Benha University
Faculty of Engineering- Shoubra
Electrical Engineering Department
Fourth Year (Communications & Electronics)

Final-Term Exam
Date: 15/01/2017
ECE 411
Duration : 3 Hours

- Answer all the following question
- Illustrate your answers with sketches when necessary.
- The exam consists of **Two** pages
- Total Mark: **75** Marks
- Examiners: Dr. Gehan Sami - Dr. Moataz Elsherbini

Part (1) …*(38 Marks)*

1. (a) ***Prove*** *that the beam area of an isotropic antenna is* 4π *Sr.* **(5 marks)**

(b) *A wave traveling normally out of the page is resultant two elliptically polarized (EP) waves, one with components* $E_x = 2Cos(\omega t)$ *and* $E_y = -2Cos(\omega t + 90)$ *and another with components* $E_r = 4e^{j\omega t}$ *and* $E_L = 3e^{-j(\omega t + \pi)}$. *For the resultant wave,* ***find*** *(a) AR, and (b) the band of rotation and polarization.* **(8 marks)**

(c) ***Construct*** *an antenna array using* **2**-*isotropic elements to produce the cardioid radiation pattern shown in figure (1).* **(7 marks)**

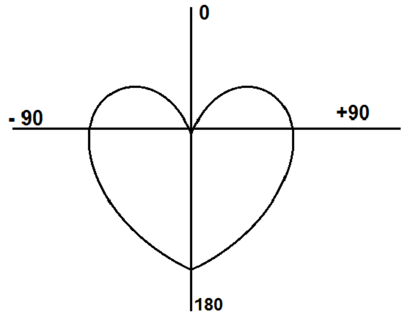


Figure (1)

2. (a) ***Derive*** *an expression for E (Φ) for an array of* **4** *identical isotropic sources arranged in a square array as shown in the figure(2). The spacing "d" between each source and the center point of the array is* $\lambda/2$. *Sources 1 and 2 are in phase, sources 3 and 4 in opposite phase with respect to 1 and 2.* ***Plot*** *the obtained radiation pattern* **(10 marks)**

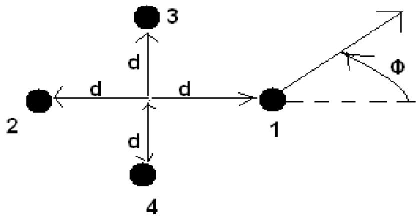


Figure (2)

(b) ***Design*** *an ordinary end-fire uniform array so that its directivity is* **20** *dB (above isotropic). The spacing between the elements is* $\lambda/4$, *and its length is much greate than the spacing (L>>d). Determine:* **(8 marks)**

i) number of elements
ii) overall length of the array (in wavelengths)
iii) approximate half-powerbeamwidth (in degrees)
iv) progressive phase excitation between the elements (in degrees).

End of Part 1

1-a) $\Omega_A = \int_0^{2\pi}\int_0^{\pi} \sin\theta \, d\theta \, d\phi = 2\pi\left[-\cos\theta\right]_0^{\pi} = 2\pi[1+1] = 4\pi \text{ sr}$

(5 marks)

1-b) $E_x = 2\cos\omega t$

$E_y = -2\cos(\omega t + 90) = +2\sin\omega t$

$E_r = 4\cos\omega t + j4\sin\omega t$

$\therefore E_x' = 4\cos\omega t$ (8 marks)

$E_y' = 4\sin\omega t$

$E_l = 3\cos(\omega t + \pi) - 3j\sin(\omega t + \pi)$

$= -3\cos\omega t + 3j\sin\omega t$

$\therefore E_x'' = -3\cos\omega t$

$E_y'' = 3\sin\omega t$

$\therefore E_{xt} = 2\cos\omega t + 4\cos\omega t - 3\cos\omega t = 3\cos\omega t$

$E_{yt} = 2\sin\omega t + 4\sin\omega t + 3\sin\omega t = 9\sin\omega t$

Elliptical, $\left(\frac{E_y}{9}\right)^2 + \left(\frac{E_x}{3}\right)^2 = 1$

$AR = 9/3 = 3$

rotation $\omega t = 0 \rightarrow x = 3, \; y = 0$

$\omega t = 90 \rightarrow x = 0, \; y = 9$

CCW

(7 marks)

1-c) $E_n = \cos(\psi/2) = \cos\left(\frac{kd\cos\theta + \delta}{2}\right)$

$\theta_{max} = \pi \rightarrow \psi = 0 \quad \therefore E_1 = \cos\left(\frac{-kd + \delta}{2}\right)$

or $\delta = kd = 2\pi d/\lambda \rightarrow (1)$

nulls at $\theta = 0° \rightarrow E = 0 \quad \therefore 0 = \cos\left(\frac{kd + \delta}{2}\right)$

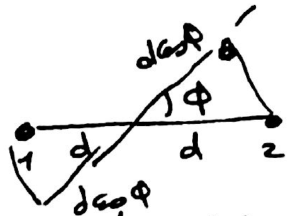
$\therefore \frac{kd + \delta}{2} = \pm(2k+1)\pi/2 \quad \therefore$ at $k = 0 \quad \therefore \pm\pi = \frac{2\pi d}{\lambda} + \delta \rightarrow (2)$

Sub(1) in (2) $\therefore \pm\pi = \frac{2\pi d}{\lambda} + \frac{2\pi d}{\lambda} = \frac{4\pi d}{\lambda} \quad \therefore d = \lambda/4$, $\delta = \frac{2\pi d}{\lambda} = \pi/2$

2/

2-a)
10 marks

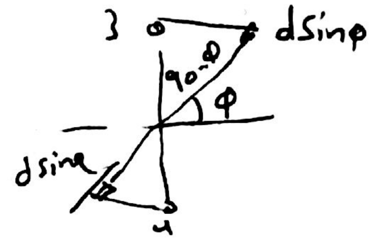
$E_{12} = \cos\frac{\psi}{2} = \cos\left(\frac{k(2d)\cos\phi + \delta}{2}\right)$



$\delta = 0 \rightarrow$ in phase

$\therefore E_{12} = \cos\left(\frac{2kd\cos\phi}{2}\right) = \cos(kd\cos\phi) = \cos\left(\frac{2\pi d}{\lambda}\cos\phi\right)$

$E_{3,4} = \cos\left(\frac{2kd\sin\phi + \delta}{2}\right)$, $\delta = 0$



$\therefore E_{34} = \cos\left(\frac{2\pi d}{\lambda}\sin\phi\right)$

E_{34} out of phase with E_{12}

4 marks

$\therefore$ $\boxed{E_{total} = E_{12} - E_{34} = \cos\left(\frac{2\pi d}{\lambda}\cos\phi\right) - \cos\left(\frac{2\pi d}{\lambda}\sin\phi\right)}$

6 marks

nulls $E_{total} = 0 \therefore \cos\left(\frac{2\pi d}{\lambda}\cos\phi\right) = \cos\left(\frac{2\pi d}{\lambda}\sin\phi\right)$

or $\frac{2\pi d}{\lambda}\cos\phi = \pm\left(\frac{2\pi d}{\lambda}\sin\phi\right)$

$\therefore \tan\phi = \pm 1$, $\boxed{\phi = \pm 45, \pm 135}$ ϕ_{nulls}

max $E_{total} = \pm 2$ $(1-(-1))$ or $(-1-(+1))$ $d = \lambda/2$

$\therefore \cos\left(\frac{2\pi d}{\lambda}\cos\phi\right) = \pm 1$

$\frac{2\pi d}{\lambda}\cos\phi = \overset{(+1)}{0}$ or $\overset{(-1)}{\pm\pi}$

$\phi_m = \pm 90$, $0, \pi$

$\cos\left(\frac{2\pi d}{\lambda}\sin\phi\right) = \pm 1$

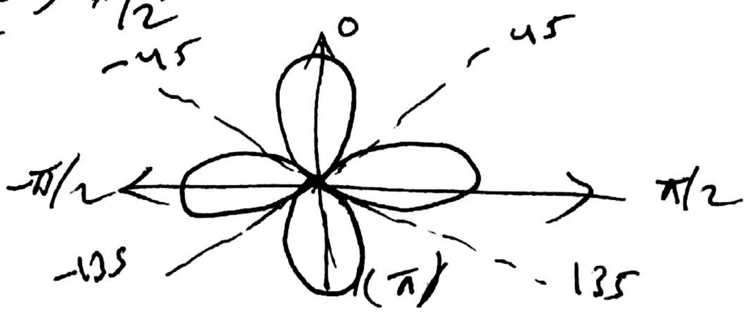
$\frac{2\pi d}{\lambda}\sin\phi = \overset{(+1)}{0}$, $\overset{(-1)}{\pm\pi}$

$\phi_m = 0, \pi$ $\phi_m (\pm 90)$

ϕ_m at $(+1, -1)$ $\Rightarrow \pm 90$
$(+1-(-1)) = 2$

ϕ_m at $(-2) \Rightarrow 0, \pi$

$\therefore \phi_m = [0, \pi/2, \pi, -\pi/2]$



3)

$D = \cancel{10}\log(\cancel{x}) = 20\,dB$

$\therefore x = 100 \quad \therefore \boxed{D = 100}$, $d = \lambda/4$

8 marks

a) $D = 4Nd/\lambda = 100 = 4N\frac{(\cancel{\lambda}/4)}{\cancel{\lambda}} \quad \therefore N = 100$

b) $\ell = (N-1)d = 99\,\lambda/4$

c) $D = \frac{41253}{(\theta_{HP})^2} = 100 \quad \therefore \theta_{HP} = \sqrt{412.53} = 20.3^\circ$

d) End fire $\theta_{max} = 0, \pi$ at $\psi = 0$

$\therefore \delta = \pm kd = \pm\left(\frac{2\pi}{\lambda}\right)\left(\frac{\lambda}{4}\right) = \pm\pi/2$