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An orbital angular momentum multiplexing communication system at 28 GHz with an active uniform circular array

Key words: Orbital angular momentum (OAM); Active phased array; Communication system

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Motivation

1. **Enhancing spectral efficiency**: The OAM multiplexing communication system can transmit more data within the same spectrum bandwidth, achieving higher spectral efficiency. This means that the limited spectrum resources can be utilized more fully, reducing communication costs and improving the economic benefits of the communication system.

2. **Strengthening anti-interference ability**: In the OAM multiplexing communication system, different OAM modes are orthogonal to each other, which can resist multipath fading, co-channel interference, etc. to a certain extent. Even in a complex electromagnetic environment, through mode selection and signal processing techniques, the reliability and stability of communication can be ensured.

Main idea

1. With active uniform circular array technology, the system allows independent configuration of receiving and transmitting states for each UCA and seamless switching between different OAM modes.

2. The OAM multiplexing communication system aims to increase data rate and demonstrate scalability by leveraging the orthogonality of OAM modes, while ensuring high isolation and purity of signals.

Method

1. To achieve a high isolation OAM multiplexing communication system, dedicated antennas are individually designed for each OAM mode. Fig. 1 presents the schematic diagram of the transceiver system that comprises a dual-loop UCA, an integrated front-end module, a beam control board, and a back-end processing module.

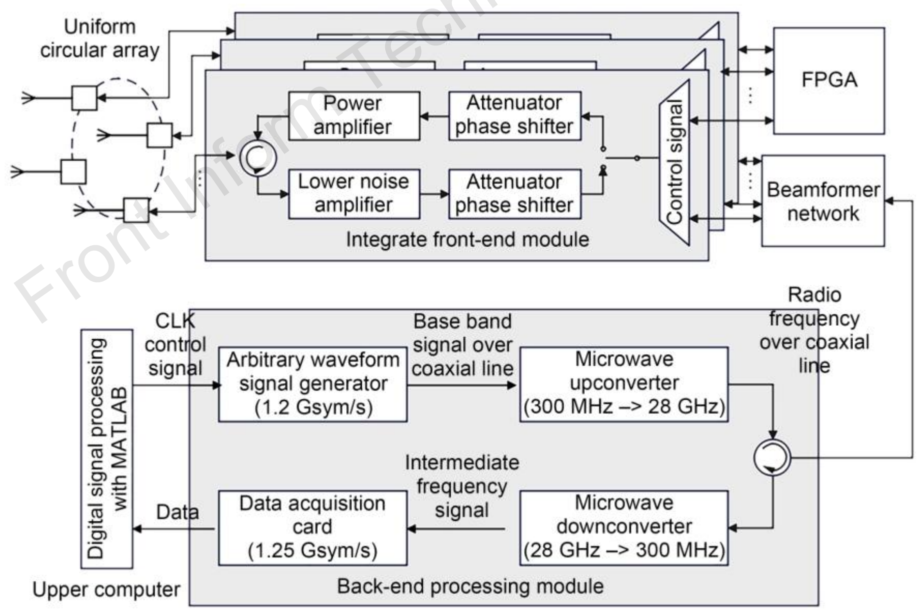


Fig. 1 Diagram of multi-mode orbital angular momentum (OAM) transceiver system

Method

2. To transmit and receive high-purity OAM modes, we adopt the distribution of dual-loop UCAs and assign separate channels to each mode.

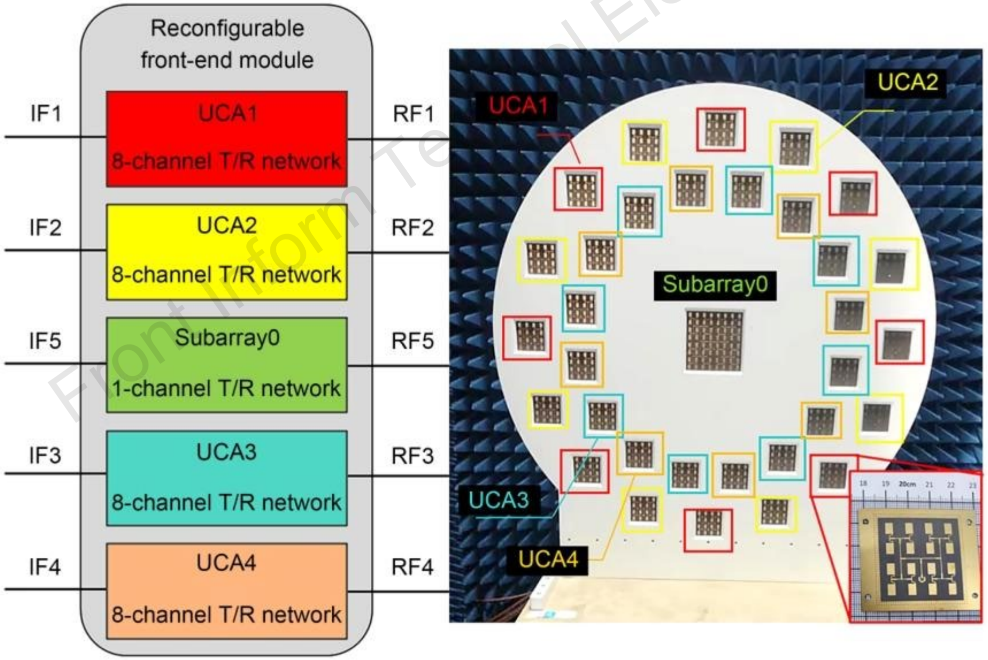


Fig. 2 Front view of OAM spatial multiplexing antenna with simultaneous five-mode transmission architecture

Method

3. To calibrate the phase of each channel and verify the purity of the calibrated OAM in the near field, we need a scanning frame in conjunction with a vector network analyzer to collect the spatial field distribution using an open-ended waveguide probe.

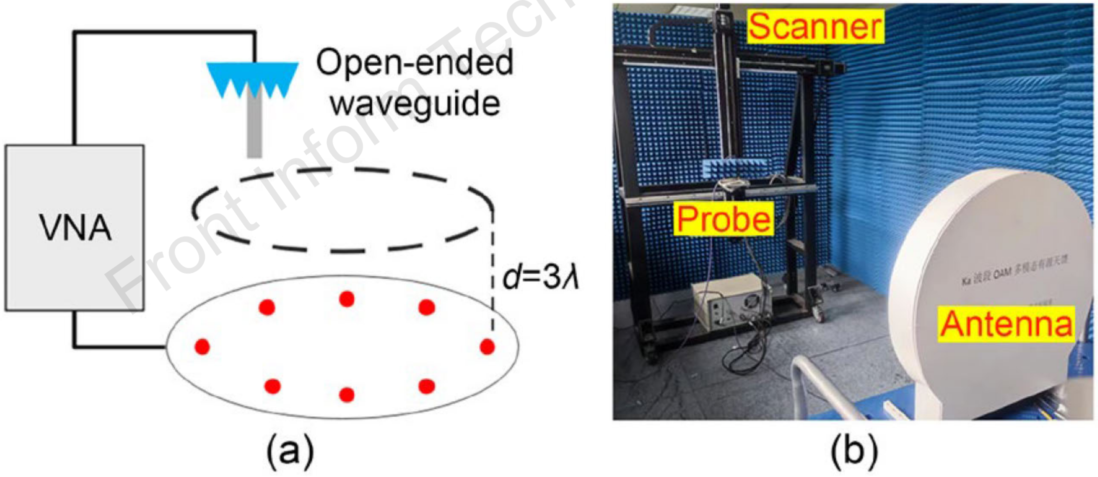
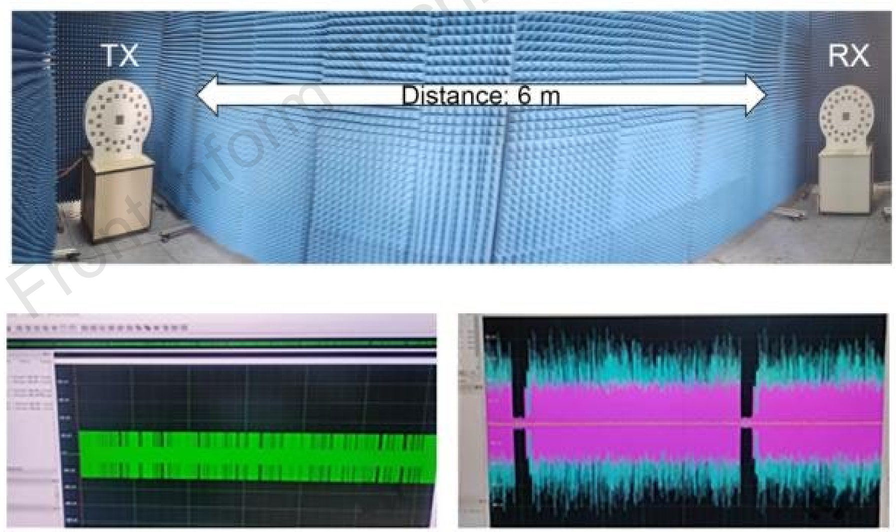


Fig. 3 Diagram of near-field phase calibration (a) and photo of near-field measurement scenarios (b)

Method

4. The experimental platform uses a data acquisition card and an arbitrary waveform generator. MATLAB is used on the computer to demodulate the collected data, recover user data, and display the constellation diagram.



(a) (b)

Fig. 4 Transmitting (a) and receiving (b) waveform

Major results

Near-field measurement and OAM spectrum

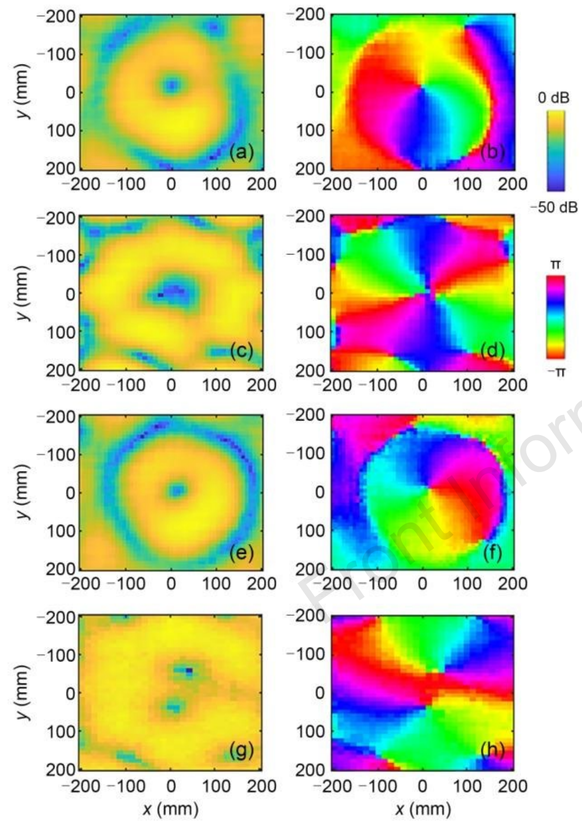


Fig. 5 Measured transverse electric field intensity of generated OAM modes +1 (a), +2 (c), −1 (e), and −2 (g); measured phase distributions with OAM modes +1 (b), +2 (d), −1 (f), and −2 (h)

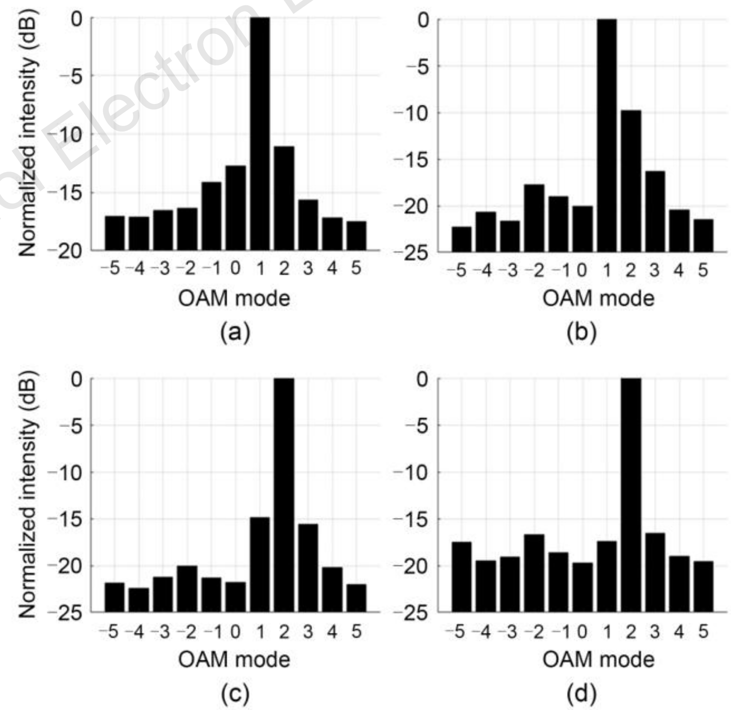


Fig. 6 Measured OAM spectrum of proposed system with four non-zero OAM streams: (a) TX mode +1; (b) RX mode +1; (c) TX mode +2; (d) RX mode +2

Major results

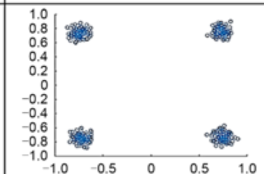
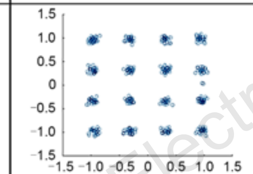
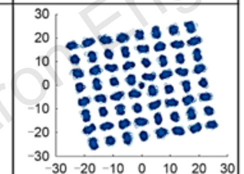
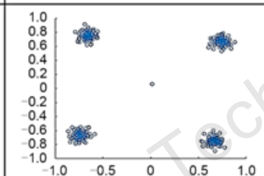
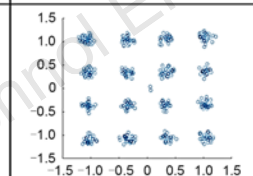
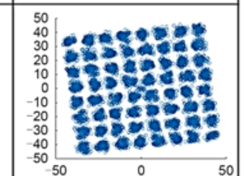
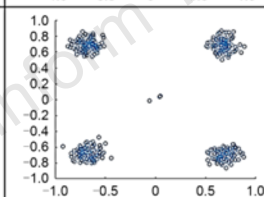
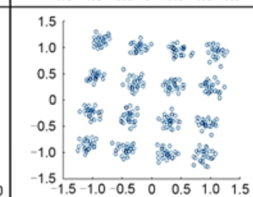
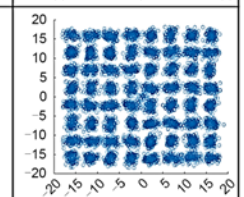
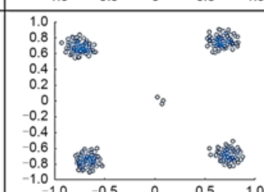
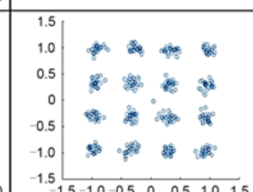
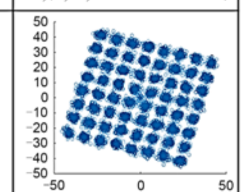
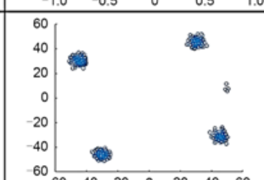
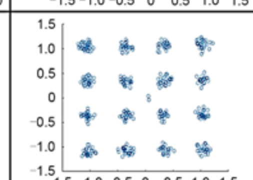
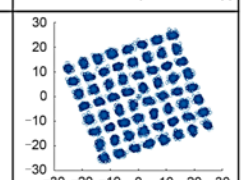
Intermediate frequency (IF) power measurement

Fig. 7 TX OAM mode-checking: an 11-dB difference in intermediate frequency (IF) power. The TX mode is +1 while the RX UCA is −1 (matched) and +1 (mismatched)

RX mode	IF power (dB)				
	TX mode=+1	−1	+2	−2	0
−1	0	−9.4	−10.4	−14.8	−8.4
+1	−10.9	0	−10.8	−11.8	−18.2
−2	−11	−16.2	0	−10.7	−5.6
+2	−5	−17.6	−6.8	0	−5
0	−25.3	−11.8	−20.6	−11.6	0

Major results

Constellation diagrams with five streams (0, ±1, ±2) simultaneous communication

Modulation	QPSK	16-QAM	64-QAM
Symbol rate	1.2 Gsym/s	1.2 Gsym/s	1.2 Gsym/s
Bandwidth	100 MHz	100 MHz	100 MHz
OAM mode: 0 constellation			
OAM mode: 1 constellation			
OAM mode: −1 constellation			
OAM mode: 2 constellation			
OAM mode: −2 constellation			

Conclusions

1. A 6-m OAM link is designed to achieve the simultaneous transmission of five OAM streams with a transmission rate of 3 Gbit/s.

2. An experimental method of measuring the difference in intermediate frequency power was adopted to verify the effectiveness of the isolation between different OAM modes.

3. Future work will focus on designing longer communication links, addressing the OAM divergence angle, and exploring high-speed and long-distance communication potential.

Yu GAN received B.S. degree from Southeast University, Nanjing, China, in 2017, where he is currently pursuing the Ph.D. degree in the electromagnetic field and microwave technology. His current research interests include orbital angular momentum and millimeter-wave phase array.

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