Learning Objective 4.2: I can calculate range resolution, unambiguous range, and Doppler shift for a given radar waveform.

Show your work. Use $c = 3.00 \times 10^8$ m/s. A **Documentation** line at the end is required (write **None** if you did not collaborate).

1. **Range and unambiguous range.** A pulsed surveillance radar transmits a pulse every 0.5 ms, a pulse repetition frequency of 2 kHz.

   (a) An echo arrives 40 μs after its pulse. Find the target's range.

   R =

   (b) Find the unambiguous range.

   R_{ua} =

   (c) A large aircraft is 90 km away. At what range does the radar report it?

   R_{apparent} =

   (d) The radar must report every target out to 120 km without ambiguity. Find the highest PRF it can use.

   PRF =

   (e) The operator switches the PRF from 2 kHz to 1.25 kHz and the aircraft of part (c) jumps from 15 km to 90 km. In one or two sentences, explain how this change shows which reading is true.

2. **Range resolution.** A radar resolves two targets when their echoes do not overlap in time.

   (a) A radar transmits a $0.5\ \mu$s pulse. Find its range resolution.

   $\Delta R =$ ____

   (b) Two aircraft fly in formation, 50 m apart in range. Describe what the radar of part (a) reports, and why.

   (c) Find the bandwidth a waveform needs to resolve targets 0.30 m apart.

   $B =$ ____

   (d) ADI's FMCW lab halves the PHASER's chirp bandwidth to 250 MHz. Find the new range resolution.

   $\Delta R =$ ____

   (e) Two corner reflectors sit at 1.50 m and 1.70 m from the kit. State whether the 500 MHz chirp separates them, and say what you would change to separate them.

   (f) A classmate proposes doubling the transmit power to improve the range resolution. Explain in one or two sentences why that does not work.

3. **The Doppler shift.** The Doppler shift of an echo is $f_D = 2v_r/\lambda$, positive for a target closing on the radar.

   (a) ADI's CW radar lab quotes 716 Hz at 2.4 GHz and 2982 Hz at 10 GHz for a car at 100 mph (1 mph $= 0.44704$ m/s). Recompute both.

   f_D = ____

   f_D = ____

   (b) A target moves directly away from a 10 GHz radar at 15 m/s. Find its Doppler shift, with its sign.

   f_D = ____

   (c) An aircraft flies at 200 m/s on a heading 60° off the line of sight, toward the radar. Find the Doppler shift at 10 GHz.

   f_D = ____

   (d) The same aircraft turns to fly across the line of sight. State its Doppler shift and what that means for a radar that separates targets by Doppler.

   (e) Explain in two or three sentences why an approaching target raises the echo's frequency.

4. **Doppler resolution and ambiguity.** ADI's range-Doppler lab sends a burst of 256 chirps, 0.5 ms apart, at about 10 GHz ($\lambda = 3.0$ cm). Each chirp gives one sample of the target's Doppler phase.

   (a) Find the burst length, its frequency resolution, and its velocity resolution.

   T =

   Δv =

   (b) Find the unambiguous velocity.

   v_{ua} =

   (c) ADI suggests changing the number of chirps to 128. State what happens to the velocity resolution and to the unambiguous velocity.

   (d) A car closes on this radar at 25 m/s. Find its true Doppler shift and the velocity the radar reports.

   f_D =

   v_{rep} =

   (e) Find the unambiguous range of this pulse spacing, and show that the product $R_{\text{ua}} v_{\text{ua}}$ equals $c\lambda/8$.

   R_{ua} =

5. **CW radar, the fan, and micro-Doppler.** ADI's CW lab points an unmodulated 10 GHz radar at a fan. Its script forms each spectrum from 65,536 samples taken at 0.6 MHz.

   (a) Find the time each spectrum spans, its bin width, and the velocity one bin represents.

   Δf = ____

   Δv = ____

   (b) The fan is 0.30 m across and turns at 1200 rpm, seen edge-on. Find the blade-tip speed and the edges of the band its blades fill.

   v_{tip} = ____

   f_{edge} = ____

   (c) A different fan, 0.25 m across, shows a band with edges at ± 800 Hz. Find its speed in rpm.

   rpm = ____

   (d) Explain in one or two sentences why this CW radar measures the fan's blade speed but not its range.

   (e) Place the fan of part (b) in front of the range-Doppler radar of Question 4. Explain what happens to its blade returns there, and why the CW radar avoids it.

(f) A person walks toward the radar at 1.3 m/s, and the swinging limbs reach 4.0 m/s. Find the Doppler of the torso and the peak Doppler of the limbs.

f_{torso} =

f_{limb} =