Model Answer Antenna and Waves course E1411

Q 1

(a) HPBW:- In a plane containing the direction of maximum of beam; the angle between the two directions in which the radiation intensity is one-half value of the beam.

(b) $\text{Gain} = \dfrac{4\pi U_{max}}{P_{in}}$

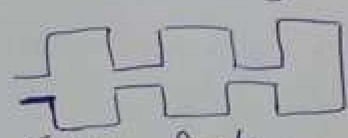
$$A_{eff} = \frac{\lambda^2}{4\pi}(\text{Gain})\left(1-|\Gamma|^2\right)(PLF)$$

(c) radiation resistance referred to the radiated power from antenna. $R_r = 20\left(\frac{L}{\lambda}\right)^2 \pi^2$

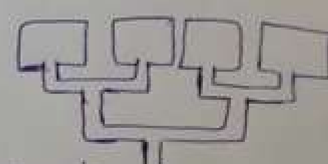
(d) Conditions of max power:-

1. polarization matching $\Rightarrow PLF = 1$
2. Impedance matching $|\Gamma| = 0$
3. Lossless materials $\Rightarrow \xi_{cd} = 1$

(e) array feeding

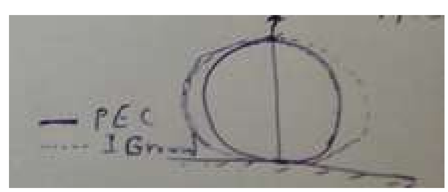


Series feeding



Corporate feeding

f- Horizontal dipole mounted on imperfect ground plane because the resultant field pattern maximum is less sensitive to the ground properties (μ, ϵ, σ)



array / parameters	Uniform broad-side	binomial	Tsch.
HPBW	best	worth	Moderate
S.L.L.	fixed $= -13.5\,dB$	$= -\infty\ dB$ at $d = \lambda/2$	Can be Controlled.
Complexity in design & fabrication	simple	Complex	Complex

$\boxed{Q2}$

$$U_n = \sin\theta \cos^2\phi$$

(a) x-z-plane $\Rightarrow \phi_{max} \Rightarrow U = \sin\theta$

HPBW $\sin\theta = \frac{1}{2} \Rightarrow \theta = 30°$

Max $\theta = 90$

$HPBW = 2|90 - 30| = 180° = \pi$

(b) aZimuthal x-y-plane $\Rightarrow \theta_{max}$

$\Rightarrow U = \cos^2\phi$ & $\phi_{max} = 0°$

HPBW $\cos^2\phi = \frac{1}{2} \Rightarrow \phi = 45°$

$\Rightarrow HPBW = 2|0 - 45| = \frac{\pi}{2}$

$\Rightarrow$ (c) $D_{krauss} = \dfrac{4\pi}{\pi \times \frac{\pi}{2}} = \dfrac{8}{\pi} = 10\log\left(\frac{8}{\pi}\right) \simeq 4.06\,dB$

exact

$$P_{rad} = \iint U\,d\Omega = \int_0^{\pi}\int_0^{2\pi} \sin\theta \cos^2\phi \,\sin\theta\, d\theta\, d\phi$$

$= \frac{2\pi}{2} * \frac{\pi}{2} = \frac{\pi^2}{2}$

$U_{max} = 1$

$\Rightarrow D = \frac{4\pi U_{max}}{P_{rad}} = \frac{4\pi}{\frac{\pi^2}{2}} = \frac{8}{\pi} = 10\log\left(\frac{8}{\pi}\right) \simeq 4.06 \, dB$

(d) directional pattern

(e) broadside as $\theta_{max} = 90°$ (perpendicular to z axis)

(Q3) $f = 1 \, GHz \Rightarrow \lambda = \frac{c}{f} = \frac{3\times10^8}{1\times10^9} = 0.3 \, m$

$G_1 = 20dB = 10\log G_1 \Rightarrow G_1 = 100$

$G_2 = 10dB = 10$

$\frac{P_r}{P_t} = \left(\frac{4\pi}{\lambda}\right)^2 D_1 D_2 \; PLF \left(1-|\Gamma_1|^2\right)\left(1-|\Gamma_2|^2\right) \xi_{cd1} \xi_{cd2}$

$D_1 = G_1$ & $D_2 = G_2$ due to $\xi_{cd} = 100\%$

$\Gamma_1 = 0.9 = \Gamma_2$

$PLF = \left| \left(\frac{\hat{a}_x + j5\hat{a}_y}{\sqrt{26}}\right) \cdot \left(\frac{\hat{a}_x - j\hat{a}_y}{\sqrt{2}}\right) \right|^2 = \left(\frac{1+5}{\sqrt{52}}\right)^2 = \frac{36}{52} = \frac{18}{26}$

$= \frac{9}{13}$

$\Rightarrow P_r = 100 * \left(\frac{9}{13}\right)\left(1 - 0.81\right)^2 * 100 \times 10 \times \left(\frac{\lambda}{4\pi \times 500}\right)^2$

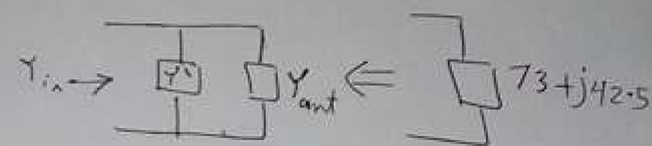
$= 5.7 \, \mu watt$

(Q4)

(a) $\frac{\lambda}{2}$ dipole $Z_{in} = 73 + j42.5$

(b) $D = 1.643 = 10\log 1.643 = 2.15\,dB$

(c)



$$Y_{ant} = \frac{1}{Z_{ant}} = \frac{1}{73+j42.5}$$

$$= 0.01 \times 10^{-3} - j\,0.005$$

to Cancel $-j\,0.005 \Rightarrow$ Use $Y' = j\,0.005 \Rightarrow$ Capacitive load

$Y' = j\omega C = j\,0.005 \Rightarrow \omega C = 0.005$

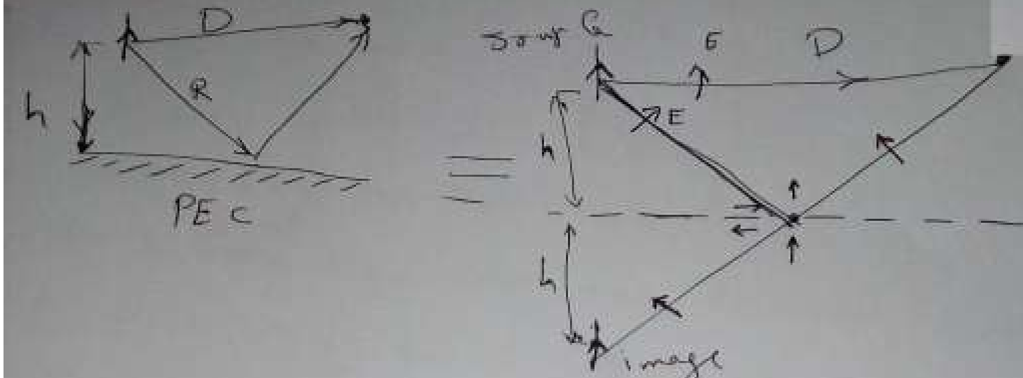
$2\pi f C = 0.005 \Rightarrow$ Capacitance $= \dfrac{1}{2\pi f \times 0.005}$ Farad.

$Y_{in} = 0.01 \Rightarrow Z_{in} = \dfrac{1}{Y_{in}} = 100\ \Omega$

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{100 - 50}{100 + 50} = 0.33$$

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} = 2$$

(Q5) Image theory: the signal from Transmitter mounted a h height above PEC is Collection of two paths direct path and reflected path. we referred to reflected



(a) Total field $= E_1 + E_2$

$$= \frac{j30 I_o k l\, e^{-jkr}}{r}\left[e^{jkh\cos\theta} + e^{-jkh\cos\theta} \right]\sin\theta$$

$$= j\underbrace{\frac{30 I_o k l}{r} e^{-jkr}\sin\theta}_{\text{Element}}\left[\underbrace{2\cos(kh\cos\theta)}_{\text{A.F.}}\right]$$

(b) $h = \lambda$

for vertical dipole mounted on PEC

Total no of lobes $= \frac{2h}{\lambda} + 1 = 2+1 = 3$

(c) $$D_{h=\lambda} = \frac{2}{\left[\frac{1}{3} - \frac{\cos(2kh)}{(2kh)^2} + \frac{\sin(2kh)}{(2kh)^3}\right]}$$

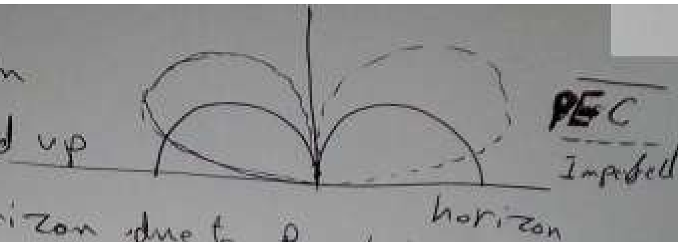
$2kh = 2\times\frac{2\pi}{\lambda}\lambda = 4\pi$

$$D = \frac{2}{\frac{1}{3} - \frac{1}{(4\pi)^2}} = 6.116 = 7.86\,dB$$

II:- $$E_t = E_d + E_r = j\frac{30 I_o k l}{r}\left[e^{+jkh\cos\theta} + R_v e^{-jkh\cos\theta}\right]\sin\theta$$

for imperfect ground plane, $R_v \neq 1$

So the maximum of beam is tilted up

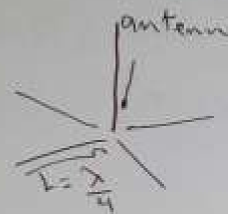


away from horizon due to $R_v \neq 1$ $\theta = 90$

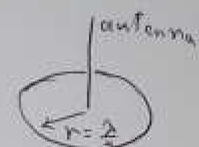
~~So~~ to direct ~~make~~ beam maximum toward horizon

(a) put wiring radial if $\lambda >> l$ & $l = \frac{\lambda}{4}$

(b) put a ~~mettalic~~ metallic disc where radius $= \frac{\lambda}{4}$



or



Q6 $D = 10dB = 10 \log d \Rightarrow D = 10$

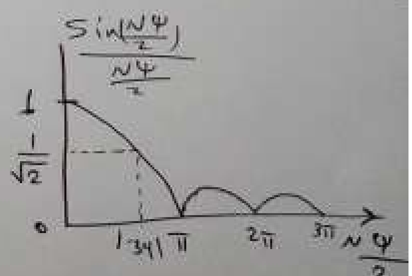
$D = 10 = 2N \frac{d}{\lambda}$. where d: distance between elements

so $10 = 2N \frac{\lambda/2}{\lambda} \Rightarrow N = 10$

(a) no of elements $= 10$

(b) $L = (N-1)d = \frac{9}{2}\lambda$

(c) $HPBW\Big|_{d=\frac{\lambda}{2}} = 2\left|90 - \theta_{hp}\right|$



~~[illegible]~~

$\frac{N\Psi}{2} = 1.391 \Rightarrow \frac{10}{2}(kd\cos\theta_{hp} + 0) = 1.391$

$5 \times \frac{2\pi}{\lambda} \frac{\lambda}{2} \cos \theta_{hp} = 1.391$

$\theta_{hp} = 85^\circ$

$HPBW = 2|90 - 85| = 10.16^\circ$

(d) FNBW nulls at $\frac{N\psi}{2} = m\pi$

$\frac{N\psi}{2} = \pi$ for $m = 1$ first null

$5\pi \cos \theta_n = \pi$

$\theta_n = 78.4^\circ$

$FNBW = 2|90 - 78.4| = 23^\circ$

(e) $S.L.L. \simeq -13.5\,dB$

(f) $\beta = 0$ (broad-side)

(g) no of side lobes = no. of nulls - 1

nulls $\frac{N\psi}{2} = 5 \cos \theta_n = m\pi$

So $m = 5$ is max as $\cos \theta_n = 1$

and $m > 5$ refuse because $\cos \theta_n > 1$ doesn't exit

So we have 5 nulls

So no of side lobes $= 5 - 1 = 4$ #

(h) $m = 1$ $\theta_n = 78.4^\circ$

$m = 2 \Rightarrow \theta_n = \cos^{-1}\left(\frac{2}{5}\right) = 66.4$

$m = 3 \Rightarrow \theta_n = \cos^{-1}\left(\frac{3}{5}\right) = 53.1$

Q7

5 elements

1

1 1

1 2 1

1 3 3 1