Learning Objective 1.4: I can calculate input impedance, feed considerations, and the role of baluns in an antenna feed system.

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

1. **Radiation resistance and efficiency.** A short dipole has length $\ell = 0.08\lambda$. Its conductors contribute a loss resistance of $R_{\text{loss}} = 1.5\,\Omega$.

   (a) Compute the radiation resistance $R_{\text{rad}} = 80\pi^2(\ell/\lambda)^2$.

   R_{rad} =

   (b) Compute the radiation efficiency η_{rad}.

   η_{rad} =

   (c) The short dipole's directivity is $D = 1.5$ (1.76 dBi). Find the gain in dBi.

   G =

2. **Feeding a half-wave dipole with $50\ \Omega$ coax.**

   (a) A dipole trimmed to resonance presents $Z_{in} = 70 + j0\ \Omega$. Find Γ, VSWR, return loss, and mismatch loss on a $50\ \Omega$ line.

   Γ =

   VSWR =

   RL =

   L_{mm} =

   (b) An *untrimmed* half-wave dipole presents $Z_{in} = 73 + j42.5\ \Omega$. Find $|\Gamma|$ and VSWR on the same line.

   $|\Gamma|$ =

   VSWR =

   (c) Compare (a) and (b): in one sentence, what did trimming to resonance buy you, and why?

   (d) A third dipole on the same $50\ \Omega$ line measures VSWR $= 1.5$, and you know it is purely resistive at that frequency. What two real Z_{in} are consistent with that reading? State what a VSWR measurement alone can and cannot tell you.

   Z_{in} =

3. **Quarter-wave transformer.** A resonant antenna presents a real input impedance $R_L = 36\,\Omega$. You want to match it to a $50\,\Omega$ feed line with a quarter-wave transformer.

   (a) What characteristic impedance Z_1 must the $\lambda/4$ section have?

   Z_1 = [ ]

   (b) What is Γ at the design frequency?

   (c) In one sentence, what happens to the match off the design frequency, and why?

   (d) The antenna in this problem is purely resistive. Explain in one or two sentences why a quarter-wave transformer is the wrong tool the moment Z_{in} has a reactive part.

4. **L-match design.** A compact antenna presents $Z_{in} = 25 - j40\,\Omega$ at $f = 1.5$GHz. You must match it to a $50\,\Omega$ line with lumped elements. Work the match in two moves: *cancel the reactance*, then *transform the resistance*.

   (a) Find $|\Gamma|$ and VSWR for the raw, unmatched antenna.

   $|\Gamma|$ = ____

   VSWR = ____

   (b) **Move 1.** What series reactance cancels the load reactance, and what component value does it correspond to at 1.5GHz?

   X_1 = ____

   L_1 = ____

   (c) **Move 2.** With $R_L = 25\,\Omega$ real, design the L-network that transforms it to $50\,\Omega$. Use $Q = \sqrt{Z_0/R_L - 1}$, series $X_s = QR_L$ on the load side and shunt $X_p = Z_0/Q$ on the line side. Give both reactances and both component values, and combine the two series inductors.

   L_{tot} = ____

   C = ____

   (d) The loaded Q of this match came out at 1. Compare the bandwidth and the practicality of this L-match against the $\lambda/4$ transformer of Question 3, and say which you would build for a 1.5GHz handheld radio.

5. **Mismatch that kills the amplifier.** A power amplifier (PA) delivers a forward power of $P_{fwd} = +40$ dBm toward a transmit antenna. A shunt protection diode at the PA output fails catastrophically if it must dissipate more than $P_{max} = +30$ dBm . Model *all* of the reflected power as landing on the diode, so $P_{ref} = |\Gamma|^2 P_{fwd}$.

   (a) Convert P_{fwd} and P_{max} to watts.

   P_{fwd} = ____

   P_{max} = ____

   (b) Find the largest $|\Gamma|$ the system can tolerate before the diode is destroyed.

   $|\Gamma|_{max}$ = ____

   (c) Convert to a VSWR limit and a return-loss limit, and state the datasheet rule that follows.

   $VSWR_{max}$ = ____

   RL_{min} = ____

   (d) In one sentence: how does a circulator or isolator between the PA and antenna change this picture?

6. **Baluns.**

   (a) In one or two sentences, explain why feeding a dipole *directly* with coax (no balun) distorts the pattern.

   (b) You must feed a folded dipole ($Z_{in} \approx 292\,\Omega$) with $75\,\Omega$ coax. Which balun would you choose, and what does it do?

   (c) You feed a straight resonant dipole ($\approx 70\,\Omega$) with $50\,\Omega$ coax. Which balun would you choose, and why is it a *different* choice than (b)?

Documentation: _____