# Compact Circularly Polarized Antenna Design

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***Abstract*—This report summarizes the results of research activity conducted during the summer of 2014, supported by the MTT-S Undergraduate research scholarship. The project goal is to design a compact circularly polarized antenna for use in space communications. An initial design was created and simulated. A rough prototype was built and tested. This project is still ongoing as the author's masters thesis.**

## I. Introduction

THIS research project seeks to design a compact circularly polarized antenna for use on future communication devices. Possible applications include compact satellites and arctic communications. Circularly polarized (CP) antennas are often used for space based communications because they can establish a link without needing to be as perfectly aligned unlike a linearly polarized antennas would be. Since satellite launches are extremely expensive, reducing the size and weight of satellites has been a priority of many companies in the aerospace industry. Making the antennas on a satellite smaller helps to reduce the weight of the satellite, as well as save space for other components such as solar panels. Compact CP antennas also have some applications in long range land communications such as in the arctic, or for small tracking devices in which the orientation of the antenna can vary, such as RFID tags.

## II. Antenna design

For satellite applications circular polarization (CP) is required because linearly polarized signals may be rotated as the signal passes through the atmosphere which in turn would reduce signal reception or prevent connection entirely. CP is also used for satellites because the movement of the satellite makes aligning linear polarized antennas difficult. Depending on the application requirements, a wide beam pattern may be advantageous. It is also desirable to use a low profile antenna to eliminate the need for an antenna deployment mechanism and make the design more robust. Low profile antennas can also reduce satellite launch costs by weighing less than alternative antennas [1].

An initial literature review provided a basis for possible circularly polarized antenna designs. Circular polarization can be achieved in one patch antenna element by truncating a square patch or adding a slot. These modifications cause two orthogonal patch modes to be generated and thus the electric fields to rotate around the patch with time. An example of this method was designed by Nasimudden et. al. in [2] Their design used a circular slot in a patch with a parasitic patch above with another circular slot to achieve a wider bandwidth. Another way to achieve circular polarization is to have four rectangular patches oriented perpendicularly in a circular array and fed in quaduture. Quaduture is a feeding scheme in which each of the four elements are fed ninety degrees out of phase from one another. An example of this method by Podilchak et. al. in [3]. This design used folded shorted patches rather than single layer patches to reduce size from 0.5 $\lambda$ to 0.06 $\lambda$.

Antenna size can be reduced by folding and shorting patches along the null in their electric field. This null occurs at the center of a typical rectangular patch [4]. Thus shorting at this point can reduce the antenna size by fifty percent. Also using high dielectric constant substrates shortens the guided wavelength and thus the length of patch necessary to have the same electrical length as compared to a substrate with a lower dielectric constant.

While many designs are being considered, the first to be examined in detail was to attempt to achieve circular polarization using two folded shorted patches fed ninety degrees out of phase. Different orientations were examined and the one shown in Figure 1 resulted in the best performance. This design is more compact than having four patches fed in quaduture. Having multiple antenna elements placed closely together leads to high mutual coupling between elements. The coupling between antenna elements was measured by $S_{1,2}$ to be -20dB at its highest, which can be improved upon to increase the gain of the antenna. Different methods are being investigated to mitigate this issue, for example defected ground structures, parasitic patches and

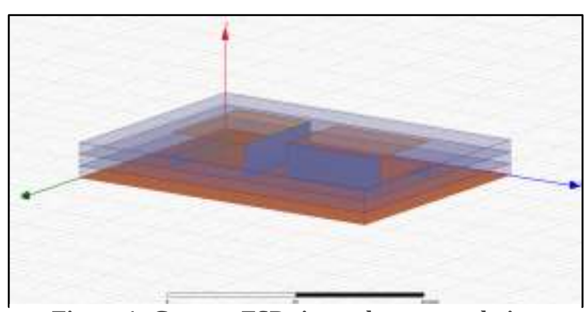

**Figure 1: Current FSP circ. pol. antenna design**

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decoupling networks. The orientation of the patches shown in Figure 1 does reduce the coupling slightly as opposed to other orientations, however further reduction in the coupling is necessary.

## III. Fabricated Prototype

A single element folded shorted patch antenna was fabricated rather than the two element design. This single element consisted of three layers of dielectric substrate. The patches on the layers were chemically etched from the substrate.

The fabricated antenna was then measured to compare against simulation results. Firstly the $S_{1,1}$ reflection coefficient was measured using a Vector Network Analyzer. The reflection coefficient represents the ratio of the power reflected to power introduced at the input port. Therefore a lower value for the reflection coefficient is desired since more power will be radiated by the antenna instead of being reflected at the source. This results in a more efficient antenna. The fabricated antenna did not perform as well as the simulation predicted. This is due to errors in the fabrication process used, as measurements and chemical etching was all done by hand. A more precise manufacturing method will be used to test the final design.

**Figure 2: Image of Fabricated FSP Antenna, 2 folds**

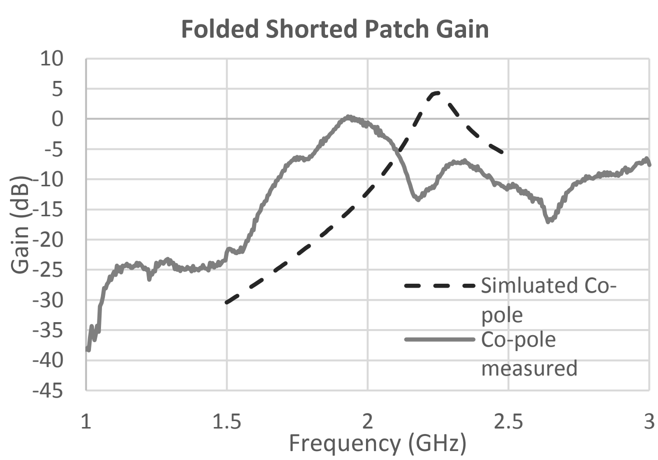


**Figure 3: Gain of single FSP**

Then the antenna gain was measured using the anechoic chamber. The gain of an antenna is a measure of the efficiency of an antenna to convert electrical power input to radiate waves in a certain direction or vice versa for a receiving antenna. The anechoic chamber measures this by dampening nearly all reflections of the electromagnetic waves produced by the antenna. It also shields the contents from external signals to prevent interference with measurements. Then it measures the power received by a known receiving antenna compared to the amount of power it input in to the transmitting antenna. The chamber was calibrated using a standard transmitting horn antenna. Once again the fabricated antenna performs poorly due to errors in its fabrication. The fabricated patch achieved 0dB of gain rather than the expected 4dB.

## IV. Conclusion

Circularly polarized antennas are very useful for satellite communications. Making these antennas smaller and more efficient can greatly improve satellite abilities and reduce costs. This research project aims to create an improved design which will have these benefits while maintaining good performance. Thus far a design and prototype have been created and still require further improvement.

## V. Future Work

This project is continuing as the author’s masters thesis after beginning as an undergrad summer research project. Further research into antenna element isolation techniques and other antenna compacting techniques will be conducted. Other possible designs will be explored and evaluated. Professional fabrication of a prototype will be conducted near the end of the project.

The MTT-S undergraduate research scholarship has encouraged and supported me in entering the field of antenna design as well as their integration with feeding networks, optimization approaches, and isolation techniques for improved device efficiency. Support in attending an MTT-S conference will allow me to broaden my knowledge in the field and make connections in the industry. After completing my masters I plan to enter the communications or aerospace industries as an antenna or RF circuit engineer.

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