ECE422 Radio and Microwave Wireless Systems

Lab #2: Antenna Arrays

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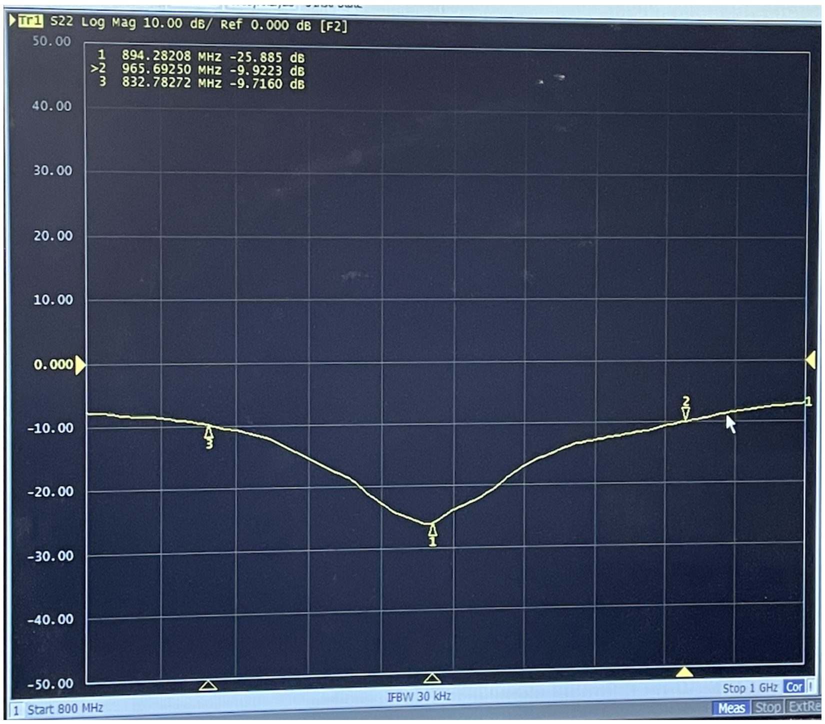
Note to TA: Our axes for the Theoretical and Experimental Radiation Pattern differ (sometimes pi/2 starts in the middle, whereas other times it's on the left-most side). We used matplot in Python and it tends to randomize the polar plot axes it generates. Rest assured, our patterns still follow the general shape and expected peaks.

2 Before You Start

After calibrating the network analyzers, determine the frequency at which the Yagi Antenna and the dipoles are operating by measuring their input reflection coefficient, and setting the marker to report measurements at this frequency. Take screen shots.

Figure 1: Logarithmic Scale



The frequency recorded was $f \approx 894\ MHz$

3 Two Element Linear Array

3.1 Two-Element Array with $d = \lambda/2$ and $\delta = 0^{\circ}$

Plot the pattern and compare it to the theoretical pattern expected from a half-wave dipole array in this configuration.

When comparing our data to the theoretical pattern, we can see it to be very similar, there are two main lobes (max radiation at 90 and 270 degrees). Any distortion could be caused by interference of ourselves or by other groups antennas as there was not a lot of space between our and other groups setups.

Figure 2: Expected Radiation Pattern of Two-Element Array with $d = \lambda/2$

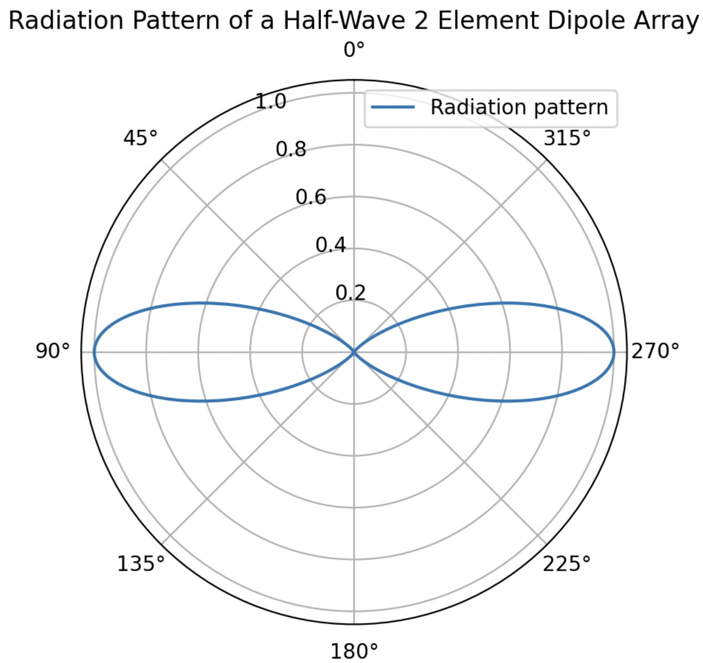
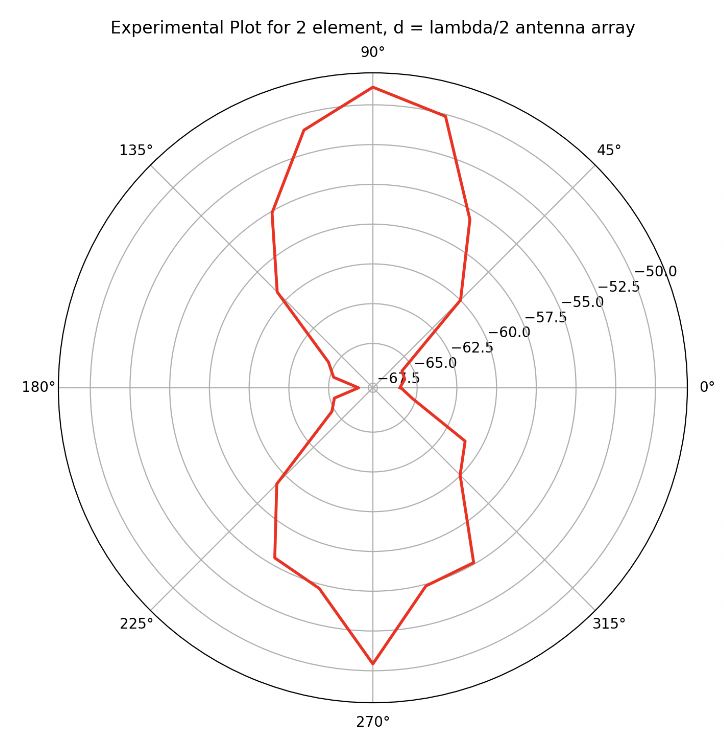


Figure 3: Experimental Radiation Pattern of Two-Element Array with $d = \lambda/2$



Degrees Rotated	dB
0	-66.089
15	-65.708
30	-65.670
45	-59.980
60	-55.570
75	-50.120
90	-48.890
105	-51.020
120	-55.094
135	-59.272
150	-64.560
165	-65.230
180	-66.887
195	-65.280
210	-64.810
225	-59.230
240	-55.440
255	-54.732
270	-50.432
285	-54.890
300	-55.099
315	-60.020
330	-61.080
345	-65.220

360	-66.020

3.2 Two-Element Array with $d = \lambda$ and $\delta = 0^{\circ}$

Figure 4: Expected Radiation Pattern of Two-Element Array with $d = \lambda$

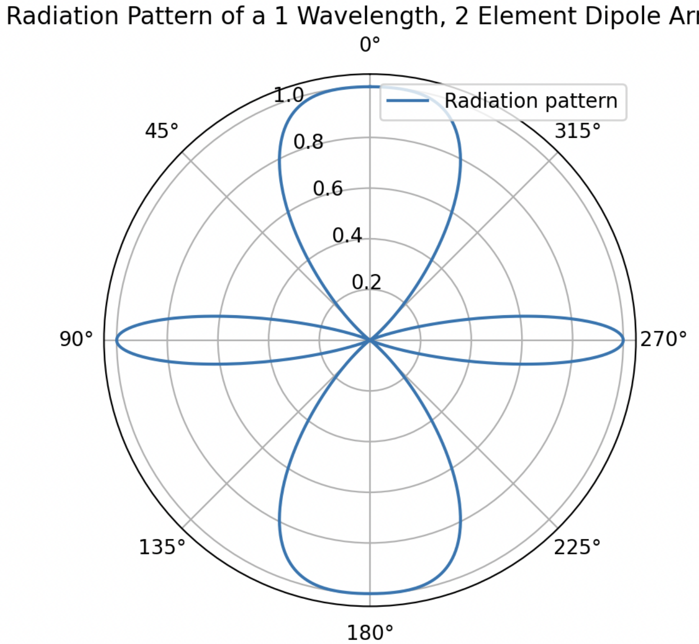
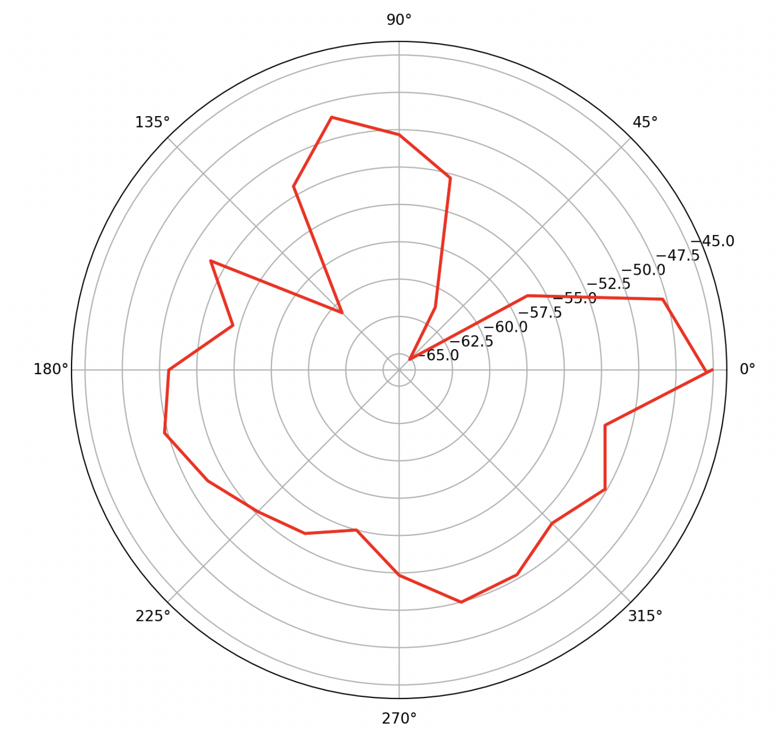


Figure 5: Experimental Radiation Pattern of Two-Element Array with $d = \lambda$



Degrees Rotated	dB
0	-45.546
15	-47.773
30	-56.132
45	-65.080
60	-61.224
75	-52.783
90	-50.334
105	-48.567
120	-51.890
135	-50.668
150	-51,467
165	-54.532
180	-50.620
195	-49.778
210	-51.246
225	-52.670
240	-53.443
255	-54.990
270	-52.340
285	-49.990
300	-50.260
315	-51.570
330	-50.123
345	-51.775
360	-45.092

Plot against the theoretical array factor.How many lobes do you observe in the pattern? Compare measurements to theory and comment on what you observe.

From 0 to 180 degrees, we observe 3 main lobes (at 0, 90, and 180 degrees). This matches our theoretical expectation as well, even though our experimental plot has multiple distortions, and no distinct minima. The sources of error have been addressed towards the end of the lab document.

3.2 Modified Two-Element Array with $d = \lambda$

Figure 6: Expected Radiation Pattern of Two-Element Array with $d = \lambda$, elements facing each other

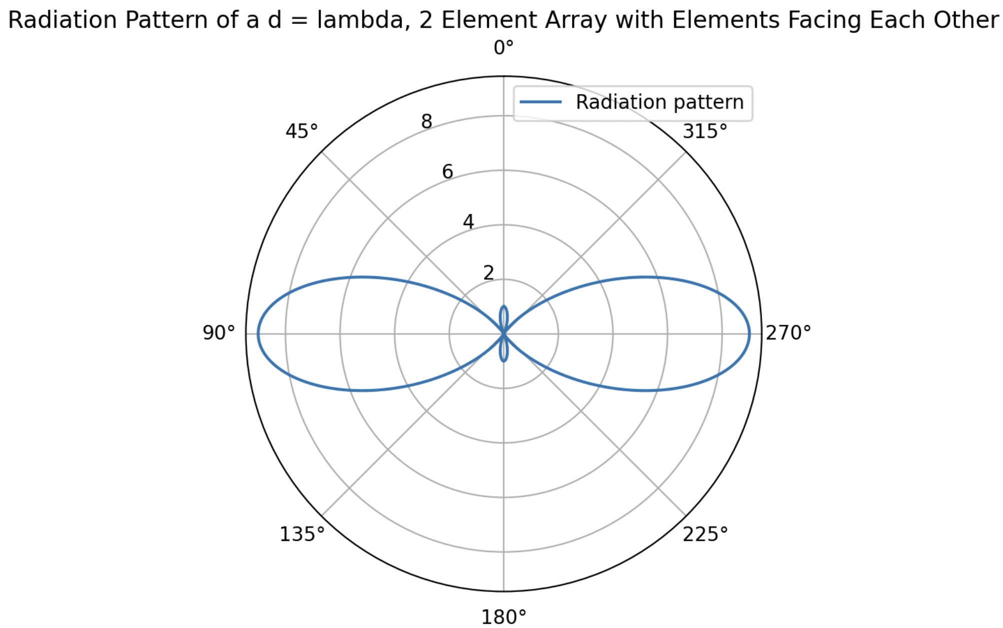
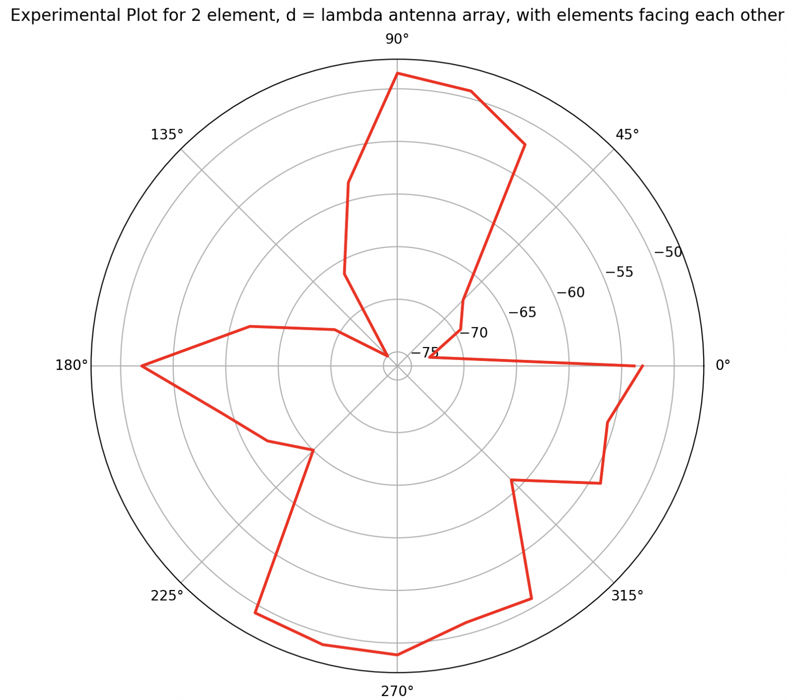


Figure 7: Experimental Radiation Pattern of Two-Element Array with $d = \lambda$, elements facing each other



Degrees Rotated	dB
0	-53.807
15	-73.171
30	-69.390
45	-67.510
60	-52.043
75	-49.290
90	-48.510
105	-58.290
120	-66.230
135	-75.009
150	-69.432
165	-61.809
180	-52.004

195	-59.020
210	-62.070
225	-65.020
240	-49.240
255	-48.911
270	-48.870
285	-51.090
300	-50.810
315	-61.020
330	-54.023
345	-55.640
360	-53.020

Explain the difference you observe compared to Section 3.2, and plot the measurements against the expected pattern.

Theoretically the side lobes at 0 degrees and 180 degrees should be smaller but in our data the lobes seem to reach max radiation, this could be due to human error when we collected this data, interference could have impacted our results

A main lobe at 90 degrees, a back lobe at 270 degrees, and side lobes at 0 and 180, are observed.

4 Four-Element Linear Array with $d = \lambda/2$

4.1 Uniform Array $\alpha = 0^{\circ}$

Figure 8: Expected Radiation Pattern of Four-Element Array with $d = \lambda/2$

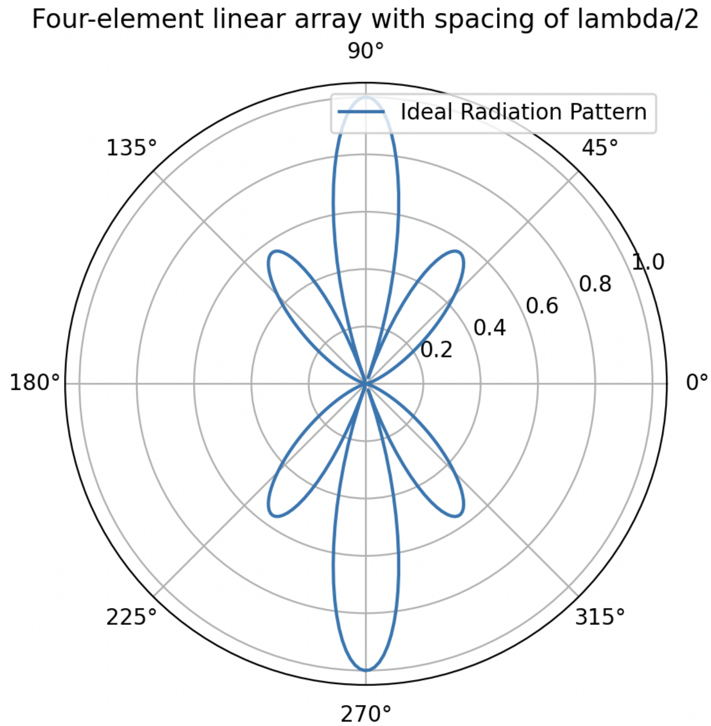
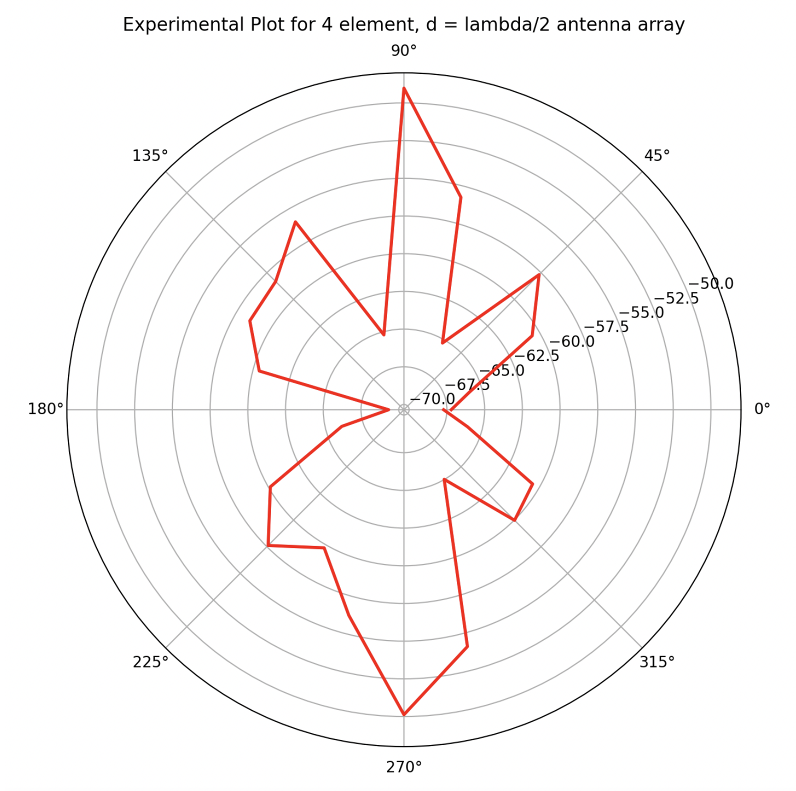


Figure 9: Experimental Radiation Pattern of Four-Element Array with $d = \lambda/2$



Degrees Rotated	dB
0	-67.213
15	-65.860
30	-60.532
45	-57.680
60	-55.240
75	-47.762
90	-47.021
105	-50.210
120	-51.960
135	-55.320
150	-60.550
165	-67.419
180	-69.332
195	-69.085
210	-63.123
225	-53.617
240	-54.770
255	-56.230
270	-52.123
285	-60.089
300	-68.019
315	-61.977
330	-65.500
345	-66.987
360	-67.718

Compare the pattern to theoretical expectations

Our theoretical expectations were to see maximum gains at 0 and 270 degrees. Again, our experimental plot follows this, albeit we observe distortions again. Any distortion could be caused by interference of ourselves or by other groups antennas as there was not a lot of space between our and other groups setups.

4.2 Progressive Phase Shift with $\alpha = 90^{\circ}$

Figure 10: Expected Radiation Pattern of Four-Element Array with $d = \lambda/2$, $\alpha = 90^{\circ}$

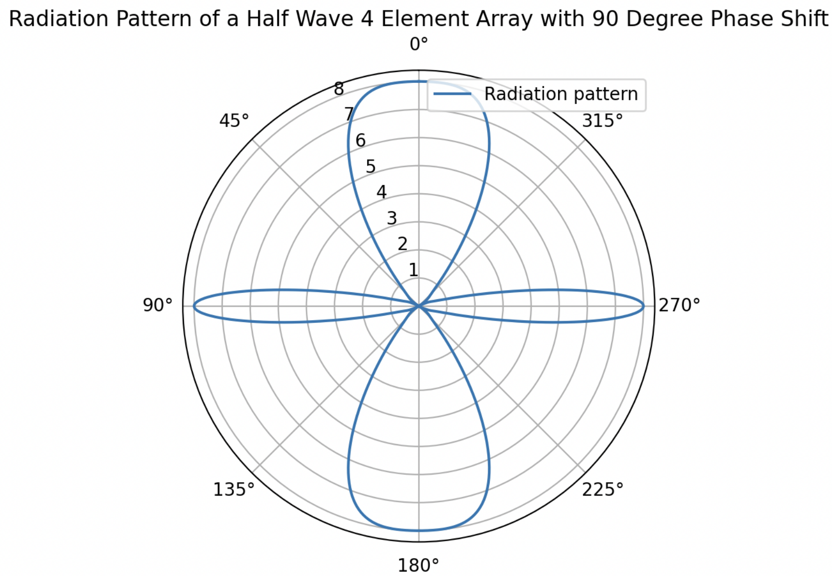
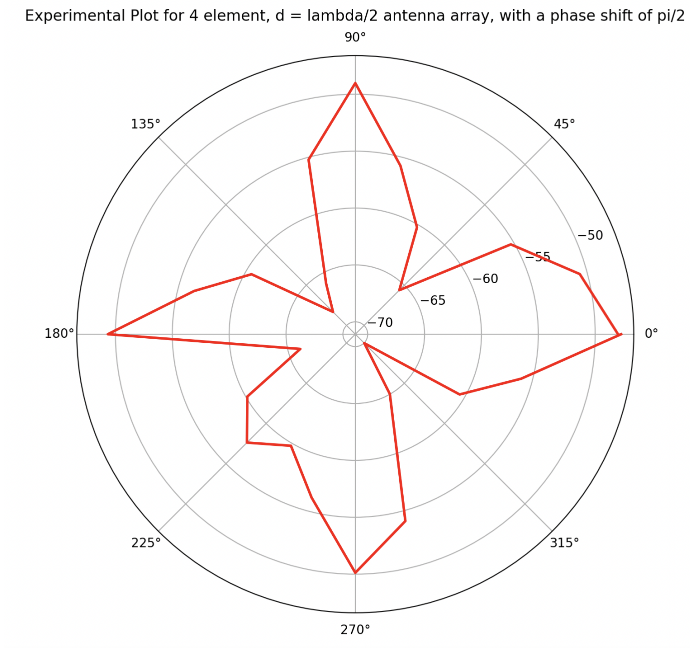


Figure 11: Experimental Radiation Pattern of Four-Element Array with $d = \lambda/2$, $\alpha = 90^{\circ}$



Degrees Rotated	dB
0	-47.993
15	-50.660
30	-55.308
45	-65.620
60	-60.081
75	-55.442
90	-49.660
105	-55.701
120	-65.230
135	-68.949
150	-60.110
165	-56.212
180	-49.980
195	-66.542

210	-60.630
225	-57.820
240	-59.223
255	-44.496
270	-57.852
285	-50.616
300	-54.701
315	-69.912
330	-69.977
345	-55.987
360	-47.943

Calculate the expected beam angle (relative to broadside) and compare it to your measurements

Expected Beam Angle:
$\theta = sin\text{^}(-1)(\lambda/(D * sin(\varphi)))$
Where θ is the beam angle (relative to broadside), λ is the wavelength of the signal, D is the distance between the adjacent elements in the array (in this case, D = λ), and φ is the phase difference between adjacent elements.
θ = sin^(-1)(λ/(D*sin(φ)))*
= *sin^(-1)(1/(1*sin(90)))
= sin^(-1)(1)
= 90 degrees

From our Data the first NULLS are at 45 degrees and 135 degrees, which corresponds to the theoretical calculation.

How would you reverse the beam angle so that it is steered on the opposite side of the broadside axis?

To reverse the beam angle so it is steered on the opposite side of the broadside axis I would apply a phase shift of 180 degrees to reverse the beam angle.

5 Additional Questions

1. Classify each pattern obtained as either broadside, endfire, or other.

Two-Element Array with $d = \lambda/2$ and $\delta = 0^{\circ}$ - Broadside

Two-Element Array with $d = \lambda$ and $\delta = 0^{\circ}$- Other
Modified Two-Element Array with $d = \lambda$ - Broadside

Four-Element Linear Array with $d = \lambda/2$ with Uniform Array $\alpha = 0^{\circ}$ - Broadside
Four-Element Linear Array with $d = \lambda/2$ with Progressive Phase Shift with $\alpha = 90^{\circ}$- Other

2. What is the approximate change in measured signal power from the array beam between the two-element array and the four-element array? Does it correspond to theoretical expectations?

Peak Gain Of Two Element Array (when $d = \lambda/2$): - 48.890 dB
Peak Gain Of Four Element Array (when $d = \lambda/2$): - 47.021 dB

In our data we can see that the four element array has a slightly less negative dB value which would result in the four element array having a larger signal power in terms of magnitude.

In theory the measured signal power should be measured higher in the 4 element array versus the 2 element array. This is because the addition of two more elements increases the directivity and gain of the antenna.

3. Explain how the patterns would have changed if the dipoles could have been mounted vertically (with the dipoles pointing along the same axis). Would it be possible to reconfigure each setup to realize this axial configuration? Why or why not?

The patterns would change as the maximum gain would be in the endfire direction instead of being in the broadside direction which is the direction they are in, in this experiment. This is because maximum radiation would be in the direction of the array axis, whereas in the experiments the maximum radiation is perpendicular to the array axis. It may be possible to reconfigure the setup by adjusting the way the antennas are mounted vertically.

Sources of Error
While constraints such as the distance between the antennas to create a far-field, and our minimal movement while taking VNA measurements were maintained, some of the following sources of errors could have been the result of our experimental plots looking vastly different

from the theoretical ones:

1) Cable losses: The cables used to connect the antenna to the VNA ports, even after calibration, can introduce losses that affect the measured power.
2) Antenna misalignment: If the antenna is not properly aligned, it may not be receiving the full signal, which can affect the measured power.
3) Signal reflections: Signal reflections from nearby structures or other antennas can cause interference and distort the measured power.
4) Interference from other sources: Other nearby sources of electromagnetic radiation, such as from other groups performing experiments closeby, radio or TV stations, may have interfered with the signal and affected the measured power.