

ECE 4370: Antenna Design

Fall 2012

Design Project: 5.8 GHz High-Directivity Antenna

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Specifications:

The antenna was required to operate with linear polarization in the 5.725-5.850 GHz frequency band. This device must attach to a standard 50Ω SMA cable, and be no larger than 20cm x 20cm x 5cm. The main goal was optimization of the design to produce high directivity.

Design:

The selected topology was a microstrip patch array, fabricated on a PCB. This type of antenna is easily manufactured, and many patches can be arranged in the given space requirements to achieve high gain. It was decided that a 4 x 4 patch array (for a total of 16 patches) would be designed, shown in Figure 1.

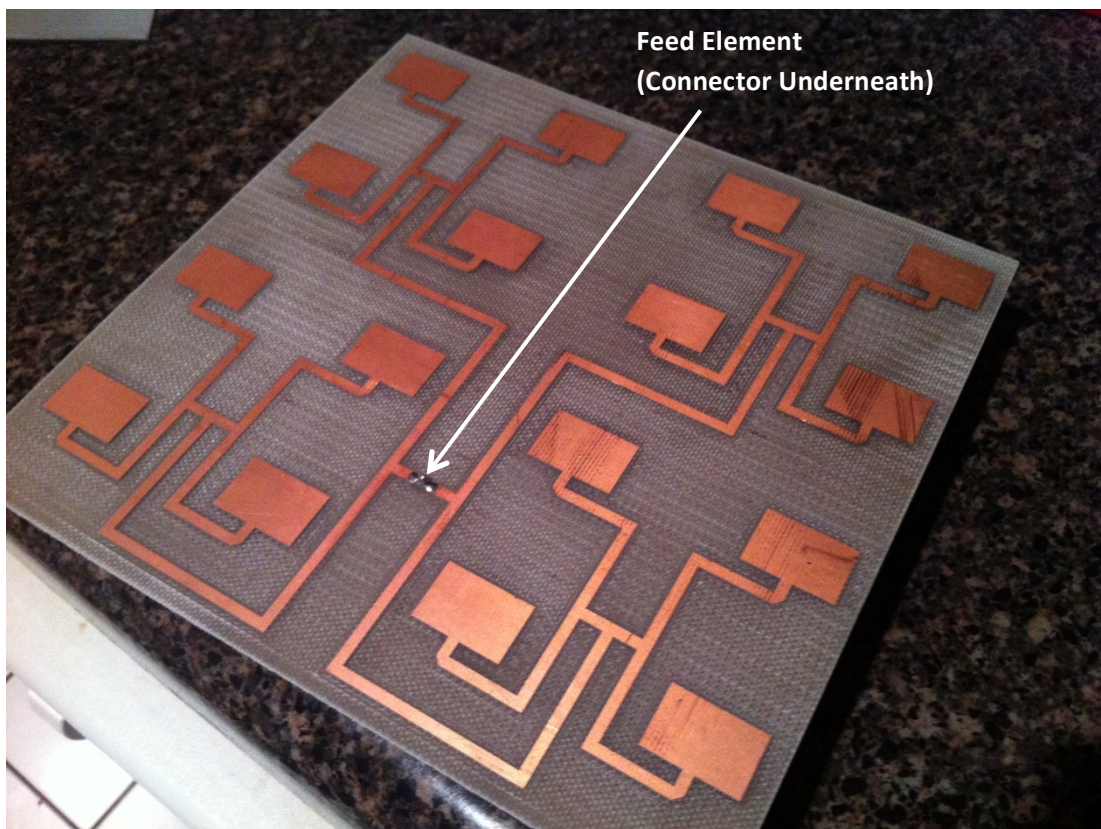


Figure 1. Fabricated 4 x 4 Microstrip Patch Antenna.

The architecture of the design was based on a paper by M. T. Ali, T. A. Rahman, M. R. Kamarudin, M. N. Md Tan and R. Sauleau. [1] The layout of the array was chosen in order to keep all of the individual patches in phase with each other simply without requiring curves for the feeding lines. While most arrays on PCB use impedance matching techniques, such as transformers and inset feeds, the design in Figure 1 does not. The width of the feeding line and the width of the patch were the only elements altered to reduce reflections. The length of the patch was chosen to be the half wave length for the dielectric substance, originally calculated at 12.46 mm. The width was chosen to be the same length, and the transmission line width to be 50Ω at 2mm. Due to our limited knowledge of computer design software, only 16 corners are chamfered. A design implementing matching transmission lines, quarter wave transformers, and patch insets was designed as well, though due to size constraints, spacing adjustments, and an exponential increase in simulation calculation time length, it was difficult to optimize properly and get a higher gain in the time allotted. The design can be viewed in Appendix A.

Computer simulation technology (CST) was used in the design of the antenna. Even with these anticipated impedance mismatches and other design issues, running simulations that included non-ideal conditions (lossy materials, etc) the antenna produced 17.6 dBi of peak directive gain. The optimization technique was done upon the width and length of the patch, as well as the wire width, optimizing for the realized gain. The resulting width of the patch was 17.476 mm and length of the patch 11.675, where the wire width remained at 2 mm.

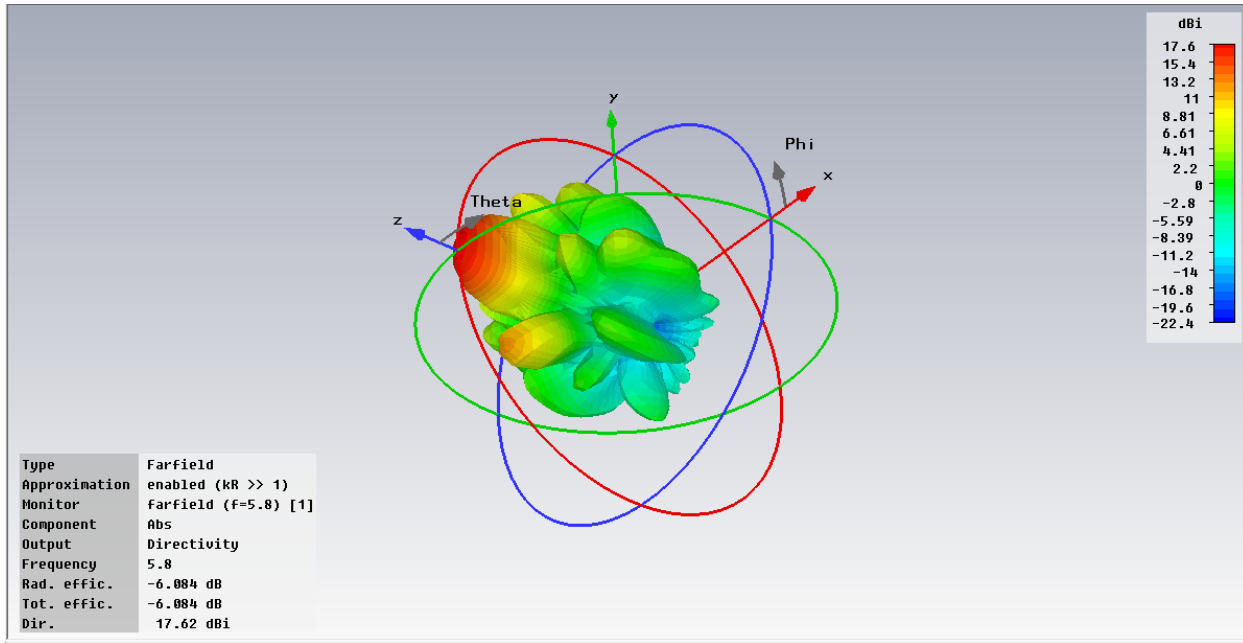


Figure 2. Non-Ideal Gain Pattern Simulation Results.

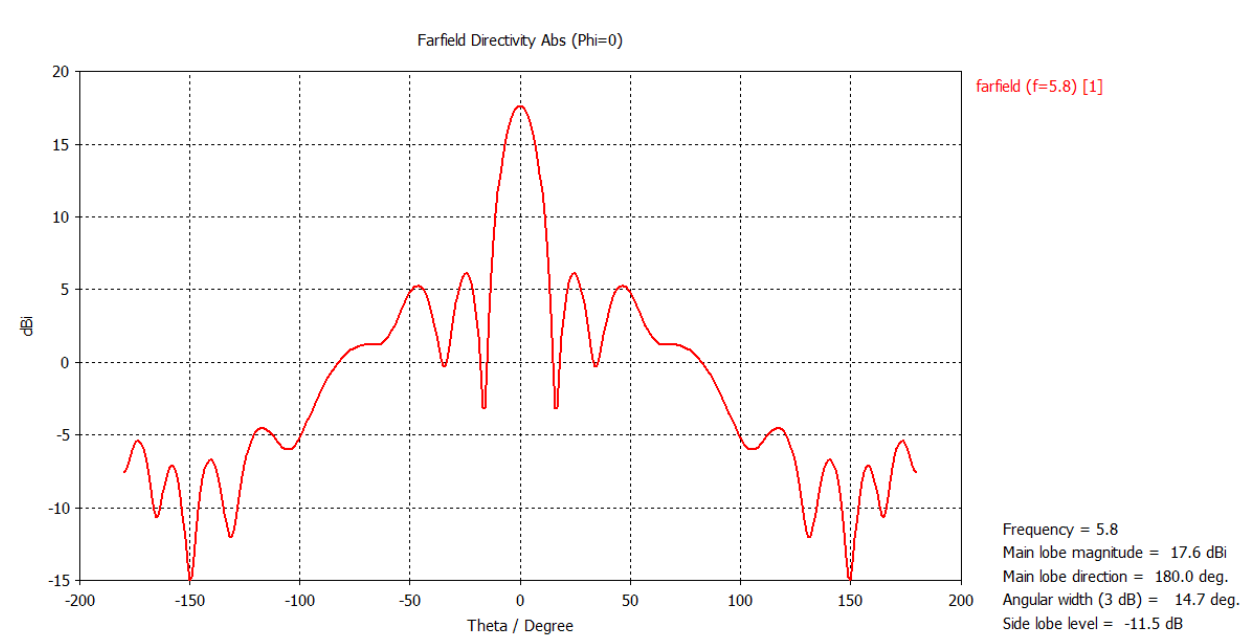


Figure 3. Directive Gain Simulation Results.

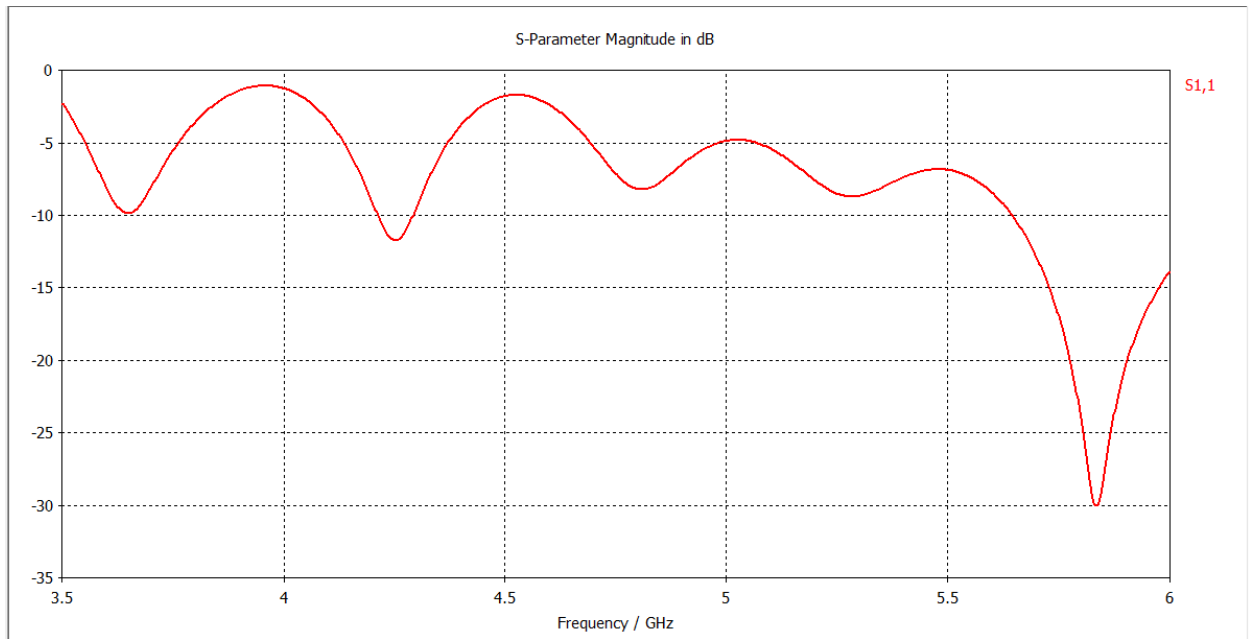


Figure 4. S11 Simulation Results.

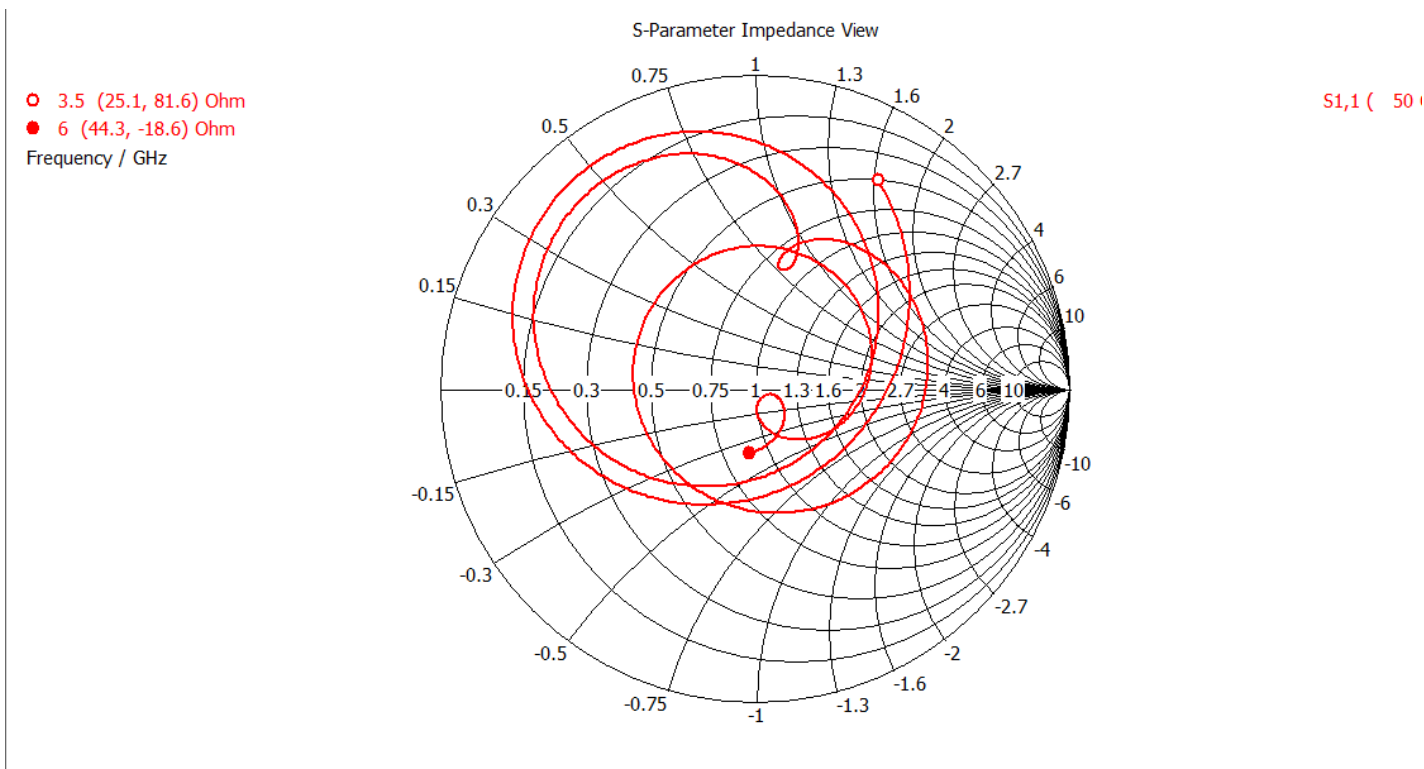


Figure 5. Smith Chart

The antenna was designed and simulated on 59mil FR-4 PCB, which has a dielectric constant of approximately 4.3. A connector was soldered in place on the back

side of the PCB, or the ground plane, and the feed element passed through a hole drilled in the board and was soldered to the microstrip lines. Other simulation files are included in Appendix B. The project costs totaled to at approximately \$33 dollars, \$6 for an SMA connector and \$26 for shipping. The double sided FR4 was provided by James Steinberg.

Testing:

After calibrating the test equipment, the patch array was rotated around the range on three degree intervals along the vertical axis of the antenna. The peak gain was found to be 18.5523dBi (Fig. 6). Phase, reflection coefficient, and smith chart figures are shown below (Fig. 7-9).

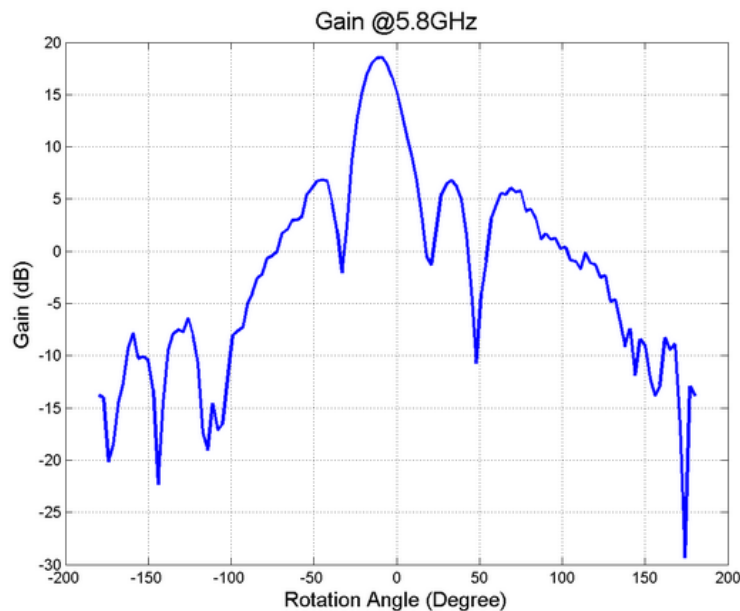


Figure 6. Gain vs. Rotation Plot of Test Results.

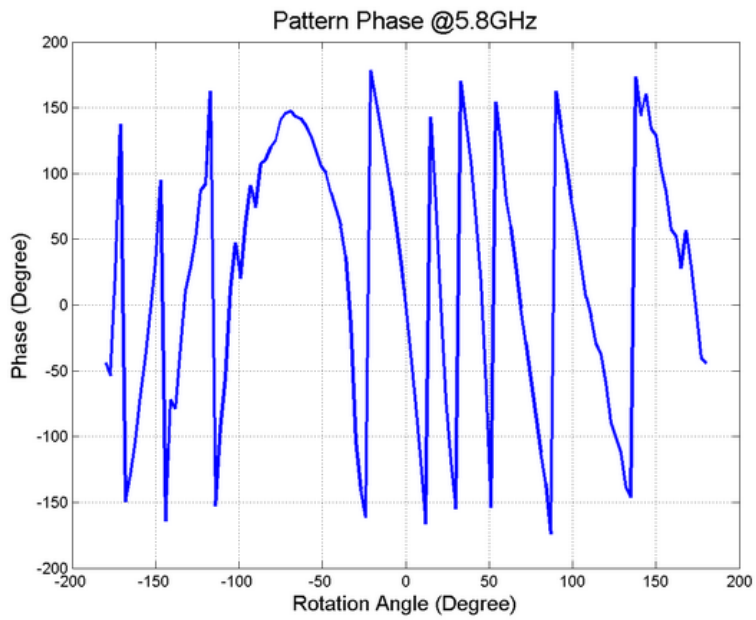


Figure 7. Phase Shift vs. Rotation Plot of Test Results.

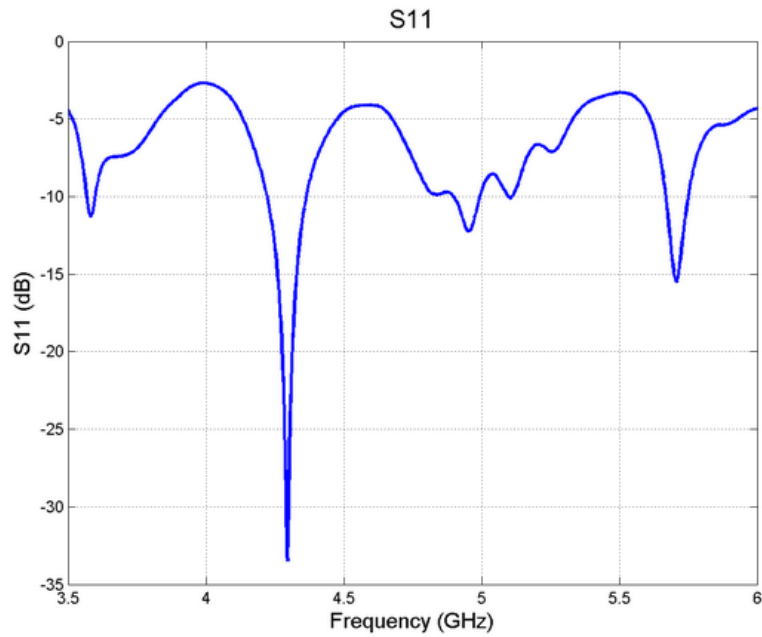


Figure 8. Reflection Coefficient vs. Frequency Plot of Test Results.

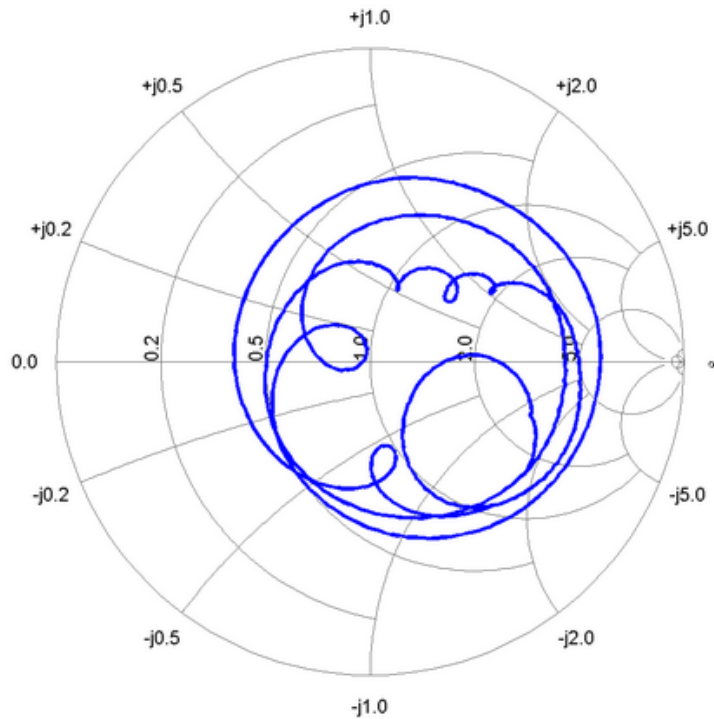


Figure 9. Smith Chart (3.5-6 GHz)

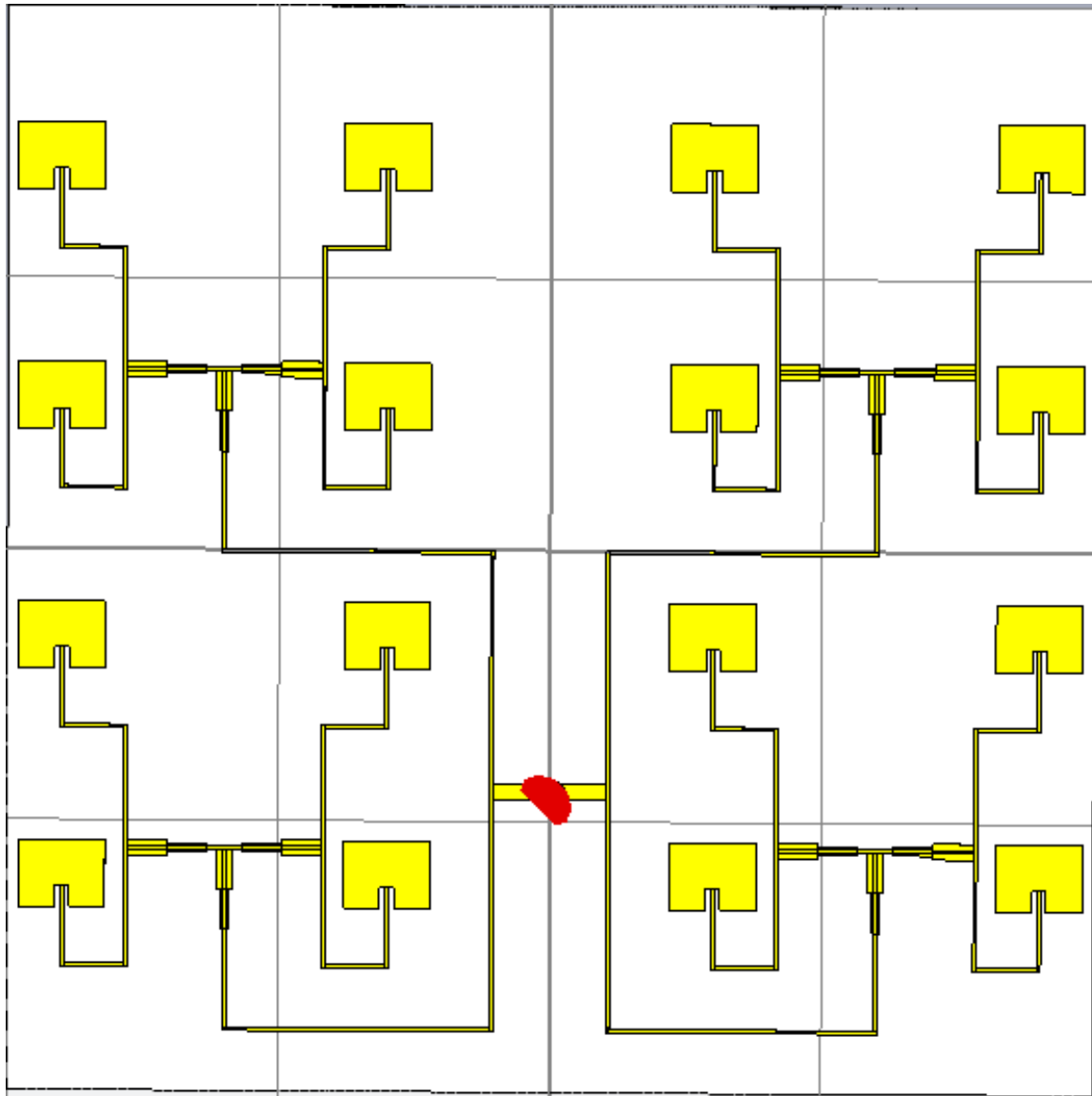
From the S11 graph (Fig. 8) it is clear the antenna accepts power at 4.3 GHz and 5.8 GHz. This is acceptable because there were no restrictions regarding possible dual-band operation.

Conclusions:

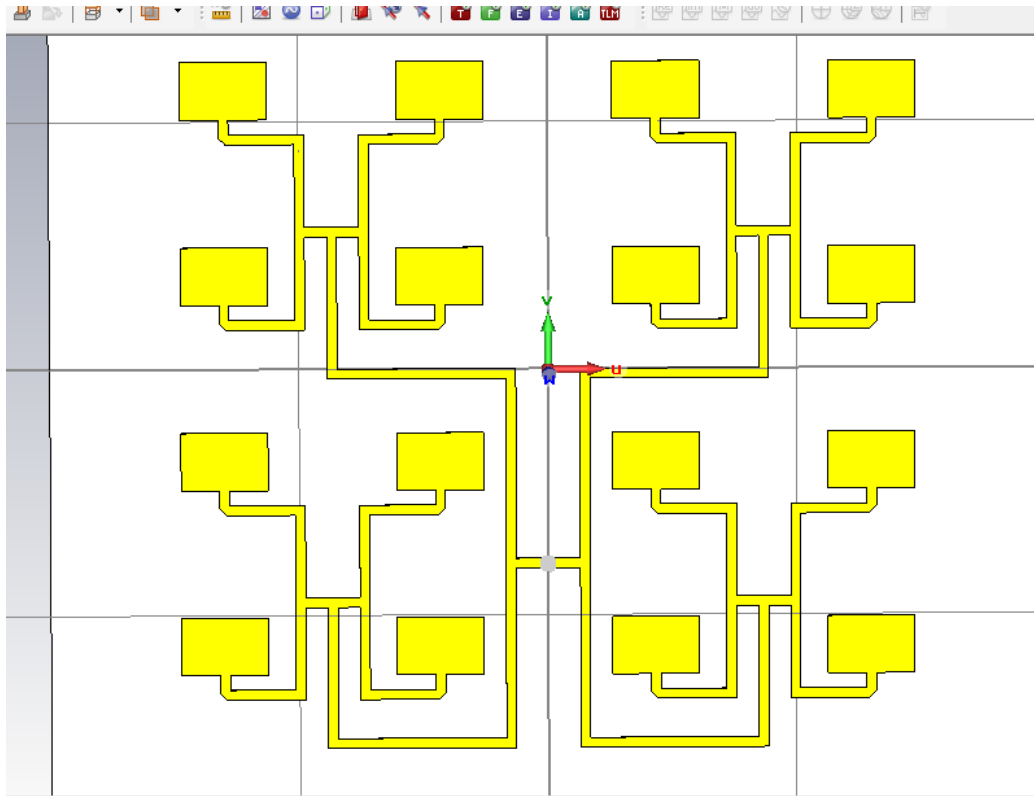
This design is an effective way to produce a high-gain antenna. Further improvements like using impedance-matching transformers and rounding edges on transmission lines will improve performance on a 50 ohm transmission line, as well as using a higher quality substrate. Also, the array performs well in the 4.2-4.4 GHz frequency range, resulting in 15 dBi of gain, which is currently allocated for Marine Mobile use. We were very satisfied at the gain that was produced from this antenna.

Appendix A:

CST Design Images with Matching Network



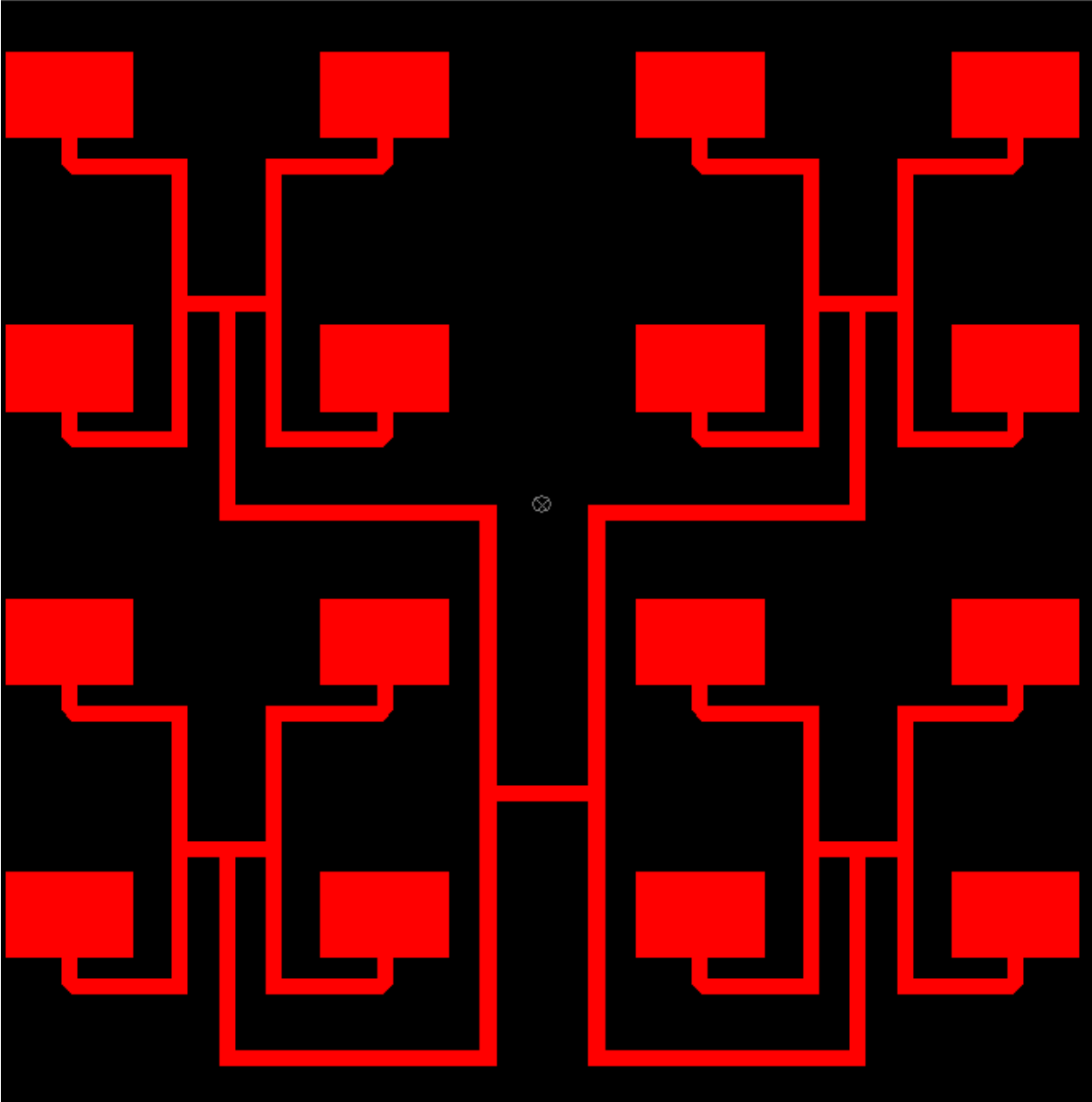
Appendix B: CST Final Design Images.



Name	value	Description	type
feedheight	- .25*200		Undefined
fr4height	1.524		Undefined
fr4width	200		Undefined
l4	51.7241/4		Undefined
lpatch	11.674941897631		Undefined
matchingstubl	0		Undefined
matchingstubw	0		Undefined
midstart	l4		Undefined
midstop	l4+lpatch		Undefined
midxstart	l4		Undefined
midxstop	l4+wpatch		Undefined
sidetl	wpatch		Undefined
spacing	25.86205		Undefined
tl	8.25		Undefined
tlw	.5		Undefined
topstart	l4+lpatch+spacing		Undefined
topstop	l4+lpatch+spacing+lpatch		Undefined
wavelength	51.7241		Undefined
wirethick	.0381		Undefined
wirewidth	2.0031348320574		Undefined
wpatch	17.476		Undefined

Global

**Appendix C:
Gerber Image**



Citation:

[1] M. T. Ali, T. A. Rahman, M. R. Kamarudin, et al, "A PLANAR ANTENNA ARRAY WITH SEPARATED FEED LINE FOR HIGHER GAIN AND SIDELobe REDUCTION," *Progress In Electromagnetics Research C*, Vol. 8, 69-82, 2009