USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 31 LAB - Micro-Doppler Classification and Dismount Tracking
Lab Packet
Fall 2026

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

Learning Objective 4.8: I can integrate FMCW radar processing with a phased-array front-end to track a moving target.

Learning Objective 4.9: I can classify a detected target from its micro-Doppler signature and report the classifier's accuracy.

This packet is the L31 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, in the Phaser app's Range-Doppler view on your own kit, and three short tasks in the course's notebook, run on the course's records. 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 L31 page.

Due: the date on the L31 Lab's Gradescope assignment.

Grading. The packet is checked and returned with feedback. It is 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. This is the last of the four Module 4 packets, so it ends with what you carry into the report from all four.

The radar is the Phaser app's FMCW **Range + Velocity** preset: $300\ \mu$s chirps, one every 0.5 ms, $B = 500$ MHz at 9.9 GHz, so $\lambda = 3.03$ cm, a range bin is 0.30 m, and the slow-time spectrogram spans ± 1 kHz, or ± 15.2 m/s. Velocity is positive closing.

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

1. **The four signatures.**

   (a) Fill in the largest speed along the line of sight and its Doppler shift for each target, held edge-on where it has a rotor. A walker's limbs swing up to 2.7 m/s about the torso.

Target	Largest speed	Doppler
Walker, torso closing at 1.3 m/s		
Fan, 15 cm across, 1000 rpm		
Spinner, 7 cm across, 1200 rpm		
Hand, 0.2 m each way at 1.5 Hz		

   (b) The same fan at 800 rpm is held 45° off edge-on, so only $\cos 45^\circ$ of each blade's motion lies along the line of sight. Find its largest speed, and name the target in part (a) it matches.

(c) A spinner's weight sits at its rim, so each arm's speed along the line of sight is $v_{\text{tip}} \sin \Omega t$. A fan blade's points are spread evenly from the hub to the tip, so a point at radius ρ moves at $v_{\text{tip}}(\rho/R) \sin \Omega t$. Find the RMS speed of each as a fraction of v_{tip}: the **shape** of the band, its spread over its edge. Does it change with the tilt or the rate?

2. The spectrogram window. A walker's limbs change their Doppler at up to $\dot{f}_D = 1122$ Hz/s. A window of N chirps lasts $T_w = N(0.5\text{ ms})$, resolves $1/T_w$, and smears a changing line by $\dot{f}_D T_w$.

(a) Fill in the table.

N	T_w	**Resolution**	**Limb smear**
16			
64			
256			

(b) Which window shows the limbs best, and which shows the torso line best? Explain in one sentence each.

3. Reading a confusion matrix. A classifier is scored on 16 records, four of each target, each scored by a classifier trained on the other 15. Its matrix, rows the true class and columns the call, is below.

true \ called	walker	fan	spinner	hand
walker	3	0	0	1
fan	0	3	1	0
spinner	0	2	2	0
hand	0	0	0	4

(a) Find the accuracy, and say which class it is worst at.

accuracy = ____

(b) Why must no record be scored by a classifier that was trained on it?

4. Noise against lag. The notebook tracks the walk with an alpha-beta filter, $\beta = \alpha^2/(2-\alpha)$, one update a frame, $\Delta t = 128$ ms. For steady noise, the track's RMS error is the detections' RMS times

$$\sqrt{\frac{2\alpha^2 + 2\beta - 3\alpha\beta}{\alpha(4 - 2\alpha - \beta)}},$$

and under a steady acceleration a the track trails the target by $a\,\Delta t^2/\beta$ once it settles. At the turn of Part B the walker's speed swings from $+1$ to -1 m/s in 1 s, as a cosine, so its acceleration peaks at π m/s^2.

α	β	**Noise ratio**	**Lag at π m/s^2**
0.2			
0.5			
0.8			

Which α do you expect to give the smallest RMS error over the whole walk, and why is the lag at $\alpha = 0.2$ unlikely to reach the table's value?

5. Monopulse on the walk. The two subarray centers are $D = 56$ mm apart. Mark A is 12° to the E1 side of broadside (negative) and mark B 10° to the E8 side (positive).

(a) Find the phase between the channels at A and at B, and check that both lie inside the unambiguous window.

A: ____

B: ____

(b) The walker goes from A to B in about 2.7 s. Find the average change in angle per 128 ms frame, and compare it with the array's 13.7° beamwidth.

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

Follow the procedure on the L31 page. Transmit antenna on **OUT2**, connected before you power the kit. Hold rotors edge-on, keep your fingers clear of the fan, and walk a lane no one else is using. Every row below can also be filled from the course's recorded data: with no kit, play the files in the app's browser simulator with **Load Recording** and check your readings against the notebook's Procedure A and B cells, as the page's *No Hardware?* frame describes, and mark which rows are recorded rather than your own.

Kit: _____ Recorded data? _____

6. **Table A: four targets in the Range-Doppler view** (Procedure A), MTI on; or, recorded, record 1 of each target.

Target	Predicted	Read: $-$ / $+$	Centered?	Recorded data
Walker				
Fan				
Spinner				
Hand				

7. **Table B: the crossing walker** (Procedure B), MTI on; or, recorded, `L31_dismount.npz`. At the turn, record the torso.

Where	Range	Velocity or angle	Recorded data
Mark A, by tape			
Mark B, by tape			
Just after A, going out			
At B, the turn			
Just before A, coming back			
Sign of the angle at B	–		

8. **Table C: the classifier's records** (Procedure C, step 1), from the notes the notebook's first code cell prints. For each record, give the setting, the tilt or the pace, and the range.

Target	**1**	**2**	**3**	**4**
Walker				
Fan				
Spinner				
Hand				

9. **Table D: notebook task (a)**, the window, on the spinner's and the walker's record 1.

`N_WIN`	**Resolution**	**Spinner's line**	**Walker's torso**	**Walker's spread**
16				
64				
256				

10. Table E: notebook task (b), the confusion matrices, each record scored by a classifier trained on the other 15. Columns: walker, fan, spinner, hand.

	Three features				**+ edge**				**+ shape**			
true	W	F	S	H	W	F	S	H	W	F	S	H
walker												
fan												
spinner												
hand												
accuracy												

Records called wrong with your best features: _____

Your two lines in `my_features`:

11. Table F: notebook task (c), the track of the recorded walk, `L31_dismount.npz`, scored against its truth after the first second; $\beta = \alpha^2/(2-\alpha)$. Errors are track minus truth.

	Range RMS	**Largest range error**	**Range error at the turn**	**Angle RMS**
Detections alone		–	–	
$\alpha = 0.5$				
$\alpha = 0.2$				
$\alpha = 0.8$				
Your choice: _____				

Part 3: Writeup (individual, after the bench)

12. What told your targets apart. From Table E and the features the notebook printed: which feature separates the walker, which the hand, and what separates the two rotors? Explain why the shape helped where the edge did not, and why your best classifier still calls a record wrong. What would you change to fix it?

13. One gain does not suit both. From Table F and Question 4: explain the trade between noise and lag in range, why the angle track wants a larger α than the range track, and what the canceller did to the detections at the turn. Which gains would you run on this radar?

14. **Range from the chirp, angle from the array.** Describe how this lab's track combines the FMCW processing and the phased array, and how the track's prediction would steer the beam in a radar that follows a walker. Name two limits of what you measured.

15. **What you carry into the report.** This is the last lab. List what you take from each of the four Module 4 labs into the final report.

Documentation: _____