"Orbital Angular Momentum of Radio Waves for Microwave Remote Sensing"

Daniel J Orfeo, University of Vermont Department of Mechanical Engineering

AY 2018-2019 Progress Report

Background & Significance

Orbital angular momentum (OAM) can be utilized to increase spectral efficiency because it allows for multiplexing multiple channels at the same frequency and wavelength using microwaves with different OAM. OAM may also improve radar sensitivity to certain object-shapes. At the macroscopic scale, orbital angular momentum can appear as paraxial beams with Gauss-LaGuerre (GL) modes. Each mode has a helical shape with mode number corresponding to the number of intertwined helices. The effect is vortex-shaped waves with the vortex pitch length being on the order of the wavelength and energy concentrated in a ring around the propagation axis. GL modes are mutually orthogonal and represent a means of propagating EM waves with different information content along the same beamline at the same wavelength. An OAM helical wave front can be synthesized by using a coherent array of antenna emitters, each of which can be phase controlled to create a beam.

Project Goals

This Fellowship from the Vermont Space Grant Consortium and NASA EPSCoR has funded Daniel Orfeo's research and education. Scientific and professional goals and outcomes of this fellowship include:

i. **Generate OAM Waveform**
Keysight benchtop equipment has been used to successfully generate and collect an OAM waveform, Figure 1(c)

ii. **Self-Healing of OAM Waveform**
Preliminary tests indicate OAM beams may have a self-healing property such that they can overcome partial obstruction.

iii. **Model macroscopic OAM waveform**
Macroscopic vortex wave numerical modeling with MATLAB, Figure 1(d)

iv. **Reporting and Publication**
Portions of this research were accepted as a conference paper and presentation by Orfeo for the 2019 IEEE International Symposium on Phased Array Systems and Technology in Waltham, Massachusetts. Orfeo also presented posters at the 2019 NASA Fundamental Physics and Quantum Technology Workshop in Washington DC, and the 2019 UVM Student Research Conference.

v. **Continued progress towards completion of Ph.D.**

Summary of Key Findings

The test setup is a benchtop phased array configuration using an arbitrary waveform generator (AWG) and digitizer system to enable synthesis and reception of microwave OAM vortex waves via a four-antenna transmit, four-antenna receive arrangement. To synthesize an OAM vortex, each of the circular phased array elements was configured to transmit with the following phase offsets: channel 1 (0°), channel 2 (120°), channel 3 (240°). Channel 4 transmission was turned-off. The received data for this test are shown in Figure 1(c). Channel 1, channel 2, and channel 3 are denoted by data1, data2, and data3, respectively. The recorded phasing of the received signal is evidence of the formation of the OAM vortex. A simulation (Figure 1(d)) shows the phase front of the OAM waveform (mode +1) produced by three transmitting antennas.

Additionally, some Bessel beams have a self-healing property such that they can overcome partial obstruction due to a self-compensating diffraction. A test was performed to evaluate the effect of an obstruction on transmission of OAM mode 1. With Channel 1 unobstructed and Channels 2-4 obstructed by a steel screen, Channel 1 registered a stronger received signal with OAM mode 1 phasing than with traditional in-phasing. Future work will focus on further verification and refinement of the test procedures. Additional applications may include ghost imaging via differential signal analysis between an OAM vortex and a plane wave without OAM characteristics. Orfeo is currently exploring the viability of exploiting the OAM vortex for use in a counter-stealth microwave radar, as well as in land mine detection applications.

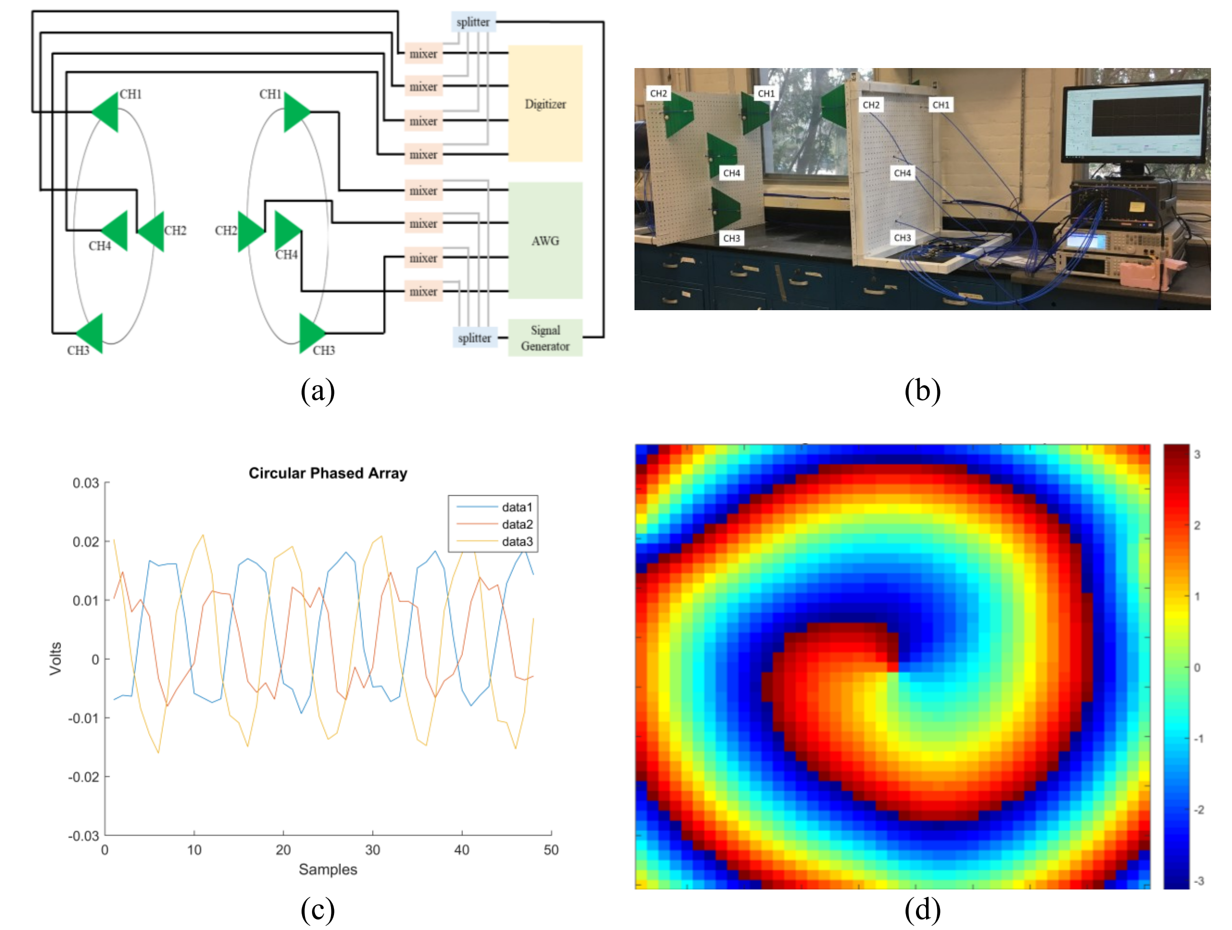

Figure 1 (a) System block diagram, (b) photograph of circular phased array OAM system, (c) phased received signal indicative of OAM waveform, (d) phase front of OAM waveform produced by three transmitting antennas, as simulated by custom MATLAB program