B.Sc (HONS.) ECE PART-III, SIXTH SEMESTER EXAMINATION, 2019
ANTENNA AND PROPAGATIONS
Subject Code: ECP-314
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Time: 3 hours
Full marks: 80

N.B. The figures in the right margin indicate full marks. Answer any five questions

Marks

Question 1 (a) What do you mean by Antenna? What are the necessary conditions for radiation from antenna? (2+4=6 marks)

Antenna Definition (2 marks): An antenna is a metallic structure or device that converts electrical energy into electromagnetic waves for transmission and vice versa for reception. It acts as a transducer between guided waves (transmission lines) and free space electromagnetic waves.

Necessary conditions for radiation from antenna (4 marks):

1. **Time-varying current: The current through the antenna must be time-varying (AC current)**
2. **Acceleration of charges: Electrons must be accelerated or decelerated to produce electromagnetic radiation**
3. **Proper impedance matching: The antenna impedance should match the transmission line impedance**
4. **Appropriate physical dimensions: Antenna length should be comparable to the wavelength (typically $\lambda/4$, $\lambda/2$, etc.)**

(b) Based on frequency range of operation, classify antenna with applications (6 marks)

Frequency-based Classification:

1. **VLF Antennas (3-30 kHz)**
   - **Applications: Submarine communication, navigation**
2. **LF Antennas (30-300 kHz)**
   - **Applications: AM broadcasting, navigation beacons**
3. **MF Antennas (300 kHz-3 MHz)**
   - **Applications: AM radio broadcasting**
4. **HF Antennas (3-30 MHz)**
   - **Applications: Shortwave broadcasting, amateur radio**
5. **VHF Antennas (30-300 MHz)**
   - **Applications: FM radio, TV broadcasting, air traffic control**
6. **UHF Antennas (300 MHz-3 GHz)**
   - **Applications: TV broadcasting, mobile communications, GPS**
7. **Microwave Antennas (Above 3 GHz)**
   - **Applications: Satellite communication, radar systems, Wi-Fi**

(c) Define the terms (4 marks)

(i) Self and mutual impedances:

- **Self impedance: The input impedance of an antenna when all other antennas are absent**

- **Mutual impedance: The impedance between two antennas due to electromagnetic coupling**

(ii) Bandwidth and percentage bandwidth:

- **Bandwidth: The frequency range over which antenna operates satisfactorily (typically VSWR ≤ 2)**
- **Percentage bandwidth: $(BW/f_0) \times 100\%$, where f_0 is center frequency**

Question 2

(a) What do you mean by radiation pattern of antenna? Describe radiation lobes and beamwidths of an antenna pattern with figure (6 marks)

Radiation Pattern: A radiation pattern is a graphical representation of the antenna's radiating properties as a function of space coordinates. It shows how the antenna radiates power in different directions.

Components:

1. **Main lobe: The radiation lobe containing the maximum radiation**
2. **Side lobes: Radiation lobes other than the main lobe**
3. **Back lobe: The radiation lobe opposite to the main lobe**
4. **Nulls: Directions of zero or minimum radiation**

Beamwidths:

- **Half Power Beamwidth (HPBW): Angular width between half-power points (-3dB points)**
- **First Null Beamwidth (FNBW): Angular width between first nulls on either side of main beam**

(b) Define the terms (4 marks)

(i) Power gain: Ratio of radiation intensity in a given direction to average radiation intensity

(ii) Directivity: Maximum value of directive gain = $4\pi \times$ (maximum radiation intensity)/(total radiated power)

(iii) Half power beamwidth: Angular separation between two directions where power is half the maximum

(iv) First null beamwidth: Angular separation between first nulls on either side of maximum radiation

(c) What is radiation power density? Write its expression (6 marks)

Radiation Power Density: It represents the power flow per unit area in the far-field region of an antenna.

Expression: $S = |E|^2/(2\eta_0) = |H|^2\eta_0/2$

Where:

- **S = Power density (W/m^2)**
- **E = Electric field intensity (V/m)**
- **H = Magnetic field intensity (A/m)**
- **$\eta_0 = 377\Omega$ (free space impedance)**

Alternative form: $S = (P^t G)/(4\pi r^2)$

Where:

- **P^t = Total transmitted power**

- **G = Antenna gain**
- **r = Distance from antenna**

Question 3

(a) Explain near field and far field region with diagram (3 marks)

Near Field Region (Fresnel Zone):

- **Distance < $2D^2/\lambda$**
- **Reactive field dominates**
- **Field pattern depends on distance**

Far Field Region (Fraunhofer Zone):

- **Distance > $2D^2/\lambda$**
- **Radiation field dominates**
- **Field pattern independent of distance**
- **Angular field distribution independent of distance**

(b) Describe the construction and working principle of microwave dish antenna (6 marks)

Construction:

1. **Parabolic Reflector: Large metallic dish with parabolic curvature**
2. **Feed System: Horn antenna or dipole at focal point**
3. **Support Structure: Mechanical support and positioning system**

Working Principle:

- **Parabolic shape reflects all incident waves toward focal point**
- **Feed antenna at focus radiates/receives electromagnetic energy**
- **Parallel rays from distant source converge at focus after reflection**
- **For transmission: Feed illuminates reflector, creating parallel beam**
- **High gain achieved due to large aperture and focused radiation**

(c) What do you mean by radiation resistance and radiation efficiency? (4 marks)

Radiation Resistance (R_r): The equivalent resistance that would dissipate the same power as radiated by the antenna $R_r = 2P_r/I^2$

Radiation Efficiency (η): Ratio of radiated power to input power $\eta = P_r/(P_r + P_l) = R_r/(R_r + R_l)$ Where P_l is power lost in antenna structure

(d) Define isotopic, directional and omni-directional antenna (3 marks)

Isotropic Antenna: Hypothetical antenna radiating equally in all directions (sphere pattern)

Directional Antenna: Radiates more power in some directions than others (e.g., dish, horn)

Omni-directional Antenna: Radiates equally in one plane, typically horizontal (e.g., vertical dipole)

Question 4

(a) Draw a simple block diagram of RADAR system and describe its operation (6 marks)

RADAR Block Diagram Components:

1. **Transmitter → Duplexer → Antenna**
2. **Antenna → Duplexer → Receiver → Display**

Operation:

- **Transmitter generates high-frequency pulses**

- **Duplexer switches between transmit and receive modes**
- **Antenna radiates pulses and receives echoes**
- **Receiver amplifies and processes returned signals**
- **Display shows target range and bearing**
- **Range = $(c \times t)/2$, where t is round-trip time**

(b) Calculate the maximum effective aperture of a microwave antenna which has a directivity of 65 degree (3 marks)

Given: Directivity = 65 dB D = $10^{(65/10)} = 3.16 \times 10^6$

Maximum effective aperture: $A_e = (\lambda^2 D)/(4\pi) = (\lambda^2 \times 3.16 \times 10^6)/(4\pi)$

(c) What is satellite communication and radio astronomy? (4 marks)

Satellite Communication: Communication system using artificial satellites as relay stations. Enables long-distance communication via uplink and downlink frequency bands.

Radio Astronomy: Study of celestial objects through radio frequency emissions. Uses large dish antennas to detect radio waves from space objects.

(d) Draw the block diagram of MTI RADAR (3 marks)

MTI RADAR blocks: Transmitter → Circulator → Antenna Antenna → Circulator → Mixer → IF Amplifier → Phase Detector → Video Amplifier → Display Local Oscillator → Mixer Reference Signal → Phase Detector

Question 5

(a) Define scattering and diffraction for antenna propagation (4 marks)

Scattering: Phenomenon where electromagnetic waves change direction due to interaction with objects smaller than or comparable to wavelength.

Diffraction: Bending of electromagnetic waves around obstacles or through apertures, allowing communication beyond line-of-sight.

(b) Explain the working principles of loop antenna (4 marks)

Loop Antenna Working:

- **Current flows in a closed loop creating magnetic dipole**
- **Radiation pattern: figure-8 in plane of loop, null along axis**
- **Small loop (circumference < $\lambda/10$): acts as magnetic dipole**
- **Radiation resistance: $R_r = 20\pi^2(A/\lambda^2)^2$ for small loop**
- **Used for direction finding and AM radio reception**

(c) Loop antenna calculation (4 marks)

Given: Radius = $\lambda/25$ Physical area = $\pi r^2 = \pi(\lambda/25)^2 = \pi\lambda^2/625$

Maximum effective aperture = $3\lambda^2/(8\pi)$

Ratio = $(3\lambda^2/8\pi)/(\pi\lambda^2/625) = (3\times625)/(8\pi^2) = 1875/(8\pi^2) \approx 23.7$

(d) Define satellite communication terms (4 marks)

(i) Tracking: Following satellite movement to maintain antenna pointing

(ii) Telemetry: Monitoring satellite health and status parameters

(iii) Command: Sending control signals to satellite systems

(iv) Monitoring: Continuous observation of satellite performance

Question 6

(a) Describe construction and working principles of Horn antenna (6 marks)

Construction:

- **Rectangular or circular waveguide with flared opening**
- **Gradual taper from waveguide to free space**
- **Metallic walls guide electromagnetic waves**

Working Principle:

- **Provides impedance transformation between waveguide and free space**
- **Flaring reduces reflection and improves radiation efficiency**
- **Aperture size determines beamwidth and gain**
- **Commonly used as feed for dish antennas**
- **Types: E-plane, H-plane, and pyramidal horns**

(b) Horn antenna directivity calculation (4 marks)

Given: $a = 0.5\lambda$, $b = 0.25\lambda$, $b_1 = 2.75\lambda$, $p_1 = 6\lambda$

For pyramidal horn: $D = (32abp_1p_2)/(\lambda^2(2b_1+p_1)(2a_1+p_2))$

Need to find a_1, p_2 from given dimensions and apply formula.

(c) What is propagation? Explain ground wave propagation method (6 marks)

Propagation: Process of electromagnetic wave transmission from transmitter to receiver through various paths.

Ground Wave Propagation:

- **Wave travels along Earth's surface**
- **Frequency range: LF to lower HF (up to 2 MHz)**
- **Components: Direct wave, ground-reflected wave, surface wave**
- **Attenuation increases with frequency and distance**
- **Suitable for AM broadcasting and navigation**
- **Range depends on antenna height and frequency**

Question 7: Short Notes (Any four - 4×4=16 marks)

(a) Yagi-Uda Antenna (4 marks)

Structure and Components:

- **Multi-element directional antenna array consisting of three types of elements**
- **Driven Element: Connected to transmission line, usually $\lambda/2$ dipole**
- **Reflector: Single element behind driven element, length > $\lambda/2$ (typically 5% longer)**
- **Directors: Multiple elements in front, length < $\lambda/2$ (typically 5% shorter)**

Working Principle:

- **Reflector re-radiates signal in phase with main beam**
- **Directors focus energy in forward direction through parasitic coupling**
- **Spacing between elements typically 0.15λ to 0.25λ**
- **Achieves high directivity and front-to-back ratio (15-25 dB)**

Applications:

- **Television reception antennas**
- **Amateur radio communication**
- **Point-to-point communication links**
- **VHF/UHF frequency bands**

(b) Satellite Payload (4 marks)

Definition and Purpose:

- **Complete set of equipment carried by satellite to perform its mission**
- **Converts uplink signals to downlink signals with amplification**

Major Components:

- **Transponders: Receive, amplify, and retransmit signals**
- **Antennas: For uplink and downlink communication**
- **Power System: Solar panels, batteries, power conditioning units**
- **Attitude Control: Gyroscopes, thrusters for satellite positioning**
- **Telemetry & Command: Monitoring and control systems**

Transponder Operation:

- **Receives uplink signal (C-band: 6 GHz, Ku-band: 14 GHz)**
- **Down-converts to intermediate frequency**
- **Amplifies using traveling wave tube amplifier (TWTA)**
- **Up-converts to downlink frequency (C-band: 4 GHz, Ku-band: 12 GHz)**

Types of Payloads:

- **Communication payload (voice, data, video)**
- **Earth observation payload**
- **Navigation payload**
- **Scientific research payload**

(c) Frequency Independent Antenna (4 marks)

Definition:

- **Antennas whose electrical characteristics remain relatively constant over a wide frequency range**
- **Performance parameters like impedance, radiation pattern remain stable**

Design Principles:

- **Based on scaling theorem and self-complementary structures**
- **Geometry defined by angles rather than linear dimensions**
- **Uses logarithmic or spiral configurations**

Types and Examples:

- **Log-Periodic Dipole Array (LPDA): Most common type**
  - **Multiple dipoles of different lengths**
  - **Spacing and length follow geometric progression**
  - **Bandwidth ratio can be 10:1 or higher**
- **Spiral Antennas: Archimedean or logarithmic spiral**
- **Biconical Antennas: Cone-shaped elements**

Characteristics:

- **VSWR < 2:1 over entire band**
- **Relatively constant gain and beamwidth**
- **Input impedance approximately constant (typically 50-300Ω)**

Applications:

- **Broadband communication systems**
- **EMI/EMC testing**
- **Direction finding systems**

- **Military communication**

(d) Space Wave Propagation (4 marks)

Definition:

- **Electromagnetic wave propagation in free space between transmitting and receiving antennas**
- **Also called line-of-sight (LOS) propagation**

Frequency Range:

- **VHF (30-300 MHz)**
- **UHF (300 MHz - 3 GHz)**
- **Microwave frequencies (above 3 GHz)**

Propagation Characteristics:

- **Travels in straight lines in homogeneous medium**
- **Limited by Earth's curvature and obstacles**
- **Radio Horizon: $d = \sqrt{(2h_t)} + \sqrt{(2h_r)}$ km (h in meters)**
- **Path loss follows free space propagation model**
- **Fresnel Zone: Ellipsoidal region around direct ray path**

Types:

- **Direct Wave: Travels directly from transmitter to receiver**
- **Ground Reflected Wave: Reflects from Earth's surface**
- **Tropospheric Propagation: Uses atmospheric layers**

Factors Affecting Propagation:

- **Antenna heights**
- **Earth's curvature**
- **Atmospheric conditions**
- **Terrain obstacles**
- **Weather conditions (rain, snow for higher frequencies)**

Applications:

- **FM radio broadcasting**
- **Television broadcasting**
- **Cellular mobile communication**
- **Satellite communication**
- **Microwave links**

(e) Lens Antennas (4 marks) __Working Principle:

- **Uses dielectric lens to transform spherical waves into plane waves**
- **Similar to optical lens but operates on electromagnetic waves**
- **Provides phase correction to achieve desired radiation pattern**

Types of Lens Antennas:

- **E-Plane Sectoral Lens: Controls radiation in E-plane**
- **H-Plane Sectoral Lens: Controls radiation in H-plane**
- **Pyramidal Lens: Controls both E and H planes**
- **Zoned Lens: Step approximation to reduce thickness**

Construction:

- **Made from low-loss dielectric material (polystyrene, Teflon)**
- **Lens shape: convex, concave, or stepped**
- **Fed by horn antenna or primary radiator at focal point**

Design Considerations:

- **Focal Length: $f = R/(n-1)$, where n = refractive index**

- **Lens Thickness: Controls phase transformation**
- **Aperture Size: Determines gain and beamwidth**
- **Dielectric Constant: Affects focusing properties**

Advantages:

- **High gain and efficiency**
- **Low side lobe levels**
- **Good impedance matching**
- **Mechanical simplicity**

Disadvantages:

- **Heavy weight**
- **Limited bandwidth**
- **Expensive dielectric materials**
- **Temperature sensitivity**

Applications:

- **High-gain microwave antennas**
- **Radar systems**
- **Point-to-point communication**
- **Radio astronomy**

(f) Self and Mutual Impedances (4 marks)

Self Impedance (Z_{11}):

- **Input impedance of antenna element when all other elements are absent**
- **Expression: $Z_{11} = R_{11} + jX_{11}$**
- **R_{11} = Radiation resistance + Loss resistance**
- **X_{11} = Reactance component (inductive or capacitive)**
- **For half-wave dipole: $Z_{11} \approx 73 + j42.5\ \Omega$ (in free space)**

Mutual Impedance (Z_{12}):

- **Impedance between two antenna elements due to electromagnetic coupling**
- **Expression: $Z_{12} = R_{12} + jX_{12}$**
- **Definition: $Z_{12} = V_1/I_2$ (when $I_1 = 0$)**
- **Depends on separation distance, relative orientation, and frequency**

Factors Affecting Mutual Impedance:

- **Distance between elements (strongest factor)**
- **Relative orientation of elements**
- **Operating frequency**
- **Medium between elements**

Importance in Array Design:

- **Determines input impedance of array elements**
- **Affects radiation pattern of antenna arrays**
- **Array Input Impedance: $Z_1 = Z_{11} + Z_{12}(I_2/I_1) + Z_{13}(I_3/I_1) + \ldots$**
- **Critical for impedance matching and VSWR control**

Applications:

- **Phased array antenna design *Yagi-Uda antenna optimization*MIMO antenna systems*Interference analysis between antennas**

Measurement Methods:

- **Network analyzer measurement 2) Induced EMF method 3)S-parameter measurement**