DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
END-TERM EXAMINATION (AUTUMN 2024 – 2025)
ECC 203: ELECTROMAGNETICS AND RADIATING SYSTEMS

Total Marks:50 **Duration: 3.0 hours**

1. An antenna has a far-field Electric field given by $E(\theta) = \cos^3\theta \cdot \cos(3\theta)$ for $0° \leq \theta \leq 90°$ (and zero elsewhere). Find :
   (*a*) the half-power beam width (HPBW) and
   (*b*) the beamwidth between first nulls (FNBW)

2. The normalized radiation intensity of an antenna is rotationally symmetric in ϕ, and it is represented by

$$U = \begin{cases} 1 & 0° \leq \theta < 30° \\ 0.5 & 30° \leq \theta < 60° \\ 0.1 & 60° \leq \theta < 90° \\ 0 & 90° \leq \theta \leq 180° \end{cases}$$

   What is the directivity (above isotropic) of the antenna (in dBi)?

3. An antenna with a radiation resistance of 46 ohms, a loss resistance of 3 ohms, and a reactance of +70 ohms is connected to a generator with an open-circuit voltage of 25 V and internal impedance of 50 ohms via a $3\lambda/4$ long transmission line with a characteristic impedance of 100 ohms.
   (a) Draw the equivalent circuit
   (b) Determine the power supplied by the generator
   (c) Determine the power radiated by the antenna

4. Show numerically why the narrow dimension (*b*) of the rectangular waveguide is typically equal to half the broader dimension (*a*) i.e. why $b = a/2$? [Hint : maximize the power and maximize the TE_{10} bandwidth]

5. It is measured in laboratory waveguide test-bench setup that 'a = 22.86 mm' and guided wavelength 'λ_g = 50 mm' for TE_{10} mode. Determine the operating frequency of the source.

6. Two different PCB sheets with the following characteristics are available in the laboratory:

   PCB1: εr = 2.2, h = 1.6 mm   PCB2: εr = 3.2, h = 0.125 mm

   In order to design a compact rectangular microstrip antenna at 11 GHz resonant frequency, which substrate one needs to choose? Explain your answer with the necessary calculations.

7. Three isotropic electromagnetic sources with spacing d between them, are placed along the z-axis. The excitation coefficient of each outside element is unity while that of the center element is 2. For a spacing of $d = \lambda/4$ between the elements, find the

(a) array factor.

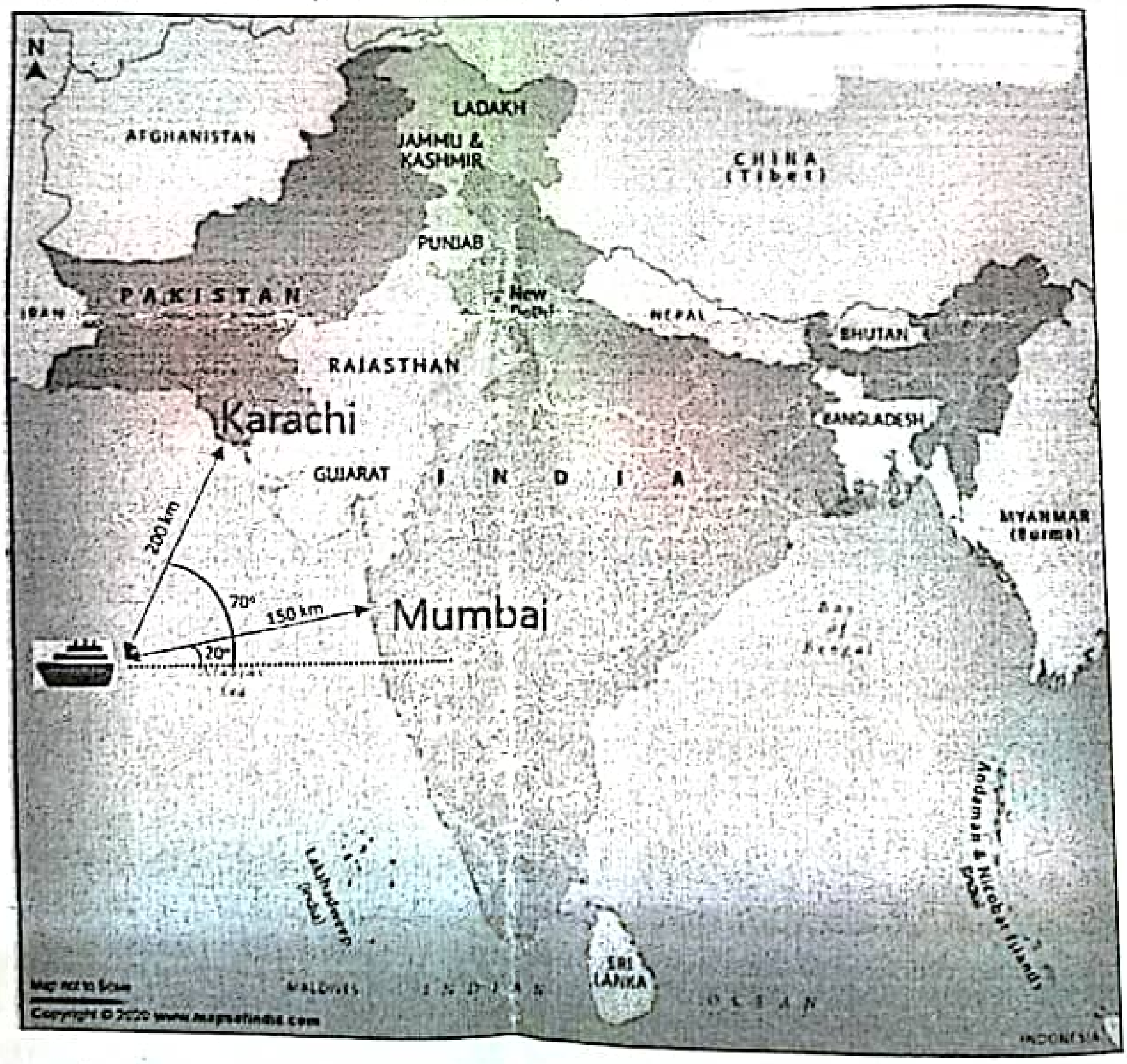
(b) angles (in degrees) where the nulls of the pattern occur ($0° \leq \theta \leq 180°$)

(c) angles (in degrees) where the maxima of the pattern occur ($0° \leq \theta \leq 180°$)

8. A Mumbai-bound ship in the Arabian sea receives 10μW of power when it is aligning its antenna in 20° direction. It receives 50% more power when the ship antenna is aligned in 70° direction, because of the high power that the Karachi port antenna is sending to spoof with false information (see Figure below). This communication is occurring at 9 GHz frequency with identical antennas at the ports and on the ship. Assume that the ship antenna is aligned towards the antennas at the port for maximum reception, i.e. the antennas are polarization matched. If the Mumbai port antenna is sending 20W power signal:

   a. Find the gain of the antennas.

   b. What is the transmitted power of the Karachi port antenna?



9. Four isotropic sources are placed along the z-axis. Assuming that the amplitudes of elements #1 and #2 are +1 and the amplitudes of elements #3 and #4 are −1 (or 180 degrees out of phase with #1 and #2),

(a) find the array factor in simplified form,

(b) angles (in degrees) where the nulls of the pattern occur ($0° \le \theta \le 180°$)

(c) angles (in degrees) where the maxima of the pattern occur ($0° \le \theta \le 180°$)

10. Determine (a) the direction of maximum radiation, (b) directivity, and (c) half-power beamwidth for an antenna that radiates only into the upper hemisphere with normalized radiation intensity given by $U(\theta, \phi) = \cos^2(\theta)$. Plot the normalized radiation pattern as a function of θ.

Useful formulae :

$$P_{rad} = P_{av} = \int_0^{2\pi}\int_0^{\pi} U \underbrace{\sin\theta\, d\theta\, d\phi}_{d\Omega}$$

$$\beta_z^2 = \beta^2 - \left(\frac{m\pi}{a}\right)^2 - \left(\frac{n\pi}{b}\right)^2$$

$$\beta_z = \frac{2\pi}{\lambda_g}$$

$P = k \cdot a \cdot b$, where is k proportionalty constant

$$\beta^2 = \omega^2 \mu\varepsilon$$

$$f_c = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

$$L = \frac{\upsilon_o}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

$$W = \frac{\upsilon_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$