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Wideband Interference Management for Free Space Optical Communication Based on Photonic Signal Processing

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Abstract: We design and experimentally demonstrate a wideband interference management system for free space optical communication using photonic blind source separation and photonic signal processing to achieve real-time interference cancellation up to 3 GHz.

OCIS codes: 060.0060 Fiber optics and optical communications, 060.5625 Radio frequency photonics

1. Introduction

Free space optical (FSO) communication offers a higher data rate and provides a wider bandwidth compared to wireless radio frequency (RF) communication. The broadcasting method is commonly applied to FSO communication, and interference between different broadcasting channels affects the performance of FSO communication [1]. The bandwidth for FSO channels is in GHz range, which creates a challenge for traditional digital processing methods to process signals, digital signal processing for FSO range requires a great computational capability to separate signals from interference within different transmitters and receivers [2].

Photonic signal processing (PSP) overcomes the limitations of conventional digital signal processing. PSP can achieve signal processing in GHz range in real-time. Meanwhile, blind source separation is proven effective to separate multiple unknown sources of mixture signals from each other using principal component analysis (PCA) and independent component analysis (ICA) [3]. PCA sorts the principal components in descending order of statistical relevance, while ICA separates a mixed signal into independent subcomponents [4]. This blind source separation method can be applied to FSO systems using photonic signal processing to cancel interference between channels [5].

In this paper, we exploit a wideband interference management system for free space optical communication that uses blind source separation method and photonic signal processing technique. For a 2x2 FSO MIMO, the transmission matrix can be collected by capturing the four spectral responses within the two transmitters and two receivers. Once the proportion of the different signals is calculated by blind source separation, photonic signal processing methods can be used to modify the intensity and phase of the corresponding mixtures, and the signals will be separated from the mixture by combining different modulated mixtures.

2. Experimental Setup

Fig. 1 shows the experimental setup of the wideband interference management for free space optical communication based on photonic signal processing. TX1 is the signal of interest (SOI) transmitter, TX2 is the interference generator, and the MIMO receiver contains two receiver lenses C and D. Both SOI and interference signal are intensity-modulated on to two different amplified spontaneous emission (ASE) sources with frequency from 1520 nm to 1560 nm. The wideband ASE sources can serve as both emitting source and transmitting source, and the wide bandwidth of 40 nm provides a short coherent length which also prevents the coherence issue with commonly used DFB (distributed feedback) lasers. Both the SOI and interference transmitted through optical fiber and coupled correspondingly into two laser collimator lenses A and B. Both transmitting lenses A and B distribute wide beam into two of the Lenses C and D of the MIMO Receivers. The distance between SOI transmitter's Lens A and MIMO receiver C and D is 17 cm, and the distance between interference transmitter's Lens B and MIMO receiver C and D is 11.5 cm, the receiver lenses C and D are 1.5 cm apart.

This setup demonstrates a 2x2 FSO MIMO system for wideband interference cancellation based on photonic signal processing. The SOI transmitting through Lens A gets interference from the signal generated and transmitted through Lens B. Both Lenses C and D for MIMO Receiver receive a mixture of SOI and interference in different proportions. By collecting the received signals from Lenses C and D, blind source separation is performed with principal component analysis and independent component analysis based on blind source separation. After these processes, SOI and interference are separable by altering the intensity and delay of the two mixtures with EDFAs (erbium-doped fiber amplifier), optical tunable delays (TD), and optical tunable attenuators (TA). Once the interference signal in both paths is intensity and phase matched, they are combined and canceled within the balanced photodetector (BPD), and SOI is recovered and converted to radio frequency for further modulation and analysis.

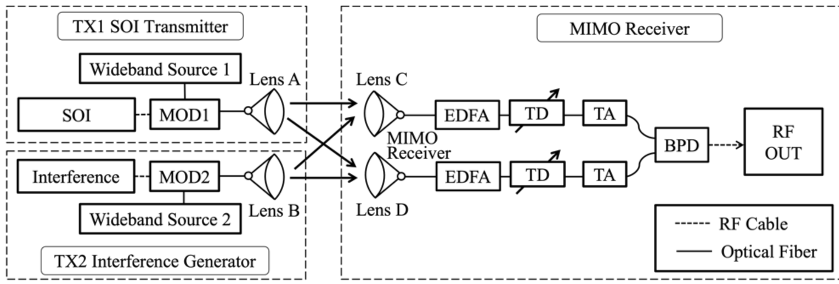

Fig. 1. System setup for wideband interference management for free space optical communication (MOD: optical intensity modulators, SOI: signal of interest, EDFA: Erbium-Doped Fiber Amplifier, TD: optical tunable delay, TA: optical tunable attenuator, BPD: balanced photodetector).

3. Results and Analysis

Fig. 2 (a) shows the spectral response of the FSO MIMO for wideband photonic interference cancellation for up to 3 GHz. The black line shows the spectral response without cancellation, and the red line shows the spectral response with cancellation. The system can work in real-time with a wide bandwidth of 3 GHz and achieves an average cancellation of 32.75 dB. Fig. 2 (b) and (c) represent the eye diagrams received from Lens C of the MIMO receiver without and with photonic interference cancellation. SOI tested with the result is a 3G pseudorandom binary sequence (PRBS) and interference is set to a 3G Gaussian noise. By comparing (b) and (c), the received signal recovered from a 120 mV peak to peak random noise to a clear 3G PRBS signal with a clear-opening eye diagram after photonic interference cancellation.

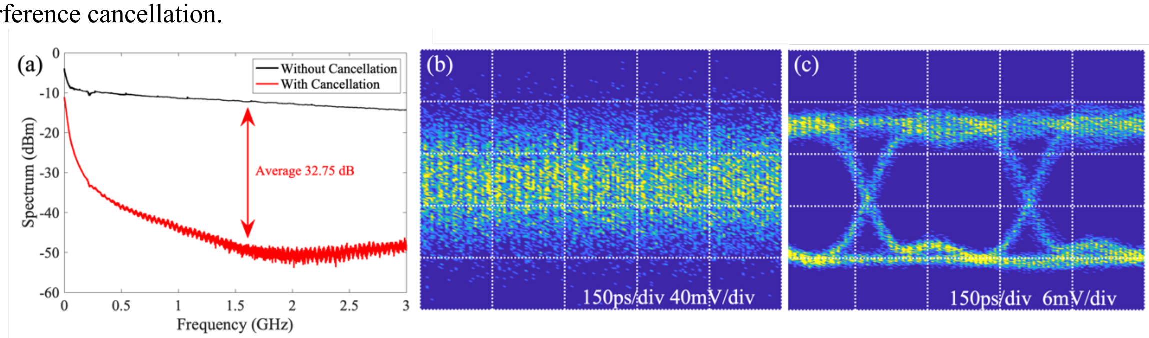

Fig. 2. (a) Comparison of the received spectrum with and without interference cancellation; eye diagrams received of the mixed 3G PRBS signal and Gaussian interference from FSO MIMO receiver Lens C (b) before and (c) after photonic interference cancellation.

4. Conclusion

In this paper, we design and experimentally demonstrate wideband interference management for free space optical communication based on photonic signal processing that can achieve real-time interference cancellation up to 3 GHz. The system uses the blind source separation method to separate two received signals with a mixture of both SOI and interference with different proportions, and by adjusting the EDFAs, tunable attenuators, and tunable delays to alter the interference in both receivers in FSO MIMO receivers to match the intensity and phase of the interference, both received signal are then combined to the balanced photodetector and the interference gets canceled while SOI gets recovered. This system performs an average of 32.75 dB real-time cancellation up to 3 GHz. A 3 GHz PRBS signal is tested and recovered from a 3 GHz Gaussian noise. This work was supported by the National Science Foundation (NSF) under Grant ECCS-2128608.

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