USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 29 LAB - Range-Doppler and MTI
Lab Packet
Fall 2026

Name: _____ **Section:** _____ **Date:** _____

Learning Objective 4.5: I can process FMCW radar data to produce range, range-waterfall, and range-Doppler results.

Learning Objective 4.6: I can apply moving target indication (MTI) processing to distinguish moving targets from clutter.

This packet is the L29 Lab, in three parts, and you turn it in once, complete. Do **Part 1** before you go to the bench: the predictions you will test. **Part 2** is your own measurements, read from the Phaser app's range-Doppler view on your own kit, and three short tasks in the course's notebook, run on the bursts you saved. Do **Part 3** after the bench: compare the measurements with the predictions and explain the differences. You work this lab on your own, outside class, following the procedure on the L29 page, and you start from the Module 4 folder of the L28 Lab.

Due: see Gradescope.

Grading. The packet is checked and returned with feedback. It is the second piece of scaffolding for your final report, not part of the report: the report explains the radar in your own words, and text lifted from this packet earns nothing there.

The radar is the PHASER's FMCW mode with the Phaser app's **Range + Velocity** preset: a 9.9 GHz carrier, $M = 256$ chirps of bandwidth $B = 500$ MHz and length $T_s = 300$ μs, one every $T_{\text{PRI}} = 0.5$ ms, sampled at $f_s = 2$ MSPS. Use $c = 3.00 \times 10^8$ m/s. Velocity is positive closing, toward the kit.

Part 1: Pre-Lab (individual, before the bench)

1. **The burst.**

   (a) Find the samples in one chirp, the beat per meter of range, the range cell, and the time the whole burst takes.

   N = ____

   beat = ____

   ΔR = ____

   burst = ____

   (b) Predict each row. The floor is the noise floor of the map, relative to the first row; a target's level does not change.

Burst	Δv	$v_{\max}$	ΔR	**Floor**
256 chirps, 500 MHz				reference
128 chirps				
64 chirps				
256 chirps, 200 MHz				

2. A hand. Procedure B pushes a hand from 1.0 m toward the kit at 1.0 m/s, then pulls one away at 1.5 m/s.

(a) For the closing hand, find the Doppler frequency, the phase it advances from one chirp to the next, and how far it moves during one burst. Is that more or less than a range cell?

f_D =

$\Delta\phi$ =

moves =

(b) For the opening hand, find the Doppler frequency and the velocity the map should show, with its sign.

f_D =

v =

3. A fidget spinner. Three identical arms turn on a circle of radius $a = 3.0$ cm at $f_{\text{rev}} = 15$ revolutions a second, held edge-on to the kit, its plane of rotation along the line of sight.

(a) Find the tip speed and the Doppler frequency of the band's edges.

v_{tip} =

f_D =

(b) The three arms make a pattern that repeats every third of a turn, so the band is made of lines. Find their spacing in hertz and in m/s, and how many 256-chirp velocity cells fit between two lines.

spacing =

cells =

(c) Predict what happens to the band when you turn the spinner face-on to the kit, and why.

4. The cancellers. The 2-pulse canceller's power gain is $|H_2|^2 = 4\sin^2(\pi f_D T_{\text{PRI}})$, and the 3-pulse canceller's is its square.

Return	2-pulse	3-pulse	On the map
The wall, 0 m/s			
The hand, $+1.0$ m/s			
A target at 14 m/s			
The hand, held still			
The hand, moved across			

(a) Show the work for the hand and the 14 m/s row.

(b) Noise passes through the canceller too. Find the noise's power gain averaged over all velocities, for each canceller.

Part 2: Measurements (your kit, and the notebook)

Follow the procedure on the L29 page. Transmit antenna on **OUT2**, connected before you power the kit. Stand clear of the beam for every static and MTI reading. **Save Capture** saves the raw chirps whatever the MTI setting. Read every level by hovering over the Range-Doppler view. If a burst fails, use the page's *No Hardware?* frame: the app's simulator and **Load Recording** with the course's recorded bursts. Mark which rows are recorded rather than your own.

Kit: _____ Static target: _____ Recorded data? _____

5. **Table A: calibrate** (Procedure A).

Quantity	**Measured**	**Expected**
f_0, your kit		
Leakage: range, velocity, level		
Wall: tape range		
Wall: range, velocity, level on the map		
Static-scene burst file		

6. **Table B: a hand** (Procedure B). Copy your Question 2 predictions first.

Motion	**Predicted** v	**Range**	**Velocity**	**Burst file**
Closing				
Opening				

7. Table C: a fidget spinner (Procedure C).

Quantity	Measured	Recorded data
Arm radius a, ruler		
Range of the band		
Band edges		
Spacing of the lines		
Spin rate from the edge, $v_{\text{tip}}/2\pi a$		
Spin rate from the lines		
Face-on: what the band does		
Burst files		

8. **Table D: chirp count and bandwidth** (Procedure D). Your hand, pushing as in Procedure B. The app's presets all send 256 chirps of 500 MHz, so the 128- and 64-chirp rows come from the notebook's task (a) and the 200 MHz row from the recorded burst. The floor is the notebook's. Copy your Question 1(b) predictions first.

Burst	Predicted cell	Spot width, 3 dB	Floor, dBFS	Burst file
256 chirps				
128 chirps				same burst, first 128 chirps (task a)
64 chirps				same burst, first 64 chirps (task a)
200 MHz, in range				_B200 (recorded)

9. **Table E: MTI** (Procedure E). Copy your Question 4 predictions first. Levels in dB from the app's hover readout, at each return's range: the wall at 0 m/s, a hand at its spot.

Return	Off	2-pulse	3-pulse
The wall's cell			
The pushing hand			
The hand held still			
The hand moved across the beam			

10. Table F: the notebook (Procedure F). Run `L29_range_doppler.ipynb` with the course's `radar_lab.py` on your hand burst with the wall in view, and on your spinner burst. Each task changes the lines its cells name. Upload the saved `.ipynb`, with its edits and plots, with this packet.

Task (a), the chirp count. `M = 256`, then `128`, then `64`.

Quantity	$M = 256$	$M = 128$	$M = 64$
`dv`			
Hand's width 3 dB down			
Hand's level			
Floor			

Task (b), the canceller. Your `H_DB` line, then `KIND = "2pulse"` and `KIND = "3pulse"`.

Quantity	**2-pulse**	**3-pulse**
Hand's change, and `H_DB`		
Wall's drop		
Floor in the hand's column		
Floor near 14 m/s		

Your `H_DB` line:

Task (c), the spinner's spectrogram. Your `R_SPIN` _____ m.

Quantity	`N_WIN = 64`	`N_WIN = 32`
Doppler cell		
Time between columns		
Band within 10 dB of its peak		

Part 3: Writeup (individual, after the bench)

11. **The velocity cell.** Using Tables D and F, compare the width of your hand's spot with $\lambda/(2MT_{\text{PRI}})$ at each chirp count. Why is the spot a little wider than one cell, and what did the shorter bursts gain in exchange for their coarser cells and higher floor?

12. **The spinner.** From Table C, find your spinner's spin rate two ways. Which do you trust more, and why? Explain why the band is brightest at its edges.

13. **What MTI removes, and what it costs.** Using Tables E and F: what disappeared under each canceller, and what stayed? The hand dropped by 13.7 or 27.4 dB. Did MTI cost it SNR on the map? Why did your wall not vanish as completely as the recorded one?

14. **What you carry forward.** List what you keep from this lab for the L30 and L31 Labs and for the final report.

Documentation: _____