Space-Time Coding for Atmospheric Turbulence Mitigation in OAM FSO Communications

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Abstract: We propose space-time coding at the transmitter to enhance the BER performance against atmospheric turbulence. Furthermore, we derive an analytical expression of the error probability and a good agreement is found with Monte Carlo simulations.

1. Space-Time coding for OAM FSO systems

In analogy to mode-division multiplexing in few-mode fiber systems, orbital angular momentum (OAM) multiplexing is proposed to transmit multiple signals over free space channels. This simultaneous transmission of information on OAM modes is possible thanks to the orthogonality property of OAM beams that allows propagation without interference between signals. Orbital angular momentum (OAM) is proposed as a versatile technique to transmit multiple signals over free space channels [1]. OAM modes are orthogonal which makes them suitable to co-propagate and carry independent data streams in free space. In the presence of atmospheric turbulence (AT), the power of a signal carried by a particular OAM mode is spread to other modes which results in modal crosstalk. The latter is mode dependent and engenders the break of orthogonality between OAM modes resulting in power imbalance known as mode-dependent loss (MDL) that causes performance degradations at the system level. In this work, we propose space-time (ST) coding to enhance the BER performance of OAM FSO systems. The principle of ST coding consists in sending a coded linear combination of modulated symbols during several channel uses. At the receiver side, the same signal is received on all OAM modes, this allows the maximum likelihood detector to retrieve the data from different copies attenuated differently by AT and hence gives a better estimate. In Fig. 1, we plot the BER performance for a 3×3 MIMO FSO system. From the figure, we notice that more than 1.5 dB gain is obtained by ST coding compared to the uncoded scheme for both the weak and strong AT regimes. Furthermore, we have derived an analytical expression for the error probability as shown in equation (1). For this aim, we modeled the channel crosstalk coefficients h_{ij} as Gaussian random variables, whereas, the channel self-fading gains h_{ii} were considered as Nakagami distributed. In Fig. 2 we compare the BERs of numerical simulations to the obtained error probability for a 3×3 MIMO FSO system for weak and strong AT regimes. The figure shows a good match between the obtained theoretical results and numerical simulations.

$$\mathrm{P_r} = \frac{1}{\pi}\int_0^{\pi/2}\prod_{i,j=1}^{M}\frac{\sin^2\theta}{\sin^2\theta+\gamma_i\sigma_{0,j}^2}\exp\left(\frac{-\left|u_{ji}h_{jj}\right|^2\gamma_i}{\sin^2\theta+\gamma_i\sigma_{0,j}^2}\right)d\theta \qquad (1)$$

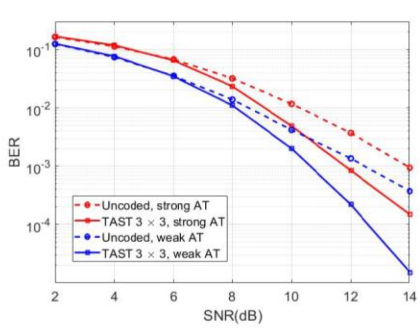

Fig.1: BER vs SNR comparison for a 3 × 3 MIMO system for weak/strong AT regimes

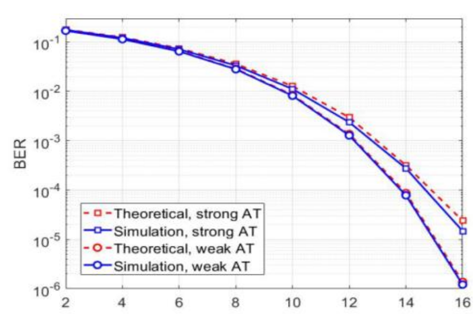

Fig.2: BER vs SNR comparison between simulations and analytical results

2. References

[1] A. E. Willner, J. Wang, and H. Huang, “A different angle on light communications,” Science, vol. 337, pp. 655–656, 2012.
[2] J. Harshan and E. Viterbo, “Full-rate integer space-time block codes for 2× 2 MIMO channels,” in IEEE International Conference on Communications, 2013, pp. 3187–3191.