USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 21 LAB - Antenna Pattern
Lab Packet
Fall 2026

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

Learning Objective 3.6: I can distinguish between array factor and true antenna pattern and account for element pattern effects.

This packet is the L21 Lab, in three parts, and you turn it in once, complete, before Lesson 22. Do **Part 1** on your own before the lab period: the predictions you will test, and the error budgets of the two ways you will measure the pattern. 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, compare the two methods, and work two 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, 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. 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, range, and distance.** Use the HB100 frequency your kit reported with **Find HB100** in the L18 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 far-field distance of the array at your frequency.

   r = _____

   (c) Today's source sits 1.2 m from the array, nearly twice the far-field distance. In the Module 3 dry run, the drop in peak level at 30° read -0.7 dB with the source at 1.2 m and only -0.2 to -0.4 dB at 1 m, against an ideal-element prediction of -0.6 dB . In two or three sentences, explain why a distance that clears the far-field criterion can still be too close for a level comparison of under a decibel.

2. Reading dBc off a trace. A beam-held trace gives peak readings of -18.4 dBFS for the main lobe, -31.2 dBFS for the left first sidelobe, and -29.9 dBFS for the right first sidelobe.

(a) Convert both sidelobe readings to dBc.

L_{left} = ____

L_{right} = ____

(b) Raising **Rx Gain** by 6 dB and repeating the measurement changes the three dBFS readings. State what happens to them and to the two dBc values, and explain why the two answers differ.

3. The beam held at broadside. In Part 2 you will hold the beam at 0° and measure the pattern with the source at known angles. Predict what you should see. The array factor of a uniform array is $|AF| = |\sin(N\psi/2)/(N\sin(\psi/2))|$ with $\psi = kd(\sin\theta - \sin\theta_0)$, and the ideal element's power pattern is $\cos\theta$ (Lesson 21).

(a) Find the angles of the first three nulls on each side.

θ_1 =

θ_2 =

θ_3 =

(b) The first sidelobes of the array factor sit at $\pm 21.4^\circ$, 12.8 dB below the peak. Include the element pattern and give the first-sidelobe level you expect to measure, in dBc.

L_1 =

(c) Part 2 records the level at 10° marks across the front of the array. Using your null angles, name the marks that fall within a few degrees of a null, and explain in one or two sentences why the coarse marks alone cannot give you the sidelobe levels.

4. The beam held at 30°. Now hold the beam at $\theta_0 = 30^\circ$.

(a) Find the first null on each side of the steered beam.

inner =

outer =

(b) Find the drop in peak level relative to the broadside beam of Question 3, for the ideal element and for a patch that rolls off as $\cos^{1.4}\theta$ in power.

ideal =

patch =

(c) The array factor alone puts both first sidelobes 12.8 dB below the peak, the inner one at 7.7° and the outer one at 60.0°. Fill in the table for the array factor alone and for the element pattern times the array factor. Express each sidelobe relative to its own trace's peak.

	Array factor alone	**Element $\times$ array**
Peak angle		
Inner first sidelobe		
Outer first sidelobe		

(d) Part 2 also takes one reading with the kit turned to 180°, the source behind the board. Predict that reading, and give the reason.

5. Two ways to move the source, and their error budgets. Part 2 measures the pattern twice with the beam held fixed. In the **hand walk** you carry the HB100 around a taped arc of radius 1.2 m while the GUI plots received level against time. In the **rotation** the HB100 stays on its tripod 1.2 m out, and you turn the kit about the center of the array on its rotating stand, reading the level at known angles.

(a) During a walk your radius drifts by 10 cm either way. Received power goes as $1/r^2$. Find the change in the reading for a radius of 1.1 m and of 1.3 m.

1.1 m: ____

1.3 m: ____

(b) The walk's x-axis is time. If you convert it to angle by assuming a constant walking speed, and your hand actually moves up to 30% faster or slower than average while crossing the main lobe, give the range of half-power beamwidths the conversion reports for a true 13.0° beam.

range = ____

(c) In the rotation, suppose the kit turns about a point 20 mm from the center of the array. Find the largest angle error and the largest change in level this offset can produce at 1.2 m.

$\Delta\theta$ = ____

ΔL = ____

(d) A reflection from the room adds to the direct path in both methods. Find the relative amplitude ρ of a single reflected path that moves the reading by $+1$ dB when the two add in phase, and express ρ in dB.

(e) In two or three sentences, say which of the errors above the rotation removes, and which it leaves in place.

Part 2: Measurements (your kit, in class)

Follow the procedure on the L21 Lab page. Before you record anything, set **Rx Gain** so that the main-lobe peak, with the source at boresight and the beam at 0°, reads -10 ± 3 dBFS on the FFT, and leave it there for the whole lab. Keep the HB100 at patch-row height, 1.2 m from the array. Record each reading as you take it.

Signal Freq from **Find HB100**: _____ Rx Gain: _____ Source distance: _____ Updates/s: _____

6. **Table A: check the angle axis.** With the beam sweeping as in the L18 Lab, turn the kit so the source sits at each angle below, and record the **Angle** readout, set to **Peak**. Turning the kit's face toward E1, as seen from the source, puts the source on the $+$ side, and the stand's scale reads the opposite sign: -30 on the stand puts the source at $+30^\circ$.

Source angle (stand reads)	-30° ($+30$)	0° (0)	$+30^\circ$ (-30)
Angle (Peak)			

7. **Table B: the electrical sweep.** Kit back at 0°, beam sweeping. Read the trace.

Peak (dBFS)	**HPBW**	**Left sidelobe (dBc)**	**Right sidelobe (dBc)**

8. **Table C: the hand walk.** Beam held at 0°. Walk the HB100 from -90° to $+90^\circ$ on the taped 1.2 m arc, aimed at the array, three times. Record each walk's main-lobe peak and both first sidelobes.

	Walk time (s)	**Peak (dBFS)**	**Left SL (dBc)**	**Right SL (dBc)**
Walk 1				
Walk 2				
Walk 3				
Spread (max $-$ min)				

9. Table D: the rotation, beam held at 0°. HB100 on its tripod at boresight, 1.2 m out, beam sweeping. One rotation pass fills Tables D and E: each sweep sample is the beam held at that steer angle, so the trace at 0° steer is this table and the sample nearest 30° is Table E. Turn the kit to each mark, record the **Angle** readout (the kit's true angle; use the mark where it wanders, beyond about $\pm 70^\circ$), and record the trace at 0° relative to its value with the kit at 0°, in dB. Write "floor" where the reading stops changing as you turn.

Mark	-90°	-80°	-70°	-60°	-50°	-40°	-30°	-20°	-10°	0°
Readout										
Level										

Mark	$+10^\circ$	$+20^\circ$	$+30^\circ$	$+40^\circ$	$+50^\circ$	$+60^\circ$	$+70^\circ$	$+80^\circ$	$+90^\circ$	
Readout										
Level										

Now turn the kit slowly through each lobe and null below, and record the angle and level of its extreme, the highest reading for a lobe and the lowest for a null.

	Angle	**Level**
Main lobe		
Left first null		
Right first null		
Left first sidelobe		
Right first sidelobe		

10. Table E: the rotation, beam held at 30°. The same pass, read at the sweep sample nearest 30°. Record each level relative to the *Table D* reference, so that the drop in peak level shows directly, and place each reading at the angle the readout gave in Table D.

Angle	-90°	-80°	-70°	-60°	-50°	-40°	-30°	-20°	-10°	0°
Level										

Angle	$+10^\circ$	$+20^\circ$	$+30^\circ$	$+40^\circ$	$+50^\circ$	$+60^\circ$	$+70^\circ$	$+80^\circ$	$+90^\circ$	180°
Level										

	Angle	**Level**
Main lobe		
Inner first null		
Outer first null		
Inner first sidelobe		
Outer first sidelobe		

Part 3: Writeup (individual, after the lab)

11. Reconcile the rotation with the two predictions. Answer each part in three or four sentences, using your numbers from Part 2 and your own predictions from Part 1.

(a) Compare the first sidelobes of Table D with your prediction from Question 3, and with the electrical sweep of Table B. Say whether the element pattern is visible at broadside.

(b) Find the drop in peak level from Table D to Table E and compare it with the ideal and patch predictions of Question 4. State whether your measurement resolves the drop, given the error budget of Question 5.

(c) Compare the inner and outer first sidelobes of Table E with the two columns of your Question 4 table. Which model does your measurement support, and how large is the asymmetry compared with the measurement's uncertainty?

(d) Report your 180° reading and explain it. Then explain why the electrical sweep of Table B cannot show the sidelobe asymmetry of Table E, however carefully it is taken.

12. The walk against the rotation. Use Table C and Tables D and E.

(a) Compare the spread of your three walks with the repeatability you saw in the rotation. Could a single walk resolve the 0.6 dB scan loss? The 2.9 dB sidelobe asymmetry? Give the reason for each answer.

(b) A walk runs from $t = 0.00$ s at -90° to $t = 7.40$ s at $+90^\circ$, with the beam held at 0°, and the main-lobe peak lands at $t = 3.10$ s. Convert that time to an angle assuming a constant walking speed, and state the error.

θ =

error =

(c) Explain why the lobe *levels* on a walked trace are usable while the lobe *angles* are not, and name what an antenna range uses instead of a protractor to record the angle.

(d) The main-lobe peak and a sidelobe peak each carry their own ± 1 dB of reflection ripple. Give the worst-case uncertainty on the sidelobe level in dBc, and the range a true -13 dBc sidelobe could read.

uncertainty =

range =

(e) A customer wants written proof that this array's sidelobes are below -25 dBc. State whether either of today's measurements can support that claim, and give the two reasons that decide it.

13. How far out is far enough. A Ku-band panel with a 0.200 m aperture is to be measured at 15.0 GHz.

(a) Find its far-field distance.

r =

(b) The panel is measured on today's 1.2 m range anyway. The extra path from the source to the aperture edge, relative to its center, is about $D^2/8r$. Find the edge phase error and compare it with the 22.5° the far-field criterion allows.

$\Delta\phi$ =

(c) Describe what that phase error does to the measured pattern, and say which pattern feature it corrupts worst.

Documentation: _____