An Efficient channel model for Orbital Angular Momentum transmission supporting Multiple Users

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Abstract

In this paper, we propose an efficient channel model to analyze the performance for supporting multiple orbital angular momentum (OAM) users. OAM transmission has challenges on divergence, misalignment and supporting multiple users. The efficient channel model can be derived with divergence intensity and modified Bessel function by simplifying system model. The partial number of OAM modes are activated to avoid the inter beam interference. In addition, OAM mode combination is required to divide full OAM modes into partial OAM modes. According to mode combination, the performance of the proposed system model is derived and simulated in terms of divergence intensity, capacity per user and sum capacity.

Ⅰ. Introduction

Wireless communication technology has integrated and supported various types of mobile equipment. These equipment can be cellular, internet of things device, automation vehicles and robots [1]. The core trend of next generation has released such as data rate increase with guaranteed low latency, additional spectrum availability in above 6GHz, focusing on network densification, ubiquitous global connectivity and incremental improvement of 5G applications [2]. Especially, there is a key technology get paired with spectrum availability. The orbital angular momentum (OAM) has revealed its potential in radio frequency 3,4,5].

To generate vortex beams, various antenna types are recommended such as spiral phase plate antennas, holographic gratings, spiral reflectors, meta surfaces, and uniform circular array (UCA) antennas. The UCA antenna has significant attention because of its adjustable size and supporting multiple OAM modes [6].

OAM transmission makes possibility to transmit multiple OAM modes without interference between OAM beams. In addition, discrete Fourier transform (DFT) and inverse DFT (IDFT) are applied to detect OAM mode information. Nonetheless, OAM transmission has challenges on divergence, misalignment and supporting multiple OAM users [7,8]. In particular, we consider divergence and supporting multiple users in the manner of channel modeling. To the best of our knowledge, a research on supporting multiple OAM users is required to enhance the diversity of OAM transmission because most of researches have focused on the antenna design or architecture.

In this paper, the generalized system model assumes that a base station (BS) which has concentric transmit UCA antenna and multiple OAM user which has receive UCA antenna. The design of BS allows to communicate with multiple OAM users. The partial number of OAM modes are activated to avoid the inter beam interference.

Ⅱ. System model

In this section, a generalized system model is shown that a BS and multiple OAM users. The I_n number of transmit UCA elements and J_n number of receive UCA elements are equipped for n-th user, respectively. The UCA antenna on the BS is concentric to share OAM transmission for multiple OAM users.

Without loss of generality, consider three OAM users such as cell center user (CCU) J_1, cell middle user (CMU) J_2, cell edge user (CEU) J_3 as shown in Figure 2. The OAM channels for CCU, CMU and CEU are $h_{1,\mathcal{L}_1}$, $h_{2,\mathcal{L}_2}$ and $h_{3,\mathcal{L}_3}$ assigning mode combination $\mathcal{L}_1$, $\mathcal{L}_2$ and $\mathcal{L}_3$.

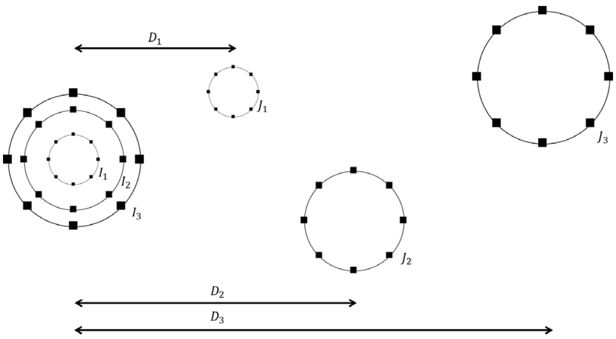

Figure 1 Simplified system model

Ⅲ. Simulation results & Conclusion

The numerical results are shown in terms of divergence intensity, capacity per user and sum capacity. Moreover, the simulations are performed in MATLAB platform. The simulation parameters are considered such as $\lambda = 0.01$ [m] where carrier frequency is 30GHz and $\beta = 4\pi$. The antenna parameters have an equal unit λ for parameter normalization.

In Figure 2, the divergence intensity z is shown with respect to the center distance where the radii of transmit and receive UCA antennas $r = R = 10\lambda$. The center distances are assigned from 500λ to 1000λ. As it can be seen, the blue line has highest divergence intensity because it is merged as {0, 5} combination. In addition, the divergence intensity is decreased by the increase of center distance.

In this paper, we propose an efficient channel model to analyze the performance for multiple OAM users. The misalignment parameters such as elevation and oblique angles are replaced into integrated parameter. The effect of divergence intensity is shown with the relation where center distance is given. The numerical results on effective channel model are derived and simulated in terms of divergence intensity, capacity per user, and sum capacity. The next challenge can consider finding optimal mode combination by applying efficient channel model.

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References

[1] W. Saad, M. Bennis, M. Chen, A vision of 6g wireless systems: Applications, trends, technologies, and open research problems, IEEE network 34 (3) (2019) 134-142.

[2] 6g white paper - mediatek's vision for the next-generation of cellular mobile technologies (2022).

[3] S. M. Mohammadi, L. K. Daldorff, J. E. Bergman, R. L. Karlsson, B. Thid´e, K. Forozesh, T. D. Carozzi, B. Isham, Orbital angular momentum in radio—a system study, IEEE transactions on Antennas and Propagation 58 (2) (2009) 565–572.

[4] Y. Yan, G. Xie, M. P. Lavery, H. Huang, N. Ahmed, C. Bao, Y. Ren, Y. Cao, L. Li, Z. Zhao, et al., High-capacity millimetrewave communications with orbital angular momentum multiplexing, Nature communications 5 (1) (2014) 1-9.

[5] T. Hu, Y. Wang, X. Liao, J. Zhang, Oam-based beam selection for indoor millimeter wave mu-mimo systems, IEEE Communications Letters 25 (5) (2021) 1702-1706

[6] R. Chen, H. Zhou, M. Moretti, X. Wang, J. Li, Orbital angular momentum waves: generation, detection, and emerging applications, IEEE Communications Surveys & Tutorials 22 (2) (2019) 840–868.

[7] M. J. Padgett, F. M. Miatto, M. P. Lavery, A. Zeilinger, R. W. Boyd, Divergence of an orbital-angular-momentum-carrying beam upon propagation, New Journal of Physics 17 (2) (2015).

[8] H. Tian, Z. Liu, W. Xi, G. Nie, L. Liu, H. Jiang, Beam axis detection and alignment for uniform circular array-based orbital angular momentum wireless communication, Iet Communications 10 (1) (2016) 44-49.