USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 22–23 LAB - Tapering, Squint, and Quantization
Lab Packet
Fall 2026

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

Learning Objective 3.7: I can apply amplitude tapering (uniform, cosine, Chebyshev, Taylor) to control sidelobe level and predict the pattern trade-off.

Learning Objective 3.8: I can identify grating lobes, beam squint, and quantization effects in a phased array and describe their impact on system performance.

This packet is the L22–23 Lab, in three parts, and you turn it in once, complete, before Lesson 24. Do **Part 1** on your own before the lab period: the predictions you will test 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: compare the measurements with the predictions and explain the differences.

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, so the aperture spans $D = 98$ mm between the outer element centers. Facing the patches, E1 is on the right and E8 on the left, and $+\theta$ is on the E8 side. The Element Gains sliders are voltage amplitudes in percent of full scale. Use $c = 3.00 \times 10^8$ m/s, and report every lobe level relative to its own trace's main-lobe peak, in dBc, unless a question asks otherwise.

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

1. **Frequency and distance.** Use the HB100 frequency your kit reported with **Find HB100** in an earlier lab. If you did not record one, use the nominal 10.525 GHz and say so. Every prediction in this packet is made at that frequency.

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

   f = [ ]

   d/λ = [ ]

   (b) Find the far-field distance of the array. The bench places the source 1.2 m away, and level comparisons in Part 2 need that much. In one or two sentences, say why a distance just past the far-field criterion is not enough for a comparison of a fraction of a decibel.

2. Reading a taper off the sliders. You find the eight Element Gains sliders set to

$$30,\ 60,\ 90,\ 100,\ 100,\ 90,\ 60,\ 30 \text{ percent},$$

with the HB100 at boresight and a uniform-taper sweep frozen as the reference trace. This taper is a good starting point for the custom taper in Part 2.

(a) Compute the amplitude sum $\sum a_n$ and the peak drop this taper will show on the sweep plot relative to the frozen uniform trace.

$\sum a_n$ =

peak drop =

(b) Compute the taper efficiency η_t for this distribution, as a ratio and in dB.

η_t =

η_t =

(c) Your two answers differ by 2.5 dB. State which one the Rectangular plot shows you, and which one belongs in a link budget as the antenna's loss.

(d) The uniform 8-element array has a broadside directivity of about 8.9 dB. What is the directivity of the tapered array?

D =

3. Predicting the presets. The Hann, Blackman, and Chebyshev presets set the sliders to

$$12,\ 43,\ 77,\ 100 \qquad 6,\ 27,\ 66,\ 100 \qquad 4,\ 23,\ 62,\ 100$$

percent from the end element inward, mirrored on the other half. The array factor, evaluated at 10.443 GHz, gives half-power beamwidths of 13.1° (uniform), 18.9°, 21.4°, and 22.6°; use those as your predicted HPBW. They assume the slider is linear in voltage, which the Phaser software provides once your kit has the gain-slider fix.

(a) Fill in the predicted columns of Table A in Part 2: the peak drop and η_t (as a ratio and in dB) for each preset.

(b) Theory puts Blackman's first sidelobe about 50 dB below its own peak. The sweep's floor in the dry run sat 17 to 31 dB below the uniform peak, depending on the setup. What will you see at that sidelobe's angle, and what belongs in the sidelobe column?

(c) A classmate argues that Blackman is the better taper because its sidelobes are lower than Hann's. Using only what this measurement can show, evaluate that claim.

4. Predicting the three departures. Work at your frequency.

(a) **Grating lobes.** Lab preset 4 leaves Rx1, Rx4, and Rx7 on, so the active spacing is $3d = 42$ mm; later you leave only Rx1 and Rx5 on, $4d = 56$ mm. For each, find every grating-lobe angle in visible space and the peak drop against the uniform trace. Fill in the calculated columns of Table C.

(b) **Beam squint.** Lab preset 5 sets **Signal BW** to 500 MHz: the GUI computes the steering phases for a frequency 500 MHz below your Signal Freq and receives at the Signal Freq. With the source at 45°, at what commanded angle will the sweep find the source, and how far will the Angle readout move from its 10 MHz reading?

(c) **Phase quantization.** Lab preset 6 holds the beam at 15° with the Blackman taper while you walk the source. Find the phase step between neighboring elements for a 15° beam, the LSB at 7, 4, 3, and 2 bits, and the rule-of-thumb lobe level $-6B$ dB. Then round the ramp onto each grid and predict which bit counts will change the walked trace.

Part 2: Measurements (your kit, in class)

Follow the procedure on the L22–23 Lab page. Open the **Lab Presets** section before you press a preset. Press **Calibrate**, then **Find HB100**. Set **Rx Gain** so that the uniform main-lobe peak, source at boresight, reads -10 ± 3 dBFS on the FFT, and leave it there. Keep the source 1.2 m from the array, and keep $\pm 40^\circ$ of the bench clear of walls and people. Record each reading as you take it.

Signal Freq from **Find HB100**: _____ Rx Gain: _____ Distance: _____ Floor (dBc): _____

5. **Table A: the presets.** Source at boresight, Lab preset 3, Enforce Symmetric Taper on. Freeze the uniform trace as the reference. If the uniform trace's two first sidelobes differ by more than about 2 dB, recalibrate before you go on.

Preset	HPBW pred	HPBW meas	Drop pred	Drop meas	First sidelobe	η_t (dB)
Uniform	13.1°		0 dB			
Hann	18.9°					
Blackman	21.4°					
Chebyshev	22.6°					

6. **Table B: your custom taper.** Design a symmetric taper with an HPBW no wider than 17° and the first sidelobe below -20 dBc. Start with the end elements near 25 to 30% and step smoothly up to 100% in the middle; iterate two or three times.

Rx1, Rx8	Rx2, Rx7	Rx3, Rx6	Rx4, Rx5	HPBW meas	Drop meas	First sidelobe

7. **Table C: grating lobes.** Source at boresight, Enforce Symmetric Taper off, Lab preset 4 (Rx1, Rx4, Rx7 on). Then Rx4 and Rx7 to 0% and Rx5 to 100%. Read each lobe's angle and its height against the 0° lobe, and the peak drop against the frozen uniform trace.

Elements on	d_{eff}	Lobes calc	Lobes meas	Height vs 0°	Drop calc	Drop meas
Rx1, Rx4, Rx7	42 mm					
Rx1, Rx5	56 mm					

8. **Table D: beam squint.** Move the HB100 to about 45° on the 1.2 m arc and press the Uniform preset. Set **Signal BW** to 10 MHz, sweep, and record **Angle** (set to **Peak**). Then press Lab preset 5, **check that Signal BW reads 500 MHz** (Calibrate, Find HB100, and the Rect preset all reset it to 0), and sweep again.

Signal BW	Angle (Peak)	Shift calc	Shift meas
10 MHz			
500 MHz			

9. **Table E: phase quantization.** Lab preset 6 holds the beam at 15° with the Blackman taper and opens Signal vs Time. Walk the HB100 from -90° to $+90^\circ$ on the 1.2 m arc, in about 20 s, at Phase Shift Bits 7, 4, 3, and 2, with Use Bits checked before each walk. On each trace read the main-lobe peak and the strongest lobe outside the main lobe, in dBc. Write "floor" where nothing rises out of it.

Bits	LSB	$-6B$ rule	Strongest lobe outside the main lobe	Where
7				
4				
3				
2				

Before you leave: Use Bits on, Phase Shift Bits 7, Signal BW 10 MHz, and the Uniform preset.

Part 3: Writeup (individual, after the lab)

10. The two numbers and the floor. A short paragraph each.

(a) The tapered sidelobes disappear from the plot, but the beamwidth change is easy to see and easy to measure. Using your floor reading, explain why the measurement gives a good number for one and no number at all for the other.

(b) Explain why the peak drop you measured is not the directivity the array lost, and what each number would be used for.

(c) Compare your Table A with the predictions. Say whether your kit's slider is linear in voltage, and how you can tell.

11. A measurement that disagrees. A student applies the **Hann** preset, predicts a -4.7 dB peak drop, and measures -6.8 dB against the frozen uniform trace, on a kit with the gain-slider fix. The beam is also wider than the 18.9° predicted.

(a) Run the peak-drop formula backwards to find the amplitude sum the array achieved.

$\sum a_n =$ ☐

(b) Identify the fault. Which element is misbehaving, and what amplitude is it contributing?

(c) Name one feature of the trace itself, other than the peak level, that confirms your diagnosis.

12. The three departures. Two or three sentences each, using your Tables C, D, and E.

(a) Compare your grating-lobe angles with the predictions. Then explain why a grating lobe stands as tall as the main lobe when a sidelobe never does.

(b) The source did not move between your two squint sweeps. What did, and why does the beam move instead of breaking up?

(c) Compare Table E with the $-6B$ rule and with your Part 1 prediction. Did the 3- and 4-bit walks match the 7-bit walk? What does your answer say about when quantization matters?

Documentation: _____