Learning Objective 1.5: I can identify and distinguish the reactive near-field, radiating near-field, and far-field regions and calculate the boundaries for a given antenna.

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate).

1. **Three terms in one equation.** The exact E_θ of an infinitesimal dipole is a sum of three pieces, and kr alone sets their relative sizes:

$$E_\theta \propto \underbrace{\frac{1}{r}}_{\text{radiation}} + \underbrace{\frac{1}{kr^2}}_{\text{induction}} + \underbrace{\frac{1}{k^2r^3}}_{\text{electrostatic}}$$

Throughout this question the antenna operates at $f = 915\text{MHz}$.

(a) We call the innermost region *reactive*. Justify that word in one or two sentences, using what the complex Poynting vector does there.

(b) Normalizing the radiation term to 1, give the relative sizes of the three terms at $kr = 0.1$ and at $kr = 10$, and name the dominant term in each case.

$kr = 0.1$:

$kr = 10$:

(c) Find the distance at which the radiation and induction terms are equal. Give it in wavelengths and in centimeters at 915MHz.

r =

(d) A colleague measures this antenna's gain with a probe held 2 cm away. In two sentences, say what is wrong with the number he reports.

2. **An electrically large antenna.** An X-band ground-station reflector has diameter $D = 3.0$m and operates at $f = 8$GHz. The boundaries are $r_{\text{react}} = 0.62\sqrt{D^3/\lambda}$ and $r_{\text{ff}} = 2D^2/\lambda$.

   (a) Find λ and the electrical size D/λ. Is this antenna electrically large?

   λ =

   D/λ =

   (b) Compute both region boundaries.

   r_{react} =

   r_{ff} =

   (c) The only outdoor range on base is 150m long. Which region does that put the source in, and what fraction of the far-field distance is it?

   region =

   fraction =

   (d) You need this dish's sidelobe pattern and you cannot build a 480m range. Give two ways out and state what each costs.

3. **An electrically small antenna.** A 915MHz ISM whip on a sensor node has largest dimension $D = 8$ cm. Recall $\lambda = 0.328$m at this frequency.

   (a) Compute D/λ, $2D^2/\lambda$, and $0.62\sqrt{D^3/\lambda}$.

   D/λ =

   $2D^2/\lambda$ =

   $0.62\sqrt{D^3/\lambda}$ =

   (b) Your $2D^2/\lambda$ came out *smaller than a wavelength*. Explain in two or three sentences why that number is not the far-field boundary here, and say what replaces it.

   (c) Compute $\lambda/2\pi$ for this antenna, and state the distance at which you would actually stand to measure its pattern (use the $r \geqslant 5\lambda$ practical rule).

   $\lambda/2\pi$ =

   r_{meas} =

   (d) You are offered a 3m anechoic chamber to characterize this whip. Is it long enough? Name the error source that actually limits the measurement, given your answer to (c).

4. **Why ranges are long: the $\pi/8$ criterion.** A source a distance r away is farther from the *edge* of an aperture of size D than from its center, by a path difference $\Delta \approx D^2/(8r)$. The agreed tolerance is $\Delta \leqslant \lambda/16$. Take the lesson's reflector: $D = 1.2$m at $f = 10$GHz, so $\lambda = 0.03$m.

   (a) At $r = 30$m, find the path difference Δ and the phase error it produces across the aperture, in degrees.

   Δ = [ ]

   $\Delta\phi$ = [ ]

   (b) Impose $\Delta \leqslant \lambda/16$ and solve for the minimum range. Show that the $\pi/8$ tolerance is what produces the familiar $2D^2/\lambda$.

   r_{ff} = [ ]

   (c) Your chamber is the 30m one from part (a) and the program will not fund a 96m outdoor range. State what the 72° of residual phase error does to the measured pattern, and decide whether you would accept the 30m data for a *gain* check, for a *beamwidth* check, and for a *sidelobe* check.

   (d) Why is 22.5° "good enough"? Answer in one or two sentences, saying what would change if the tolerance were tightened to $\pi/16$.

5. **Two antennas on one airframe.** A 3GHz ($\lambda = 0.1$m) installation carries a half-wave dipole ($D = \lambda/2 = 0.05$m) and a 2.0m reflector, mounted 10m apart.

   (a) Inside $2D^2/\lambda$ the field is radiating — energy is leaving and never coming back — and yet the *pattern* still changes as you walk outward. Explain why, in words.

   (b) Compute $2D^2/\lambda$ for each antenna.

   dipole =

   dish =

   (c) At the 10m separation, which region is each antenna in with respect to the other?

   dish:

   dipole:

   (d) The EMC engineer wants to predict the coupling between the two with Friis. Is that legitimate here? Say what you would do instead, and what it costs.

Documentation: _____