Solution
Internal Assessment Test III – May 2019

Sub:	RADAR Engineering							**Code:**	15EC833
Date:	15/05/2019	Duration:	90mins	Max Marks:	50	**Sem:**	8	**Branch:**	ECE

Note: Answer Any Five Questions

Question #		Description	Marks Distribution		Max Marks
1.		**What are the various antenna parameters? Discuss in detail. Discuss the effect of aperture efficiency on radar performance and why it should not be interpreted as an indicator of power loss.** (i) Directive gain (ii) Power gain (iii) Antenna radiation pattern (iv) Effective aperture (v) Sidelobe radiation (vi) Polarization (vii) Aperture efficiency and its effects	2 M 1 M 1 M 1 M 1 M 1 M 3 M	10 M	10 M

1\. Antenna Parameters:

i) Gain : The gain of the antenna is defined as the ability of the antenna to transmit the energy in the desired direction.

We can define gain as i) Directive gain
ii) Power gain,

* Directive gain is the directivity of the antenna where as the power gain which is simply called as gain is the directivity which includes losses of the antenna itself.

Directive Gain is defined as

$$G_D = \frac{\text{max radiation intensity}}{\text{avg. radiation intensity}}$$

where radiation intensity is power per unit solid angle along the direction (θ, ϕ) denoted as $I(\theta, \phi)$ and its unit is watts per steradian.

Average radiation intensity over the solid angle 4π is equal to the total radiation intensity divided by 4π

$$\therefore G_D = \frac{4\pi \cdot \text{max. radiation intensity}}{\text{Total radiation intensity}}$$

$$G_D = \frac{4\pi \; P(\theta, \phi)_{max}}{\iint P(\theta, \phi) \cdot d\theta \cdot d\phi}$$

$$G_D = \frac{4\pi}{B}$$

where B is the beam area ; $B = \frac{\iint P(\theta, \phi) \, d\theta \cdot d\phi}{P(\theta, \phi)_{max}}$

Beam area is also defined with the half beamwidth θ_B and ϕ_B as

$$B = \theta_B \phi_B$$

$$\therefore \quad G_D = \frac{4\pi}{\theta_B \phi_B}$$

The above gain expressions are in radians expressing it in degrees we get

$$G_D = \frac{41,253}{\theta_B \phi_B}$$

~~For Gaussian shaped beam~~ For practical antenna :

$$G_D = \frac{30,000}{\theta_B \phi_B}$$

* Gain : This gain gives the directive gain along with the dissipative losses of the system. It doesnot include the loss due to mismatch or the polarization losses.

and is defined as

$$G = \frac{\text{max. radiation intensity}}{\text{net power accepted by the system}}$$

(or)

$$G = \frac{\text{radiation intensity by the practical antenna}}{\text{radiation intensity of the isotropic antenna with same power input}}$$

G_D and G are related by

$$G = \eta_n G_D$$

where η_n is the radiation efficiency. If we have uniform and is defined as total power radiated to the net power accepted by the system.

ii) Effective Aperture

Effective Aperture is defined as the area provided by the antenna for the incident energy. The gain and effective area is defined by the relation

$$G = \frac{4\pi A_e}{\lambda} = \frac{4\pi \eta_a A}{\lambda}$$

where A_e - effective aperture $= \eta_a A$

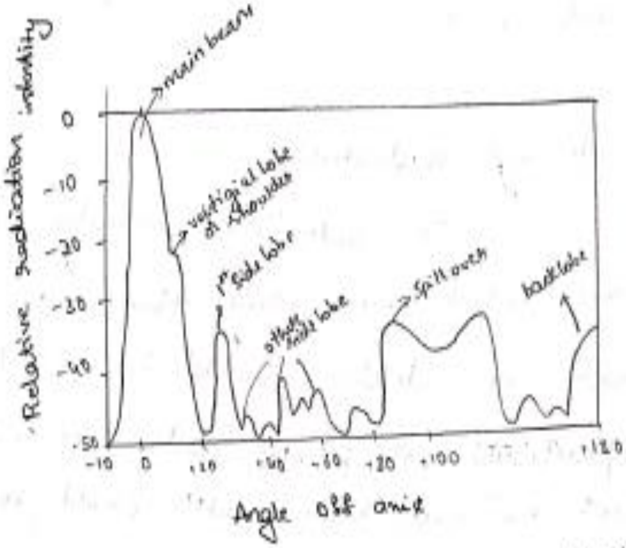
η_a - Aperture efficiency

A - physical area

λ - wavelength.

If we have uniform illumination fa=1 which increase the sidelobe level equal to the main lobe.

iii) Radiation intensity pattern.



The radiation intensity when plotted against the angular coordinated we get radiation pattern. On relative basis it can be normalized by equating the maximum value to unity.

Consider the radiation pattern of the parabolic reflector antenna as shown.

The main beam occurs at 0°, there is vestigial lobe or shoulders which occurs when there is errors in aperture illumination and this is not present for all antennas. The 1st side lobe will be in the position of shoulder if there was no errors in aperture illumination.

conventional reflectors will have spill over as shown in the figure.

Back lobes are produced due to leakage at the edges of the reflector antenna and due to the mismatch as well.

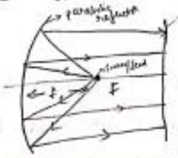
iv) Side lobe radiation:

The side lobe radiation are the patterns which are other than main beam. Ideally no-sidelobes should be present which is practically not possible and if no sidelobes were present the main beam width would be wide.

But low side lobe levels are useful in determining the angle, range and helping the directivity by making the main beam narrow.

v) Polarization:

Polarization is the alignment of the electric field ie the direction of electric field it can be linearly polarized. It can have horizontal polarization which is used in Air-surveillance radar. It can have vertical polarization used in tracking radar.

		Circular polarization is obtained by rotating the antenna at the rate of RF frequency with constant amplitude. Elliptical polarization is also obtained similar to circular polarization but here the amplitude varies. Circular polarization is used in the midst of rain polarization vi) Aperture efficiency: The aperture efficiency is different from the radiation efficiency. If ~~aperture~~ radiation efficiency is less than unity then the energy is lost. If aperture efficiency is less than unity means the energy is not lost it is re-radiated in angle, therefore it should not be interpreted as an indicator of power loss. The Aperture efficiency is not that important when we consider in Radar Engineering it is tolerable or made less to achieve other parameters of radar such low side lobe level, range, system performance etc.,			
2.		**What is a feed in parabolic reflector antenna? What are the various types of feeds used? Explain with neat figures.** (i) Explanation of feed (ii) Rear feed using half wave dipole and reflector (iii) Rear feed using horn, front horn feed (iv) Offset- fed reflector (v) Cassegrain feed (vi) Polarization twist cassegrain 2. The parabolic reflector antenna is illuminated with the source at focus which is known as the feed as shown below.  fig. a 	2 M 1 M 2 M 1 M 2 M 2 M	10 M	10M

Types of feeds.

i) feed with dipole and parasitic reflector.

The dipole is used as the feed along with the parasitic reflector to direct all of its energy to the parabolic surface. Although we use dipole its utility is less i.e power handling capacity of dipole is low and it is not effective at microwave frequencies hence we go for ii) open ended antenna where the power handling capability of the high comparatively and works at microwave frequencies of radar.

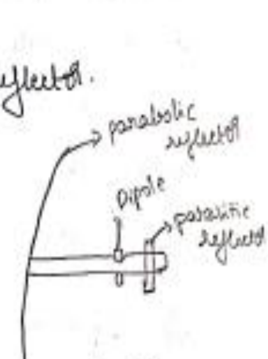


fig. 2.a

If we want to increase the directivity and guided wave can be used as shown in fig. 2.b


fig. 2.b


fig. 2.c

iii) horn support can also be provided as the feed as shown in fig. 2.c but in this there

<table>
<tr><td></td><td></td><td>is aperture blocking, where the reflected rays is blocked by the support and also there is a mismatch due to the reflected rays obtaining the horn and the transmission line.

iv) Offset Parabolic Antenna

The figure is as shown in fig 2.d where the we have the feed located at the focus and it is tipped. The Parabolic surfaced is halfed and only the half is used as shown. This will not have any aperture blocking (or) the mismatch due to feed (VSWR). Due to the asymmetry of the Antenna, there will be cross-polarized lobes which disturbs the polarization of the system and effects the system performance


fig. 2.d

v) Cassegrain Reflector Antenna.

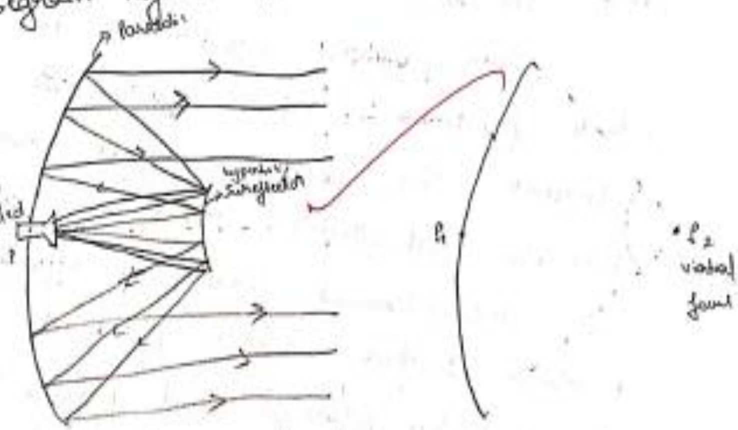


fig. 2.e</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>(a)</td><td>Why does a parabolic surface make a good reflector antenna? When might each of the following parabolic reflector antennas be used: (a) paraboloid (b) section of a paraboloid (c) parabolic cylinder.
(i) Explanation of parabolic reflector antenna with figure
(ii) Paraboloid
(iii)Section of a paraboloid
(iv) Parabolic cylinder</td><td>3 M
1 M
1 M
1 M</td><td>06 M</td><td>06 M</td></tr>
</table>

		3. a) Parabolic surface make a good reflector antenna i) The rays from the focus of the parabola reflects at the parabolic surface and travels in the direction parallel to parabola axis. ii) The rays reflected from the focus travels the same distance to the direction of which ever angle they emanate from the focus. a) Paraboloid - is obtained by rotating the the parabolic surface around the focus ⇒ Used in Tracking Radar. b) Section of Paraboloid - Obtained when elliptical surface is cut (i.e cut from the parabola as elliptical). It is used as 2-dimensional reflector. ⇒ Used in Air-Surveillance Radar c) Parabolic Cylinder - Obtained when parabolic surface is moved parallelly and linear array is used as the feed ⇒ Used in Air - Surveillance for Marine operations			
	(b)	**Write short notes on grating lobes.** (i) Definition (ii) Conditions to avoid grating lobes	2 M 2 M	4 M	4 M

<table>
<tr><td></td><td></td><td>b) Grating lobes:

The beam which has maximum peak other than the main beam is the Grating lobe which effects the system performance, false detection of target.

This occurs where the spacing between the target phase array elements (d) is greater than half the wavelength.

∴ The spacing between the array elements should be less than or equal to half the wavelength.

Grating lobe can be found by equating the Denominator of array factor to 0

$N^2 \sin^2\left(\pi (d/\lambda) \sin\theta\right) = 0$

$\pi \cdot \frac{d}{\lambda} \sin\theta = \pm n\pi$

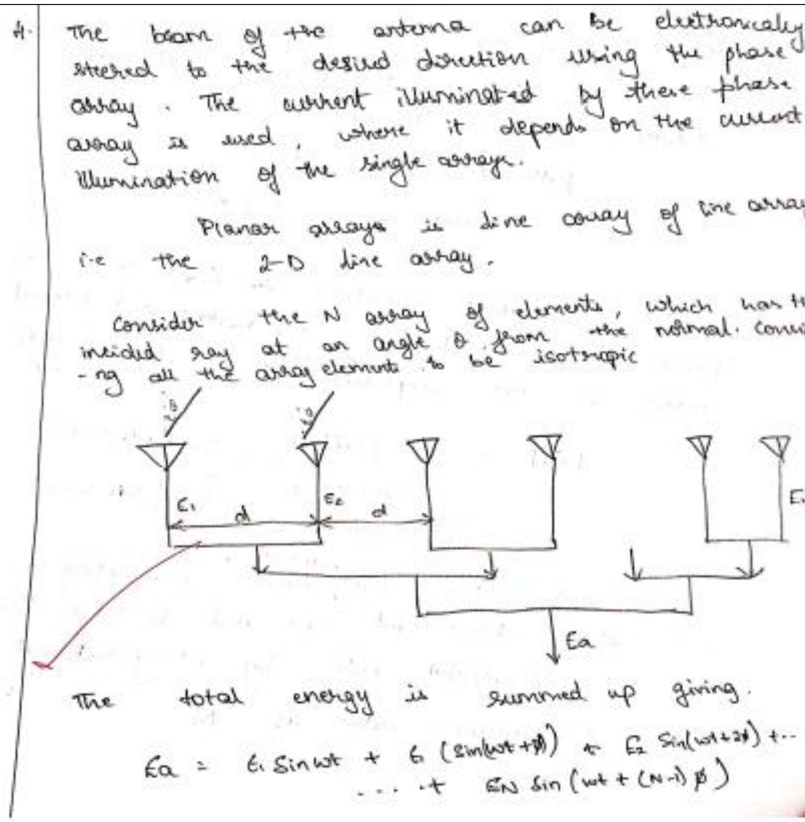
$\sin\theta = \pm \frac{n\lambda}{d}$

4

hence above equation tells $d \le \lambda/2$ (or)

$d = 0.54\lambda$.</td><td></td><td></td><td></td></tr>
<tr><td>4.</td><td></td><td>What are electronically steered phased array antennas? Obtain the array factor for a uniformly spaced linear array of N isotropic elements. When radiating elements are not isotropic, how is the antenna radiation pattern modified?

(i) Definition and Explanation
(ii) Array factor derivation for isotropic elements
(iii) Array factor derivation for non-isotropic elements</td><td>4 M
4 M
2 M</td><td>10 M</td><td>10 M</td></tr>
</table>

		 4. The beam of the antenna can be electronically steered to the desired direction using the phase array. The current illuminated by these phase array is used, where it depends on the current illumination of the single array. Planar arrays is line array of line array i.e the 2-D line array. Consider the N array of elements, which has the incided ray at an angle θ from the normal. Considering all the array elements to be isotropic The total energy is summed up giving. $Ea = E_1 \sin\omega t + E_2 (\sin(\omega t+\phi)) + E_3 \sin(\omega t+2\phi) + \ldots \ldots + E_N \sin(\omega t + (N-1)\phi)$ (iv)			
5.		**Explain conical scan tracking radar with a neat block diagram.** (i) Basic concept of conical scan (ii) Conical scan tracking diagram (iii) Block diagram (iv) Explanation	3 M 2 M 3 M 2 M	10 M	10 M
6.	(a)	**Derive and obtain the expression that defines the system noise figure when it includes the effects of antenna temperature and effective noise temperature.** (i) Noise figure of a linear network, its interpretations with modified expressions (ii) Effective noise temperature, Te (iii) Expression of Ts in terms of Fs (iv) Explanation	2 M 1 M 2 M 1 M	06 M	06 M
	(b)	**Which are the parameters that determine the noise figure of a mixer? Give relevant expressions** (i) Conversion loss with expression (ii) Noise temperature ratio with expression (iii) Expression for Fm in terms of Lc and tr (iv) Explanation	1 M 1 M 1 M 1 M	04 M	04 M
7.		**Explain balanced duplexer using dual TR tubes with a neat figure. Why is a diode limiter following the duplexer sometimes used as a receiver protector?** (i) Explanation of balanced duplexer	3 M	10	10 M

		(ii) Figure (Transmit & Receive condition) (iii) Diode limiters as receiver protector	3 M 4 M	M	
8.		**How does mixer act as a key element in a super heterodyne receiver of radar? Explain various types of mixers with relevant figures.** (i) Importance of mixer, explanation (ii) Types of mixers (5 types explanation + figures)	2 M 5+3 M	10 M	10 M