USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 20 LAB - Array Factor
Lab Packet
Fall 2026

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

Learning Objective 3.2: I can derive the array factor for an arbitrary linear array and apply pattern multiplication.

This packet is the L20 Lab, in three parts, and you turn it in once, complete, before Lesson 21. Do **Part 1** on your own before the lab period: derive the array factor for each configuration you will sweep and predict what the trace will show. 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. **Your kit's frequency.** Every prediction in this packet depends on the source frequency. Use the HB100 frequency your kit reported in the L18 Lab. If you did not record one, use the nominal 10.525 GHz and say so. At the bench, recompute if **Find HB100** reports a frequency more than 50 MHz from the one you used here.

Signal Freq = ☐ λ = ☐

d/λ = ☐ kd = ☐

2. **Uniform apertures.** In Part 2 you sweep three contiguous, centered apertures with every active gain at 100: all eight elements, E3 to E6, and E4 and E5.

   (a) Fill the prediction table at your frequency. State which method you used for each half-power beamwidth. The change from $N = 8$ is the ideal voltage-sum prediction for the peak.

Active	Nd	**HPBW**	**FNBW**	**First SLL**	**Change from $N = 8$**
8 (E1–E8)					reference
4 (E3–E6)					
2 (E4, E5)					

(b) For the two-element row, solve the half-power beamwidth directly from $AF = \cos(\psi/2), \psi = kd\sin(\theta)$. Then evaluate the $0.886\lambda/(Nd)$ rule and state its percentage error.

θ_{HP} =

error =

(c) Evaluate $\lambda/2d$ at your frequency. Use it to explain what you entered for the two-element FNBW and first SLL, and why.

3. Two elements, far apart. The last sweep in Part 2 leaves only E1 and E8 on, so the array is two elements again, but now $D = 7d = 98$ mm apart instead of 14 mm.

(a) Write the array factor for this pair and say how it differs from the E4 and E5 pair.

(b) Find every angle in visible space where the array factor reaches its full peak.

peaks =

(c) Find the half-power beamwidth and the first-null beamwidth of the lobe at 0°.

θ_{HP} =

FNBW =

(d) Predict the change from $N = 8$ for this pair's peak. Then explain, in two or three sentences, why two elements give a main lobe narrower than all eight do, and why the trace shows several lobes instead of one.

4. **Simulator rehearsal.** Open the hosted simulator at `https://livethisdream.github.io/phaser/`. Its source is fixed at boresight, so it can rehearse every sweep in Part 2.

   1. Open the **Lab Presets** section, press **2 Array Factor**, then press **Start**. Record the Signal Freq it reports.
   2. In **Element Gains**, set E2 through E7 to 0, leaving E1 and E8 at 100. Press **Start**.
   3. On the **Rectangular** tab, read the angles of the full-height lobes and the half-power width of the lobe at 0°.

Signal Freq	**Full-height lobes**	**HPBW at 0°**

   In one sentence, compare the simulator's lobe angles with your Question 3(b), and say why any difference is expected.

Part 2: Measurements (your kit, in class)

Follow the procedure on the L20 Lab page in read mode. Bring the kit up as in the L17 Lab: the HB100 at boresight, about 1 m out at patch-row height, then **Find HB100**, then **Calibrate**. Load **2 Array Factor** under **Lab Presets**, and set **Rx Gain (dB)** for an FFT peak of -10 ± 3 dBFS. Leave the gain there for all four sweeps, so the peaks compare against each other. Read each sidelobe or lobe level relative to that trace's own peak.

Signal Freq after Find HB100 = _____ Rx Gain = _____

5. **Table A: four apertures.** One row per sweep.

Active	**Peak (dBFS)**	**Change from $N = 8$ (dB)**	**HPBW**	**FNBW**	**First SLL (dBc)**
8 (E1–E8)		reference			
4 (E3–E6)					
2 (E4, E5)					
2 (E1, E8)					

6. **Table B: the E1 and E8 lobes.** From the E1 and E8 trace, read the angle and the level (relative to the trace's peak) of each full-height lobe.

Lobe m	-3	-2	-1	0	$+1$	$+2$	$+3$
Angle							
Level (dBc)				0			

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 the measured beamwidths of the three uniform apertures with Question 2. Does the beam double at each halving? Name the cause of any difference larger than a degree.

(b) Compare the E1 and E8 row with the E4 and E5 row. Both have two active elements. Explain, with your numbers, why their peaks agree and their beams do not.

(c) The voltage sum predicts a 6.0 dB peak change per halving. Compare your two measured changes with it. Leakage through the elements set to 0 and receiver compression were ruled out on the dry-run kit; propose one other possible cause of a shortfall, and describe a measurement on your kit that would test it.

8. Reading a sweep. A cadet sweeps the PHASER with all eight elements active and a source at boresight, at 10.3 GHz. The table lists every third sample of the trace, about 2.8° apart. The peak reads -4.1 dBFS.

θ (°)	0.0	2.8	5.6	8.4	11.3	14.1	16.9	19.7	22.5	25.3
Power (dBFS)	-4.1	-4.6	-6.2	-9.1	-14.3	-24.1	-22.0	-17.4	-16.6	-18.1

(a) Using linear interpolation between the two listed samples that bracket the half-power level, find the half-power beamwidth. The trace is symmetric about 0°.

θ_{HP} = ____

(b) Find the first-null beamwidth from the listed samples, and compare it with the array factor's value. Say why they differ.

FNBW = ____

(c) No sample reads below about -24 dBFS, 20 dB below the peak, yet the floor on this kit is 23 dB below the peak. Explain in one or two sentences why the deepest sample sits 3 dB above the floor rather than on it.

9. Reconciling a sidelobe. A cadet measures the first sidelobe of the full eight-element array at -11.5 dBc, while the array factor for $N = 8$ predicts -12.8 dB. The noise floor sits at -23 dBc.

(a) Treating the floor and the sidelobe as uncorrelated powers, compute the level the sweep should report for a true -12.8 dB sidelobe on a -23 dBc floor.

SLL = ____

(b) The floor explains 0.4 dB of the 1.3 dB difference. Name two other contributions that plausibly make up the rest, and say for each whether it moves the reading up or down.

10. Design judgment. You are asked to demonstrate a 20° beam on the PHASER at 10.3 GHz, using only the Element Gains controls.

(a) How many adjacent elements must be active to give a half-power beamwidth closest to 20°? Give the aperture and the resulting beamwidth.

N = ____

θ_{HP} = ____

(b) A classmate proposes E1 and E8 alone instead, since a two-element array "has a wide beam." Using your Part 2 data, explain in two sentences why that does not produce a 20° beam.

(c) Another classmate suggests a Hann taper on all eight elements, which widens the beam to about 19.5°. State one advantage and one disadvantage of the taper against switching elements off, and say which you would choose for a demonstration whose purpose is to show that beamwidth depends on aperture.

Documentation: _____