USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 18 LAB - Beam Steering
Lab Packet
Fall 2026

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

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

This packet is the L18 Lab, in three parts, and you turn it in once, complete, before Lesson 19. Do **Part 1** on your own before the lab period: the predictions, and a rehearsal of the procedure on the hosted simulator. You need it at the bench. **Part 2** is your own measurements, from your own kit, recorded in class. Do **Part 3** on your own after the lab: reconcile the measurements with the predictions and work three analysis problems.

Grading. One submission, counted toward your 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.

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

1. **The prediction table.** Every phase in this lab depends on the source frequency. Use the HB100 frequency your kit reported in the L17 Lab. If you did not record one, use the nominal 10.525 GHz and say so.

   (a) Record the frequency you are using, then find the wavelength, the electrical spacing d/λ, and kd in degrees.

   f = _____

   d/λ = _____

   kd = _____

   (b) Find the progressive phase $\Delta\phi$ that steers the beam to each angle in the table.

θ_0	0°	15°	30°	45°
$\Delta\phi$				

(c) Fill in the 30° ramp. Lesson 18 numbers the elements $n = 0$ to 7, so element E$(n+1)$ is set to $n\Delta\phi$. Give each value unwrapped, then wrapped into 0° to 360°, and name the first element that wraps.

Element	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**
Unwrapped								
Wrapped								

(d) E6 carries 442.0° in one table and 82.0° in the other. In two or three sentences, explain why both settings give the same pattern, and state what the wrapped table no longer records.

2. **What Phase Control will show.** At the bench you will type 30 into **Steer Angle (deg)** and press **Apply**. The GUI computes $\Delta\phi$ from the Signal Freq on screen and writes $-n\Delta\phi$, rounded to a whole degree and *not* wrapped, into the **Phase Control** boxes as per-element offsets. Write those offsets as $-n\Delta\phi_0$.

   (a) Predict the eight values Phase Control will show after Apply 30.

Element	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**
Phase Control								

   (b) During a beam sweep the backend adds its own ramp, $+n\Delta\phi_s$, to whatever Phase Control holds, and the plot's x-axis is the angle that $\Delta\phi_s$ alone would steer to. With the source at boresight and the Apply 30 offsets loaded, at which plotted angle does the total ramp vanish? Use your answer to explain, in one or two sentences, why Apply writes the ramp with a minus sign.

   (c) Reduce E6's Phase Control value modulo 360° and compare it with E6's wrapped entry in Question 1(c).

E6 =

3. The beam and the error budget. Continue with your frequency from Question 1. The source sits on a protractor arc 1.00 m from the array.

(a) Use $\theta_{\text{HP}} \approx 0.886\lambda/(Nd\cos\theta_0)$ to predict the half-power beamwidth, and $10\log_{10}(\cos\theta_0)$ to predict the drop in peak level relative to broadside (the ideal-element scan loss).

θ_0	0°	30°	45°
θ_{HP}			
Scan loss			

(b) Lab Preset 1 sweeps by stepping $\Delta\phi_s$ one phase-shifter LSB, 2.8125°, at a time. One step moves $\sin\theta$ by $2.8125^\circ/kd$. Find the angle step at 0° and at 30°, and the worst-case error of a peak read off this grid at 30°.

step at 0° = ____

step at 30° = ____

half step = ____

(c) How far along the arc is one degree? If you can place the tripod to within 25 mm, how large is the error in the reference angle?

per degree = ____

aim error = ____

(d) A reflection from the bench arrives 20 dB below the direct path, an amplitude ratio of 0.1. Find the largest and smallest total level it can produce, in dB relative to the direct path alone.

largest = ____

smallest = ____

(e) Combine the three independent peak-angle errors at 30° (grid half step, aim 1.5°, multipath 1.0°) as a root sum of squares, $\sqrt{a^2 + b^2 + c^2}$. State a pass standard for the lab in degrees, and name the term you could reduce most.

RSS =

pass =

4. **Simulator rehearsal.** Open the hosted simulator at `https://livethisdream.github.io/phaser/`. It runs the bench GUI in your browser with nothing to install, and its source is fixed at boresight, so it can rehearse the commanded run of Part 2 (Run 2).

    1. Open the **Lab Presets** section, press **1 Steering Angle**, then press **Start**.
    2. Open the **Rectangular** tab and turn on **Show Peak Angle Marker** under **Plot Options**.
    3. In **Beam Steering**, enter each angle in **Steer Angle (deg)** and press **Apply**. Record **Angle** and **Peak Gain**, and the E2 and E8 boxes in **Phase Control**.
    4. Press **Reset** under **Phase Control** and record the last row.

Apply	Angle	Peak Gain	E2	E8
15				
30				
45				
Reset				

In one sentence, where does the trace peak after Apply 30, and why is that the angle Question 2(b) predicts?

Part 2: Measurements (your kit, in class)

Follow the procedure on the L18 Lab page in read mode. Bring the kit up as in the L17 Lab: the HB100 powered, 1 m out at boresight, then **Find HB100**, then **Calibrate**. Open the **Lab Presets** section and load **1 Steering Angle**, set **Rx Gain (dB)** for an FFT peak of -10 ± 3 dBFS as in the L17 Lab, turn on **Show Peak Angle Marker**, press **Start**, and work on the **Rectangular** tab. Read each half-power beamwidth as the distance between the two angles where the trace is 3 dB below its own peak. Facing the patches, E1 is on your right and E8 on your left, and $+\theta$ is toward E8.

Take the angles and beamwidths on the 1 m arc. Take the Peak Gain column of Table A at 1.2 m (4 ft) or more, on the same three lines: at 1 m the scan-loss drop reads smaller than theory. If the room forces you closer, record the distance you used and say so in Part 3.

Signal Freq after Find HB100 = _____

5. **Table A: the physical run.** Phase Control at zero; move the source along the arc.

Source on arc	Angle	Difference	HPBW	Peak Gain
$0°$				
$30°$				
$45°$				

At $45°$, if Angle jumps to about $-90°$, record the main lobe's angle read off the trace.

Distance for the Peak Gain column = _____

6. **Table B: the commanded run.** Source back at boresight; Apply each Steer Angle.

Apply	Angle	Difference	HPBW	Peak Gain
15				
30				
45				

At 45, if Angle jumps to about $-90°$, record the main lobe's angle read off the trace.

With Apply 30 loaded, read the eight Phase Control boxes. The prediction row is your Question 2(a).

Element	E1	E2	E3	E4	E5	E6	E7	E8
Predicted								
Read back								
Difference								

Part 3: Writeup (individual, after the lab)

7. Reconcile the measurements. Answer each part in three or four sentences, using your numbers from Part 2 and your own predictions from Part 1.

(a) Compare each Table A difference with the pass standard from Question 3(e). For any row outside it, name the error source in your budget most likely responsible, and say how you would check it.

(b) Compare the 30° rows of Tables A and B: Angle, HPBW, and Peak Array Gain. Explain why the beamwidths agree but only the physical run loses peak level. State the distance at which you took Table A's levels, and if it was under 1.2 m, say how that affects the comparison.

(c) Compare the Phase Control read-back with your prediction. Explain the sign in your own words, and account for any nonzero difference.

(d) Compare each measured HPBW with its calculated value, and explain why the lab quotes beamwidth to the nearest degree.

8. Reading a measured sweep. A classmate places the HB100 at $+30.0^\circ$ on the arc with Phase Control at zero. The trace peaks at an Est. Angle of 28.5°, its half-power crossings are at 20.5° and 35.8°, its peak sits 0.7 dB below the boresight trace, and its first sidelobes read -11.8 dB relative to its own peak.

(a) Find the measured half-power beamwidth and compare it with the $1/\cos\theta_0$ prediction from the 13.0° broadside value.

θ_{HP} = ____

predicted = ____

(b) Find the difference between Angle and the arc angle, and express it in grid steps.

offset = ____

(c) The classmate reports the array as broken because the peak did not land on 30°. In two or three sentences, say whether the data support that conclusion.

(d) The peak fell 0.7 dB , while the ideal-element bound is -0.6 dB . Give the most likely reason the measured drop is the larger, and say whether you would expect the gap to grow or shrink at 50°.

9. Working backwards from Phase Control. A lab partner recorded the Phase Control boxes after an Apply but not the Steer Angle typed in. Signal Freq read 10.525 GHz.

Element	E1	E2	E3	E4	E5	E6	E7	E8
Phase Control	0	-125	-250	-375	-500	-626	-751	-876

(a) Find the element-to-element step. Explain why one difference is 1° larger than the others, and use the span of the array to get the step to a tenth of a degree.

step =

(b) Phase Control holds $-n\Delta\phi_0$. Find the Steer Angle that was applied.

θ_0 =

(c) With the source at boresight and these offsets loaded, where does the swept trace peak? Where would the beam point if the backend stopped sweeping and held only these offsets?

(d) Had a data file stored these values wrapped into 0° to 360°, the step would also be consistent with $125.1^\circ - 360^\circ = -234.9^\circ$. Explain in one or two sentences why we can discard that solution for this array.

10. Two frozen traces. A classmate freezes the boresight trace of the physical run, then moves the source to 45° on the arc and sweeps again. The boresight trace is 13.1° wide at half power and sets the 0 dB reference. The new trace peaks at an Angle of 45.7°, is 18.9° wide at half power, and its peak is 1.7 dB below the boresight peak.

(a) Predict the half-power width at 45° from the measured boresight width, and compare it with the measurement.

θ_{HP} =

(b) Predict the peak drop from the ideal-element bound and compare it with the measured 1.7 dB .

ΔG =

(c) Name the geometric fact behind the wider beam, and the one behind the lower peak.

(d) A specification calls for a 13° beam held out to 45° of scan. How many elements would the array need at the same 14 mm spacing? Name the hardware tradeoff of that choice in one sentence.

N =