# Dual Feed Omni-directional Antenna for Adaptive Polarization and MIMO Transceivers

Dr. Steven Schennum, Brian Gravelle, Caitlin Croskrey, James Smock (Gonzaga University, Spokane, WA USA), Robert Conley (Eigen Wireless, Liberty Lake, WA USA)

**ABSTRACT**

A prototype for an omni-directional multi-port antenna was developed. This antenna consists of two collinear helical elements fed from transceivers having a common local oscillator for phase control. The helical elements are orthogonal. One helix generates a right-hand circular wave, while the other generates a left-hand circularly polarized wave. From these elements, any polarization can be transmitted or received in an omni-directional pattern by controlling the phase and magnitude of the signals feeding the two elements.

Measured results from the prototype show reasonable agreement with the simulated results. The prototypes have a center frequency of 874MHz, and a gain of 0dBi. They are cylindrical in overall shape, having a 2” diameter and a 5” length. This scalable design is suitable for mobile and fixed multiport transceiver deployments.

## 1. INTRODUCTION

MIMO system capacity can be dramatically improved via antenna polarization selection and array configuration [1]. Multi-Feed Multi-Polarized (MFMP) antenna arrays are enjoying increased availability in frequency bands associated with MIMO industry-standards based equipment such as LTE Advanced base stations and 802.11n/802.11ac access points. These MFMP arrays typically exhibit directional patterns as are generally required in LTE cellular deployments and to achieve low cost construction for consumer Wi-Fi access points. MFMP arrays which exhibit deep antenna pattern nulls will not realize the expected MIMO capacity improvements.

Cognitive Radio (CR) techniques are now being applied to existing single antenna radio systems to improve capacity and avoid interference [2]. CRs can employ a number of techniques to improve communication performance in interference burdened environments. For example the CR may adjust physical layer and Media Access Control (MAC) layer parameters through power control, adaptive beam forming, adaptable data rate, dynamic frequency selection, adaptive receive filtering etc. [3]. Although extensively studied [4,5,6,7], Adaptive Polarization (AP) is an oftentimes overlooked technique for interference mitigation [8], particularly in the context of Single Input Single Output (SISO) radio standards.

Just as MIMO channel capacity is improved by careful antenna array selection, AP enabled CR systems benefit by adding high performance MFMP arrays to their CR toolbox.

### 1.1 Theory

The antenna presented here combines two basic theoretical concepts to produce the desired result. First, radial mode helical antennas are known to produce circular polarization in an omni-directional, or dipole, pattern [9]. Recently, Iqbal et al. have presented a circularly polarized helical antenna with an omni-directional radiation pattern and improved radiation characteristics [10] as illustrated in Figure 1. This design can produce either right or left hand circular polarization, depending on the direction of helix rotation. Furthermore, it has been shown that an antenna comprised of two elements with orthogonal polarization, specifically right and left hand polarization, can produce any desired polarization by manipulating the phase of the signals feeding the elements.

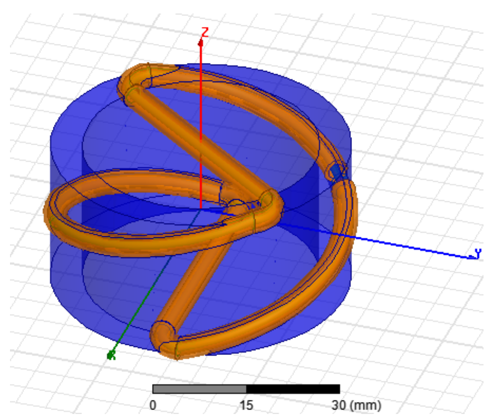


**Figure 1 Helical Element with Form**

By combining two elements fashioned as in Iqbal's antenna but with opposite winding directions from one another as illustrated in Figure 2, the fields can be manipulated to produce any linear or elliptical polarization in an omni-directional pattern. For example, feeding the elements in phase produces a horizontally polarized wave, and a factor of (1+j) applied to one feed and (1-j) applied to the other should produce a slant 45° polarization. Thus, the combined antenna will have an omni-directional pattern having any polarization required.

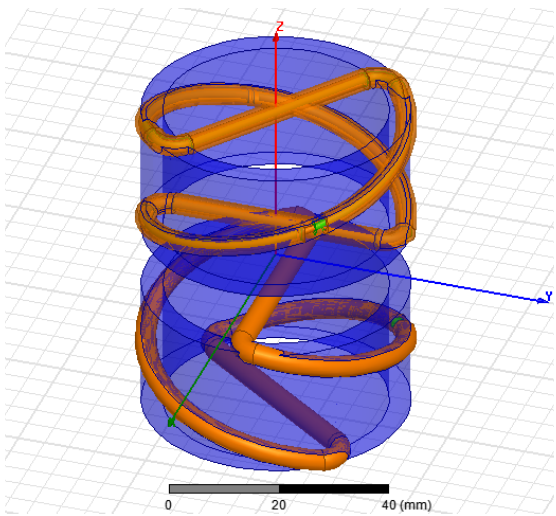


**Figure 2 RH and LH Helical Elements with Forms**

## 2. Omni-directional Multiple Polarization Helical Antenna (OMPHA)

### 2.1 Implementation

The antenna element was first implemented in Ansys HFSS as shown in Figure 3. The antenna was constructed using a 0.086" coaxial cable model.

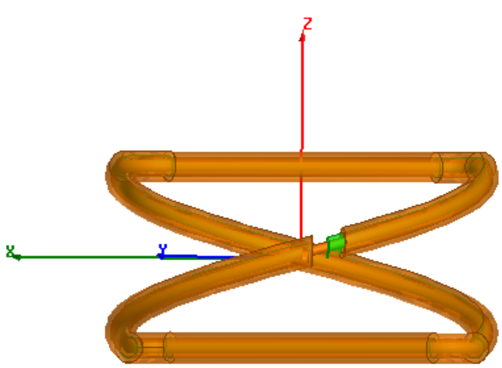


**Figure 3 Helical Element (Side View, Form removed)**

The coaxial cable jacket is the radiating conductor and also provides the function of a balun. For clarity a top view is also provided in Figure 4.

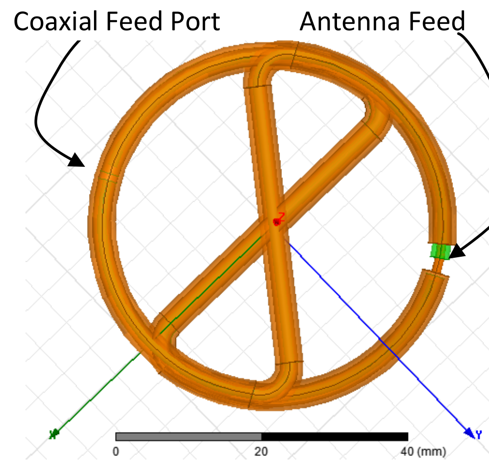


**Figure 4 Helical Element (Top View, Form removed)**

The HFSS coaxial feed lumped port is embedded within the coaxial cable between the center conductor and the inside diameter of the jacket as shown in Figure 4 and detailed in Figure 5.

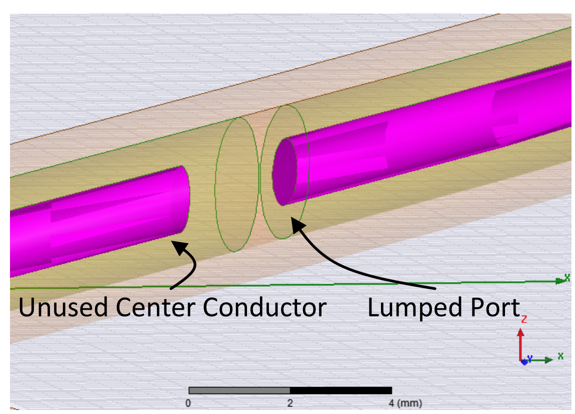


**Figure 5 Helical Element Coaxial Feed Port**

## 3. OMPHA Simulation

These elements were then simulated using HFSS software to establish the orthogonality between right and left handed polarizations.

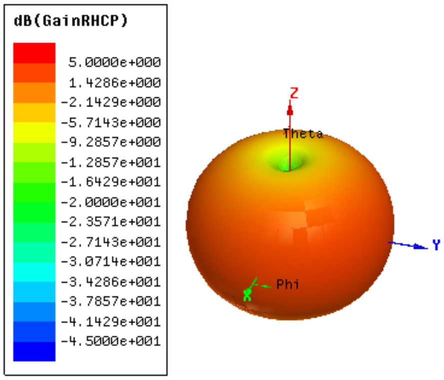


**Figure 6 Right Handed Pattern from Right Handed Element**

Figure 6 shows the right handed circularly polarized (RHCP) pattern from an RCHP element, while Figure 7 shows the left handed circularly polarized (LHCP) response, or cross polarized response, from the RHCP element.

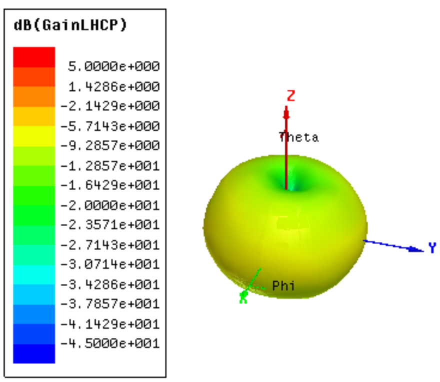


**Figure 7 Left Handed Pattern from Right Handed Element**

Note that Figure 7 indicates a similar pattern to Figure 6, but the pattern is attenuated by roughly 15 dB. This result indicates good cross polarization rejection. The simulated results for the left handed element are identical to those of the right handed element, therefore they are not illustrated here. Incidentally the vertical and horizontal components of the pattern are identical and are 3db below the RHCP polarization as expected.

## 4. OMPHA Fabrication and Measurement

The OMPHA is comprised of a rectangular loop of coax wrapped around a plastic form fabricated on a 3D printer.

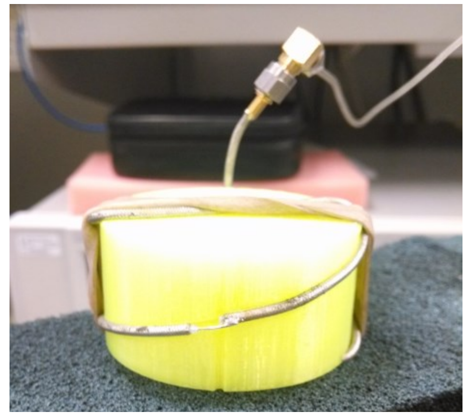

**Figure 8 Helical Element on Printed Form**

The physical antenna elements were fabricated on a 3D printed form as shown in Figure 8.

### 4.1 OMPHA Pattern Measurements

The antenna pictured in Figure 8 was collinearly aligned with its polarization counterpart and mounted on the multi-axis positioner in the anechoic chamber.

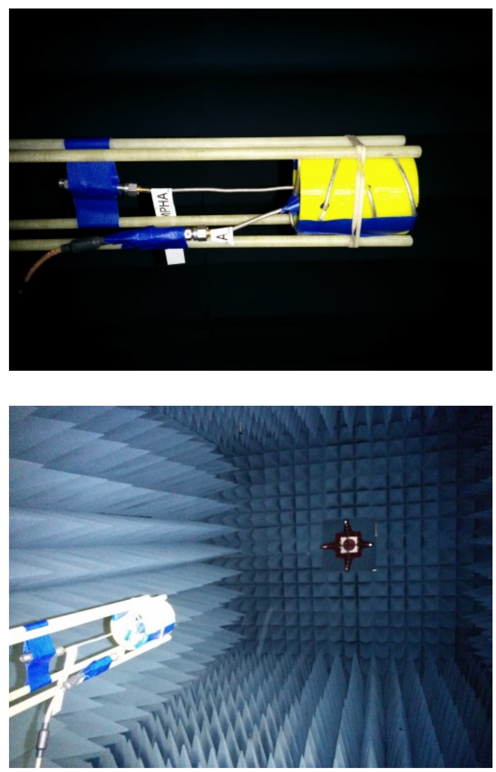

**Figure 9 Chamber Measurement Setup**

The measurement setup is shown in Figure 9.

### 4.2 Measured Results

Figure 10 shows the measured pattern of an individual element. This pattern has an irregularity near the top possibly due to the mounting hardware. The gain was approximately 0dB in the x-y plane. The gain is illustrated in more detail in the axial and azimuthal cuts in Figure 11, Figure 12 and Figure 13.

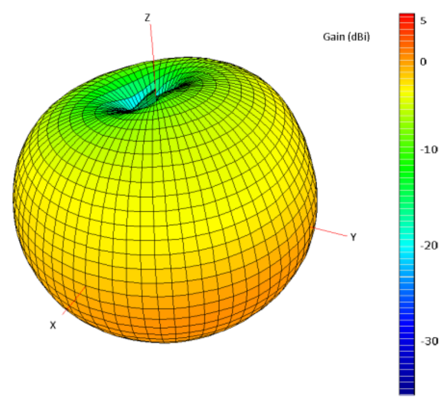


**Figure 10 Measured LHCP pattern**

The azimuthal pattern shows a gain of almost 0dBi at a measurement angle of 60° and the azimuthal variation is less than 2dB. The other patterns show a similar maximum. The scales on Figures 10-12 are all 2dB/div, and the outermost circle is 2dBi.

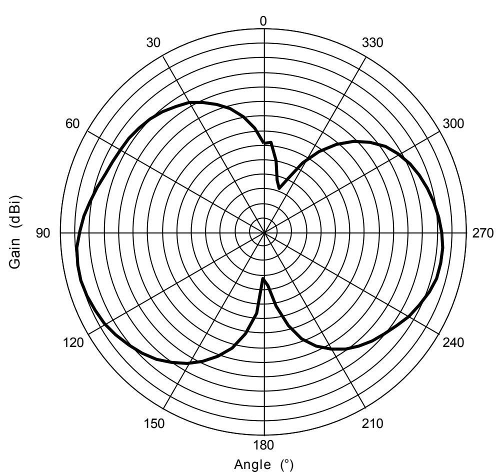


**Figure 11 Measured LHCP pattern in x-z plane**

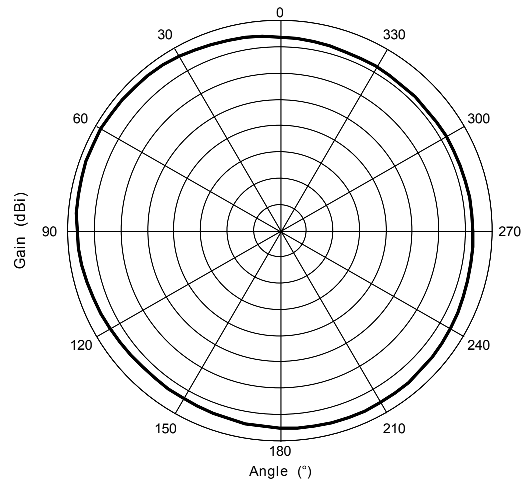


**Figure 12 Measured LHCP pattern in x-y plane**

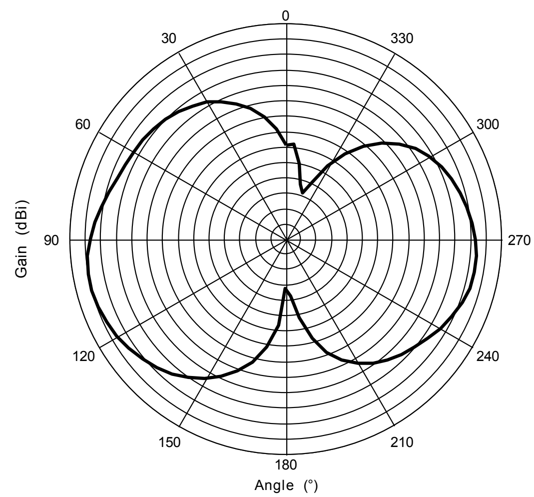


**Figure 13 Measured LHCP pattern in y-z plane**

Figure 14 shows the resulting pattern when the RHCP and LHCP elements are connected through an equal phase Wilkinson Splitter. This phase relationship will result in a horizontal polarization.

Note that the pattern shows some aberrations that may be due in part to the test set-up. Note also that the overall gain is less than that of a single element, as shown by the azimuthal cut in Figure 15, as the outer circle represents -2dBi.

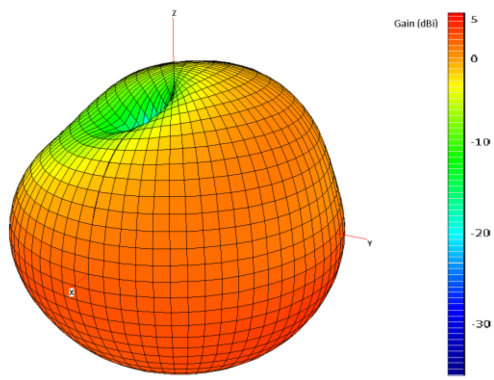


**Figure 14 Measured horizontal pattern**

This is partially due to the losses in the splitter, and also due to expected destructive interference between the antenna elements.

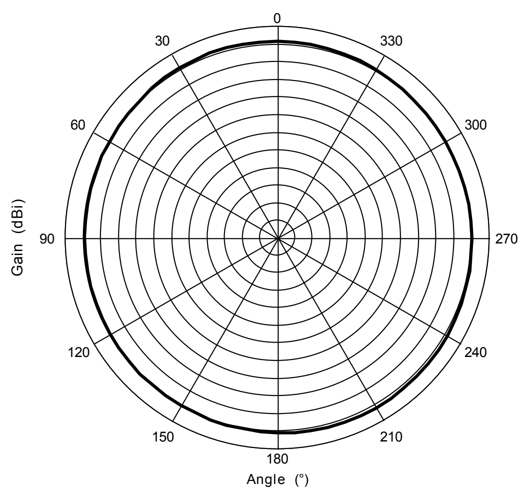


**Figure 15 Azimuthal cut (x-y) of measured horizontal pattern**

### 4.3 Conclusions

The measurement results match those predicted in full wave simulation, but leave several areas for improvement. First, the frequency differed slightly from expected. This is expected since the modeled plastic form does not accurately represent the porous 3D printed version. Second, the gain and phase variations around the azimuth were unexpected and likely caused by the feed cable and test set-up. Future versions will work to correct these issues and more accurately model the fabricated version.

**Acknowledgments**

The authors would like to thank Gonzaga University's SEAS administration, faculty and staff for supporting the establishment of the Gonzaga Smart Antenna and Radio Laboratory (SARL). This work was supported in part by MRI grant number 1040327 from the National Science Foundation. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

**References**

[1] L. Dong, H. Choo, R. Heath, H. Ling, "Simulation of MIMO Channel Capacity With Antenna Polarization Diversity", IEEE Transactions on Wireless Communications, Vol. 4, No. 4, July 2005.
[2] Robert Conley, Steven Schennum, Tim Hillstrom "Interference Mitigation Using Adaptive Polarization," Proceedings of SDR-WInnComm 2014, pp. 101-112, March 2014.
[3] S. Haykin, "Cognitive Radio: Brain-Empowered Wireless Communications", IEEE JSAC, Vol. 23, No. 2, pages 201-220, February 2005.
[4] Carl B. Dietrich, Jr. "Adaptive Arrays and Diversity Antenna Configurations for Handheld Wireless Communication Terminals" Dissertation submitted to the Faculty of the Virginia Polytechnic Institute and State University, Feb. 15, 2000.
[5] R.T. Compton, Jr., "On the Performance of a Polarization Sensitive Adaptive Array," IEEE Transactions on Antennas and Propagation, Vol. AP-29, No. 5, pp. 718-725, Sept. 1981.
[6] T. Pratt, H. Tapse, R. Baxley, B. Walkenhorst, G. Acosta-Marum, "Polarization-Based Zero Forcing with Channel Estimation" MILCOM11, Baltimore, MD, November 7-11, 2011.
[7] B.T. Walkenhorst and T.G. Pratt, "Polarization-Based Interference Mitigation for OFDM Signals in Channels with Polarization Mode Dispersion", MILCOMM08, San Diego, CA, November 17-19, 2008.
[8] "Wireless Innovation Forum Top 10 Most Wanted Wireless Innovations", Document WINNF-11-R-0014, Version V3.0.0, September 24, 2013.
[9] Wheeler, H.A., "A Helical Antenna for Circular Polarization," Proceedings of the IRE , vol.35, no.12, pp.1484,1488, Dec. 1947
[10] Iqbal, S.; Amin, M.; Yousaf, J., "Designing Omnidirectional Bifilar Helix Antenna for Circular Polarization," Satellite Telecommunications (ESTEL), 2012 IEEE First AESS European Conference on , vol., no., pp.1,6, 2-5 Oct. 2012