\lvert V_R \rvert = 6.74 \times 10^{-6} \times 10 \times 10^{9} \times 10^{-3} \times \sqrt{300/1.75}) - 300$	
	$\lvert V_R \rvert = -367.08 \text{ volts}$.	
2b)	Transmission Line Equation	
		02
	Final Equation $\dfrac{\partial^2 v}{\partial z^2} = RGv + (RC+LG)\dfrac{\partial v}{\partial t} + LC\dfrac{\partial^2 v}{\partial t^2}$	04.
	$\dfrac{\partial^2 i}{\partial z^2} = RGi + (RC+LG)\dfrac{\partial i}{\partial t} + LC\dfrac{\partial^2 i}{\partial t^2}$.	
	$V(z) = V_+ e^{-rz} + V_- e^{rz}$	
	$I(z) = I_+ e^{-rz} + I_- e^{+rz}$.	
	$r = \alpha + j\beta$.	04.
	possible solution. $V = V_+ e^{-rz} + V_- e^{rz} = V_+ e^{-\alpha z} e^{-j\beta z} + V_- e^{\alpha z} e^{j\beta z}$.	
	$I = Y_0 (V_+ e^{-\alpha z} e^{-j\beta z} - V_- e^{\alpha z} e^{j\beta z})$	
	$Z_0 = \dfrac{1}{Y_0} = \sqrt{Z/Y} = \sqrt{\dfrac{R+j\omega L}{G+j\omega C}} = R_0 + jX_0$.	

(3/13)

Subject Title : Subject Code :

Question Number	Solution	Marks Allocated
	$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)}$ $= \frac{1}{2}\left(R\sqrt{C/L} + G\sqrt{L/C}\right) + j\omega\sqrt{LC}$. $\alpha = \frac{1}{2}\left(R\sqrt{C/L} + G\sqrt{L/C}\right)$ $\beta = \omega\sqrt{LC}$, $Z_0 = \sqrt{L/C}$.	
2b)	Reflection Coefficient $= \frac{Z_l - Z_0}{Z_l + Z_0}$ $= \frac{70 + j50 - 75 - j0.01}{70 + j50 + 75 + j0.01}$ $= 0.33 \angle 76.68$ $= 0.08 + j0.32$.	02
	Transmission Coefficient $= \frac{2Z_l}{Z_l + Z_0} = 1.12 \angle 16.51$ $= 1.08 + j0.32$.	02
	Standing wave $= \frac{1 + 0.08}{1 - 0.08} = 1.174$.	02.
3a)	In a reciprocal n/w the impedance & admittance matrices are symmetrical and the junction media are characterized by scalar electrical parameter μ and ϵ $V_i V_j V_{ij} = V_j V_i V_{ji}$ or $Y_{ij} = Y_{ji}$	05
b)	Characteristics of Magic T ① If two waves of equal magnitude and the same phase are fed into port 1 and port 2, the o/p will be zero at port 3 and additive at port 4. ② If wave is fed into port 4 (the H arm) it will be divided equally b/n port 1 and port 2 of the collinear arms and will not appear at port 3 (the E arm).	

Question Number	Solution	Marks Allocated
	(3) If a wave is fed into port 3 (the E arm) it will produce an o/p of equal magnitude & opposite phase at port 1 and 2 $S_{13} = -S_{23}$. the o/p at port 4 is zero. That is $S_{43} = S_{34} = 0$	
	(4) If a wave is fed into one of the Collinear arms at port 1 or port 2, it will not appear in the other Collinear arm at port 2 or port 1 because the E arms causes a phase delay while the H arm causes a phase advance. That is $S_{12} = S_{21} = 0$	04
	S matrix relation $[S] = \frac{1}{\sqrt{2}} \begin{vmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & 1 \\ 1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 \end{vmatrix}$	06.
c)	H Plane S matrix relation	
	$[S] = \begin{bmatrix} 1 & -1 & \sqrt{2} \\ -1 & 1 & \sqrt{2} \\ \sqrt{2} & \sqrt{2} & 0 \end{bmatrix}$ $P_1 = \frac{1}{2}\|b_1\|^2(1-\|\Gamma_1\|^2)$	01
	$P_2 = \frac{1}{2}\|b_2\|^2(1-\|\Gamma_2\|^2)$	01
	$\Gamma_1 = \frac{\|40-50\|}{\|40+50\|} = \frac{1}{9}$	
	$\|\Gamma_1\|^2 = 0.01234$	
	$\|\Gamma_2\| = 8.269 \times 10^{-3}$	01
	$P_1 = 0.005(1-0.01224) = 4.93\,mW$	01
	$P_2 = 0.005(1-8.269\times10^{-3}) = 4.95\,mW.$	01
4(a)	S-matrix representation for multiport network	
	$S_{11} = \left(b_1/a_1\right)_{a_2=0}$, $S_{22} = \left(b_2/a_2\right)_{a_1=0}$ $S_{12} = \left(b_1/a_2\right)_{a_1=0}$ $S_{21} = \left(b_2/a_1\right)_{a_2=0}$	04

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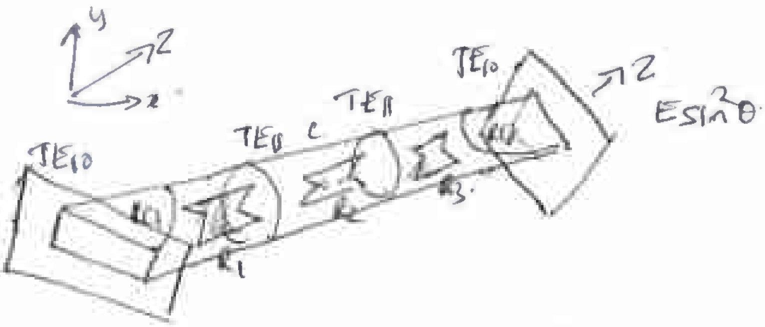
Subject Title : **Subject Code :**

Question Number	Solution	Marks Allocated
	$$\begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_N \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{1N} \\ S_{21} & S_{22} & S_{2N} \\ \vdots & & \\ S_{N1} & S_{N2} & S_{NN} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_N \end{bmatrix}$$	
	Insertion loss $= 20 \log \frac{1}{\lvert S_{21}\rvert} = 20 \log \frac{1}{\lvert S_{12}\rvert}$	
	Transmission loss or attenuation (db) $= 10 \log \frac{1-\lvert S_{11}\rvert^2}{\lvert S_{12}\rvert^2}$	04.
	Reflection loss $= 10 \log \frac{1}{1-\lvert S_{11}\rvert^2}$	
	Return loss $= 20 \log \frac{1}{\lvert S_{11}\rvert}$	
b)	precision type variable attenuator	
	A precision type variable attenuator consists of a rectangular to circular transition, a piece of circular waveguide and a circular to rectangular transition	03.
		02
c)	A waveguide Tee is formed when 3 wave guides are interconnected in the form of english alphabet T and thus waveguide tee is a 3 port junction. 2 types (I) H-Plane Tee junction (II) E-plane Tee junction.	02
	A Combination of these two tee junctions is called a hybrid tee or Magic tee.	05
	Basic types with neat diagram	

5a) (i) $w = \frac{377}{\sqrt{\epsilon_{rd}}} \frac{d}{z_0} = \underline{12.31 \times 10^{-3} m}$ 02

02

(ii) $C = \frac{\epsilon_d w}{d} =$ 163.50 PF/m

iii) $L = \frac{\mu_r d}{w} =$ 0.41 μH/m 02

(iv) Phase velocity $v_p = \frac{c}{\sqrt{\epsilon_{rd}}} = \frac{3 \times 10^8}{\sqrt{6}} = 1.22 \times 10^8 m/s$. 02

5b) (i) Directivity: It is defined as the ratio of the maximum power density $P(\theta,\phi)_{max}$ (watt/m²) to the average value over a sphere as observed in the far field of an antenna. 02

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

(ii) Beam Area: Beam Area Ω_A is the solid angle through which all of the power radiated by antenna would stream if $P(\theta,\phi)$ maintained its maximum value over Ω_A and was zero. 02

$$\Omega_A = \iint_{4\pi} P_n(\theta,\phi) d\Omega \quad (Sr)$$

(iii) Radiation pattern: Radiation pattern is the graphical representation of radiation properties of the antenna as a function of space. 02

5c) $U = U_m \sin\theta \sin^2\phi$. $\quad D = \frac{4\pi U_m}{P_{avg}}$.

$$P_{avg} = \int_{\theta=0}^{\pi} \int_{\phi=0}^{\pi} U \sin\theta d\theta d\phi.$$ 02

$$= \int_{\theta=0}^{\pi} \int_{\phi=0}^{\pi} U_m \sin\theta \sin^2\phi) (\sin\theta d\theta d\phi).$$ 02

$=$

$P_{rad} = U_m \left[\frac{\pi^2}{4}\right]$

$D = \frac{4\pi U_m}{U_m\left(\frac{\pi^2}{4}\right)}$

$D = \frac{16}{\pi} = \underline{5.09}$ } 02.

$D_{db} = \underline{7.07 db}$

6a) Given $d = 30$ statutemile ; $G_T = G_R = 45 db$, $f = 3 \times 10^9 Hz$.

1 statute mile $= 1609.5 m$

$d = 30 \times 1609.5 = 48280.5 m$ 01

$\lambda = c/f = 0.1 m$.

$G_t = G_r = \text{Antilog}_{10}\left(\frac{G_t \text{ or } G_r \text{ in db}}{10}\right) = \underline{31.62 \times 10^3}$ 01

using friis Tx formula $P_r = P_t (G_r \times G_t)\left(\frac{\lambda}{4\pi d}\right)^2$ 01

$P_r = P_t (31.62 \times 10^3 \times 31.62 \times 10^3)\left(\frac{\lambda = 0.1}{4\pi \times 48280.5}\right)^2$ 02

$P_t = 36.815$ watts 01.

6b) — written in ~~next page~~..

6c) $U = U_m \sin^2\theta \sin^3\phi$

(i) Exact method

$P_{rad} = \int_0^{\pi}\int_0^{\pi} U_m \sin^2\theta \sin^3\phi \sin\theta d\theta d\phi$

$P_{rad} = \frac{U_m}{16}\left[\frac{16}{3}\right]\left[\frac{16}{3}\right] = \frac{16 U_m}{9}$

$D = \frac{4\pi U_m}{\frac{16 U_m}{9}} = \frac{9\pi}{4} = \underline{7.0685}$

$D_{in db} = \underline{8.49 db}$

(ii) approx method

$D = \frac{41253}{\theta_{HP}\phi_{HP}}$

To find θ_{HP} take $\phi = 90°$

$U = U_m \sin^3\phi \sin^2\theta$. Let $\theta = \phi 1$

$U = \frac{U_m}{2} = U_m \sin\theta_1$.

$\frac{1}{2} = \sin^2\theta$

$\theta = 45°$

$\theta_{HP} = 180 - 2\theta_1$

$180 - 2(90)$ 04

$\theta_{HP} = 90°$ +

$\phi_{HP} = ?$ $\theta = 90°$ 04.

$U = U_m \sin^3\theta$

$\frac{U_m}{2} = U_m \sin^3\phi_1$

$\phi_1 = \underline{52.53}$

$\phi_{HP} = 180 - 2\phi_1$

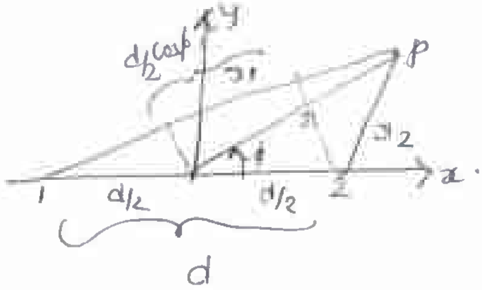
$= \underline{74.9}$

$D = \frac{41253}{(90)(74.9)}$

$D = 6.88$ or $\underline{7.86 db}$

6b Losses in microstrip line (1) Dielectric loss (2) Ohmic skin loss. } Explanation (8113) 03+03

7a) Field pattern for two point source

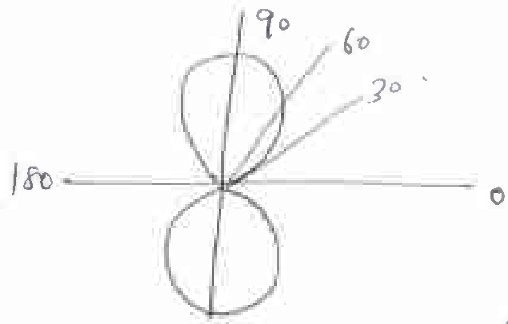


$E_p = E_1 + E_2$

$E_p = 2E_0 \cos\frac{\psi}{2}$ 08

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

The pattern is bidirectional figure of 8



02

7b) Radiation Resistance of Short dipole.

We know $S = \frac{1}{2} Re(E \times H)$

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

$S_r = \frac{1}{2}|H_\phi|^2 \sqrt{\mu/\varepsilon}$. 03

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

$|H_\phi| = \frac{\omega I_0 L \sin\theta}{4\pi c r}$ $r = \frac{\lambda}{2\pi}$.

$P = 60\pi\int_0^{2\pi}\int_0^{\pi}\left(\frac{I_0^2 L^2}{4\lambda^2 r^2}\right) r^2 \sin^3\theta\, d\theta\, d\phi$ 03

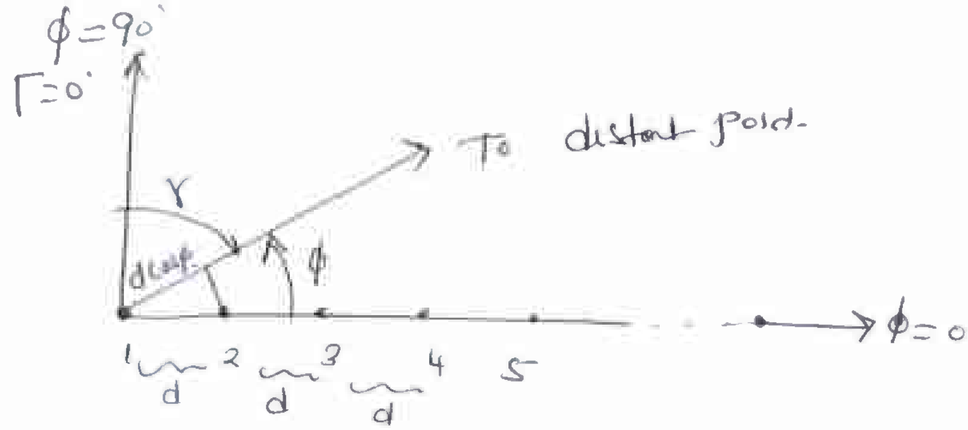
$= \frac{15\pi I_0^2 L^2}{\lambda^2}\int_0^{2\pi}\int_0^{\pi}\sin^3\theta\, d\theta\, d\phi$

$= \frac{40\pi^2 I_0^2 L^2}{\lambda^2}$ 02

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

$$R_r = \frac{80\pi^2 I_0^2 L^2}{\lambda^2 I_0^2}$$ 02

8(a). Array factor expression for linear array of n isotropic point source.



01

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

$$\psi = (2\pi d/\lambda)\cos\phi + \delta = d_r \cos\phi + \delta \quad \text{—(2)}$$

× by $e^{j\psi}$ to eqn (1)

$$E e^{j\psi} = e^{j\psi} + e^{j2\psi} + e^{j3\psi} + \dots + e^{jn\psi} \quad \text{—(3)}$$

(1) − (2) $$E = \frac{1 - e^{jn\psi}}{1 - e^{j\psi}} \quad \text{—(4)}$$ 04

$$E = \frac{e^{jn\psi/2}}{e^{j\psi/2}} \frac{\left[e^{jn\psi/2} - e^{-jn\psi/2}\right]}{\left[e^{j\psi/2} - e^{-j\psi/2}\right]} \quad \text{—(5)}$$

$$E = e^{j\xi} \frac{\sin\frac{n\psi}{2}}{\sin\frac{\psi}{2}} \quad \text{— 6}$$

$$E = \frac{\sin\frac{n\psi}{2}}{\sin\frac{\psi}{2}} \angle\xi \quad \text{— 7}$$

$$\xi = \left(\frac{n-1}{2}\right)\psi \quad \text{— 8}$$ 04

$$E = \frac{\sin\frac{n\psi}{2}}{\sin\psi/2}$$ if phase is referred to the centre of the array. —9

10/13

When $\psi = 0$, we have the relation that

$E = n$.

$E_{max} = n$

$$E = \left(\frac{1}{n}\right)\left[\frac{\sin\frac{n\psi}{2}}{\sin\psi/2}\right] \quad \text{--- (10)}$$ 01

Above Equ is Array factor.

8b) For field Component of Short dipole

From vector potential $A_z = \frac{\mu[I]l}{4\pi r}$ 03

$A_r = A_z \cos\theta$

$A_r = \frac{\mu[I]l\cos\theta}{4\pi r}$

$A_\theta = -A_z \sin\theta$

$= -\frac{\mu[I]l}{4\pi r}\sin\theta$

$A_\phi = 0$.

From Scalar potential $V = \frac{1}{4\pi\varepsilon}\left[\frac{q}{r_1} - \frac{q}{r_2}\right]$ 02

$E = -j\omega A - \nabla V$

$E = E_r a_r + E_\theta a_\theta + E_\phi a_\phi$

$A = A_r a_r + A_\theta a_\theta + A_\phi a_\phi$

For field Components $E_\phi = 0$ 05

$E_r = 0$

$$E_\theta = \frac{[I]l\sin\theta}{4\pi\varepsilon}\left[\frac{j\omega}{c^2 r}\right]$$

$$E_\theta = \frac{j60\pi[I]l\sin\theta}{r\lambda}.$$

Magnetic fields $H_r = 0$, $H_\theta = 0$

$$H_\phi = \frac{j[I]l\sin\theta}{2r\lambda}$$

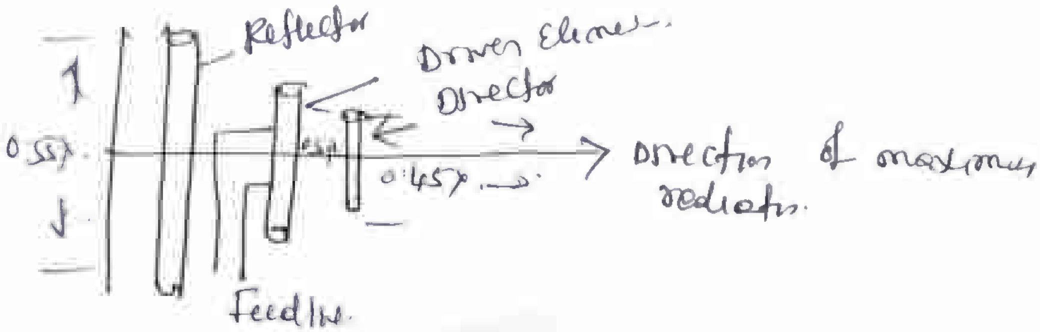
9a) Expression for far field for small loop

$$E_\phi = -E_{\phi_0} e^{j\psi/2} + E_{\phi_0} e^{-j\psi/2}$$
$$= -2j E_{\phi_0} \sin \psi/2$$
$$\psi = d_r \cos\phi = \frac{2\pi a \cos\phi}{\lambda}$$
} 02

$$\sin\phi = 90 - \theta, \quad \cos\phi = \sin\theta.$$
$$\psi = \frac{2\pi a}{\lambda} \sin\theta \qquad \sin \psi/2 = \sin\left(\frac{\pi a}{\lambda}\right) \sin\theta$$
$$\sin\left[\frac{\pi a}{\lambda} \sin\theta\right) = \frac{\pi a}{\lambda} \sin\theta$$
$$E_{\phi_0} = \frac{j 60\pi [I] a}{r\lambda}.$$
} 02

$$E_\phi = \frac{120\pi^2 [I] \sin\theta}{r} \left(\frac{A}{\lambda^2}\right]$$
$$H_\theta = \frac{E_\phi}{120\pi}$$
$$H_\theta = \frac{\pi [I] \sin\theta}{r} \left[\frac{A}{\lambda^2}\right]$$
} 04.

9b) (i) Yagi-Uda Antenna : It is an array antenna which consists of one active element and few parasitic elements. The active element consists of a folded dipole whose length is $\lambda/2$. parasitic element consists of one reflector & few directors. The length of reflector is greater than $\lambda/2$. The purpose of reflector & directors is to increase the gain but they load the driven element. 06.



(ii) ~~Parabolic reflector~~ It is a reflector antenna which has the shape of paraboloid and employs the properties of parabola. The types 06.
(1) paraboloid (2) Cylindrical.

(10a) Radiation Resistance of Loop Antenna

We know $P = \frac{I_0^2}{2} R_r$. 01

$$S_r = \frac{1}{2}|H|^2 Z = \frac{1}{2}|H|^2 120\pi = H^2 60\pi$$

$$S_r = 60\pi\left[\frac{\beta a I}{2r} J_1\left[\frac{2\pi}{\lambda} a \sin\theta\right]\right]^2$$

$$P = \int_0^{2\pi}\int_0^{\pi} 15\pi\left[\frac{\beta a I}{r} J_1\left[\beta a \sin\theta\right]\right]^2 r^2 \sin\theta\, d\theta\, d\phi$$ 06

$$P = 10\,\beta^4 A^2 I^2$$

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

$$R_r = 31200\left(\frac{nA}{\lambda^2}\right)^2 \Omega$$ 03

n = no of turns.

(10b) Given $a_E = 10\lambda$, $\delta_E = 0.2\lambda$ $\delta_H = 0.375\lambda$ $L = ?$

$\delta_H = ?$, $\theta_H = ?$ $(\theta_{HP})_E = ?$, $(\theta_{HP})_H = ?$

Axial length $L = \frac{a^2}{8\delta}$ for E plane $a_E = 10\lambda$ $\delta_E = 0.2\lambda$ 02

$$L = \frac{a_E^2}{8\delta_E} = 62.5\lambda.$$

For H plane $L = \frac{a_H^2}{8\delta_H}$ = $a_H^2 = 8L\delta_H$ 01

$a_H^2 = 187.5\lambda^2$

$a_H = 13.69\lambda$

Angle $\theta_E = 2\tan^{-1}\left(\frac{a_E}{2L}\right) = 2\tan^{-1}\left(\frac{10\lambda}{2\times 62.57}\right)$

$\theta_E = 9.15 \qquad \theta_H = 2\tan^{-1}\left(\frac{a_H}{2L}\right)$ 02

$\theta_H = 12.5$

Half power beam width

$$(HPBW)_E = (\theta_H P)_{H\,plane} = \frac{56\lambda}{a_E}$$

$$\frac{56\lambda}{10\lambda} = \underline{\underline{5.6}}$$ 01

$$(HPBW)_H = (\theta_H P)_{H}\,plane = \frac{67\lambda}{a_H} = \frac{67\lambda}{13.69\lambda}$$ 01

$$= \underline{\underline{4.89}}$$

<u>Directivity</u> $\quad D = \frac{7.5 A_p}{\lambda^2} \qquad A_p = a_E a_H.$

$$D = \frac{7.5(10\lambda)(13.69\lambda)}{\lambda^2}$$ 02

$$\underline{\underline{D = 1026.97}}$$

Power gain $\quad G_p = 0.6D = \frac{4.5A_p}{\lambda^2} = \underline{\underline{616.185}}$ 01