USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 30 LAB - CFAR Processing
Lab Packet
Fall 2026

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

Learning Objective 4.7: I can apply constant false-alarm rate (CFAR) processing to radar data and evaluate detection performance.

This packet is the L30 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, with the Phaser app's CFAR on your own kit, and three short tasks in the course's notebook, run on range-Doppler bursts. 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 L30 page.

Due: see Gradescope.

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.

The radar is the PHASER's FMCW mode, on two of the Phaser app's presets. **Range (CFAR)**, for the app's CFAR and Tables A to C: one chirp of $B = 500$ MHz in 0.5 ms at 10 GHz each display update, so a range cell is 0.30 m; the app's profile runs from 0 to 20 m. **Range + Velocity**, for the notebook's bursts and Tables D to F: 256 chirps of 300 μs, one every 0.5 ms, 500 MHz at 9.9 GHz, so a range-Doppler cell is 0.30 m by 0.118 m/s. The detector is cell-averaging CFAR unless a question says otherwise: the threshold is α times the mean power of the N reference cells. The app's Guard Cells and Ref Cells count one side of the cell under test, and it averages power, so Ref Cells $= 4$ is $N = 8$.

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

1. **The bias from the false-alarm probability.**

   (a) The notebook's 2D window has 2 guard cells and 4 reference cells on each side of the cell under test, in range and in Doppler. Count its reference cells, N.

   $N =$ ____

   (b) Fill in the bias, in dB, for each window and design P_{fa}. The first row is a short window in the app, 4 Ref Cells a side; the second is the lesson's one-dimensional window, 2 guard and 16 reference cells a side.

Window	N	$P_{fa} = 10^{-3}$	$P_{fa} = 10^{-4}$	$P_{fa} = 10^{-6}$
4 a side, range only	8			
16 a side, range only	32			
4 each way, 2D				

(c) Show that as N grows without limit the bias for $P_{fa} = 10^{-6}$ approaches the 11.4 dB threshold of Lesson 27, and explain in one sentence why a window with fewer reference cells needs a higher bias.

(d) The notebook tests $64{,}106$ cells of an empty map. How many false alarms do you expect at each design P_{fa}, and what scatter should you allow on each count?

(e) In Procedure C the app runs 3 guard and 4 Ref Cells a side ($N = 8$) over the 63 cells of its profile beyond 1 m. Predict how many of 30 empty updates hold a crossing at a 13, 10, and 7 dB bias.

2. The CFAR loss. For a target that fluctuates from map to map, Swerling's first case in Lesson 27, the probability of detection has a closed form both with the noise power known and with cell-averaging CFAR over N independent reference cells:

$$P_d = P_{fa}^{1/(1+\mathrm{SNR})} \qquad \text{and} \qquad P_d = \left(1 + \frac{\alpha}{N(1+\mathrm{SNR})}\right)^{-N}.$$

(a) Find the SNR, in dB, that gives $P_d = 0.9$ at $P_{fa} = 10^{-6}$ with the noise known.

SNR = ____

(b) Find the same SNR for CA-CFAR with $N = 32$ and with $N = 144$, and the CFAR loss of each, the extra SNR it needs.

Detector	α	**SNR for** $P_d = 0.9$	**CFAR loss**
Noise known			–
CA-CFAR, $N = 32$			
CA-CFAR, $N = 144$			

3. Masking. A weak target sits four range cells nearer than a strong one, at almost the same velocity, and 8.3 dB below it. With the Hann window, the strong target's peak cell and its eight neighbors hold about 2.25 times its peak power, and all nine lie in the weak target's reference ring of 144 cells. Ignore the noise beside them.

(a) Find the CA threshold at the weak target, in dB relative to the strong target's peak, with the 10^{-6} bias. Is the weak target found?

(b) Greatest-of and smallest-of average the nearer and the farther half of the ring separately, 68 cells each. Which half holds the strong target? Predict whether each method finds the weak target, at the same bias.

4. The bias and the range. In Procedure A a target at 3 m stands M dB over the threshold. In Procedure B you walk out with the threshold applied, then raise the bias by 3 dB and walk again. Assume nothing but the target enters the window.

Predict how far out the threshold still finds the target for $M = 40$ dB, and how far with the bias 3 dB higher.

range =

$+3$ dB =

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

Follow the procedure on the L30 page. Transmit antenna on **OUT2**, connected before you power the kit. Point the kit along a clear line and walk slowly. **One rule for every table:** fill it once, from your own kit or from the course's recorded data, and tick which. Without a kit, play the recording the table names through the app's **Load Recording** and read the numbers from the notebook's cell for that procedure, as the page's *No Hardware?* frame describes. The key's values are the recorded data.

Kit: _____

5. **Table A: placing the threshold** (Procedure A), Range (CFAR) preset. Kit: your stand-in at 3 m. Recorded: update 0 of `L30_range_person.npz`, a person at 3.0 m. Kit ▫ Recorded ▫

Quantity	Value
Guard Cells (a side)	
Ref Cells (a side)	
CFAR Bias	
Peak over the threshold	
Highest noise peak under it	
Threshold at the peak, 0 Guard Cells	

6. **Table B: the walk** (Procedure B), Detections Only, at your Table A setting. Kit: from your screen recording, against the tape. Recorded: `L30_walker.npz`, 70 updates. Kit ▫ Recorded ▫

Bias	Nearest range found	Farthest range found	Anything else that crossed
Your setting			
Your setting $+3$ dB			

7. **Table C: false alarms on an empty scene** (Procedure C), 30 updates each, from the notebook's Procedure C cell. Kit: your own empty-scene capture. Recorded: `L30_range_empty.npz`. Kit ▫ Recorded ▫

Bias	Updates with a crossing	Where they land	Predicted (Q1e)
Your setting			
-3 dB			
-6 dB			

Empty capture: _____ Range + Velocity bursts: _____

8. **Table D: notebook task (a)**, the false-alarm rate on `L30_empty.npz` or your own empty burst, Range + Velocity preset. 2 guard and 4 reference cells each way. Kit ▫ Recorded ▫

Run	`BIAS_DB`	**Design count**	**Measured**	**Measured / design**
Hann, 10^{-3}				
Hann, 10^{-4}				
Rectangular, 10^{-3}				

Your `BIAS_DB` line:

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9. **Table E: notebook task (b)**, the three methods at an 11.6 dB bias. Give the number of cells in each cluster, or "missed". Kit ▫ Recorded ▫

Scene	**Cluster**	`"ca"`	`"go"`	`"so"`
Wall and hand	leakage, 0 m			
	hand			
	wall			
	anywhere else			
Weak and strong	strong target			
	weak target			
	anywhere else			

10. **Table F: notebook task (c)**, the probability of detection for the hand at 12 dB SNR over 50 maps, and the detection list. Only the noise is redrawn between maps, so the hand is a **steady** target: the measurement should match the steady-target (Marcum) columns. The Swerling 1 column, Question 2's fluctuating target, is for contrast. Kit ▫ Recorded ▫

`BIAS_DB_C`	**Measured P_d**	**Steady, noise known**	**Steady, CA-CFAR, $N = 144$**	**Swerling 1, CA-CFAR**
11.6 dB				
_____ dB				

Range	**Velocity**	**SNR**	**Cells**	**Target or false alarm?**

Part 3: Writeup (individual, after the bench)

11. **The false-alarm rate you measured.** Table D's Hann rows come out above the design, and the rectangular row does not, although the noise, the window size, and the bias are the same. Explain the difference, and say what it means for a design of 10^{-6} on Hann-windowed maps.

12. **The three methods.** From Table E and your plots: why did greatest-of leave the wall's cluster unchanged, why did smallest-of grow every cluster, and why did only smallest-of find the weak target? Describe a scene in which greatest-of would change the count at a clutter edge.

13. **Detection against the predictions.** Compare Table F's measured P_d with the steady-target and the Swerling 1 predictions, and say which model the measurement should match and why. Compare Table B with Question 4, using your Table A margin for M. Which bias would you run for the L31 Lab, and what does it cost?

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

Documentation: _____