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# Jamming-Resilient LiDAR based on Photonic Blind-Source Separation

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**Abstract:** We propose a system that cancels LiDAR interference signals in real time. This system uses blind source separation to separate signals in the same bandwidth, and is compatible with electro-optical analog circuitry. © 2022 The Author(s)

**OCIS codes:** 280.3640 Lidar; 280.3420 Laser sensors; 060.5625 Radio frequency photonics

## 1. Introduction

LiDAR is a powerful tool for detection and ranging systems. It enables much more precise position and range data for close-range targets than radar, and does not rely on the presence of natural light as cameras do. [1] The most widely used form of LiDAR system is the time-of-flight (TOF) LiDAR system. These systems transmit a laser pulse train, and measure the time delay between transmitting each pulse and receiving its reflection to calculate the distance between the transmitter and a target. While these sensors are structurally simple and easy to interface with computer systems, making them ideal for commercial use, they tend to be more vulnerable to interference than their constant-wave counterparts, meaning that they require higher optical power and more expensive circuitry to achieve a sufficient signal-to-noise ratio [2]. This problem is also likely to get worse over time, as scholarly efforts are continually working to bring free space optical communication to the commercial space [3, 4]. This vulnerability creates demand for a method of removing free space optical interference from TOF LiDAR systems.

Blind Source Separation is a method by which a MIMO system can separate mixed signals into their original forms without the use of time or frequency division multiplexing [5]. This algorithm uses the second and fourth order moments of the mixed signals with respect to one another to derive a linear transform that inverts the mixing of the two signals. This is a particularly powerful capability in the field of optics, as the linear transform can be implemented entirely using electro-optical circuit components. This capability allows for real-time cancellation of interfering signals, which stands to improve the robustness of TOF LiDAR systems to external interference.

In this paper we propose a system that can make use of blind source separation to subtract optical interference signals from a TOF LiDAR pulse train. This system uses a pair of receiver lenses to create a LiDAR receiver and reference signal receiver channel. These two channels can then be manipulated in both time and amplitude, such that the interference signals present in each channel can be aligned and amplitude-matched with one another before the two channels are subtracted. The resulting signal should be an interference-free LiDAR pulse train, plus any noise accrued by propagating through the system.

## 2. System Setup

Figure 1 shows the experimental setup used to verify the proposed system. This setup consists of a LiDAR transmitter, a free space optical interference transmitter, and a differential LiDAR receiver. The LiDAR transmitter consists of a narrow band 1550nm constant-wave laser, which is modulated into a 3MHz pulsed signal with a 0.1% duty cycle. The FSO transmitter is made up of a wide band ASE laser source, which is modulated into a 2.9GBPS pseudo-random binary signal. This bit rate was chosen so as to avoid phase alignment between the two signals, while keeping them in similar frequency bands. The differential receiver consists of a pair of recoupling lenses, tunable delays and tunable attenuators, which are used to phase and amplitude match the incoming interference signals. After being manipulated by the incoming channels, the resulting signals are directed into a bipolar photodiode, which subtracts them electrically with relatively little dependence on their optical spectrum contents. When the tunable delays and attenuators are properly adjusted, the resulting RF output will resemble the originally transmitted LiDAR pulse train.

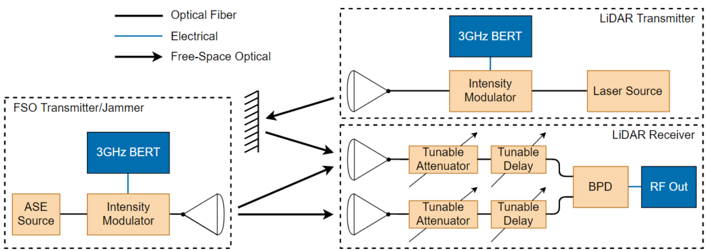


Fig. 1. System Setup (BERT: Bit Error Rate Tester, BPD: Bipolar Photodetector, ASE: Amplified Spontaneous Emission.

To test this system, the aforementioned signals were sampled at a rate of 20GHz and saved into 40000 point blocks. These blocks were then digitally combined into two 400000 point signals and mixed using a scaled model of the bipolar photodetector's frequency response. The mixed signals before separation were measured to have a signal to interference ratio of -24.2633dB. The blind source separation algorithm was then performed on the resulting mixed signal vector to demonstrate the ability of the system to cancel interference.

## 3. Results and Analysis

Figure 2(a) shows the time-domain behavior of the received signal before and after separation. Before cancellation, the PRBS signal seems to dominate the received information content. After cancellation, the LiDAR pulse is clear and with little evidence of the digital communication signal remaining. This is reflected in Figure 2(b) and Figure 2(c), which show eye diagrams of these signals over the high time of the LiDAR pulse before and after cancellation.

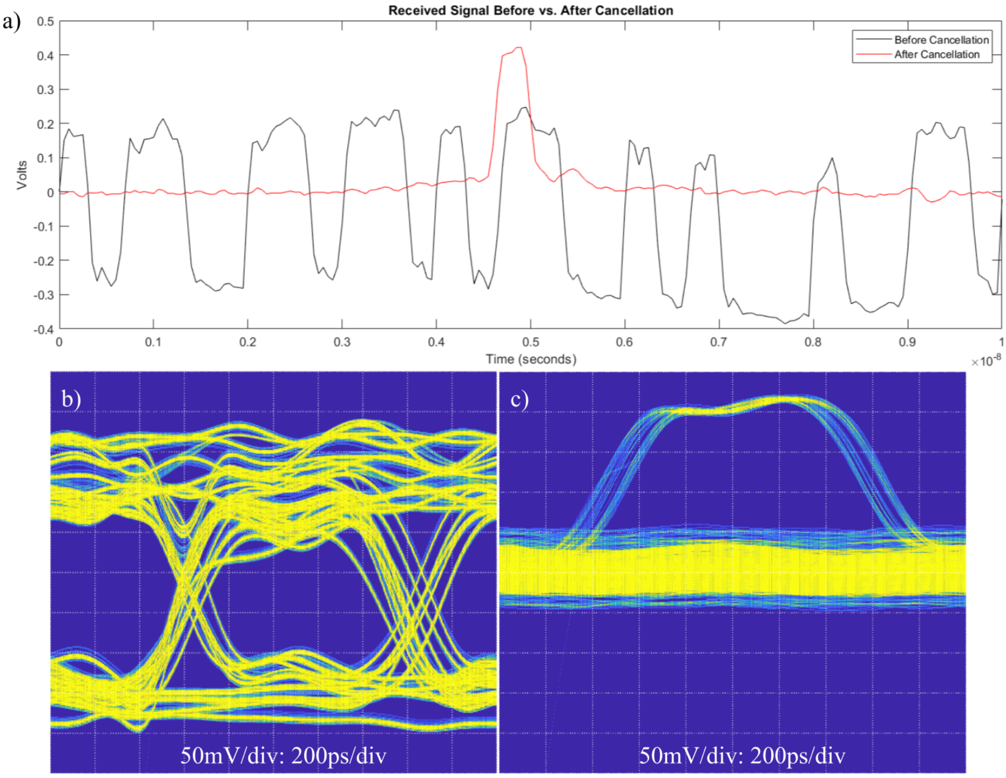


Fig. 2. Time-domain behavior of the design under test.

Measuring the power of the difference between the original and recovered signals revealed the recovered signal to have a signal to interference ratio of 13.2060dB. This shows that the blind source separation algorithm was able to achieve at least 37.4693dB of interference cancellation for TOF LiDAR signals when a reference signal is available.

## 4. Conclusion

We propose a system that cancels LiDAR interference signals. This system can use blind source separation to separate signals in the same bandwidth, and is proven to enable at least 37.4693dB of interference cancellation. The system can also be fully implemented in electro-optical analog hardware, allowing for this cancellation to occur in real time. This work was supported by the National Science Foundation (NSF) under Grant ECCS-2128608.

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