CHAPTER

8.8

ANTENNAS

1. A Hertzian dipole at the origin in free space has $dl = 10$ cm and $I = 20\cos(2\pi \times 10^7 t)$ A. The $|E|$ at the distant point (100, 0, 0) is

(A) 0.252 V/m (B) 0.126 V/m

(C) 0.04 V/m (D) 0.08 V/m

Statement for Q.2–3:

A 25 A source operating at 300 MHz feeds a Hertzian dipole of length 4 mm situated at the origin. Consider the point P(10, 30°, 90°).

2. The H at point P is

(A) $j0.25$ mA/m (B) 94.25 mA/m

(C) $j0.5$ mA/m (D) 188.5 mA/m

3. The E at point P is

(A) $j0.25$ mV/m (B) $j0.5$ mV/m

(C) $j94.25$ mV/m (D) $j188.5$ mV/m

4. An antenna can be modeled as an electric dipole of length 4 m at 3 MHz. If current is uniform over its length, then radiation resistance of the antenna is

(A) 1.974 Ω (B) 1.263 Ω

(C) 2.186 Ω (D) 2.693 Ω

Statement for Q.5–6:

A antenna located on the surface of a flat earth transmit an average power of 150 kW. Assume that all the power is radiated uniformly over the surface of hemisphere with the antenna at the center.

5. The time-average poynting vector at 50 km is

(A) $6.36\mathbf{u}_r$ μW/m^2 (B) $4.78\mathbf{u}_r$ μW/m^2

(C) $9.55\mathbf{u}_r$ μW/m^2 (D) $12.73\mathbf{u}_r$ μW/m^2

6. The maximum electric field at that location is

(A) 24 mV/m (B) 85 mV/m

(C) 109 mV/m (D) 12 mV/m

7. In free space, an antenna has a far-zone field given by $\mathbf{E} = \frac{1}{r} 10 \sin 2\theta\, e^{-j\beta r} \mathbf{u}_\theta$ V/m. The radiated power is

(A) 0.23 W (B) 0.89 W

(C) 1.68 W (D) 1.23 W

8. At the far field, an antenna produces $\mathbf{P}_{ave} = \frac{1}{r^2} \cos\theta \cos\phi\, \mathbf{u}_r$ W/m^2, where $0 < \theta < \pi$ and $0 < \phi < \frac{\pi}{2}$. The directive gain of the antenna is

(A) $\cos\theta\cos\phi$ (B) $2\sin\theta\cos\phi$

(C) $8\cos\theta\sin\phi$ (D) $8\sin\theta\cos\phi$

Statement for Q.9–10:

The radiation intensity of antennas has been given. Determine the directivity of antenna.

9. $U(\theta, \phi) = \sin^2\theta$, $0 < \theta < \pi$, $0 < \phi < 2\pi$

(A) 1.875 (B) 2.468

(C) 3.943 (D) 6.743

10. $U(\theta, \phi) = 4\sin^2\theta \sin^2\phi$, $0 < \theta < \pi$, $0 < \phi < \pi$

(A) 15 (B) 12

(C) 3 (D) 6

11. The radiation intensity of a antenna is given by $U(\theta,\phi)=8\sin^2\theta\cos^2\phi$, where $0<\theta<\pi$ and $0<\phi<\pi$. The directive gain is

(A) $6\sin^2\theta\cos^2\phi$ (B) $3\sin^2\theta\cos^2\phi$
(C) $3\sin^2\phi\cos^2\theta$ (D) $6\sin^2\phi\cos^2\theta$

Statement for Q.12–13:

At the far field, an antenna radiates a field

$$E_\phi=\frac{0.4\cos^2\theta}{4\pi r}e^{-j\beta r}\ \text{kV/m}$$

12. The total radiated power is

(A) 1.36 W (B) 2.14 W
(C) 0.844 W (D) 3.38 W

13. The directive gain at $\theta=\pi/3$ is

(A) 0.3125 (B) 0.625
(C) 1.963 (D) 3.927

14. An antenna has directivity of 100 and operates at 150 MHz. The maximum effective aperture is

(A) 31.8 m^2 (B) 62.4 m^2
(C) 26.4 m^2 (D) 13.2 m^2

15. Two half wave dipole antenna are operated at 100 MHz and separated by 1 km. If 100 W is transmitted by one, the power received by the other is ($D=1.68$)

(A) 12 μW (B) 10 mW
(C) 18 mW (D) 16 μW

16. The electric field strength impressed on a half wave dipole is 6 mV/m at 60 MHz. The maximum power received by the antenna is ($D=1.68$)

(A) 159 nW (B) 230 nW
(C) 196 μW (D) 318 μW

17. The power transmitted by a synchronous orbit satellite antenna is 480 W. The antenna has a gain of 40 dB at 15 GHz. The earth station is located at distance of 24, 567 km. If the antenna of earth station has a gain of 32 dB, the power received is

(A) 32 pW (B) 3.2 fW
(C) 10.2 pW (D) 1.3 fW

18. The directive gain of an antenna is 36 dB. If the antenna radiates 15 kW at a distance of 60 km, the time average power density at that distance is

(A) 9.42 μW/m^2 (B) 6.83 mW/m^2
(C) 1.32 mW/m^2 (D) 10.46 mW/m^2

19. Two identical antenna separated by 12 m are oriented for maximum directive gain. At a frequency of 5 GHz, the power received by one is 30 dB down from the transmitted by the other. The gain of antenna is

(A) 22 dB (B) 16 dB
(C) 19 dB (D) 13 dB

Statement for Q.20–21:

An L-band pulse radar has common transmitting and receiving antenna. The antenna having directive gain of 36 dB operates at 1.5 GHz and transmits 200 kW. The object is 120 km from the radar and its scattering cross section is 8 m^2.

20. The magnitude of the incident electric field intensity of the object is

(A) 1.82 V/m (B) 2.46 V/m
(C) 0.34 V/m (D) 0.17 V/m

21. The magnitude of the scattered electric field at the radar is

(A) 18 μW (B) 12 μW
(C) 17 mW (D) 126 mW

22. A transmitting antenna with a 300 MHz carrier frequency produces 2 kW of power. If both antennas has unity power gain, the power received by another antenna at a distance of 1 km is

(A) 11.8 mW (B) 18.4 mW
(C) 18.4 μW (D) 12.7 μW

23. A bistatic radar system shown in fig. P8.7.23 has following parameters: $f=5$ GHz, $G_{dt}=34$ dB, $G_{dr}=22$ dB. To obtain a return power of 8 pW the minimum necessary radiated power is

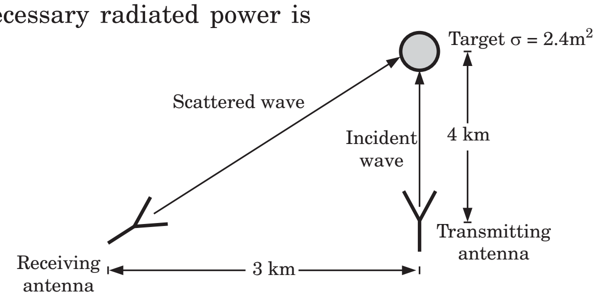

Fig. P8.7.23

(A) 1.394 kW (B) 2.046 kW
(C) 1.038 kW (D) 3.46 kW

24. The radiation resistance of an antenna is 63 Ω and loss resistance 7 Ω. If antenna has power gain of 16, then directivity is

(A) 48.26 dB (B) 12.5 dB
(C) 38.96 dB (D) 24.7 dB

25. An antenna is desired to operate on a frequency of 40 MHz whose quality factor is 50. The bandwidth of antenna is

(A) 5.03 MHz (B) 800 kHz
(C) 127 kHz (D) None of the above

26. A thin dipole antenna is $\lambda/15$ long. If its loss resistance is 1.2 Ω, the efficiency is

(A) 41.1% (B) 59%
(C) 74.5% (D) 25.5%

Statement for Q.27–29:

An array comprises of two dipoles that are separated by the wavelength. The dipoles are fed by currents of the same magnitude and phase.

27. The array factor is

(A) $2\cos(\pi\cos\theta + 45°)$ (B) $2\cos(\pi\sin\theta)$
(C) $2\cos(\pi\sin\theta + 45°)$ (D) $2\cos(\pi\cos\theta)$

28. The nulls of the pattern occur when θ is

(A) 30°, 150° (B) 60°, 120°
(C) 45°, 135° (D) 0, 180°

29. The maximum of the pattern occur at

(A) $\theta = 45°, 135°$ (B) $\theta = 0, 90°, 180°$
(C) $\theta = 30°, 150°$ (D) $\theta = 60°, 150°$

30. An array comprises two dipoles that are separated by half wavelength. If the dipoles are fed by currents, that are 180° out of phase with each other, then array factor is

(A) $\sin\left(\frac{\pi}{4}\cos\theta + \frac{\pi}{4}\right)$ (B) $\cos\left(\frac{\pi}{4}\cos\theta + \frac{\pi}{2}\right)$
(C) $\cos\left(\frac{\pi}{2}\cos\theta + \frac{\pi}{2}\right)$ (D) $\sin\left(\frac{\pi}{2}\cos\theta + \frac{\pi}{2}\right)$

31. An antenna consists of 4 identical Hertizian dipoles uniformly located along the z–axis and polarized in the z-direction. The spacing between the dipole is $\lambda/4$. The group pattern function is

(A) $4\cos\left(\frac{\pi}{4}\cos\theta\right)\cos\left(\frac{\pi}{2}\cos\theta\right)$
(B) $4\cos\left(\frac{\pi}{4}\cos\theta\right)\cos\left(\frac{\pi}{8}\cos\theta\right)$
(C) $4\cos\left(\frac{\pi}{4}\cos\theta\right)\sin\left(\frac{\pi}{2}\cos\theta\right)$
(D) $4\cos\left(\frac{\pi}{4}\cos\theta\right)\sin\left(\frac{\pi}{8}\cos\theta\right)$

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SOLUTIONS

1. (B) $\beta = \frac{\omega}{c} = \frac{2\pi\times 10^7}{3\times 10^8} = \frac{2\pi}{30}$

At far field $|E_\theta| = \frac{\eta I_o \beta dl}{4\pi r}\sin\theta$

$\eta = 120\pi = 377,\quad I_o = 20,\ dl = 10$ cm

At (100 cm, 0, 0), $\theta = \frac{\pi}{2}$

$|E_\theta| = \frac{120\pi\times 20\times 0.1}{4\pi\times 100}\times\frac{2\pi}{30} = 0.126$ V/m

2. (A) $\beta = \frac{\omega}{c} = \frac{2\pi\times 300\times 10^6}{3\times 10^8} = 2\pi$

$r = 10\,\text{m},\ \theta = 30°,\ \phi = 90°$

At far field $H = H_\phi = \frac{jI_o\beta dl}{4\pi r}\sin\theta\, e^{-j\beta r}$

$\Rightarrow\ H_\phi = \frac{j(2.5)(2\pi)(4\times 10^{-3})}{4\pi(10)}e^{-j2\pi 10} = j0.25$ mA/m

3. (C) $E = E_\theta = \eta H_\phi = 377 H_\phi = j94.25$ mV/m

4. (B) $\lambda = \frac{c}{f} = \frac{3\times 10^8}{3\times 10^6} = 100$

$\frac{dl}{\lambda} = \frac{4}{100} = \frac{1}{25} < \frac{1}{10}$

$R_{rad} = 80\pi^2\left(\frac{dl}{\lambda}\right)^2 = \frac{80\pi^2}{625} = 1.263\ \Omega$

5. (C) $P_{rad} = \int P_{ave}\cdot dS = P_{ave}\cdot 2\pi r^2$

$P_{ave} = \frac{P_{rad}}{2\pi r^2} = \frac{150\times 10^3}{2\pi(50\times 10^3)^2} = 9.55\ \mu\text{W/m}^2$

$\mathbf{P} = 9.55\mathbf{u}_r\ \mu\text{W/m}^2$

6. (B) $P_{ave} = \frac{(E_{\max})^2}{2\eta} \quad\Rightarrow\quad E_{\max} = \sqrt{2\eta P_{ave}}$

$\Rightarrow\ E_{\max} = \sqrt{2\times 377\times 9.55\times 10^{-6}} = 85$ mV/m

7. (B) $P_{ave} = \frac{|E|^2}{2\eta}$

$P_{rad} = \iint \frac{100\sin^2 2\theta}{2\eta}\sin\theta\, d\theta\, d\phi$

$= \frac{100}{2\times 120\pi}\int_0^\pi (2\pi)(2\sin\theta\cos\theta)^2\sin\theta\, d\theta$

$= \frac{10}{3}\int_0^\pi \sin^3\theta\cos^2\theta d\theta = 0.89$ W

$$G_d = \frac{4\pi(12)}{0.06}\sqrt{\frac{1}{10^3}} = 79.48 = 19 \text{ dB}$$

20. (A) $G_d = 36 \text{ dB} = 3981$

$$G_d = \frac{4\pi r^2 P_i}{P_{rad}} \quad \Rightarrow \quad P_i = \frac{G_d P_{rad}}{4\pi r^2} = \frac{|E|^2}{2\eta}$$

$$\Rightarrow \quad |E| = \sqrt{\frac{(240\pi)\, G_d P_{rad}}{4\pi r^2}}$$

$$= \sqrt{\frac{(60)(3981)(200\times 10^3)}{(120\times 10^3)^2}}$$

$= 1.82$ V/m

21. (B) $|E_s| = \sqrt{\frac{|E_i|^2 \sigma}{4\pi r^2}} = \frac{|E_i|}{r}\sqrt{\frac{\sigma}{4\pi}}$

$$= \frac{1.82}{120\times 10^3}\sqrt{\frac{8}{4\pi}} = 12 \ \mu\text{W}$$

22. (D) $\lambda = \frac{c}{f} = \frac{3\times 10^8}{300\times 10^6} = 1 \text{ m}$

$$P_r = G_{dr}G_{dt}\left(\frac{\lambda}{4\pi r}\right)^2 P = (1)(1)\left(\frac{1}{4\pi 10^3}\right)^2 2000 = 12.7 \ \mu\text{W}$$

23. (C) $P_r = \frac{G_{dr}G_{dt}}{4\pi}\left(\frac{\lambda}{4\pi r_1 r_2}\right)^2 \sigma P_{rad}$

$G_{dt} = 34 \text{ dB} = 2512,\ G_{dr} = 22 \text{ dB} = 158.5$

$r_1 = 3 \text{ km},\ r_2 = \sqrt{3^2 + 4^2} = 5 \text{ km}$

$\lambda = \frac{3\times 10^8}{5\times 10^9} = 0.06 \text{ m},\ P_r = 8 \text{ pW}$

$$8\times 10^{-12} = \frac{(2512)(158.5)}{4\pi}\left(\frac{0.06}{4\pi(3\text{k})(5\text{k})}\right)^2 (2.4) P_{rad}$$

$\Rightarrow \quad P_{rad} = 1.038$ kW

24. (B) Efficiency $= \frac{63}{63+7} = 0.9$

$$D = \frac{Gain}{Efficiency} = \frac{16}{0.9} = 17.78 = 12.5 \text{ dB}$$

25. (B) $BW = \frac{f}{Q} = \frac{40\times 10^6}{50} = 800 \text{ kHz}$

26. (C) Radiation resistance $R_r = 80\pi^2\left(\frac{dl}{l}\right)^2$

$$= 80\times \pi^2 \times \left(\frac{1}{15}\right)^2 = 3.51\ \Omega$$

Efficiency $= \frac{R_r}{R_r + R_L} = \frac{3.51}{3.51+1.2} = 74.5\ \%$

27. (D) $\beta d = \frac{2\pi}{\lambda}\lambda = 2\pi\ ,\ \alpha = 0$

$$AF = 2\cos\left(\frac{\beta d\cos\theta + \alpha}{2}\right) = 2\cos(\pi\cos\theta) = 2\cos(\pi\cos\theta)$$

28. (B) $\cos(\pi\cos\theta) = 0$

$$\Rightarrow \qquad \pi\cos\theta = \pm\frac{\pi}{2},\ \pm\frac{3\pi}{2}$$

$\cos\theta = \pm\frac{1}{2} \quad \Rightarrow \quad \theta = 60°,\ 120°$

29. (B) Maxima occur when $\frac{d(AF)}{d\theta} = 0$

$\sin(\pi\cos\theta)\,\pi\sin\theta = 0 \quad \Rightarrow \quad \theta = 0, 90°,\ 180°$

30. (B) $\beta d = \frac{2\pi}{\lambda}\frac{\lambda}{2} = \pi\ ,\quad \alpha = \pi$

$$AF = 2\cos\left(\frac{\beta d\cos\theta + \alpha}{2}\right) = \cos\left(\frac{\pi}{4}\cos\theta + \frac{\pi}{2}\right)$$

31. (A) $(AF)_N = \frac{\sin\left(\frac{N\phi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}$

$\psi = \beta d\cos\theta + \alpha\ ,\ N = 4$

$$\frac{\sin 4x}{\sin x} = \frac{2\sin 2x\cos 2x}{\sin x} = 4\cos x\cos 2x$$

$$\beta d = \frac{2\pi}{\lambda}\frac{\lambda}{4} = \frac{\pi}{2}\ ,\ \alpha = 0,\ \frac{\psi}{2} = \frac{\pi}{4}\cos\theta$$

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

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