	b)	What is Yagi-Uda Antenna? Explain the construction and operation of Yagi-Uda Antenna. Also explain its general characteristics?	L2	CO3	5 M
		UNIT-V			
10	a)	Briefly explain the following: (i) Roughness of earth (ii) Reflection factors of earth	L2	CO4	5 M
	b)	What is meant by space wave? Discuss about field strength due to space wave.	L2	CO4	5 M
		OR			
11	a)	Explain MUF and skip distance.	L2	CO4	5 M
	b)	In case of ionosphere, Explain the significance of D, E and F layers.	L2	CO4	5 M

PVP 23

Code: 23EC3503

III B.Tech - I Semester - Regular Examinations - NOVEMBER 2025

ANTENNAS AND WAVE PROPAGATION
(ELECTRONICS & COMMUNICATION ENGINEERING)

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1.a)	Define half power beamwidth of antenna.	L1	CO1
1.b)	Define beam efficiency of an antenna.	L1	CO1
1.c)	List out the some applications of helical antenna.	L1	CO2
1.d)	Define radiated power.	L1	CO2
1.e)	Explain three different types of arrays with regard to beam pointing direction.	L2	CO2
1.f)	Write weights of 5 elements binomial array.	L1	CO2
1.g)	What do you mean by F/D ratio?	L1	CO3
1.h)	Differentiate between wire grid reflectors and corner reflectors.	L4	CO3
1.i)	Define critical frequency and LOS.	L1	CO4
1.j)	Explain wave tilt.	L2	CO4

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Discuss the following: (i) Normalized field pattern (ii) Directivity	L2	CO1	5 M
	b)	Explain the radiation mechanism in short dipole.	L2	CO1	5 M
		OR			
3	a)	Explain about radiation mechanism in a single wire.	L2	CO1	5 M
	b)	Define polarization. Explain different types of polarization.	L2	CO1	5 M
		UNIT-II			
4	a)	Compare monopole antennas and dipole antennas.	L4	CO2	5 M
	b)	Define the terms: i) Radial power flow ii) Radiation resistance for a short dipole iii)Uniform current distribution.	L1	CO2	5 M
		OR			
5	a)	Define axial ratio and their significance in helical antenna.	L2	CO2	5 M
	b)	What is the effective area of a half-wave dipole operating at 200 MHz?	L3	CO2	5 M

		UNIT-III			
6	a)	What is the purpose of array of radiators? Derive the expression for field strength of two element uniform array.	L3	CO2	5 M
	b)	What are the advantages and disadvantages of binominal array and design 3-element binomial arrays.	L2	CO2	5 M
		OR			
7	a)	Estimate the resultant radiation pattern of N=8 element linear uniform distributed array using pattern multiplication.	L4	CO2	5 M
	b)	A uniform linear array is required to produce an end-fire beam when it is operated at a frequency of 10 GHz. It contains 50 radiators and Spaced at 0.5λ. Find the progressive phase shift required to produce the end-fire beam.	L4	CO2	5 M
		UNIT-IV			
8	a)	Write the salient features of microstrip antennas.	L1	CO3	5 M
	b)	What is corner reflector? List out the salient features of it.	L1	CO3	5 M
		OR			
9	a)	What is the power gain of a paraboloid reflector whose mouth diameter is equal to 8λ?	L3	CO3	5 M

Scheme of Evaluation
III-B.Tech., I-Semester-Regular Examinations-November, 2025
Antennas and Wave Propagation (23EC3503)

Part-A

1(a) Half power beam width- Definition	---	2M
(b) Beam Efficiency - Definition	---	2M
(c) Applications of Helical antenna	---	2M
(d) Radiated power- Definition	---	2M
(e) Three different types of arrays	---	2M
(f) Weights of 5-element binomial array	---	2M
(g) F/D ratio	---	2M
(h) Wire grid reflector and Corner reflector	---	2M
(i) Critical frequency and LOS	---	2M
(j) Wave tilt	---	2M

Part-B

2(a) (i) Normalized Field Pattern	---	2M
(ii) Directivity	---	3M
2(b) Diagrams	---	2M
Explanation	---	3M
3(a) Diagrams	---	2M
Explanation	---	3M
3(b) Polarization- Definition	---	1M
Different types with explanation	---	4M
4(a) Monopole and Dipole-comparison	---	5M
4(b) (i) Radial Power Flow	---	1M
(ii) Radiation Resistance for a Short Dipole	---	2M
(iii) Uniform Current Distribution	---	2M
5(a) Axial Ratio - Definition	---	2M
Axial ratio- Significance	---	3M
5(b) Formula	---	2M
Substitution and results	---	3M
6(a) Purpose of array	---	1M
Two Element Uniform Array	---	4M
6(b) Advantages and Disadvantages of Binomial array	---	2M
Design of a 3-element binomial array	---	3M

7(a) Pattern multiplication technique	---	2M
Estimation of radiation pattern	---	3M
7(b) Formula	---	2M
Substitution and results	---	3M
8 (a) Salient features of Microstrip antennas	---	5M
8 (b) Corner Reflector - Definition and diagrams	---	2M
Salient features of Corner reflector	---	3M
9(a) Formula	---	2M
Substitution and results	---	3M
9(b) Yagi-Uda antenna, Construction and Operation	---	4M
Characteristics	---	1M
10(a) (i) Roughness of Earth	---	2M
(ii) Reflection Factors of Earth	---	3M
10(b) Space wave	---	2M
The field strength due to space wave	---	3M
11(a) MUF	---	2M
Skip distance	---	3M
11(b) Significance of D, E and F Layers	---	5M

Solutions

III-B.Tech., I-Semester-Regular Examinations-November, 2025

Antennas and Wave Propagation (23EC3503)

Part-A

1(a) Half power beam width (HPBW): It is the angular width (in degrees) measured on radiation pattern of main lobe at half power points. At half power points power is half. It is also called 3-dB beam width.

1(b) Beam Efficiency: For an antenna with its major lobe directed along the z-axis, the beam efficiency (BE) is defined by

$$\text{BE} = \frac{power\ transmitted\ (received) within\ cone\ angle\ \theta_1}{power\ transmitted\ (received) by\ the\ antenna}\ \text{(dimensionless)}$$

Where θ_1 is the half-angle of the cone within which the percentage of the total power is to be found.

1(c) Applications of Helical antenna:

i) A single helical antenna or its array is used to transmit and receive VHF signals

ii) Frequently used for satellite and space probe communications

iii) Used for telemetry links with ballastic missiles and satellites at Earth stations

iv) Used to establish communications between the moon and the Earth

v) Applications in radio astronomy

1(d) The radiated power of an antenna is the total power it emits as electromagnetic waves, which can be calculated by integrating the power density over a closed spherical surface. The total power radiated is obtained by integrating the radiation intensity over the beam solid angle.

ie., $W_{rad} = \iint U(\theta, \varphi) d\Omega$

Where $d\Omega = \sin\theta\ d\theta\ d\varphi$ is the element of the solid angle of a sphere.

Radiated power is surface integration of average power density. i.e., $P_{rad} = \int W_{avg}\, dS$

Where W_{avg} is the average power density of the antenna and $dS = r^2 \sin\theta\, d\theta d\varphi$

1(e) Broadside Array: The direction of maximum radiation is perpendicular to array axis. The antenna elements fed with currents of the same magnitude and phase.

End-Fire Array: The direction of maximum radiation is along the array axis. Elements are fed with currents that have a progressive phase difference along the array axis

Phased Array (Electronically Scanned Array): This type allows the beam to be electronically steered to point in any desired direction over a wide angle without physically moving the antenna. Each element in the array is connected to a phase shifter controlled by a computer. By adjusting the relative phase and amplitude of the signals at each element, the direction of constructive interference (the main beam) can be changed dynamically.

1(f) Weights of 5 elements binomial array are **1, 4, 6, 4, 1**

1(g) F/D radio: The ratio of focal length to aperture size is known as F over D ratio. The F over D ratio is an important characteristic of parabolic reflector and its value usually varies between 0.25 to 0.50.

1(h) A corner reflector uses two or three flat, intersecting conductive surfaces to reflect radio waves back to their source, while a wire grid reflector is a mesh of wires that can replace the solid surface of a corner reflector to reduce weight and wind resistance. A corner reflector is a solid structure, while a wire grid is a simplified, open-frame version of a solid reflector, typically used to improve performance and reduce wind load.

1(i) Critical frequency: Critical frequency of an ionised layer of the ionosphere is defined as the highest frequency that can be reflected by a particular layer at vertical incidence.

LOS: It is defined as the distance that is covered by a direct space wave from transmitting antenna to the receiving antenna. It depends on Height of the transmitting antenna, Height of the receiving antenna and Effective earth's radius factor, K

1(j) Wave tilt: Wave tilt is defined as the change of orientation of the vertically polarized ground wave at the surface of the earth. Wave tilt occurs at the surface of the earth. The tilt depends on conductivity and permittivity of the earth.

PART-B

2(a) Normalized Field Pattern: The graphical representation of the radiation of the antenna as a function of direction is called the radiation pattern. If the radiation is expressed in terms of field strength, it is called as the field pattern. i.e., It is the graph between E versus θ. If the magnitude of E is equal to 1 then we get the normalized field pattern.

Directivity, D: The Maximum directive gain is called the directivity

$$D = (G_d)_{max} = \frac{4\pi Umax}{Wrad}$$

Directivity is also expressed in decibels ratio.

$$D\ (dB) = 10 \log_{10} D$$

Directivity is always greater than or equal to 1.

For isotropic source, D = 1.

Gain and Directivity are related as $G = \eta D$

2(b) Radiation Mechanism in short Dipole: Now let us explain the mechanism by which the electric lines of force are detached from the antenna to form the free-space waves. This will again be illustrated by an example of a small dipole antenna where the time of travel is negligible. This is only necessary to give a better physical interpretation of the detachment of the lines of force. Although a somewhat simplified mechanism, it does allow one to visualize the creation of the free-space waves.

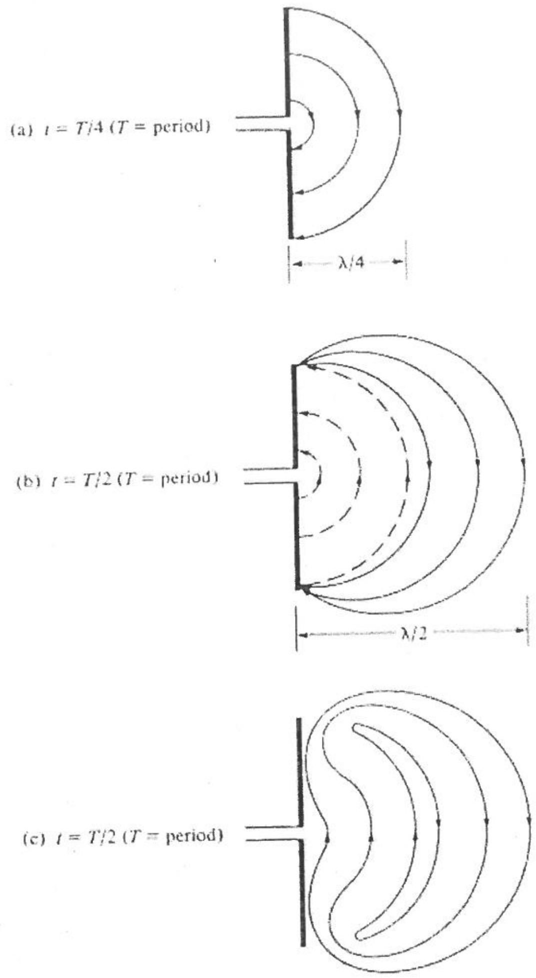
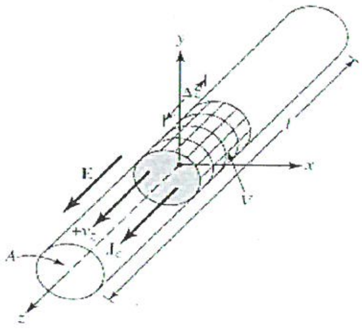


Fig: Formation and detachment of electric field lines for short dipole.

Figure (a) displays the lines of force created between the arms of a small center-fed dipole in the first quarter of the period during which time the charge has reached its maximum value (assuming a sinusoidal time variation) and the lines have travelled outwardly a radial distance λ/4. For this example, let us assume that the number of lines formed are three. During the next quarter of the period, the original three lines travel an additional λ/4 (a total of λ/2 from the initial point) and the charge density on the conductors begins to diminish. This can be thought of as being accomplished by introducing opposite charges which at the end of the first half of the period have neutralized the charges on the conductors. The lines of force created by the opposite charges are three and travel a distance λ/4 during the second quarter of the first half, and they are shown dashed in Figure (b). The end result is that there are three lines of force pointed upward in the first λ/4 distance and the same number of lines directed downward in the second λ/4. Since there is no net charge on the antenna, then the lines of force must have been forced to detach themselves from the conductors and to unite together to form closed loops. This is shown in Figure (c). In the remaining second half of the period, the same procedure is followed but in the opposite direction.

3(a) Radiation Mechanism in a single wire: Let us assume that an electric volume charge density, represented by q_v (coulombs/m^3), is distributed uniformly in a circular wire of cross-sectional area A and volume V, as shown in Figure. The total charge Q within volume V is moving in the z direction with a uniform velocity v_z (meters/sec).



It can be shown that the current density J_z (amperes/m^2) over the cross section of the wire is given by $J_z = q_v v_z$ ----- (1)

If the wire is made of an ideal electric conductor, the current density J_s on the surface of the wire and it is given by $J_s = q_s v_z$ -------- (2)

where q_s (coulombs/m^2) is the surface charge density.

If the wire is very thin (ideally zero radius), then the current in the wire can be represented by

$$I_z = q_l v_z \quad \text{---------} \; (3)$$

where q_l (coulombs/m) is the charge per unit length.

Instead of examining all three current densities, we will primarily concentrate on the very thin wire.

If the current is time varying, then the derivative of the current of (3) can be written as

$$\frac{dI_z}{dt} = q_l \frac{dv_z}{dt} = q_l a_z$$

$$where \; \frac{dv_z}{dt} = a_z \text{ is the acceleration.}$$

If the wire is of the length, l then above equation can be written as

$$l \frac{dI_z}{dt} = l q_l \frac{dv_z}{dt} = l \, q_l a_z$$

The above equation is the basic relation between current and charge, and it also serves as the fundamental relation of electromagnetic radiation. It simply states that to create radiation, there must be a time-varying current or an acceleration (or deceleration) of charge.

For radiation, there must be time varying current.

- If the charge is not moving, there is no current and hence no radiation.
- If the charge is moving with uniform velocity
  - -- There is no radiation, even if the wire is straight and is infinite in extent.
  - -- There is radiation, if the wire is curved, bent, discontinuous and terminated as shown in Fig.

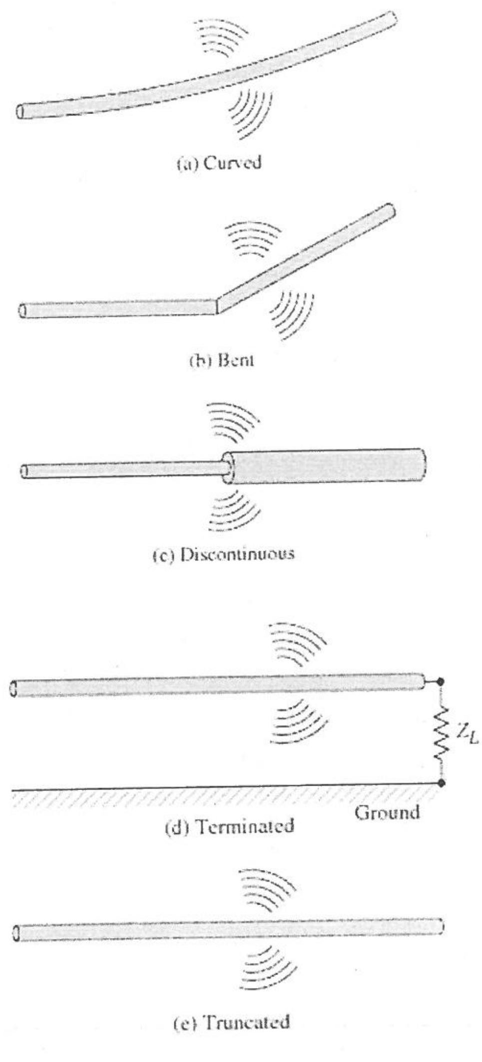


Fig: Wire configurations for radiation

3(b) **Polarization:** The orientation (or) direction of electric field vector. Polarization is always in the direction of electric field vector. There are 3-types of polarization:

1. Linear Polarization
2. Circular Polarization
3. Elliptical Polarization

1. Linear Polarization: If the polarization remains constant throughout the propagation of EM wave, then it is called linear polarization. Linear polarization is again divided into 3-types.

i) Horizontal Polarization
ii) Vertical Polarization
iii) Inclined polarization (or) θ-polarization

i) Horizontal Polarization: A wave is said to be horizontally polarized, if the electric field vector propagates parallel to the earth's surface.

ii) Vertical Polarization: A wave is said to be vertically polarized, if the electric field vector propagates perpendicular to the earth's surface.

iii) θ-polarization: A wave is said to be θ-polarized, if the electric field vector propagates at an angle θ with the earth's surface.

2. Circular Polarization: When the electric field vector traces a circle, it is called circular polarization.

3. Elliptical Polarization: When the electric field vector traces an ellipse, it is called elliptical polarization. Depending upon the direction (or) orientation of electric field vector, two cases are possible in both circular and elliptical polarizations. If the electric field vector is oriented in the clock wise direction, then the polarization is called right hand (Circular/Elliptical) polarization. If the electric field vector is oriented in anti-clock wise direction, then the polarization is called left hand (Circular/Elliptical) polarization.

4(a) Comparison of monopole antennas and Dipole antennas:

Monopole antennas	Dipole antennas
It consists of a single straight rod or conductor mounted perpendicularly over a conductive surface known as a ground plane.	It consists of two identical conductive elements (rods) that are oriented in opposite directions, connected at the center.
It requires a ground plane.	The dipole does not require a ground plane.
Total length of the monopole is typically $\lambda/4$	Total length of the dipole is typically $\lambda/2$
Higher gain	Lower gain
Narrower Bandwidth	Wider Bandwidth
Directional radiation pattern	Bidirectional radiation pattern
Commonly used in applications such as mobile phones, AM/FM radio and other wireless communication devices.	Widely used in broadcasting, amateur radio and various communication systems.

4(b) (i) Radial Power Flow: Radial power flow refers to the outward flow of electromagnetic power from an antenna or radiating source, spreading away in all directions (radially) from the antenna. It is typically described using the Poynting vector, which indicates the direction and magnitude of electromagnetic energy propagation.

(ii) **Radiation Resistance for a Short Dipole**: Radiation resistance is the equivalent resistance of an antenna that represents the power it radiates as electromagnetic waves. For a **short dipole** ($l \ll \lambda$), the radiation resistance R_r is given by the expression

$$R_r = 80\pi^2 \left(\frac{l}{\lambda}\right)^2$$

(iii) **Uniform Current Distribution**: Uniform current distribution means the current along the length of an antenna (typically a short dipole) is assumed to have the same magnitude and phase at every point. This assumption is valid when the antenna length is much smaller than the wavelength and so no significant phase variation occurs along the conductor.

5(a) Axial Ratio (AR): Axial ratio is a measure of the degree of circular polarization of an electromagnetic wave. It is defined as

$$Axial\ Ratio = \frac{major\ axis\ of\ polarization\ ellipse}{minor\ axis\ of\ polarization\ ellipse}$$

For a perfect circularly polarized wave, $AR = 1$ or $0\ dB$

The axial ratio of a helical antenna is significant because

1. It ensures good circular polarization
2. It provides better satellite link performance
3. It minimizes polarization mismatch loss
4. It improves signal reliability in multipath environments
5. It helps maintain high effective gain

5(b) Given

$$f = 200\ MHz$$

Effective area, $A_e = \frac{D\lambda^2}{4\pi}$

For a Half-wave dipole the directivity, $D = 1.641$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{200 \times 10^6} = 1.5\ m$$

$$A_e = \frac{D\lambda^2}{4\pi} = \frac{1.64(1.5)^2}{4\pi} = \frac{3.69}{12.566} \cong 0.294\ m^2$$

6(a) Purpose of array of radiators: Arrays are used to increase directivity and gain.

Two Element Uniform Array: Figure shows 2-isotropic point sources 1 and 2 are separated by a distance, d and located symmetrically with respect to the origin of the coordinate system. The angle, θ is measured counter clockwise from the positive X-axis. We have to calculate the field at a distant point, P which is at a distance, r from the origin. The origin is taken the reference point for phase calculations.

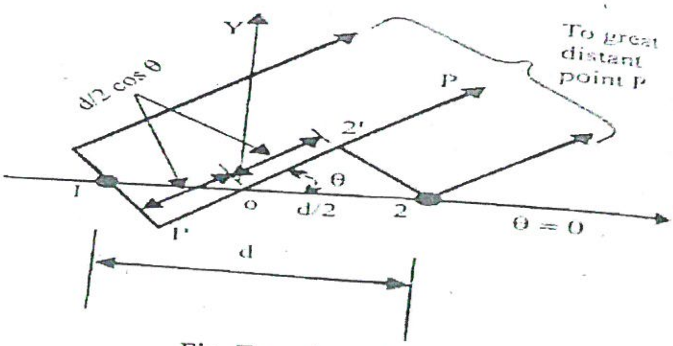


Fig: Two-element array

The field from point source 1 is retarded by $\frac{d}{2}\cos\theta$ while the field from source 2 is advanced by $\frac{d}{2}\cos\theta$. The path difference between two point sources is

Path difference $= \frac{d}{2}\cos\theta + \frac{d}{2}\cos\theta = \text{d}\cos\theta$ meters

$= \frac{\text{d}\cos\theta}{\lambda}$ Wavelengths

Phase difference (or) Phase angle, $\chi = 2\pi$ (Path difference) $= \frac{2\pi \text{d}\cos\theta}{\lambda}$

Since $\beta = \frac{2\pi}{\lambda}$. Therefore, $\chi = \beta \text{d}\cos\theta$ radians

If the excitation phase difference is α, the total phase difference is $\chi = \beta \text{d}\cos\theta + \alpha$

If E_1 and E_2 are the electric fields at the distinct point, P due to source 1 and 2 respectively, then the total field, E at point, P is given by

$$E = E_1\, e^{-j\chi/2} + E_2\, e^{+j\chi/2}$$

In this case amplitudes are equal. Hence, $E_1 = E_2 = E_0$ (say)

Therefore, $E = E_0\,(e^{-\frac{j\chi}{2}} + e^{+\frac{j\chi}{2}}) = 2E_0\,(\frac{e^{-\frac{j\chi}{2}} + e^{+\frac{j\chi}{2}}}{2}) = 2E_0\cos\frac{\chi}{2} = 2E_0\,\cos\,(\frac{\beta \text{d}\cos\theta}{2} + \frac{\alpha}{2})$

6(b) Advantages and Disadvantages of Binomial array:

The advantage of Binomial array is that, there will be no side lobes in the resultant pattern of the array.

The disadvantage is that the Beam width increases hence directivity decreases.

Design of a 3-element binomial array: A binomial array uses binomial coefficients as excitation amplitudes to reduce side lobes. For a symmetric 3-element linear array (elements at positions $x = -d, 0, +d$), choose amplitude weights proportional to the 3rd row of Pascal's triangle as $1:2:1$

Element currents (normalized): $I_1 = 1, I_2 = 2, I_3 = 1$.

Assume broadside (no progressive phase, $\alpha = 0$) and isotropic elements. The array factor (AF) for elements indexed $n = -1,0,1$:

$$AF(\theta) = 1 + 2e^{j(0)}e^{jkd\cos\theta} + 1e^{j2kd\cos\theta}$$

(shift indices if you prefer center index 0). More conveniently, with $\psi = kd\cos\theta$

$$AF(\theta) = 1 + 2e^{j\psi} + e^{j2\psi} = e^{j\psi}(e^{-j\psi} + 2 + e^{j\psi}) = e^{j\psi}(2 + 2\cos\psi)$$

Normalized magnitude (drop common phase):

$$|AF(\theta)| \propto 2(1 + \cos\psi) = 4Cos^2\left(\frac{\psi}{2}\right)$$

Typical spacing, $d = \lambda/2$ to avoid grating lobes. This binomial weighting yields much lower sidelobes than uniform weights at expense of slightly broader main lobe.

7(a) Pattern multiplication principle:

Resultant pattern = (Element pattern) x (Array Factor)

The normalized array factor (AF) for an N-element uniform linear array is given by

$$AF = \frac{\sin\left(\frac{N\psi}{2}\right)}{N\sin\left(\frac{\psi}{2}\right)}$$

With $N = 8, d = \lambda/2, \alpha = 0$

Then $\psi = \beta d\cos\theta + \alpha = \frac{2\pi}{\lambda}\frac{\lambda}{2}\cos\theta + 0 = \pi\cos\theta$

Therefore,

$$AF = \frac{\sin(4\pi\cos\theta)}{8\sin\left(\frac{\pi}{2}\cos\theta\right)}$$

Main Lobes: Maximum radiation occurs when $\psi = 2n\pi$, which for this case is at $\theta = 90^0$ and $\theta = 270^0$ (perpendicular to the array axis).

Null Positions: Nulls occur when the numerator is zero

$$\frac{N\psi}{2} = m\pi \Longrightarrow \psi = \frac{2m\pi}{N}$$

with $\psi = \pi\cos\theta$

$$\pi\cos\theta = \frac{2m\pi}{8} \Longrightarrow \cos\theta = \frac{m}{4}$$

First (adjacent) nulls around broadside: take $m = \pm 1$

$$\cos\theta = \pm\frac{1}{4} = \pm 0.25$$

Therefore, $\theta = 75.522^0, 104.477^0$

Half-Power Beam width (HPBW): For $N = 8$, $d = \lambda/2$ the HPBW is approximately equals to 12.8^0

Side lobe level (uniform excitation): The first side lobe level ≈ -12.8 dB relative to main lobe

7(b) Given

$f = 10GHz$

$N = 50$

$d = 0.5\,\lambda$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{10 \times 10^9} = 0.03\,m$$

So, the progressive phase shift is

$$\alpha_e = \pm\beta d = \frac{2\pi}{\lambda} \times 0.5\,\lambda = \pi \text{ radians}$$

8(a) Salient features of Microstrip antennas:

1. Micro strip antennas are low-profile antennas.
2. A metal patch mounted at a ground level with a di-electric material in-between constitutes a Micro strip or Patch Antenna.
3. These are very low size antennas having low radiation.
4. The patch antennas are popular for low profile applications at frequencies above 100MHz.
5. The advantages of microstrip antennas are Light weight and low volume, Low profile planar configuration, Low fabrication cost and Ease of installation.
6. The disadvantages of microstrip antennas are Narrow bandwidth, Low efficiency, Low gain, Low power handling capacity and Surface wave excitation.
7. Microstrip antennas are used in Space craft applications, Air craft applications and Low profile antenna applications.

8(b) Corner **Reflector**: Corner reflector is designed to improve the collimation of EM energy in the forward direction and to radiate elimination in the back and side directions. It is an arrangement, in which, two plane reflectors joined so as to form a corner as shown in figure.

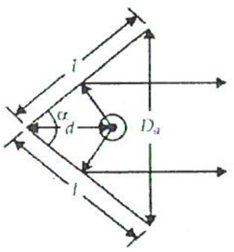


Fig (a): Side View

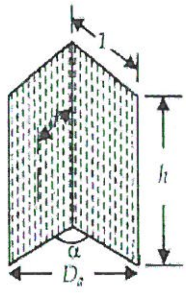


Fig (b): Perspective View

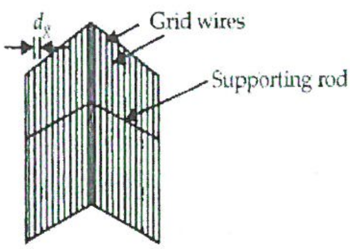


Fig (c): Wire-grid corner reflector

To reduce the wind resistance and overall system weight, the surfaces of the corner reflector is made of grid wires rather than solid sheet metal.

Salient features of Corner reflector:

1. Simple to construct
2. Used as a passive target for radar and communication applications.
3. Used in home television antennas.
4. Most preferred value of α is 90^0.
5. In order to improve efficiency, the spacing between vertex and feed element position is increased if α is decreased and vice-versa.
6. For small included angle, the side lengths should be longer.
7. For square corner reflector, $\alpha = 90^0$
8. Corner reflector antennas are used in Television, Point-to-point communication and Radio astronomy.

9(a) Given $D_a = 8\lambda$

$$\text{Power gain, } g_p \cong 6.4\left(\frac{D_a}{\lambda}\right)^2 = 6.4\left(\frac{8\lambda}{\lambda}\right)^2 = 409.6$$

$$g_p(dB) = 10\log_{10} 409.6 = 26.12$$

9(b) **Yagi-Uda Antenna**: This antenna was developed by Prof. Yagi and Prof. Uda. Hence, it is called Yagi-Uda antenna or simply Yagi anenna. Yagi-Uda antenna is used for TV reception.

Construction and Operation of Yagi-Uda Antenna: Typical structure of Yagi-Uda antenna is shown in Fig.

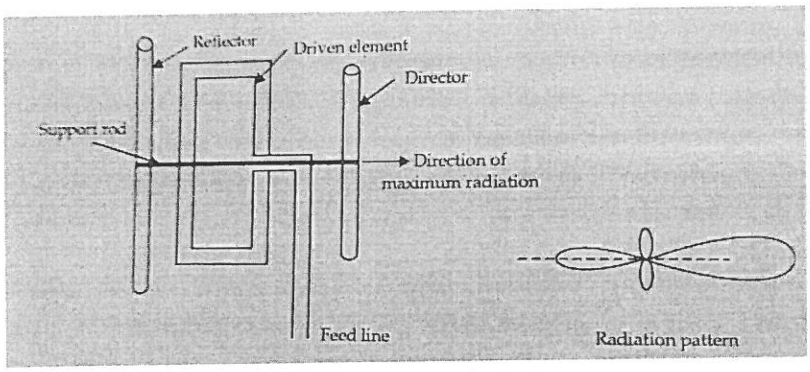


Fig: Yagi-Uda antenna and its radiation pattern

It is an array antenna, which consists of one active element and a few parasitic elements. The active element consists of a Folded dipole, whose length is $\lambda/2$. The parasitic element consists of one reflector and a few directors. The length of reflector is greater than $\lambda/2$ (ie., reflector is 5% more than driven element (or) Folded dipole antenna and it is located behind the active element.The length of directors are less than $\lambda/2$ (ie., directors are 5% less than driven element (or) Folded dipole antenna and they are placed in front of the active element. Spacing between each element is not identical and hence, it can be considered as a non-linear array. The number of directors in the antenna depends on the gain requirements. (ie., if you require more gain (or) directivity, then use more number of directors). The impedance of active element is resistive. The impedance of reflector is inductive. The impedance of directors are capacitive. Current distribution in each element depends on the length and spacing between the elements. ie., total phase of currents in director and reflector is determined not only by their lengths but also by their spacings to adjacent elements. The frequency range in which the Yagi-Uda antennas operate is around 30MHz - 3GHz which belong to the VHF and UHF bands.

In practice, for a 3-element Yagi antenna, the following formulas gives the lengths, which work satisfactorily.

$$\text{Reflector length} = \frac{500}{f(MHz)} \text{ feet}$$

$$\text{Driven element length} = \frac{475}{f(MHz)} \text{ feet}$$

$$\text{Director length} = \frac{455}{f(MHz)} \text{ feet}$$

The spacing between driven and parasitic elements are of the order of 0.10λ to 0.15λ.

Characteristics of Yagi-Uda antenna:

1. High directivity
2. Narrow beamwidth
3. Low side lobes
4. Input impedance about 300 ohms.

10(a) (i) **Roughness of Earth:** The roughness of the earth refers to the irregularities on the Earth's surface such as vegetation, buildings, rocks, and terrain variations that affect the movement of air and wind near the ground. It influences wind speed, turbulence and boundary-layer behavior. Surfaces are classified as smooth (e.g., water, flat plains) or rough (e.g., forests, urban areas).

(ii) **Reflection Factors of Earth: The** reflection factor of the earth is the fraction of incoming solar radiation that the Earth's surface reflects back into the atmosphere. It depends on surface type: snow has high reflection, while forests and oceans have low reflection. It affects temperature, heat balance and climate.

10(b) Space Wave: The radio waves having high frequencies are basically called as space waves. These waves have the ability to propagate through atmosphere, from transmitter antenna to receiver antenna. In space wave propagation, EM waves from the transmitting antenna reach the receiving antenna either directly or after reflections from ground in the earth's tropospheric region. Troposphere is that portion (or the region) of the atmosphere which extends upto 16 Km from the earth's surface. Space wave propagation is useful at frequencies above 30 MHz. It is useful for FM, TV and radar applications.

Field strength due to space wave:

The field strength of space wave propagation is influenced by several factors, including the distance between the transmitter and receiver, the height of the antennas and the presence of obstacles. The field strength can be calculated using the formula

$$E = \frac{2E_0}{d}\sin\left(\frac{2\pi h_t h_r}{\lambda d}\right) \cong \frac{4\pi h_t h_r}{\lambda d^2}E_0$$

Where E_0 is the field strength due to direct ray at unit distance.
h_t is the height of the transmitting antenna
h_r is the height of the receiving antenna
d is the distance between transmitting and receiving antennas
λ is the wavelength of the signal

11(a) Maximum Usable Frequency (MUF): The maximum possible value of frequency for which reflection takes place for a given distance of propagation is called the MUF. Generally, the value of MUF ranges between 8MHz to 35MHz.

$$MUF = \frac{Critical\ frequency, f_c}{\cos\theta} = f_c \sec\theta$$

Skip distance: It is defined as

(i) The minimum distance from the transmitter at which a sky wave of given frequency is returned to earth by the ionosphere.

(ii) The minimum distance from the transmitter to a point, where sky wave of given frequency is first received.

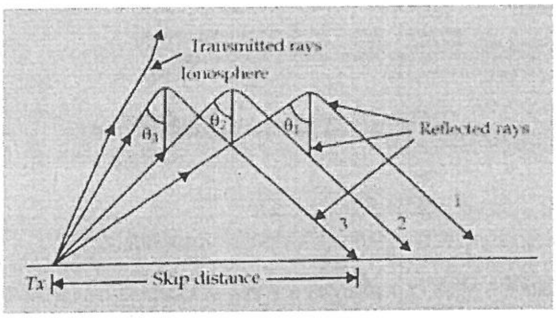


Fig: Skip Distance

11(b) Significance of D, E and F Layers:

D-Layer:

1. It is the lowest layer of the ionosphere.
2. It exists at an average height of 70 Km.
3. Its thickness is 10 Km.
4. It exists only in day-time.
5. Its ionisation properties depend on the altitude of the sun above the horizon.
6. It is not a useful layer for HF communication.
7. It reflects some VLF and LF waves.

8. It absorbs MF and HF waves to some extent.
9. Its electron density, N = 400 electrons/cc.
10. Its virtual height is 60 to 80 Km.
11. Critical frequency of the layer is 180 KHz.

E-Layer:

1. It exists next to D-Layer.
2. It exists at an average height of 100 Km.
3. Its thickness is about 25 Km.
4. It exists only in day-time.
5. The ions are recombined into molecules due to the absence of sun at night.
6. It reflects some HF waves in day-time.
7. It disappears at nights.
8. Its electron density, $N = 5 \times 10^5$ electrons/cc.
9. Its virtual height is 110 Km.
10. Critical frequency of the layer is 4 MHz.
11. Maximum single-hop range is approximately 2350 Km

F_1- Layer:

1. It exists at a height of about 180 Km in day-time.
2. Its thickness is about 20 Km.
3. It combines with F_2-layer during nights.
4. HF waves are reflected to some extent.
5. It absorbs HF to a considerable extent.
6. It passes on some HF waves towards F_2-layer.
7. Its virtual height is approximately 180 Km.
8. Its critical frequency is 5 MHz.
9. Maximum single-hop range is approximately 3000 Km

F_2- Layer:

1. It is the most important layer for HF communication.
2. It exists at a height of about 325 Km in day-time.
3. Its thickness is about 200 Km.
4. It falls to a height of 300 Km at nights as it combines with F_1-layer.
5. It exists at nights also.
6. It is the topmost layer of the ionosphere.
7. It is highly ionised.
8. Its electron density, $N = 2 \times 10^6$ electrons/cc.
9. Its virtual height is approximately 300 Km in day-time and 350 Km in night.
10. Its critical frequency is 8 MHz in day-time and 6 MHz at nights.