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Exercise 1 (10 points)

a) Write a mathematical expression for the current distribution in a half-wavelength resonant dipole and plot this current as a function of the position.

b) Plot the radiation pattern of the half-wavelength dipole (at resonance) in the E and H-plane.

c) What is the value of the input impedance of a half-wavelength dipole at resonance? Briefly comment the importance of this result.

d) Plot qualitatively (and briefly explain) the input resistance of a wire antenna as a function of its length.

e) Plot qualitatively (and briefly explain) the input reactance of a wire antenna as a function of its length.

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Exercise 2 (12 points)

The electromagnetic field radiated by an ideal dipole is given by the following formulas (in spherical coordinates):

$$\mathbf{E} = \frac{I\Delta z}{4\pi} j\omega\mu \left[1 + \frac{1}{j\beta r} - \frac{1}{(\beta r)^2}\right] \frac{e^{-j\beta r}}{r} \sin\theta\, \hat{\boldsymbol{\theta}} + \frac{I\Delta z}{2\pi} \sqrt{\frac{\mu}{\varepsilon}} \left[\frac{1}{r} - j\frac{1}{\beta r^2}\right] \frac{e^{-j\beta r}}{r} \cos\theta\, \hat{\mathbf{r}}$$

$$\mathbf{H} = \frac{I\Delta z}{4\pi} j\beta \left[1 + \frac{1}{j\beta r}\right] \frac{e^{-j\beta r}}{r} \sin\theta\, \hat{\boldsymbol{\phi}}$$

a) Explain the meaning of the far-field of an antenna; write the formulas for the electric and magnetic fields of the ideal dipole in the far-field region and justify the answer.

b) Calculate the total real power radiated by the ideal dipole.

c) Define the following quantities used to characterize an antenna: input impedance, radiation resistance, dissipation resistance.

d) Calculate the radiation resistance of the ideal dipole.

e) Under the hypothesis that the current is not uniform, but it is linearly decreasing from the feeding point to the dipole extremities (where it is 0), calculate the radiation resistance.

Exercise 3 (12 points)

A uniform array is composed of 4 isotropic antennas. The signal frequency is 2.4 GHz, the distance between two antennas is 6.25 cm and the phase delay from one antenna to the next is π radians.

a) Find the maximum directions and the null directions of the radiation pattern.

b) Plot the radiation pattern.

c) Each antenna of the array is replaced by a short dipole perpendicular to the direction of alignment of the array: plot (and explain) the new radiation pattern both in the E and H-plane.