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Implementation and Performance Analysis of Orbital Angular Momentum with OFDM Wireless Communication System

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***Abstract*— Electromagnetic (EM) wave was found to possess not only linear momentum, but also angular momentum. The OAM is a kind of wave front with helical phase. The OAM-based vortex wave has different topological charges, which are orthogonal to each other, bridging a new way for multiple accesses in wireless communications. Multiple-Input Multiple-Output (MIMO) is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time. This paper proposed implementation and performance analysis of orbital angular momentum with OFDM wireless communication system. The simulation is performed using MATLAB software.**

***Keywords*— EM, OAM, MATLAB, MIMO, Simulation, Wireless.**

I. Introduction

Ever since the revival of interest in orbital angular momentum (OAM) of light [1], research on OAM mode propagation in a dielectric waveguide such as a multimode fiber has increased significantly. In commercial telecommunications, internet, and data centers, the orthogonality of the OAM modes leads to the possibility of multifold increase in traffic flow within a fiber by stacking traffic into the different OAM modes [2]. However, a general drawback in practical fibers is the presence of imperfections such as ellipticity and fiber bends, which mix these modes, and which then must be addressed in the analysis and design of fibers.

Recently, wireless communication using Orbital Angular Momentum (OAM) has drawn much attention as an emerging candidate for beyond 5G (fifth generation) technology due to its potential as a means to enable high-speed wireless transmission. OAM is a physical property of electro-magnetic waves that are characterized by a helical phase front in the propagation direction. Since the characteristic can be used to create multiple independent channels, wireless OAM multiplexing can effectively increase the transmission rate in a point-to-point link such as wireless backhaul and/or fronthaul [1,2].

Since OAM multiplexing technology is relatively new, it is important to validate the feasibility from various perspectives. To do that, we first validated the feasibility from a theoretical perspective using simulations. We then validated the feasibility from beam generation and propagation perspectives in experiments. Finally, we concluded by validating the feasibility from the end-to-end wireless communication perspective using experiments. In our previous research, we explored the potential of wireless OAM multiplexing by conducting the following three studies.

The OAM describes the spatial coordinate dimension of the spiral beam transverse rotation mode which is perpendicular to the Poynting vector direction, and the SAM corresponds to the polarization of the electromagnetic wave. The transmission of information by modulating the OAM of electromagnetic fields is first proposed in the field of optics. Since then, the use of OAM for spatial optical communication has become a hot topic in the world [2]. Recently, the OAM has received great attention in the field of radio frequency wireless communication, since, it is possible to modulate the multiplexed signals in different OAM modes by using the mutual orthogonal characteristics between the OAM modes, and distinguish different channels according to the modes, then multiple signals can be transmitted under the same carrier frequency to achieve the purpose of improving spectrum utilization. The vortex electromagnetic wave is characterized by a helical phase factor $\exp(-il\phi)$ in the expression of the field, where l represents the quantum topological charge that can take any integer value, also called the mode number of OAM, and ϕ represents the azimuth angle [3].

II. Proposed Methodology

The proposed research work is explain by the following flow chart-

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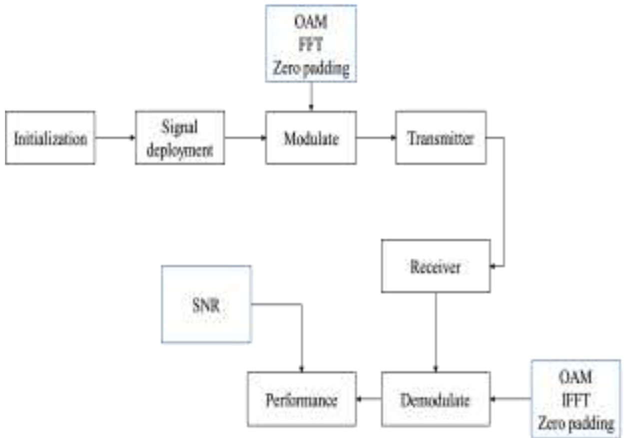

Figure 1: flow chart

The entire process is completed by the followings steps-

- Initialization
- Modulation
- Demodulation
- Performance Analysis

OAM Shift Keying (OAMSK): This scheme simply puts binary data into an OAM mode. For example, bit "0" is mapped as OAM mode 1, while bit "1" is mapped as mode -1 (minus 1). OAMSK modulated signals can be demodulated by using the phase gradient method, an FFT (fast Fourier transform) based method, or ML (maximum likelihood) detection. The gradient method uses the phase difference between two receiving antennas to determine the OAM mode.

The FFT-based method conducts the FFT process using a reception (Rx) UCA and chooses the maximum coefficients. ML detection selects the OAM mode with the closest distance to the received signal.

OAM Division Multiplexing (OAMDM): This scheme uses OAM modes to carry multiple streams of data simultaneously. An OAM mode can carry one stream, similar to the way that one OFDM (orthogonal frequency division multiplexing) subcarrier can.

This scheme potentially improves the spectrum efficiency. With it, OAMDM modulated signals are demodulated similar to the way they are with MIMO equalization techniques such as zero forcing or minimum mean square error equalization, assuming the channel information is available.

Since OAM multiplexing is expected to be used under LOS environments with static channels such as wireless fronthaul/backhaul, simplified channel estimation using Equation (2) might be. In the work we report here, we also considered two key issues regarding the mode-dependent power distribution among different OAM modes. These issues are as follows.

Peak Rx Power Degradation: As the number of OAM modes increases, the radiation becomes wider, the angle from the beam axis at the peak Rx power becomes wider, and the SNR at its peak Rx power becomes smaller. Accordingly, the performance is degraded as the number of OAM modes increases.

Non-identical Peak Rx Power Locations: The peak Rx power locations of each OAM mode are not identical because their radiation patterns are distinct. Therefore, the mode-dependent performance degradation becomes more severe when a single Rx UCA is used because some OAM modes might not have the peak Rx power at a certain location.

III. SIMULATION RESULTS

The simulation is performed using MATLAB software. MATLAB have very wide library and functions to complete the desired communication work.

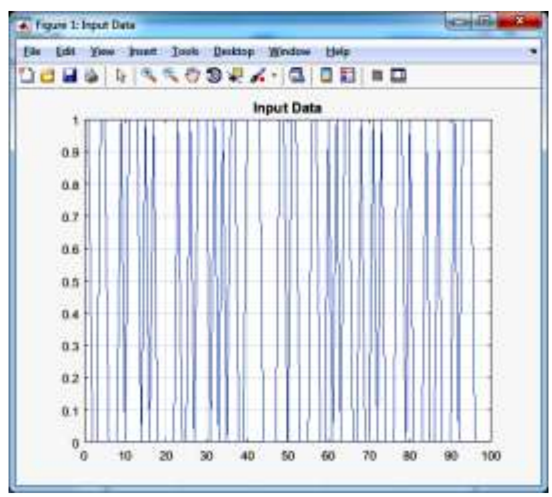

Figure 2: Input data

Figure 2 is showing the random number signal generation. The maximum amplitude is 1 and time axis shows the signal variation till the 100 sec.

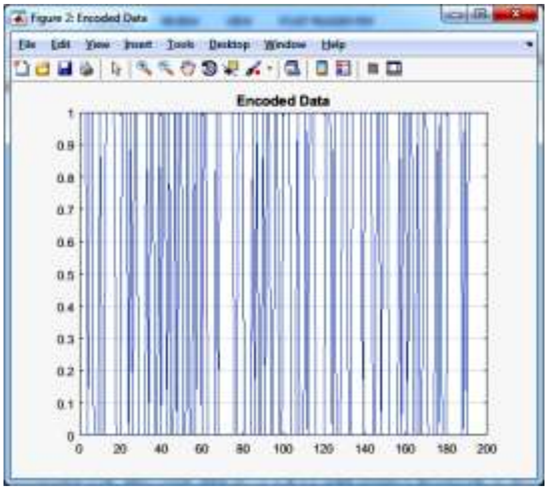

Figure 3: Encoded data

Figure 3 is showing the encoding of the data so that it can secure and contain the basic information of the various signal levels.

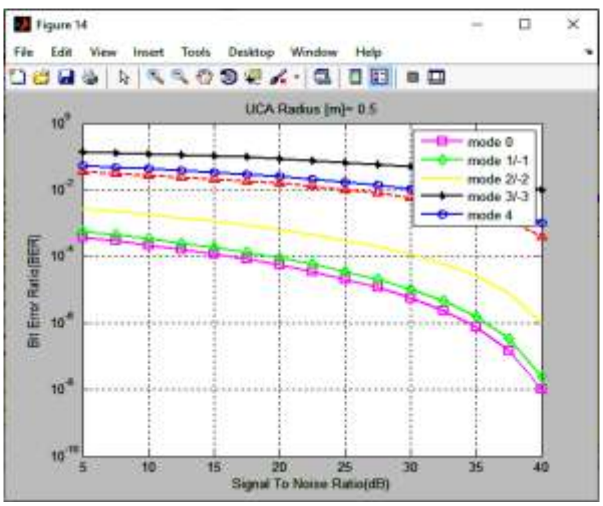

Figure 4: SNR vs BER when UCA radius = 0.5 meter

Figure 4 is showing the performance at the receiver side. The SNR is 40 dB while BER is 10e-8. All mode gives SNR and model 0 gives minimum BER of the signal.

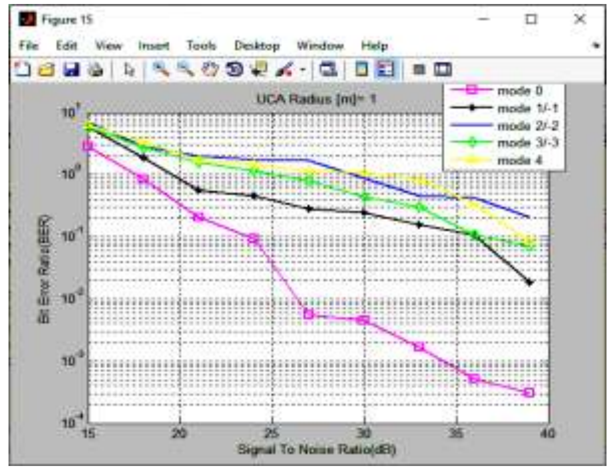

Figure 5: SNR vs BER when UCA radius = 1 meter

Figure 5 is showing the performance at the receiver side. The SNR is 40 dB while BER is $10e^{-4}$. All mode gives SNR and model 0 gives minimum BER of the signal.

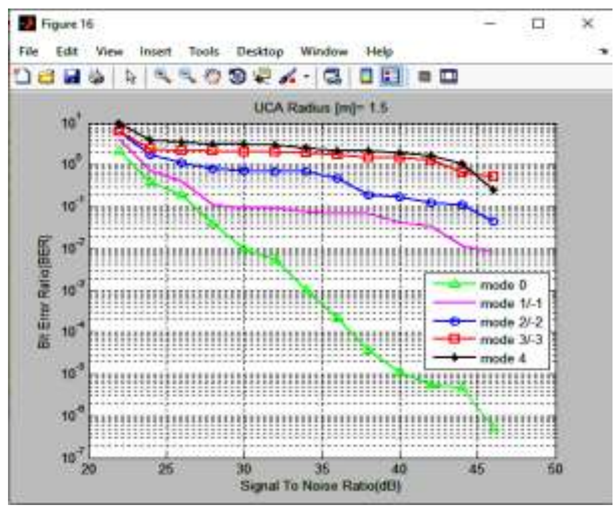

Figure 6: SNR vs BER when UCA radius = 1.5 meter

Figure 6 is showing the received power of the signal. The normalized received power is 10dB and UCA radius is 47 meter.

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Table 1:
Results comparison

Sr No.	Parameters	Previous Results[1]	Present Results
1	Method	OAM	OFDM-OAM
2	Power	-112 dB	-110 dB
3	UCA radius	0.5 m	0.5, 1 & 1.5 m
4	BER	Not Mention	$10^{-6.5}$
5	SNR	20 dB	46 dB

Therefore proposed work result is showing the improved UCA radius with saving of power consumption. This research is focus on the development of OAM with OFDM for MIMO based system.

IV. Conclusion

Orbital angular momentum (OAM) has attracted considerable attention as a novel solution for wireless communications because its orthogonal modes significantly increase the channel capacity without an additional frequency band. Simulation results show that the proposed OAM-OFDM approach simulation gives significant achievement than existing algorithm. Parameter calculation shows that the improved UCA radius with saving of power consumption. This research is focus on the development of OAM with OFDM for MIMO based system. The optimized value of signal to noise ratio is 46dB and BER is $10^{-6.5}$. The present work result is showing the improved UCA radius with saving of power consumption.

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