CMR INSTITUTE OF TECHNOLOGY

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Internal Assesment Test - III

Sub:	Microwave and Antennas							Code:	15EC71
Date:	16/ 11 / 2019	Duration:	90 mins	Max Marks:	50	Sem:	7th	Branch:	ECE
Answer Any FIVE FULL Questions									

		Marks	OBE CO	OBE RBT
1	Explain the following terms:(a) Beam area (b) Radiation intensity (c) Beam efficiency (d) Gain (e)Antenna aperture	[10]	CO1	L2

(a) Beam area is the solid angle through which all the power radiated by the antenna would stream if P (θ, Ø) maintained its maximum value over ΩA and was zero elsewhere.

b) Radiation intensity U

$$U = \frac{d\Pi_{rad}}{d\Omega}, \mathbf{W/sr}$$

A useful expression, equivalent to (4.4) is given below:

$$\Pi_{rad} = \oint\!\!\oint_{4\pi} U d\Omega, \mathbf{W}$$

From now on, we shall denote the radiated power simply by Π. There i direct relation between the radiation intensity U and the radiation power density P (that is the Poynting vector magnitude of the far field). Since

$$P = \frac{d\Pi}{ds}, \mathbf{W/m^2}$$

then:

$$U = r^2 \cdot P$$

Beam efficiency

The ***beam efficiency*** is the ratio of the power radiated in a cone of angle $2\Theta_1$ and the total radiated power. The angle $2\Theta_1$ can be generally any angle, but usually this is the first-null beam width.

$$BE = \frac{\int_0^{2\pi}\int_0^{\Theta_1} U(\theta,\varphi)\sin\theta d\theta d\varphi}{\int_0^{2\pi}\int_0^{\pi} U(\theta,\varphi)\sin\theta d\theta d\varphi}$$

(d) Antenna gain

The gain G of an antenna is the ratio of the radiation intensity U in a given direction and the radiation intensity that would be obtained, if the power fed to the antenna were radiated isotropically.

$$G(\theta,\varphi) = 4\pi \frac{U(\theta,\varphi)}{P_{in}}$$

The gain is a dimensionless quantity, which is very similar to the directivity D. When the antenna has no losses, i.e. when $P_{in} = \Pi$, then $G(\theta,\varphi) = D(\theta,\varphi)$. Thus, the gain of the antenna takes into account the losses in the antenna system. It is calculated via the *input power* P_{in}, which is a measurable quantity, unlike the directivity, which is calculated via the radiated power Π.

(e) Effective area (aperture) A_e /Antenna aperture

The ***effective antenna aperture*** is the ratio of the available power at the terminals of the antenna to the power flux density of a plane wave incident upon the antenna, which is polarization matched to the antenna. If there is no specific direction chosen, the direction of maximum radiation intensity is implied.

$$A_e = \frac{P_A}{W_i},$$

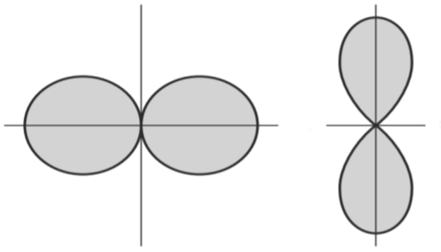
where:

A_e is the effective aperture, m^2

P_A is the power delivered from the antenna to the load, W

W_i is the power flux density (Poynting vector magnitude) of the incident wave, W/m^2

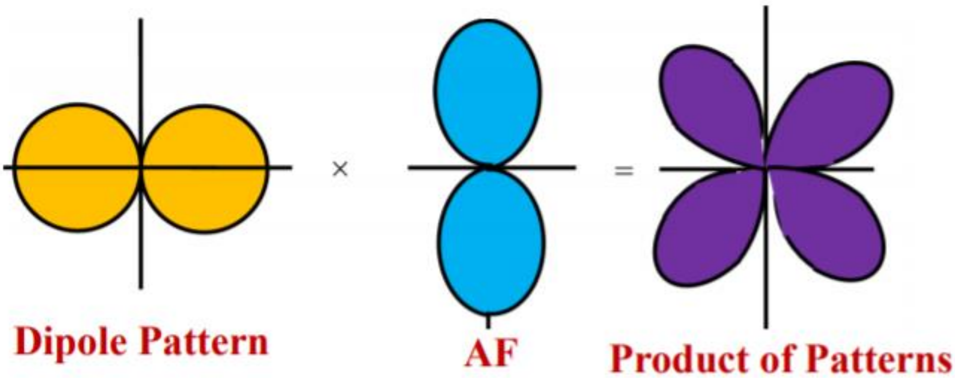
2.	What is pattern multiplication for an antenna array? Following figure (a) shows individual non-isotropic source radiation pattern and figure (b) shows of radiation pattern of array of two isotropic sources at d = λ/2 and δ = 0.	CO1	L3



(a) (b)

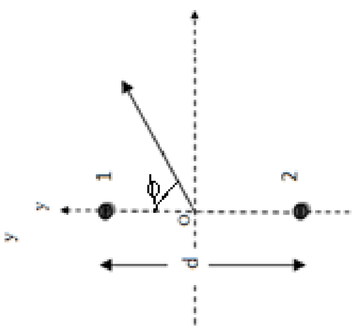
Find out the total radiation pattern.

The **pattern multiplication** principle states that the radiation patterns of an array of N identical antennas is equal to the product of the element pattern Fe(Θ) (pattern of one of the antennas) and the array pattern Fa(Θ), where Fa(Θ) is the pattern obtained upon replacing all of the actual antennas with isotropic sources. [10m]



3 Show that the pattern factor, E(ϕ), of an array of two identical isotropic in-phase point sources, arranged as in the figure shown, is given by:

E(ϕ)= cos[$\left(\frac{d_r}{2}\right)$cosϕ], where $d_r = \frac{2\pi d}{\lambda}$.

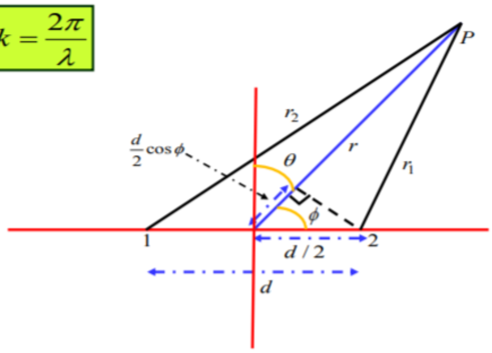


Array of Two Isotropic Point Sources

8m

$$E = E_o e^{-j\beta r_1} + E_o e^{-j\beta r_2}$$

$$\beta = k = \frac{2\pi}{\lambda}$$



$$\left.\begin{aligned} r_1 &\cong r + \frac{d}{2}\cos\phi \\ r_2 &\cong r + \frac{d}{2}\cos\phi \end{aligned}\right\} r >> d, \phi = 90 - \theta$$

$$E = E_o e^{-j\beta r}\left[e^{-j\beta\frac{d}{2}\cos\phi} + e^{j\beta\frac{d}{2}\cos\phi}\right]$$

$$= E_o e^{-j\beta r}\left[e^{-j\frac{\psi}{2}} + e^{j\frac{\psi}{2}}\right]$$

$$\psi = \beta d\cos\phi = \frac{2\pi d}{\lambda}\cos\phi$$

$$= \beta d \sin\theta = \frac{2\pi d}{\lambda}\sin\theta$$

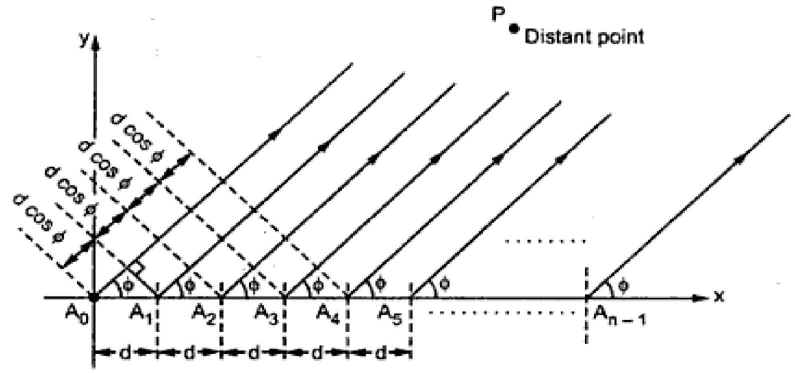
$$E = 2E_o\cos\left(\frac{\psi}{2}\right) = 2E_o\cos\left(\frac{\pi d}{\lambda}\cos\phi\right)$$

$$E = \cos\left(\frac{d_r}{2}\cos\phi\right)$$ 1m

$$d_r = \frac{2\pi d}{\lambda} = \beta d$$

For $d = \frac{\lambda}{2}$ $\quad E = \cos\left(\frac{\pi}{2}\cos\phi\right)$ 1m

4. Derive the antenna array factor for **N** isotropic point sources of the same amplitude and spacing. Discuss the condition for (i) End-fire (ii) Broad-side antenna array radiation pattern.



The total resultant field at the distant point P is obtained by adding the fields due to n individual sources vertically. Hence we can write,

$$E_T = E_0 \cdot e^{j0} + E_0\, e^{j\psi} + E_0\, e^{2j\psi} + \dots + E_0\, e^{j(n-1)\psi}$$

$$\boxed{E_T = E_0\,[1 + e^{j\psi} + e^{j2\psi} + \dots + e^{j(n-1)\psi}]}$$

- ψ= (βdcosϕ + α) indicates the total phase difference of the fields from adjacent sources at point P.
- α is the progressive phase shift between two adjacent point sources. The value of α may lie between 0° and 180°.
- If α = 0° we get n element uniform linear broadside array. If α = 1800 we get n element uniform linear endfire array.

$$E_T\, e^{j\psi} = E_0\,[e^{j\psi} + e^{j2\psi} + e^{j3\psi} + \dots + e^{jn\psi}]$$

$$E_T - E_T\, e^{j\psi} = E_0\,\{[1 + e^{j\psi} + e^{j2\psi} + \dots + e^{j(n-1)\psi}] - [e^{j\psi} + e^{j2\psi} + \dots + e^{jn\psi}]\}$$

$$E_T\,(1 - e^{j\psi}) = E_0\,(1 - e^{jn\psi})$$

$$\therefore \quad \boxed{E_T = E_0\left[\frac{1 - e^{jn\psi}}{1 - e^{j\psi}}\right]}$$

$$E_T = E_0\left[\frac{e^{j\frac{n\psi}{2}}\left(e^{-j\frac{n\psi}{2}} - e^{j\frac{n\psi}{2}}\right)}{e^{j\frac{\psi}{2}}\left(e^{-j\frac{\psi}{2}} - e^{j\frac{\psi}{2}}\right)}\right]$$

According to trigonometric identity,

$$e^{-j\theta} - e^{j\theta} = -2j\sin\theta,$$

The resultant field is given by,

$$E_T = E_0\left[\frac{\left(-j2\sin\frac{n\psi}{2}\right)e^{j\frac{n\psi}{2}}}{\left(-j2\sin\frac{\psi}{2}\right)e^{j\frac{\psi}{2}}}\right]$$

$$\therefore \quad \boxed{E_T = E_0\left[\frac{\sin n\frac{\psi}{2}}{\sin\frac{\psi}{2}}\right]e^{j\left(\frac{n-1}{2}\right)\psi}}$$

The magnitude of the resultant field is given by,

$$\therefore \quad E_T = E_0 \left[\frac{\sin n \frac{\psi}{2}}{\sin \frac{\psi}{2}} \right]$$

The phase angle θ of the resultant field at point P is given by,

$$\therefore \quad \theta = \frac{(n-1)}{2}\psi = \frac{(n-1)}{2}\beta d \cos\phi + \alpha$$

(a) Consider n number of identical radiators supplied with equal current which ***are not in phase***. Assume that there is progressive phase lag of βd radians in each radiator. Hence the maximum radiation occurs in the directions along the axis of the line of array. Hence such an array is known as end fire array.

(b) Consider 'n' number of identical radiators carries currents which are equal in magnitude and ***in phase (α=0)***. The identical radiators are equispaced. Hence the maximum radiation occurs in the directions normal to the line of array. Hence such an array is known as Uniform broadside array.

5. Drive the expression for the far field component of short electric dipole.

The short dipole

A short[2] wire of length $l \ll \lambda$ is positioned at the origin and orientated with the z-axis, as shown in Fig. 1. The current on the wire is assumed to be constant, and given by

$$\mathbf{I}(z) = \hat{a}_z I_0$$

where I_0 is constant. In the analysis of antennas we are interested primarily in the electric and magnetic fields radiated by the currents flowing on the surface of the antenna. Before analysing radiation, it is useful to briefly review how the fields are expressed mathematically.

Uniform Current –Magnetic Vector Potential

$$\underline{A} = \hat{a}_z A_z = \hat{a}_z \frac{\mu I_o \ell}{4\pi r} e^{-jkr}$$

$$A_r = A_z \cos\theta = \frac{\mu I_o \ell}{4\pi r} \cos\theta \ e^{-jkr}$$

$$A_\theta = -A_z \sin\theta = -\frac{\mu I_o \ell}{4\pi r} \sin\theta \ e^{-jkr}$$

$$A_\phi = 0$$

E and H Fields from Magnetic Vector Potential

$$H = \frac{1}{\mu}\nabla \times \underline{A} = \hat{a}_\phi \frac{1}{\mu r}\left[\frac{\partial}{\partial r}(rA_\theta) - \frac{\partial A_r}{\partial \theta}\right]$$

$$\underline{E} = -j\omega \underline{A} - j\frac{1}{\omega\mu\varepsilon}\nabla(\nabla \cdot \underline{A})$$

$$P = \frac{1}{2}\iint_S \underline{E} \times \underline{H}^* \cdot d\underline{s}$$

Uniform Current – E and H Fields

$$E_r = \eta \frac{I_o \ell}{2\pi r^2}\cos\theta\left[1 + \frac{1}{jkr}\right]e^{-jkr}$$

$$E_\theta = j\eta \frac{kI_o \ell}{4\pi r}\sin\theta\left[1 + \frac{1}{jkr} - \frac{1}{(kr)^2}\right]e^{-jkr}$$

$$E_\phi = H_r = H_\theta = 0$$

$$H_\phi = j\frac{kI_o \ell}{4\pi r}\left[1 + \frac{1}{jkr}\right]\sin\theta\, e^{-jkr}$$

6 Show that the electric field pattern of a thin linear antenna of length L=λ/2 is given by: $E = \frac{\cos((\pi/2)\cos\theta)}{\sin\theta}$

The general expression for a center-fed wire of length L is:

$$\overline{E}_{ff} \cong \hat{\theta}\frac{j\eta I_o e^{-jkr}}{2\pi r \sin\theta}\left[\cos\left(\frac{kL}{\alpha}\cos\theta\right) - \cos\frac{kL}{\alpha}\right]$$

which, for L = λ/2, reduces to:

$$\overline{E}_{ff} \cong \hat{\theta}\frac{j\eta I_o e^{-jkr}}{2\pi r \sin\theta}\cos\left(\frac{\pi}{2}\cos\theta\right)$$

$$E = \frac{\cos((\pi/2)\cos\theta)}{\sin\theta}$$

7 For a short dipole λ/15 long, find the efficiency and radiation resistance if loss resistance is 1 Ω.

Solution:

Radiation resistance: It is a fictitious resistance which would dissipate the same power as the antenna radiates if it were connected to the same transmission line.

$$R_r = 80\pi^2\left(\frac{dl}{\lambda}\right)^2 = 80\pi^2\left(\frac{\lambda}{15\,\lambda}\right)^2 = 80\pi^2\left(\frac{1}{15}\right)^2 = 3.5 \text{ ohm}$$

$$\text{the efficiency } (\eta) = \frac{R_r}{R_T} = \frac{R_r}{R_r + R_l} = \frac{3.5}{3.5+1} = 0.777 = 77.7\%$$

8. Explain the working and design consideration of Helical and log periodic antenna.

Helical Antenna

Helical antenna is useful at very high frequency and ultra high frequencies to provide circular polarization.

Consider a helical antenna as shown in figure 4.6.1.

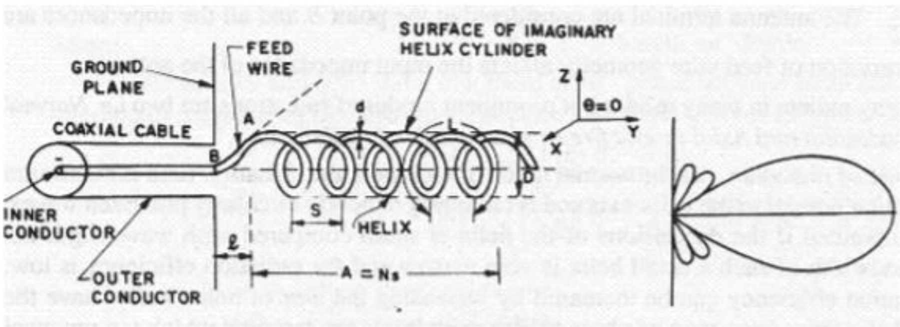


Fig 4.6.1 Helical antenna and its radiation pattern

Here helical antenna is connected between the coaxial cable and ground plane. Ground plane is made of radial and concentric conductors. The radiation characteristics of helical antenna depend upon the diameter (D) and spacing S.

In the above figure,

L = length of one turn = $\sqrt{S^2+(\pi D)^2}$

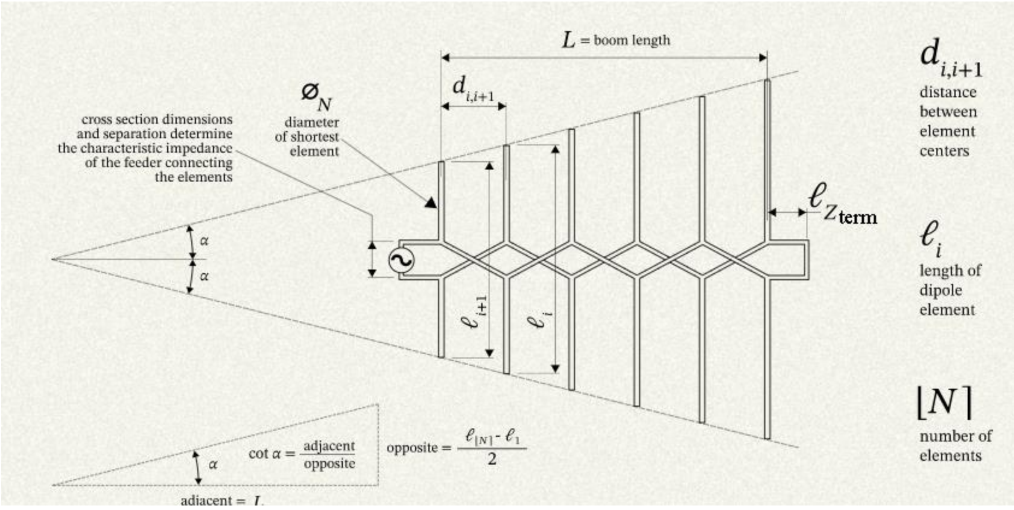
N = Number of turns

D = Diameter of helix = πD

α = Pitch angle = $\tan^{-1}(S/\pi D)$

l = Distance between helix and ground plane.

A **log-periodic antenna** (**LP**), also known as a **log-periodic array** or **log-periodic aerial**, is a multi-element, directional antenna designed to operate over a wide band of frequencies. The most common form of log-periodic antenna is the **log-periodic dipole array** or **LPDA**, The LPDA consists of a number of half-wave dipole driven elements of gradually increasing length, each consisting of a pair of metal rods. The dipoles are mounted close together in a line, connected in parallel to the feedline with alternating phase. Electrically, it simulates a series of two or three-element Yagi antennas connected together, each set tuned to a different frequency.



LPDA antennas look somewhat similar to Yagi antennas, in that they both consist of dipole rod elements mounted in a line along a support boom, but they work in very different ways. Adding elements to a Yagi increases its directionality, or gain, while adding elements to a LPDA increases its frequency response, or bandwidth.

One large application for LPDAs is in rooftop terrestrial television antennas, since they must have large bandwidth to cover the wide television bands of roughly 54–88 and 174–216 MHz in the VHF and 470–890 MHz in the UHF while also having high gain for adequate fringe reception. One widely used design for television reception combined a Yagi for UHF reception in front of a larger LPDA for VHF.