EXERCISE IV: ANTENNAS IN RECEIVING MODE

Problem (1)

A linearly polarized wave traveling in the positive *z*-direction is incident upon a circularly polarized antenna. Find the polarization loss factor PLF (dimensionless and in dB) when the antenna is (based upon its transmission mode operation):

(a) Right-handed (CW)   (b) Left-handed (CCW)

Problem (2)

The electric field of a uniform plane wave traveling along the negative z direction is given by

$$\mathbf{E}_w = (\hat{\mathbf{a}}_x + j\hat{\mathbf{a}}_y)E_0 e^{jkz}$$

and is incident upon a receiving antenna placed at the origin and whose radiated electric field, toward the incident wave, is given by

$$\mathbf{E}_a = (\hat{\mathbf{a}}_x + 2\hat{\mathbf{a}}_y)E_1 \frac{e^{-jkr}}{r}$$

Determine the following:

a) Polarization of the incident wave and it sense of.
b) Polarization of the antenna, and its sense of rotation.
c) Losses (dimensionless and in dB) due to polarization mismatch between the incident wave and the antenna.

Problem (3)

A linearly polarized wave traveling in the negative *z*-direction has a tilt angle (τ) of $45°$. It is incident upon an antenna whose polarization characteristics are given by:

$$\boldsymbol{\rho}_a = (\hat{\mathbf{x}}4 + j\hat{\mathbf{y}})/\sqrt{17}$$

Find the polarization loss factor PLF (dimensionless and dB).

Problem (4)

A CW circularly polarized uniform plane wave is traveling in the +*z* direction. Find the polarization loss factor PLF (dimensionless and in dB) assuming the receiving antenna (in its transmitting mode) is:

(a) CW circularly polarized
(b) CCW circularly polarized

Problem (5)

The field radiated by an infinitesimal dipole of very small length ($\mathrm{L} \leq \lambda/50$), and of uniform current distribution I_0, is given by

$$\mathbf{E} = \hat{\boldsymbol{\theta}}\mathrm{E}_\theta \approx \hat{\boldsymbol{\theta}}\frac{\mathrm{j}\eta \mathrm{k} \mathrm{I}_0 \mathrm{L}}{4\pi \mathrm{r}} \mathrm{e}^{-\mathrm{j}\mathrm{k}\mathrm{r}} \sin\theta.$$

1. Determine:
(a) the vector effective length
(b) the maximum value of the vector effective length. Specify the angle.
(c) the ratio of the maximum effective length to the physical length L.

2. Repeat for a half-wavelength dipole having the radiated field:

$$\mathbf{E} = \hat{\boldsymbol{\theta}} E_\theta \approx \hat{\boldsymbol{\theta}} \frac{j\eta I_0}{2\pi r} e^{-jkr} \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

where I_0 is the maximum current.

Problem (6)

A uniform plane wave, of 10^{-3} watts/cm^2 power density and a frequency of 10 GHz is incident upon a receiving antenna. Determine the maximum open-circuited voltage at the terminals of the antenna if it is:

(a) An infinitesimal dipole of length $L = \lambda/50$ and uniform current distribution.

(b) A small dipole with triangular current distribution and length $L = \lambda/10$.

(c) A half-wavelength dipole ($L = \lambda/2$) with sinusoidal current distribution.

Problem (7)

Show that the effective length of a linear antenna can be written as:

$$l_e = \sqrt{\frac{A_e |Z_t|^2}{\eta R_T}}$$

which, for a lossless antenna and maximum power transfer reduces, to:

$$l_e = 2\sqrt{\frac{A_{em} R_r}{\eta}}$$

A_e and A_{em} represent, respectively, the effective and maximum effective apertures of the antenna while η is the intrinsic impedance of the medium.

Problem (8)

A small circular parabolic reflector, often referred to as dish, is now being advertised as a TV antenna for direct broadcast. Assuming the diameter of the antenna is 1 meter, the frequency of operation is 3 GHz, and its aperture efficiency is 68%, determine the following:

(a) the physical area of the reflector (in m^2).

(b) the maximum effective area of the antenna (in m^2).

(c) the maximum directivity (dimensionless and in dB).

(d) the maximum power (in watts) that can be delivered to the TV if the power density of the wave incident upon the antenna is 10 μW/m^2. Assume no losses between the incident wave and the receiver (TV).

Problem (9)

For an X-band (8.2–12.4 GHz) rectangular horn, with aperture dimensions of 5.5 cm and 7.4 cm, find its maximum effective aperture (in cm^2) when its gain (over isotropic) is:

(a) 14.8 dB at 8.2 GHz

(b) 16.5 dB at 10.3 GHz