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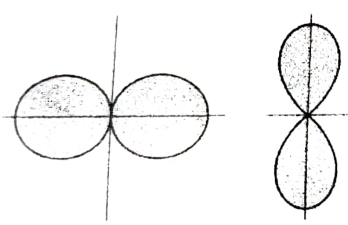
Internal Assesment Test - III

Sub:	Microwave and Antennas					Code:	18EC63
Date:	11/ 07 / 2022	Duration:	90 mins	Max Marks:	50	Sem: 7th	Branch: ECE

Answer Any FIVE FULL Questions

S. No.	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]	CO4	L2
2.	(a) The effective aperture of transmitting and receiving antennas in a communication system are $10\,\lambda^2$ and $12\,\lambda^2$ respectively with a separation of 2 km between them. The E.M wave is travelling with a frequency of 6MHz and the total input power is 28KW. Find the power received by the receiving antenna. (b) Calculate the exact directivity for the following sources having the following power patterns: **$U = U_m \sin^2\theta \sin^2\varphi$.** Where U has a value only for $0 \le \theta \le \pi$ and $0 \le \varphi \le \pi$ and zero elsewhere	[10]	CO4	L4
3.	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 $d = \lambda/2$ and $\delta = 0$.  (a) (b) Find out the total radiation pattern.	[10]	CO4	L3
4.	(a) Derive the antenna array factor for **2** isotropic point sources of the same amplitude and spacing and same phase. (b) Derive the antenna array factor for **2** isotropic point sources of the same amplitude and spacing and opposite phase.	[10]	CO4	L3
7.	What is point sources? Discuss the condition for (i) End-fire (ii) Broad-side antenna array radiation pattern form **2** isotropic point sources.	[10]	CO4	L3
8.	The radial component of the radiated power density of an infinitesimal linear dipole of length $l \ll \lambda$ is given by $$\mathbf{W}_{av} = \hat{\mathbf{a}}_r W_r = \hat{\mathbf{a}}_r A_0 \frac{\sin^2\theta}{r^2} \quad (\mathrm{W/m^2})$$ where A_0 is the peak value of the power density, θ is the usual spherical coordinate, and $\hat{\mathbf{a}}_r$ is the radial unit vector. Determine the maximum directivity of the antenna and express the directivity as a function of the directional angles θ and ϕ.	[10]	CO4	L4
9.	An antenna has a field pattern given by $E(\theta) = \cos\theta \cos 2\theta$ for $0^\circ \le \theta \le 90^\circ$. Find (a) the half-power beamwidth (HPBW) and (b) the beamwidth between first nulls (FNBW).	[10]	CO4	L3

P. E. Lal

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CCI

Q1. (a) Beam area :

- The area of strip of antenna is $r\,d\theta$ extended along the Spherical surface.

* The beam area is given by Ω_A as integral of power radiation is Known as Beam area

$$\Omega_A = \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} P(\theta,\phi)\, r\sin\theta\, d\theta\, d\phi.$$

(b) Radiation intensity :

* The power radiated per unit area is gn as Radiation Intensity
* The radiated power can be extended in the form of Radiation intensity

$$P = A_r W_{rad}$$

$$P = 4\pi r^2 W_{rad}$$

$$\frac{P}{4\pi} = r^2 W_{rad}$$

$$\boxed{U = r^2 W_{rad}}$$

(c) Beam efficiency :

* Beam area is given as the radi product of major Beam area and minor load beam. $\Omega_A = \Omega_M + \Omega_m$
* Beam efficiency is the ratio of Major beam to beam area.

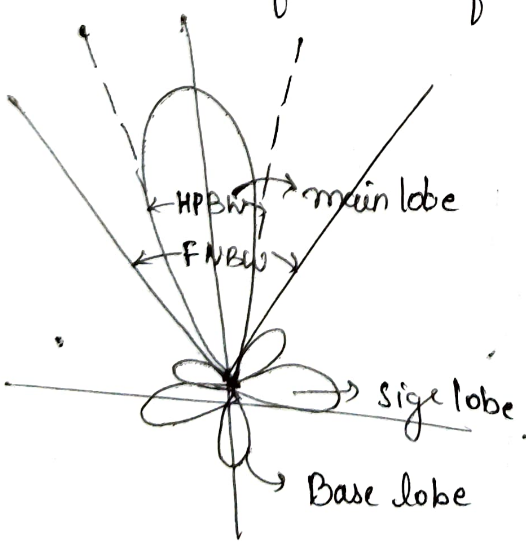
$$S = \frac{\Omega_M}{\Omega_A} = \frac{\Omega_M}{\Omega_M + \Omega_m}$$

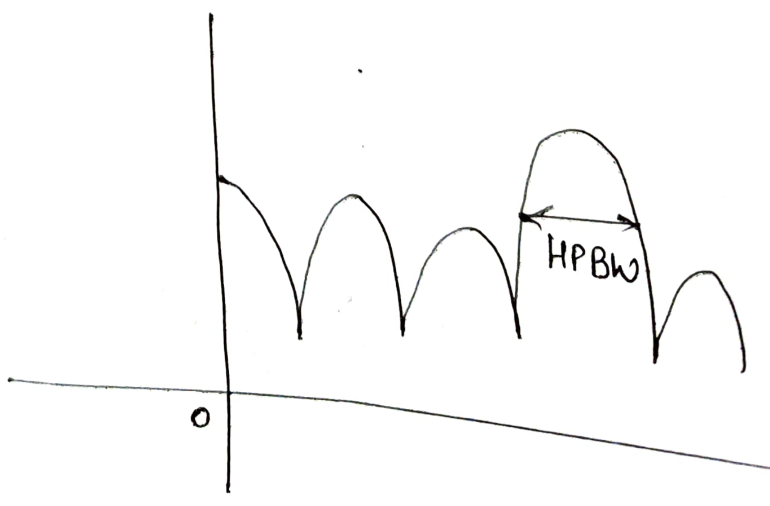
(d) <u>Gain</u> Ratio of product of 4π to the efficiency of appeature to the square of wave length of the beam. is known as gain of the antenna

$$A_{ep} = \frac{G\lambda^2}{4\pi} \Rightarrow \boxed{G = \frac{A_{ep}(4\pi)}{\lambda^2}}$$

(e) <u>Radiation / antenna appeature</u>

Radiation pattern of the antenna is given as radiation characteristic ~~as~~ function of radiation pattern
It is the 3-dimensional representation quantity of the antenna with pattern varying field/power of the antenna function of spherical co-ordinate θ, ϕ.





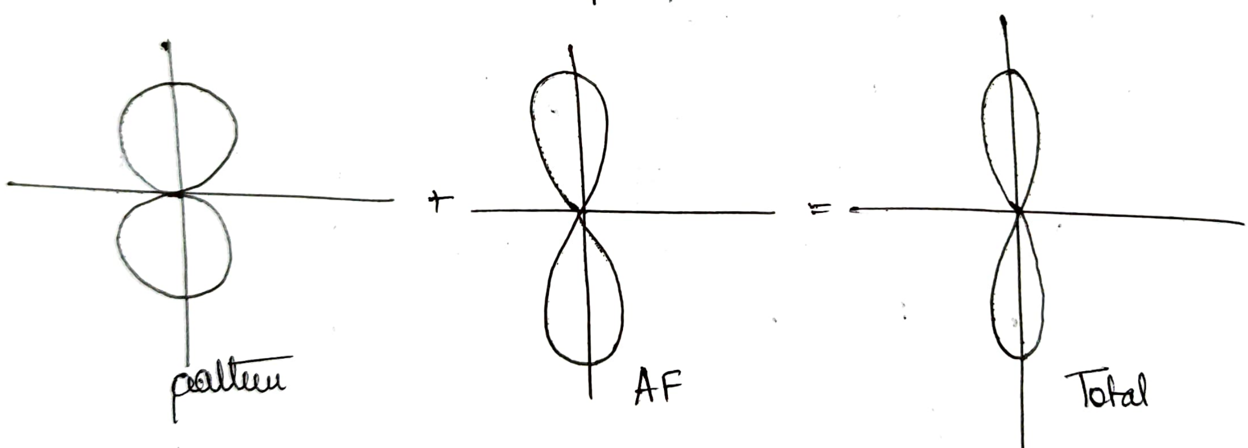
Pattern multiplication :

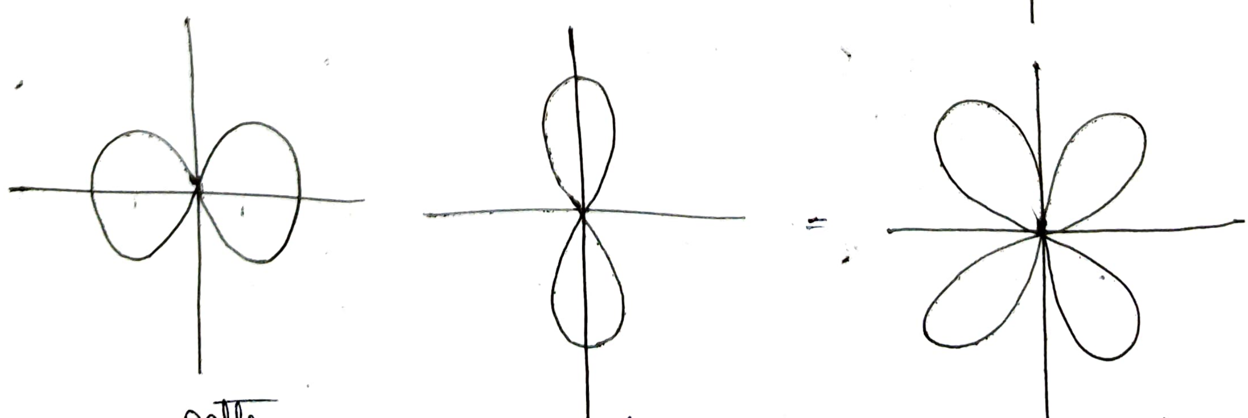
The principle of pattern multiplication states that the pattern of the antenna is the product of individual antenna pattern. The antenna of the pattern is excited (amplitude and phase) of the antenna

There are two ways where pattern multiplication can be shown :

1. Individual pattern multiplication
2. Array of pattern.

Individual pattern : The individual pattern of the antenna is multiplied. for example



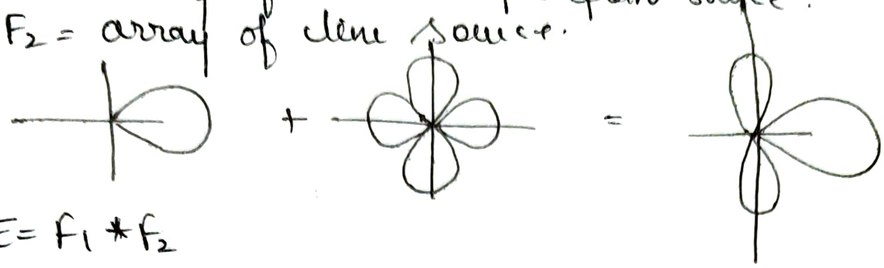


pattern AP Total pattern

Array of pattern : The function of pattern which varye with respect to the excited pattern (Amplitude and phase).

F_1 = array of two isotropic point source.

F_2 = array of line source.

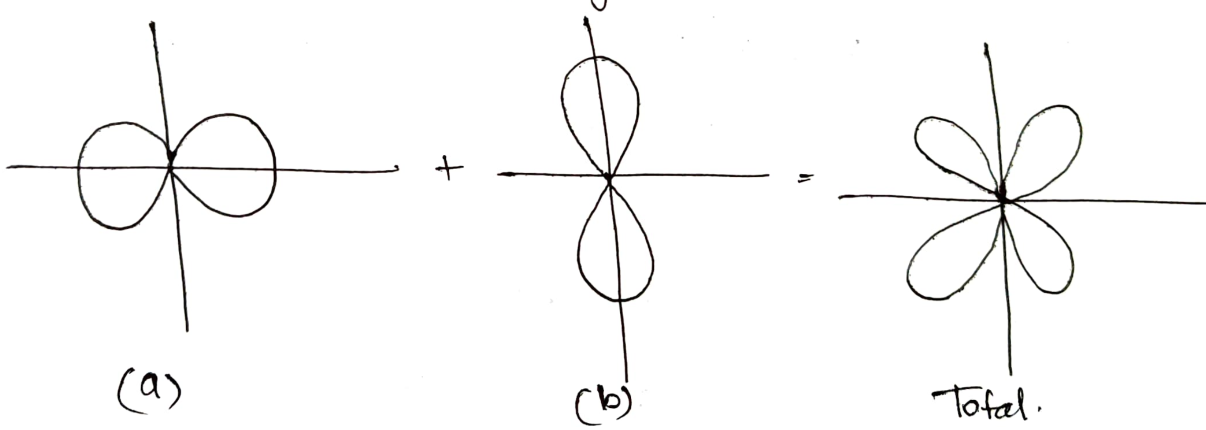


$E = F_1 * F_2$

Advantages :→ pattern multiplication is easy.

dis-Advantages :→ It is done only for similar pattern i.e the size of the pattern should be same.

The total Radiation pattern of the given example:



9.

Gn $E(\theta) = \cos\theta \cos 2\theta$.

$E(\theta) = 0.707$

$E(\theta) = \frac{1}{\sqrt{2}}$

$\cos\theta \cos 2\theta = \frac{1}{\sqrt{2}}$

$\cos\theta = \frac{1}{\sqrt{2}\cos 2\theta}$.

$$\therefore \quad \theta = \cos^{-1}\left(\frac{1}{\sqrt{2}\cos 2\theta}\right)$$

$$\theta = 0 \rightarrow \quad \theta = 20.1^\circ$$

(a) where, Half power BW $= 2\theta$

$$= 2 \times 20.1^\circ$$

$$= 40.1^\circ$$

$$\approx \underline{\underline{41^\circ}}.$$

(b) FNBW

$$E(\theta) = 0$$

$$\cos\theta \cdot \cos 2\theta = 0$$

$$\cos\theta = 0$$

$$\theta = \cos^{-1}(0)$$

$$= \underline{45^\circ}$$

$$\Longrightarrow \quad FNBW = 2\theta = 2(45^\circ) = \underline{\underline{90^\circ}}.$$

$f = 6\ MHz$ $\quad P_T = 28\ kW$ $\quad P_R = ?$

$= 6 \times 10^6\ Hz$ $\quad = 28 \times 10^3\ W$

$r = 12\ Km$

$= \underline{\underline{12 \times 1000\ m}}$

$$P_R = \frac{P_T A_{re} A_{tn}}{r^2 \lambda^2}$$

$$= \frac{(28 \times 10^3)(10 \times 12)\lambda^2}{(12 \times 1000)^2}$$

$$= \frac{(28 \times 10^3)(10 \times 12)(50)^2}{(12 \times 1000)^2}$$

$$\lambda = \frac{c}{f} = \frac{\cancel{3} \times 10^8}{2\cancel{6} \times 10^6} = \underline{\underline{50m}}$$

$$P_R = \underline{\underline{58.333W}}$$

(b) $U = U_m \sin^2\theta \sin^2\phi$ directivity = ?

$$D = \frac{4\pi}{\iint E(\theta,\phi) \cdot \sin\theta d\theta \cdot d\phi}$$

$$\int_{\phi=0}^{\phi=\pi} \left[\int_{\theta=0}^{\pi} (U_m \sin^2\theta \sin^2\phi) \sin\theta \, d\theta\right] d\phi$$

$$= \underbrace{\int_{\phi=0}^{\phi=\pi} (\sin^2\phi \cdot d\phi}_{I_1} \underbrace{\int_{\theta=0}^{\pi} \sin^3\theta \cdot d\theta}_{I_2} \text{ ——— (1)}$$

$$I_1 = \int_0^{\pi} \left(\frac{1-\cos 2\phi}{2}\right) d\phi = \frac{\pi}{2} - 0$$

$$= \pi/2 \text{ ——— (2)}$$

$$I_2 = \int_0^{\pi} \sin^3\theta \, . d\theta$$

$$= \int_0^{\pi} \frac{1}{4}\left(3\sin\theta - \sin 3\theta\right) . d\theta$$

$$= \frac{4}{3} \text{ ——— } (3)$$

put (3) & (2) in (1)

$$= \frac{\pi}{2} \times \frac{4}{3} = \frac{2\pi}{3}$$

$$D = \frac{4\pi}{\int_{\phi=0}^{\pi}\int_{\theta=0}^{\pi} U . \sin\theta d\theta . d\phi}$$

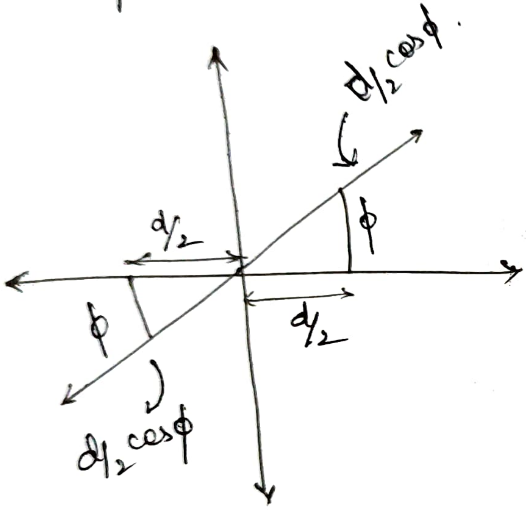
$$= \frac{\cancel{4\pi}\,2}{\cancel{2\pi}/3}$$

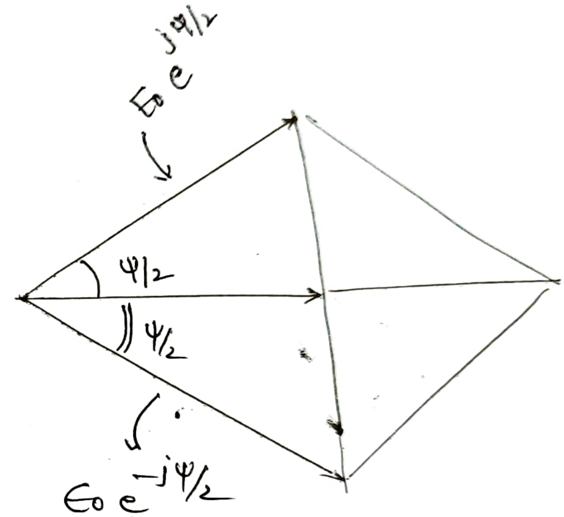
$$\boxed{D = 6}$$

Exact dielectric Value $= \underline{5.1}$.

Q7. point source : Antenna is known as two point source. which have different source of operation that need to be performed it performs Radition, transmitter, receiver. Antenna has different characteristics.

Consider, two pt. source which are placed symmetric to each other with respect to the Origin 'E₀'
Assuming that the two point source have same amplitude and distance.





(a)

$$d_r \text{ (in radians)} = \frac{\lambda d}{2\pi} = \beta d.$$

Electric field can be given by

$$E = E_0 e^{j\psi/2} + E_0 e^{j\psi/2}$$

$$= 2E_0 \left[\frac{e^{j\psi/2} + e^{-j\psi/2}}{2}\right] \qquad \psi = d_r \cos\phi$$

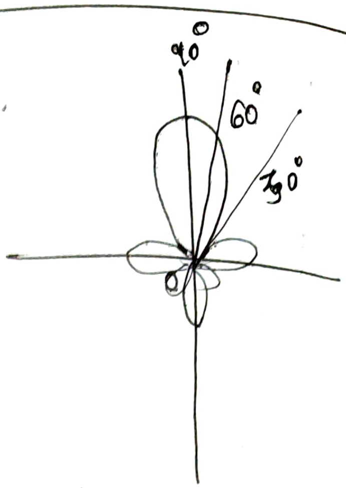
$$= 2E_0 \cos \psi/_2$$

$$= 2E_0 \left[\cos\left(\frac{d_r}{2}\cos\phi\right)\right)$$

Condition $2E_0 = 1$; $E = \cos \phi/2$

$d = \lambda/2$ then $\psi = \pi$

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



$$S = \frac{1}{2} Re(E \times H^*)$$

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

$$= \frac{1}{2} Re\, E_\theta |H_\phi|^2$$

$$E_\theta = |H_\phi|^2 = \sqrt{\frac{\mu}{\varepsilon}}$$

$$P = \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} S \cdot d\theta \cdot d\phi$$

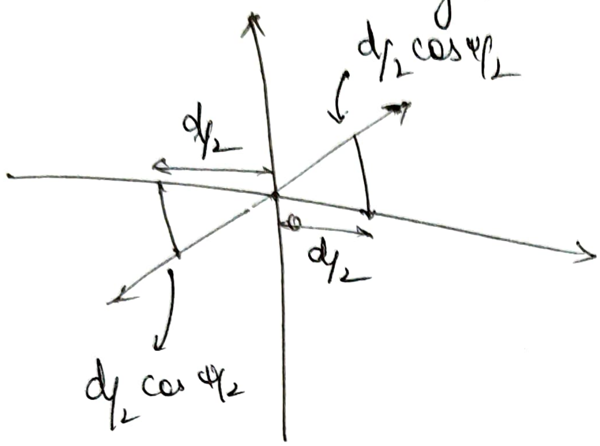
$$P = \frac{1}{2}\sqrt{\frac{\mu}{\varepsilon}}\, \frac{B^2 I_1^2 l^2}{12\pi}$$

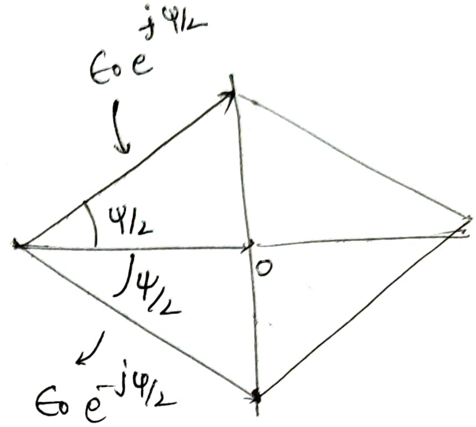
W.K.T

$$P = \left(\frac{I_0}{\sqrt{2}}\right)^2 \Rightarrow \boxed{\cancel{R_e = \frac{1}{2}\sqrt{\frac{\mu}{\varepsilon}} \cdot \frac{B^2 l^2}{6\pi}}}$$

$$\boxed{R_e = \frac{1}{2}\sqrt{\frac{\mu}{\varepsilon}}\, \frac{B^2 l^2}{6\pi}}$$

Q4. (a) Consider, two isotropic point source which have same amplitude and phase.
They are place at symmetric to each other they are placed w.r.t the origin.





$$d_r \text{ (in radians) } = \frac{\lambda d}{2\pi} = \beta d$$

$$E = E_0 e^{j\psi/2} + E_0 e^{-j\psi/2}$$

$$= 2E_0 \left[\frac{e^{j\psi/2} + e^{-j\psi/2}}{2}\right]$$

$$= 2E_0 \cos\psi/2$$

where, $\psi = d_r \cos\phi$

$$= 2E_0 \cos\left(\frac{d_r}{2}\cos\phi\right)$$

$2E_0 = 1$; $d_r = \lambda/2$ $\psi = \pi$

$$\Rightarrow \boxed{E = \cos\left(\pi/2 \cos\phi\right)}$$

$$S = \frac{1}{2} R_e [E \times H^*)^2$$

$$= \frac{1}{2} R_e E_\theta |H_\theta| |H_\phi|^2$$

$$= \frac{1}{2} R_e E_\theta |H_\phi|^2$$

$$E_\theta = |H_\phi|^2 = \sqrt{\frac{\mu}{\varepsilon}}$$

$$P = \int_\phi \int_\theta S . \sin\theta . d\theta . d\phi$$

$$= \int_{\phi=0}^{2\pi} \left(\int_{\theta=0}^{\pi} \frac{1}{2} \sqrt{\frac{\mu}{\varepsilon}} R_e E_\theta |H_\phi|^2 \sin\theta . d\theta \right) d\phi$$

$$= \frac{1}{2} \sqrt{\frac{\mu}{\varepsilon}} \frac{B^2 I_r^2 L^2}{12\pi}$$

W.K.T $P = \left(\frac{I_0}{\sqrt{2}} \right)^L$

$$\Rightarrow \boxed{R_e = \frac{1}{2} \sqrt{\frac{\mu}{\varepsilon}} \frac{B^2 L^2}{6\pi}}$$

Hence proved

Pattern multiplication :-

Given .

$$U = \begin{cases} U_m \sin^2\theta \sin^2\phi , & 0 \leq \theta \leq \pi \\ & 0 \leq \phi \leq \pi \end{cases}$$

$$D = \frac{4\pi}{\Omega_A}$$

$$\Omega_A = \int_{\phi=0}^{\pi}\int_{\theta=0}^{\pi} P_n(\theta, \phi)\, d\Omega$$

$$P_n(\theta, \phi) = \frac{U_m}{U_{max}}$$

$$= \frac{U_m \sin^2\theta \sin^2\phi}{U_m}$$

$$P_n(\theta, \phi) = \sin^2\theta \sin^2\phi$$

$$\Omega_A = \int_{\phi=0}^{\pi}\int_{\theta=0}^{\pi} \sin^2\theta \sin^2\phi \sin\theta \, d\theta \, d\phi$$

$\therefore \left(d\Omega = \sin\theta \, d\theta \, d\phi \right)$

$$= \int_{\phi=0}^{\pi}\int_{\theta=0}^{\pi} \sin^3\theta \sin^2\phi \, d\theta \, d\phi$$

$$= \int_{\theta=0}^{\pi} \sin^3\theta \, d\theta \int_{\phi=0}^{\pi} \sin^2\phi \, d\phi$$

$$= \int_{\theta=0}^{\pi} \sin^2\theta \sin\theta \, d\theta \int_{\phi=0}^{\pi} \frac{1-\cos 2\phi}{2} \, d\phi$$

$$= \int_{\theta=0}^{\pi} (1-\cos^2\theta) \sin\theta \, d\theta \left[\int_{\phi=0}^{\pi} \frac{1}{2} \, d\phi - \int_{\phi=0}^{\pi} \frac{\cos 2\phi}{2} \, d\phi \right]$$

$$= \int_{\theta=0}^{\pi}$$ let $\cos\theta = t$

$-\sin\theta \, d\theta = dt$

$$= \int_{\theta=0}^{\pi} -(1-t^2) \, dt \left[\int_{\phi=0}^{\pi} \frac{1}{2} \, d\phi - \left[\frac{\sin 2\phi}{4}\right]_{\phi=0}^{2\pi} \right]$$

$$= \int -dt + \int_0 t^2 \, dt \left[[\phi]_0^{\pi} - 0 \right]$$

$$= \left[[-t] + \left[\frac{t^3}{3}\right] \right] [\pi]$$

$$\Rightarrow \left[[-\cos\theta]_0^{\pi} + \left[\frac{\cos^3\theta}{3}\right]_0^{\pi} \right] [\pi]$$

$$\Rightarrow \frac{4}{3}\pi$$

$$\Omega_A \Rightarrow \frac{4\pi}{3}$$

$$D = \frac{4\pi}{\Omega_A} \Rightarrow \frac{4\pi}{\frac{4\pi}{3}}$$

$$\boxed{D = 3}$$