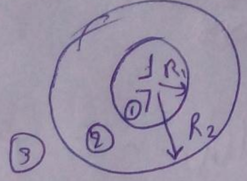
E1518 Model answer Antenna & waves

Q1

I (a)



D: antenna length

① Reactive near field $0 < r < 0.62\sqrt{D^3/\lambda}$

② Radiating near field $0.62\sqrt{D^3/\lambda} < r < 2D^2/\lambda$

③ " far field $r > 2D^2/\lambda$

3

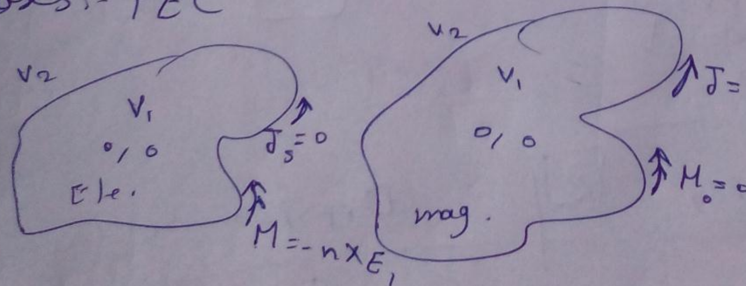
(b) HPBW: In a plane containing the direction of max. of beam, the angle between the two directions in which the radiation intensity is $\frac{1}{2}$ of max.

2

$D_0 = \dfrac{4\pi U_{max}}{\Theta_1 \Theta_2}$ where Θ_1 & Θ_2 HPBW.

(c) Love principle: a null field is produced within the imaginary surface S. where E & H = 0 within S can't be disturbed if the properties of medium are changed

Cases:- PEC



3

(d) quadratic phase effect:- the phase difference between the point at center of horn and the one at horn edges leading to the two signals are not arrived at same time on horn aperture plane.

$\delta(y') = \frac{1}{2}\left(\frac{y'^2}{\rho_1}\right)$ or $\delta(y') = \rho_e(y') - \rho_1$

phase $= k\,\delta(y')$ $\boxed{2}$

that affect the pattern specially in E-Plane which introduce ripples in pattern. To Compensate that effect, a lens are implanted on horn aperture

* optimal dimensions:-

$$a_1 = \sqrt{3\lambda\rho_2} \quad , \quad b_1 = \sqrt{2\lambda\rho_1}$$ $\boxed{2}$

(f) benefits of Corr :- $\boxed{2}$

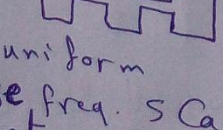
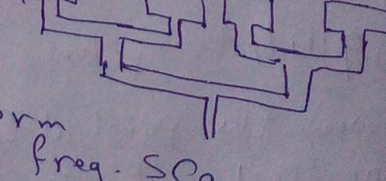
1. High impedance surface to vanish surface current.
2. Smoothing in pattern due to eliminating surface current.
3. improving back and side-lobes.
4. enhancing the efficiency

(g) Advantages of microstrip:-

- low profile.
- Conformable.
- simple & inexpensive.
- mechanically robust.
- very versatile.

$\boxed{3}$

II - $\boxed{3}$

series feeding	Corporate feeding
	
non uniform	uniform
change freq. scan.	single freq. scan
Compact	wider size
simple	bit Complex.
single feeder	Cascade feeding.
difficult implementation of active devices.	easy to implant amplifier

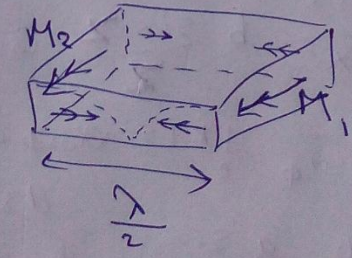
III * spillover eff: the amount of reflected field by the reflector to the emanated from the feed.
- Can be improved by moving the feed closer to reflector
* Taper eff: is a measure of how E-field is distributed (amplitude) across the antenna aperture.

$\boxed{3}$

- Can be improved by moving feeder away from reflector

$\boxed{Q2}$

(I) Cavity model :- the patch is modelled as a cavity of upper and lower PEC while the four sided walls as PMC. from point of view of radiation mechanism, the patch is modelled as a two radiating slots each one has $M = -2\hat{n} \times E$ while a two non radiating slots located on the two other sides of PMC walls. These two M (magnetic dipoles) produce a broad-side far field pattern. As shown in fig, the two radiating M dipoles are separated by $\frac{\lambda}{2}$.



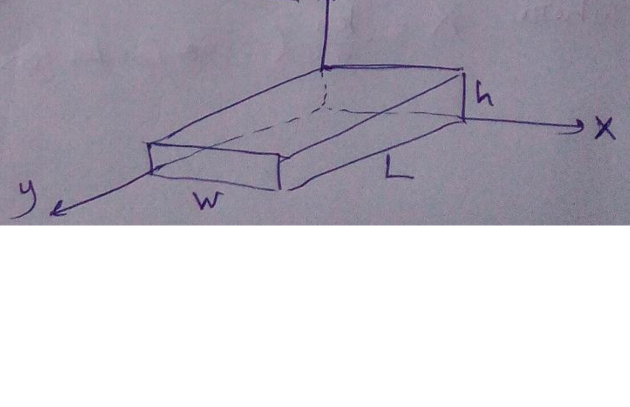
II

(a) $\beta_x = \frac{m\pi}{W}$

$\beta_y = \frac{n\pi}{L}$

$\beta_z = \frac{p\pi}{h}$

$\boxed{3}$



(b) $f_{mnp} = \frac{1}{2\pi\sqrt{\mu\epsilon}}\sqrt{\left(\frac{m\pi}{W}\right)^2 + \left(\frac{n\pi}{L}\right)^2 + \left(\frac{p\pi}{h}\right)^2}$ (2)

(c) $L > W > h$ $\quad TM_{010}$ (2)

(d) $f_{010} = \frac{1}{2\pi\sqrt{\mu\epsilon}}\left(\frac{\pi}{L}\right) = \frac{1}{2L\sqrt{\mu\epsilon}}$ (2)

III

$$E = \hat{a}_z E_o e^{-jky'\sin\phi_o} e^{jkx'\cos\phi_o}$$

at $y = 0$

$$E = E_o e^{jkx'\cos\phi_o} \hat{a}z$$ $\boxed{4}$

$$M = -2\hat{a}_y \times E = -2\hat{a}_y \times \hat{a}_z e^{jkx'\cos\phi_o}$$

$$= -2\hat{a}_x e^{jkx'\cos\phi_o} \Bigg\} \begin{array}{l} -\frac{a}{2} < x' < a/2 \\ -\frac{b}{2} < z' < b/2 \end{array}$$

$J = 0$ every where

$N_\theta = N_\phi = 0$

$$L_\theta = \iint M_x \cdot \hat{a}_\theta e^{jkx'\sin\theta\cos\phi} e^{jkz'\cos\theta} dx' dz'$$

$$= -2E_0 \cos\theta\cos\phi \int_{-a/2}^{a/2} e^{jk(\sin\theta\cos\phi + \cos\phi_o)x'} dx' \int_{-b/2}^{b/2} e^{jkz'\cos\theta} dz'$$

$$= -2E_0 \, a\frac{\sin X}{X} \, b\frac{\sin Z}{Z} \cos\theta\cos\phi$$

$$L_\phi = \iint M_x \cdot \hat{a}_\phi e^{jk(\sin\theta\cos\phi + \cos\phi_o)x'} dx' e^{jkz'\cos\theta} dz'$$ $\boxed{3}$

$$= 2E_0 \sin\phi \; a\frac{\sin X}{X} \; b\frac{\sin Z}{Z}$$

where $X = \frac{ka}{2}(\sin\theta\cos\phi + \cos\phi_o)$ & $Z = \frac{kb}{2}\cos\theta$

$$E_\theta = \frac{-jk\,e^{-jkr}}{4\pi r} L_\phi = \frac{-jkab}{2\pi r} E_0 e^{-jkr} \sin\phi \frac{\sin X}{X} \frac{\sin Z}{Z}$$

$$E_\phi = \frac{jk\,e^{-jkr}}{4\pi r} L_\theta = \frac{-jKab}{2\pi r} E_0 \cos\theta\cos\phi \frac{\sin X}{X} \frac{\sin Z}{Z} e^{-jkr}$$

$$H_\theta = \frac{-E_\phi}{\eta} \quad \& \quad H_\phi = \frac{E_\theta}{\eta}$$ $\boxed{3}$

$D_{pred.} = \frac{4\pi}{\lambda^2} A_{eff}$, $\epsilon_{ap} = 100\ \%$

So $D = \frac{4\pi}{\lambda^2} ab$ $\boxed{3}$

$\boxed{Q3}$

$\boxed{I}$ (a) $b_1 = \sqrt{2\lambda\rho_1} = \sqrt{20}\,\lambda$ $\boxed{3}$

$\rho_e = \sqrt{\rho_1^2 + \left(\frac{b_1}{2}\right)^2} = 10.24\,\lambda$

(b) $2\psi_e = 2\tan^{-1}\left(\frac{b_1/2}{\rho_1}\right) = 25.2^\circ$ $\boxed{3}$

(c) $S(y') = \frac{1}{2}\frac{(b_1/2)^2}{\rho_1} = 0.25\,\lambda$

Phase $= k\,S(y') = \frac{2\pi}{\lambda}\frac{\lambda}{4} = \frac{\pi}{2} = 90^\circ$ $\boxed{3}$

(d) $D_E = \frac{64 a \rho_1}{\pi \lambda b_1}\left[C^2\left(\frac{b_1}{\sqrt{2\lambda\rho_1}}\right) + S^2\left(\frac{b_1}{\sqrt{2\lambda\rho_1}}\right)\right]$

$C(1) = 0.78$, $S(1) = 0.438$ $\boxed{3}$

$D_E = 18.22 = 10\log(18.22) = 12.6$ dB

(e) $A_{em} = \frac{\lambda^2}{4\pi} D_E = 13.05\ Cm^2$ $\boxed{2}$

(f) $\epsilon_{ap.} = \frac{A_{eff}}{A_{phy}} = \frac{13.05\times10^{-4}}{a\,b_1} = \frac{13.05\times10^{-4}}{0.5(3\times10^{-2})(\sqrt{20})(10^{-2})}$

$= 64.8\ \%$ $\boxed{2}$

→ directional broad-side 2

Q4

I feeding methods :-

1- microstrip Line 2- Coaxial probe
3 - aperture Coupled 4- proximity Coupled. 4

- broadest bandwidth is proximity coupled

II

	parabolic reflector	Cylinderical reflector
amplitude taper:	$\frac{1}{r^2}$	$\frac{1}{\rho}$
gain :	high	low
freq. :	Microwave	VHF
focal region :	point source	Line source
feeder :	horn, aperture	dipole
Mechanical simplicity :	Complex	Simple
app.	Satellite Comm.	T.V. broad Casting

4

III reflector Types :-

1- planar 2- Corner 3- Curved. 4

function of reflector :- it reflected wave to a desired direction as to increase the total radiation intensity in Certain direction. Also to Converge or focus the ~~beam~~ reflected beam ~~from~~ ~~aff~~ which generated from wapes that emanted from the feed.

$\boxed{IV}$ $f/d = 0.3$, $d = 2m$

(a) $\theta_o = \tan^{-1}\left[\dfrac{\frac{1}{2}(f/d)}{(f/d)^2 - (\frac{1}{16})}\right] = 79.6^\circ$ $\boxed{3}$

$2\theta_o = 159.2^\circ$

(b) $\epsilon_{ap} = \cot^2\left(\frac{\theta_o}{2}\right)\left|\underbrace{\int_0^{\theta_o} \sqrt{G_f(\theta')} \tan\left(\frac{\theta'}{2}\right) d\theta'}_{X}\right|^2$

$X = \int_0^{\theta_o} \cos^2\left(\frac{\theta'}{2}\right) \tan\left(\frac{\theta'}{2}\right) d\theta'$

$= \int_0^{\theta_o} \cos\left(\frac{\theta'}{2}\right) \sin\left(\frac{\theta'}{2}\right) d\theta' = \frac{1}{2}\int_0^{\theta_o} \sin\theta' d\theta'$

$= \cancel{\frac{1}{2}\int_0^{\theta_o} \sin(\theta') d\theta'}$

$= \frac{1}{2}\left(\cos 0 - \cos\theta_o\right) = \frac{1}{2}(1 - \cos 79.6^\circ)$

So $\epsilon_{ap} = \cot^2\left(\frac{79.6}{2}\right) * \frac{1}{4}\left[1 - \cos(79.6)\right]^2$

$= 24.1\ \%$

$\boxed{3}$

(c) $D = \left(\frac{\pi d}{\lambda}\right)^2 G_{ap}$

$= 10.6 \times 10^3 = 40.2$ dB $\boxed{3}$

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Benha Faculty of Engineering
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Program: Undergraduate
Time: 3 hours
Subject: Waves and Antennas
Code: E1518
No. of Pages: 2

Answer All Questions

Question 1 : (*25 marks*)

I: (a) State antenna radiation regions? Express by equations. (3)

(b) Half-power beam width (HPBW) and its relation to directivity (approx.)? (2)

(c) What is love principle and classify its cases? (3)

(d) Explain the quadratic phase error effect in E-sectoral horn and how can be minimized? (4)

(e) What are the optimal dimensions of pyramidal horn? (2)

(f) What are the benefits of corrugation in a corrugated horn? (2)

(g) What are the advantages of microstrip antennas? (3)

II: Compare between array series feeding and corporate feeding? (3)

III: Define spillover and amplitude tapering efficiencies and how can both be improved? (3)

Question 2 : (*25 marks*)

I. Explain briefly the cavity model analysis on the mechanism of microstrip patch radiation? Support your answer by sketches. (3)

II. Find the TM^{Z}_{mnp} field configurations (modes) of the rectangular microstrip patch based on the geometry of Figure Q2.b. Determine:

a) Eigenvalues (β_x, β_y and β_z) (3)

b) Resonant frequency $(f_r)_{mnp}$ for the mnp mode. (2)

c) Dominant mode if L > W > h. (2)

d) Resonant frequency of the dominant mode. (2)

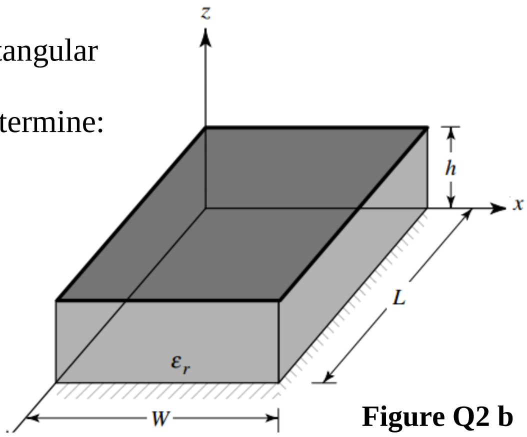

Figure Q2 b

III. A perpendicularly polarized plane wave is obliquely incident upon an aperture, with dimension a and b, on a perfectly electric conducting ground plane of infinite extent, as shown in the figure. Assuming the field over the aperture is given by the incident field. Find:

(a) Fields at aperture. (4)

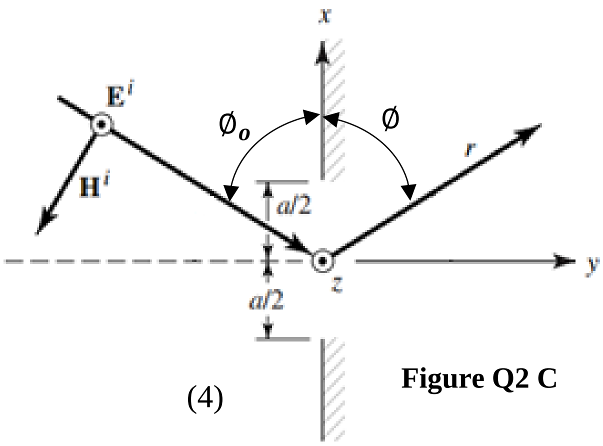

Figure Q2 C

(b) Equivalent L and N (spherical form) (3)

(c) The far-zone spherical components of the fields for y > 0. (3)

(d) What are the predicted directivity and aperture efficiency (without proof)? (3)

Question 3 (19 marks)

I. Design an optimum directivity E-plane sectoral horn whose axial length is $\rho_1 = 10\lambda$. The horn is operating at X-band with a desired center frequency 10 GHz. The waveguide feeding the horn has dimensions of 0.5λ and 0.25λ. find:

(a) Horn aperture dimensions b_1 *and* ρ_e in wavelength. (3)

(b) Calculate maximum total flare angle of the horn. (3)

(c) Maximum quadratic phase. (3)

(c) Directivity of the horn (dimensionless and in dB) (exact method). (3)

(d) Maximum effective area. (2)

(e) Aperture efficiency. (2)

(f) What is the kind of radiation patterns for that horn? (3)

Question 4 (21 marks)

I. State microstrip feeding methods and which one provides broadest bandwidth? (4)

II. Compare between cylindrical reflector and parabolic reflector? (4)

III. What is the main function of reflector and give some of its types? (4)

IV. A parabolic reflector, has an f/d ratio of 0.3 with diameter of 2 m. Determine the:

(a) Total subtended angle of the reflector . (3)

(b) Aperture efficiency assuming the feed pattern is symmetrical and its gain pattern is given by

$G_f(\theta') = \cos^4(\theta'/2)$, where θ' is measured from the axis of the reflector. (3)

(c) Directivity of the entire system when the antenna is operating at 10 GHz, and it is illuminated by the feed pattern of part (b). (3)

With my best wishes