Physical Yagi-Uda Antenna

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I. INTRODUCTION

Our group objective was to design, analyze, and fabricate a directional antenna. This task had five major objectives.

- Resonate within the 5.725 - 5.850 GHz ISM band.
- Matched to a 50-Ω SMA connector.
- No active electrical components could be present.
- Fit within a 20 cm x 20 cm x 5 cm rectangular box.
- Linearly-polarized radiation.

Any antenna topology discussed in class was acceptable but maximum directivity was the objective. The group chose to design a physical Yagi-Uda antenna. It was chosen due to its high directivity, ease of fabrication, and predictable radiation pattern.

II. Design and Simulation

Our design consisted of 12 elements: a driver element at 5.8 GHz, a reflector, and 10 directors at various lengths. The driver element was selected to be a half-wave dipole; for optimization purposes, the physical length of the driver was made just short of half a wavelength. Dimensions for the antenna were choses based on Table 1 from Balanis [1]. Once all lengths and element spacings were determined, the design was imported for simulation using NEC.

Table 1. Optimized Yagi-Uda Array Element Spacings

$d/\lambda = 0.0085$		Length of Yagi-Uda (in wavelengths)					
$s_{12} = 0.2\lambda$		**0.4**	**0.8**	**1.20**	**2.2**	**3.2**	**4.2**
LENGTH OF REFLECTOR (l_1/λ)		**0.482**	**0.482**	**0.482**	**0.482**	**0.482**	**0.475**
LENGTH OF DIRECTORS, λ	l_3	0.442	0.428	0.428	0.432	0.428	0.424
	l_4		0.424	0.420	0.415	0.420	0.424
	l_5		0.428	0.420	0.407	0.407	0.420
	l_6			0.428	0.398	0.398	0.407
	l_7				0.390	0.394	0.403
	l_8				0.390	0.390	0.398
	l_9				0.390	0.386	0.394
	l_{10}				0.390	0.386	0.390
	l_{11}				0.398	0.386	0.390
	l_{12}				0.407	0.386	0.390
	l_{13}					0.386	0.390
	l_{14}					0.386	0.390
	l_{15}					0.386	0.390
	l_{16}					0.386	
	l_{17}					0.386	
SPACING BETWEEN DIRECTORS (s_{ik}/λ)		0.20	0.20	0.25	0.20	0.20	0.308
DIRECTIVITY RELATIVE TO HALF-WAVE DIPOLE (dB)		7.1	9.2	10.2	12.25	13.4	14.2

The Yagi was simulated in NEC code before fabrication. The antenna was shown to demonstrate a peak gain of 12.8 dBi and an impendence of 25.9+j8.53Ω (Figure 1). The physical antenna model can be seen in Figure 2 and both the vertical and horizontal plane gain patterns are shown in Figures 3. A three-dimensional projection of the antenna's gain pattern is shown in Figure 4.

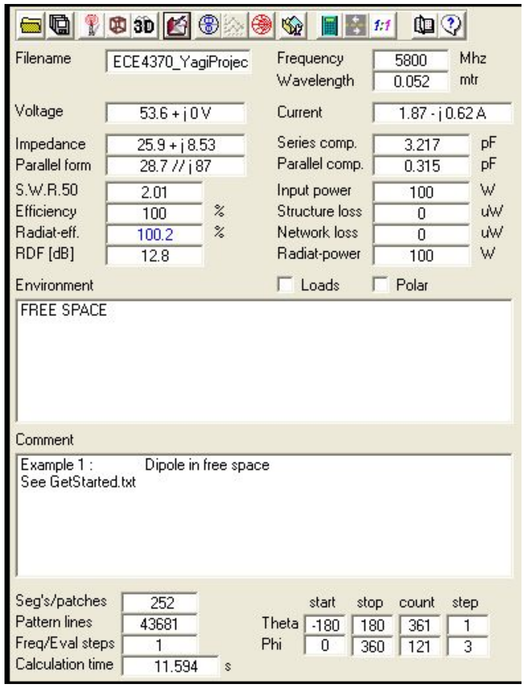

Figure 1. Horizontal and Vertical Gain Patterns

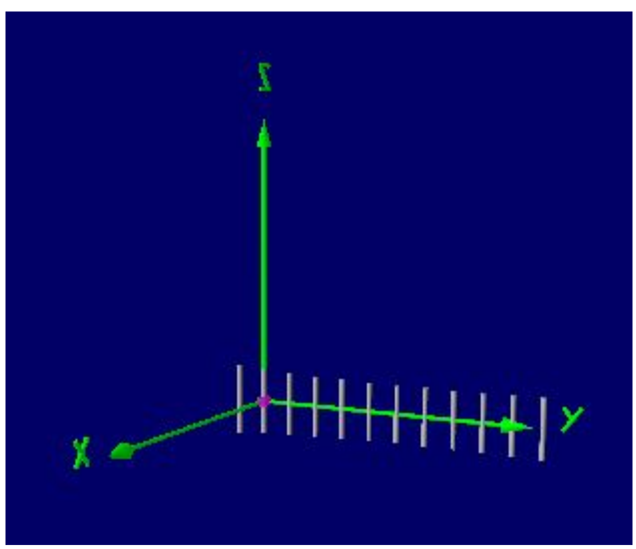

Figure 2. Physical Antenna Model

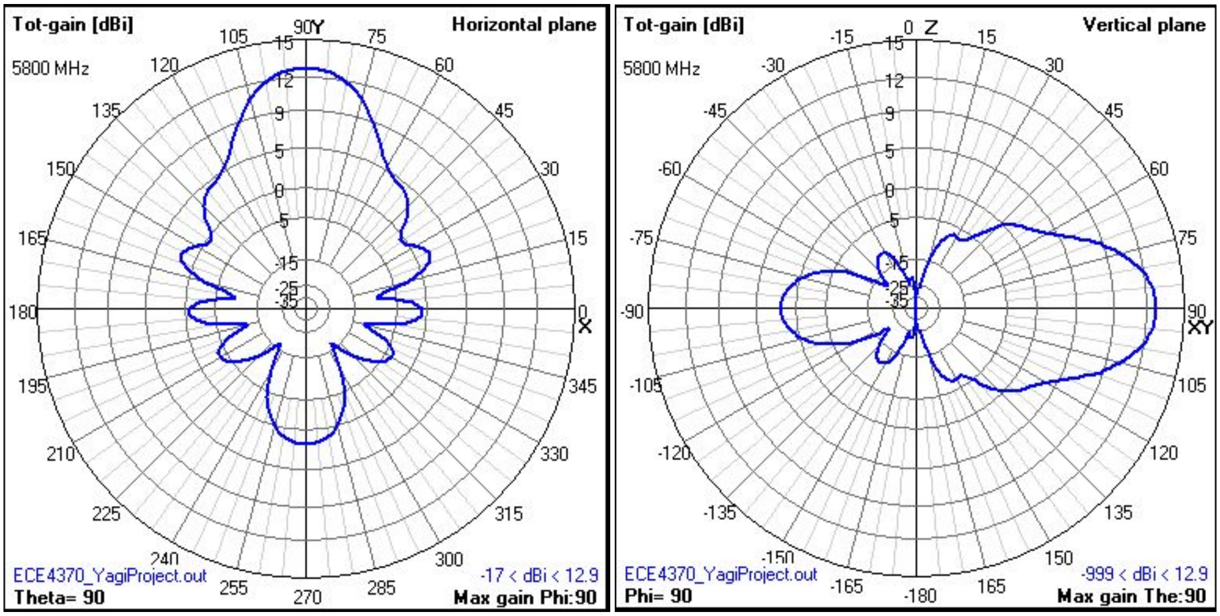

Figure 3. Horizontal and Vertical Gain Patterns

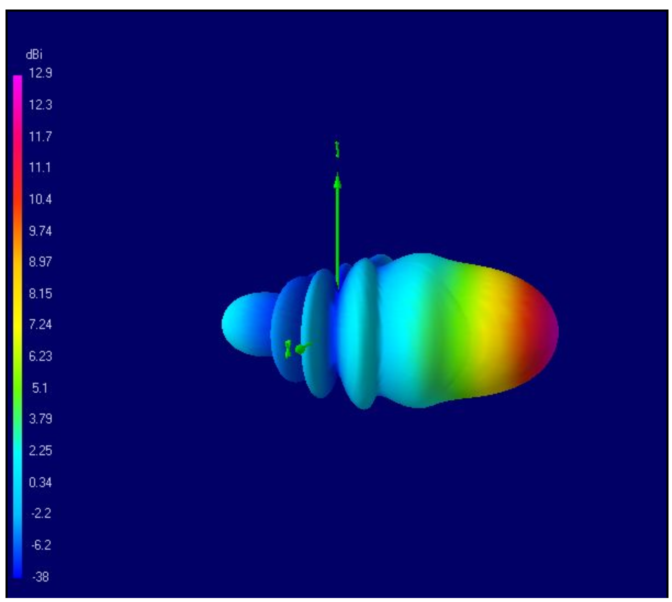

Figure 4. 3D Gain Plot

III. Fabrication

One of the major benefits of going with a physical Yagi-Uda antenna was the relative ease of fabrication. Since no milling was necessary, a micrometer was used to measure lengths of 1mm-diameter wire. These lengths were carefully cut to within 5% of the values listed in Table 1. The wire was then taped to a cardboard cutout with electrical tape. After speaking with several graduate students we were informed that neither the electrical tape nor the cardboard would significantly affect the radiation pattern, as both were insulators. The SMA connector was then soldered directly to the driving element (Figure 5). The other elements were parasitic and needed no electrical connection to impact the directional efficiency of the antenna.

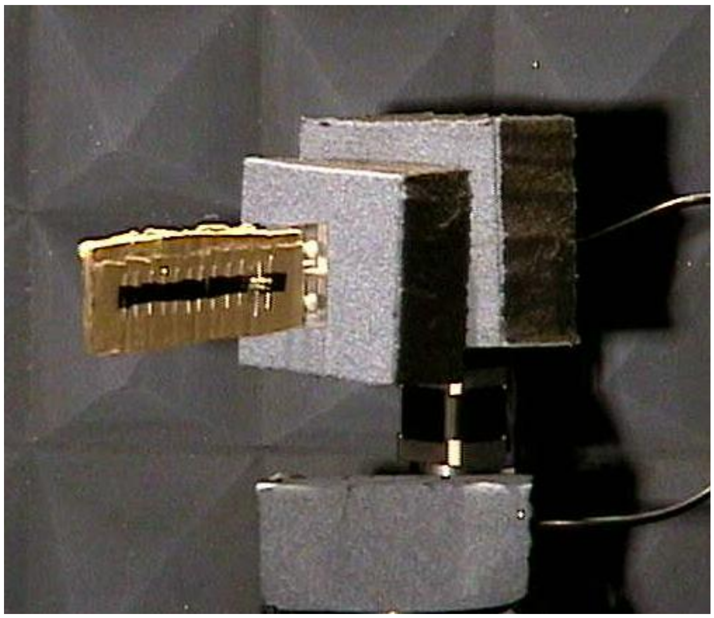

Figure 5. Photograph of Antenna in testing.

IV. Testing/Range Results

Before shipping our antenna to the range for real time testing, we connected it to a network analyzer to find the antenna's actual return loss (S11 Parameter). Figure 6 shows the image captured from the network analyzer.

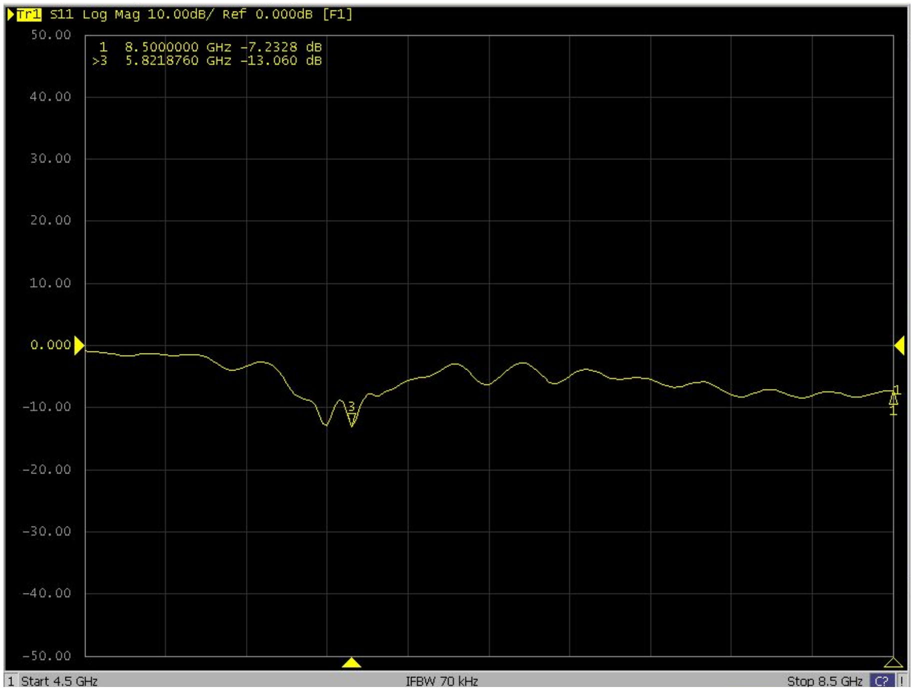

Figure 6. Return Loss - (S11 Parameter)

As shown above, the return loss at 5.821 GHz is -13 dB. We were willing to accept anything under than -10 dB, which was achieved.

Testing at the NC State antenna range produced the following results. Figure 7 shows the measured return loss at approximately -8.5.

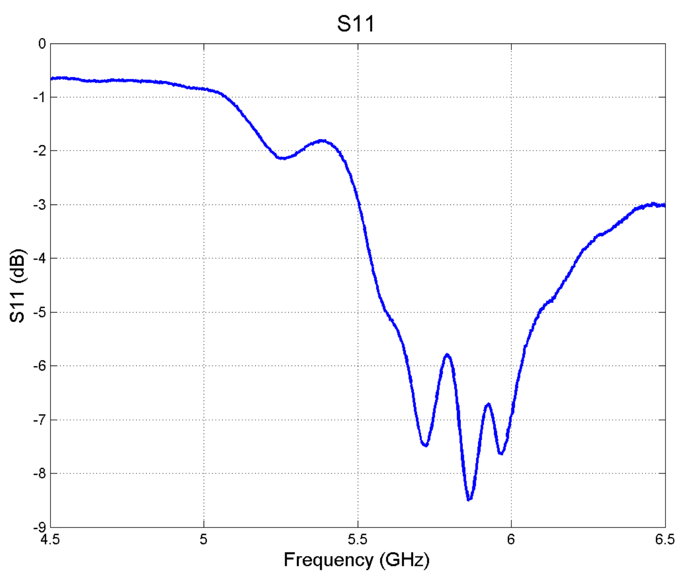

Figure 7. Measured Return Loss – (S11 Parameter)

Finally, two gain plots were measured as well. Figure 8 shows both the polar gain and the rectangular gain patterns, where we achieved a maximum gain of approximately 0 dBi.

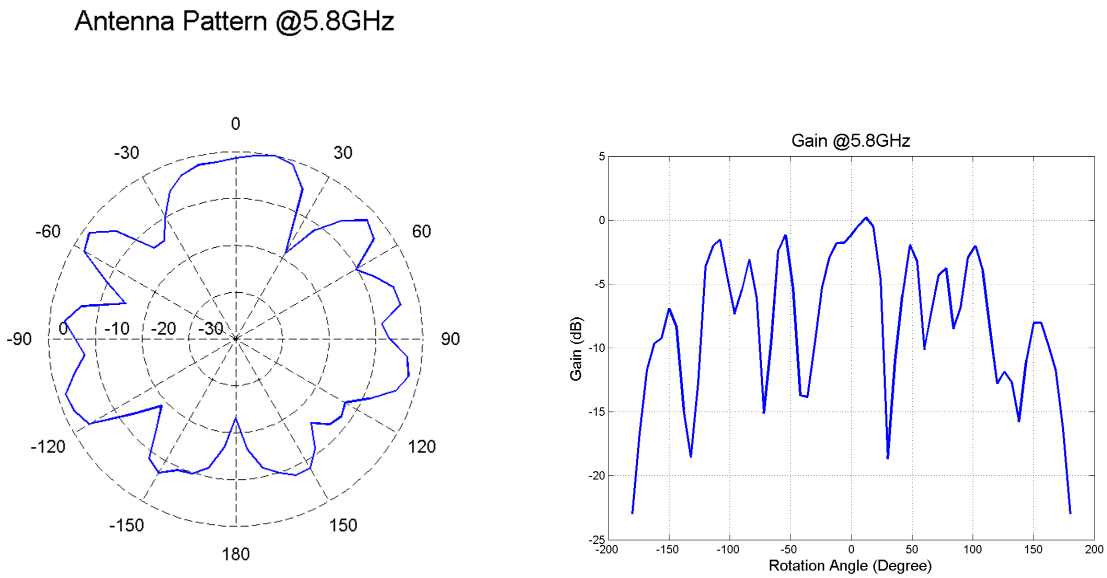

Figure 8. Measured Polar and Rectangular Gain

V. Conclusion

The data collected from the NC-State antenna range was disappointing. This could be the result of inaccuracies with the actual length of the reflector, driver, and director. Most likely, our lack of strong positive gain is the result of not including a matching network in our design. Although these patterns were measured directly at 5.8 GHz, it is very possible that the gain pattern is characteristic somewhere within the allotted bandwidth. The return loss was not minimum at the exact desired frequency; if we were to investigate other frequencies in the sideband, we could perhaps realize the expected gain from the NEC simulation.

References

[1] Balanis, Constantine A. *Antenna Theory: Analysis and Design*, ed. 3. Hoboken, New Jersey: John Wiley & Sons, Inc., 2005.