USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 19 LAB - Fox Hunt
Lab Packet
Fall 2026

Names: _____ _____ **Section:** _____

Learning Objective 3.5: I can implement beam steering on the ADALM-PHASER and verify the steered pattern against theory.

One HB100 is on, inside one of the numbered boxes downrange of a taped firing line. Your team moves its kit along the line, stopping at station marks every 0.75 m with the kit squared to the tape and broadside pointed straight downrange, and finds the live box from the bearings and levels it reads. This packet is the L19 Lab, in three parts, and your team turns in one copy, complete, before Lesson 20. **Part 1**, before the lab period, is the error budget, a station plan, and your fox-hunt notebook, tested on a supplied set of readings; you need all three at the bench. **Part 2** is your team's measurements, recorded in class, and your call, made at the bench or after class and due before I reveal the live box. **Part 3**, after the reveal, compares your fix with the live box.

Grading. One submission per team, counted toward every partner's engagement grade and graded as a genuine, documented attempt.

The array is the PHASER's: $N = 8$ elements, E1 to E8, on a $d = 14$ mm pitch. Use $c = 3.00 \times 10^8$ m/s and the HB100's nominal 10.525 GHz. The range frame puts x along the tape, with station 0 at its middle, and y straight downrange. Every Angle θ in this packet has your reference-shot sign applied, so a positive angle points toward the $+x$ end of the tape, and a bearing from station x_i is the line

$$x = x_i + y\tan(\theta_i) .$$

Part 1: Pre-Lab (before the lab period)

1. **The bearing error budget.** The **Angle** readout, set to Peak, is the steer angle of the largest sample in the beam sweep, and the sweep steps the progressive phase one ADAR1000 LSB, $360^\circ/2^7 = 2.8125^\circ$, at a time.

   (a) Find kd in degrees, the sweep's step in $\sin\theta$, and the step in angle at each Angle in the table. Then give the largest error the grid alone can cause at each angle.

Angle	0°	30°	45°
Grid step			
Largest grid error			

(b) On the range, every kit is squared to the tape with a straightedge, which holds its heading to about 1.0°. Take 1.0° for multipath and 0.3° for noise. Combine these with the grid term at 30° to find the bearing uncertainty σ_β. Then repeat for a kit aimed at a point by eye, which holds the heading only to about 1.5°.

σ_β (squared to tape) = ____ σ_β (aimed by eye) = ____

(c) A teammate sets the kit on the floor, 0.75 m below the boxes, at a station 2 m from a box that is 30° off broadside in azimuth. What does Angle read, and which way does the error always pull?

2. The range. The firing line is 3.0 m of tape with stations at $x = -1.5, -0.75, 0, +0.75, +1.5$ m. The box field is 2.0 m wide, centered on station 0, and runs from 1.0 to 2.0 m downrange; the boxes are at least 0.75 m apart. Take $\sigma_\beta = 1.5^\circ$ in this question.

(a) Find the cross-range error of one bearing line at each depth.

Depth y	1.0 m	1.5 m	2.0 m
Cross-range error			

(b) Every bearing on a firing line looks downrange, so depth is the weak direction. Two stations a baseline B apart fix a box in depth to about $\sqrt{2}\,R^2\sigma_\beta/B$, where R is the range from each station to the box and σ_β is in radians (Lesson 19, "Choosing Where to Measure"). Find the depth error for a box 2.0 m out, centered between the two stations, at each baseline.

Baseline B	0.75 m	1.5 m	3.0 m
Depth error			

(c) Bearings past $\pm 45^\circ$ are poor: the beam is wide and the plot's edge can capture the peak marker. A box sits at the field's corner, $x = +1.0$ m. List the stations that see it within $\pm 45^\circ$ of broadside when it is 1.0 m out and when it is 2.0 m out, and say why the tape runs 0.5 m past the field at each end.

(d) Write your station plan: the order in which you will visit the stations, and which two you take first. Give one sentence of reasoning.

(e) Half the box spacing is 0.375 m. Compare it with the depth error of a 2.0 m baseline for the deepest box, and say in one sentence whether naming the wrong box should be common.

3. **Your fox-hunt notebook.** Download `L19_foxhunt.ipynb` from the L19 Lab page. It holds this practice set, draws every bearing line over the boxes, and prints the results; write its four functions in Python with numpy. `solve` returns the least-squares fix and each station's residual (Lesson 19, "Many Bearings: Least Squares"); `drop_worst` finds the one station that disagrees with the rest; `rank_boxes` orders the boxes; and `amplitude_check` scores how well the levels fit a box. Run the notebook's test cell until every check passes; it checks each function on a made-up hunt with a known answer. Then run them on this practice set from an earlier class, recorded at one Rx Gain:

Station x_i (m)	**Angle θ_i**	**Peak Gain**	**Use?**
-1.5	$+52.6^\circ$	-19.6 dB	
-0.75	$+38.2^\circ$	-15.0 dB	
0.0	$+27.2^\circ$	-10.7 dB	
$+0.75$	-5.8°	-10.0 dB	
$+1.5$	-31.4°	-13.5 dB	

Boxes: **1** $(-0.75,\ 1.20)$, **2** $(0.00,\ 1.00)$, **3** $(0.55,\ 1.60)$, **4** $(-0.40,\ 1.90)$, **5** $(1.00,\ 0.90)$ m

(a) Mark in the table which stations you use, and say why you left any out.

(b) Run `solve` on the stations you kept and record the fix and the residuals. Attach your notebook.

Fix (m)	-0.75	0.0	$+0.75$	$+1.5$

(c) A good bearing here should leave a residual of a few centimeters, about $R\tan(1.5^\circ)$ at its range. Which station is the outlier? Run `drop_worst`, and record the new fix and the largest residual left.

	Station dropped	**Fix (m)**	**Largest residual left**
Outlier dropped			

(d) Name the box from each fix and give its distance. Then compare the amplitude scores of the two nearest boxes. Does the level pattern agree with the bearings?

(e) The live box was box 3. Solve again with only the two end stations you kept (-0.75 and $+1.5$), then with only stations $+0.75$ and $+1.5$. Record each fix, its distance from box 3, and the crossing angle of the pair.

Pair	**Fix (m)**	**To box 3**	**Crossing**
-0.75 and $+1.5$			
$+0.75$ and $+1.5$			

Part 2: Measurements (your team, in class)

Follow the procedure on the L19 Lab page in read mode. Bring the kit up as in the L18 Lab, with your own HB100 at boresight for **Find HB100** and **Calibrate**, and set **Rx Gain (dB)** as the page says. Your own HB100 stays on only for the reference shot. Then switch it off, disconnect its power, and, once I start the hunt, press **Find HB100** again so the kit tunes to the fox. Keep the calibration from bring-up. Once the hunt starts, do not change Rx Gain.

Own HB100 = Fox, after re-tune =

Rx Gain for the hunt =

4. **Reference shot.** Put the kit on station 0, squared to the tape. Place your own HB100 1 m downrange and 0.5 m toward the $+x$ end of the tape, facing the kit, and record Angle. If it reads positive, $s = +1$; if negative, $s = -1$. Multiply every Angle you record today by s.

Angle, source toward $+x$	s

5. **The hunt.** At each station, square the kit to the tape with the middle of the array on the mark, and read Angle on ten consecutive sweeps from the **Tracking** tab. Record s times the mean, the spread (largest minus smallest), and Peak Gain. Write "none" for a station with no clear tone. Ends first.

Station x_i **(m)**	$s\,\bar{\theta}_i$	**Spread**	**Peak Gain**	**Use?**
-1.5				
-0.75				
0.0				
$+0.75$				
$+1.5$				

6. **The call.** Before you leave the bench, type your stations into your Part 1 notebook and run its plot: the bearing lines should cross near one box, and a station whose line misses the crossing is one to retake while you still can. Then run the notebook, at the bench or after class, and submit your call before I reveal the live box. Record the fix, the largest residual, any station dropped, the box you name, and, after the reveal, the box that was live.

Fix (m)	**Largest residual**	**Dropped**	**Box named**	**Live box**

Part 3: Writeup (your team, after the reveal)

7. **Reconcile the fix.** The live box's measured position is posted after the period. Answer each part in three or four sentences, using your numbers from Part 2 and your predictions from Part 1.

   (a) Give the distance from your fix to the live box, split into its cross-range and depth parts. Compare each with your Question 2 predictions.

   (b) Use the live box's position to find the true angle from each station, $\tan^{-1}\left((x_{\text{box}} - x_i)/y_{\text{box}}\right)$, and the error of each measured angle. Which term of your error budget best explains the largest one?

   (c) If your notebook dropped a station, say whether dropping it moved the fix toward the live box, and what in the room you think caused it. If it dropped none, say what that tells you about your bearings.

8. Baseline and amplitude.

(a) Solve your own data again with only your two end stations, then with only two neighboring stations near the middle. Record both fixes and their distances to the live box. Does the result match Question 2(b)?

(b) In two or three sentences, explain why Peak Gain can help choose between two boxes but cannot give the fox's range on its own.