Temasek Defence Systems Institute

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Analysis of Interference in LiDAR System

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Background

With the increasing popularity of self-driving vehicles, surveillance drones, and other autonomous platforms, light detection and ranging (LiDAR) systems have become a preferred sensory device of choice for civilian and military applications. Advancements in LiDAR technology have supported the growing movement to outsource dull and repetitive tasks (e.g. obstacles avoidance, remote surveillance, computer vision, and 3D topographic mapping) to computers and processing systems. Today, spotting a LiDAR system is almost synonymous to identifying an autonomous platform, as LiDAR systems have become a primary sensor used in many navigation and detection applications.

Motivation

LiDAR has become one of the main sensors used for many autonomous platforms. The sensor provides essential information for the autonomous system to perform navigation and obstacle avoidance. It is essential for the LiDAR to provide precise and accurate sensory data in a timely manner. Hence, understanding the effects of external interference on the detection performance of a LiDAR system has become increasingly important

Receiver Noise Power Spectrum

There are five significant noise sources for a receiver operating in the near infrared (NIR) spectrum at 905 nm wavelength. The noise sources are Shot Noise, Background Noise, Dark Current Noise, Johnson Noise and Amplifier Noise.

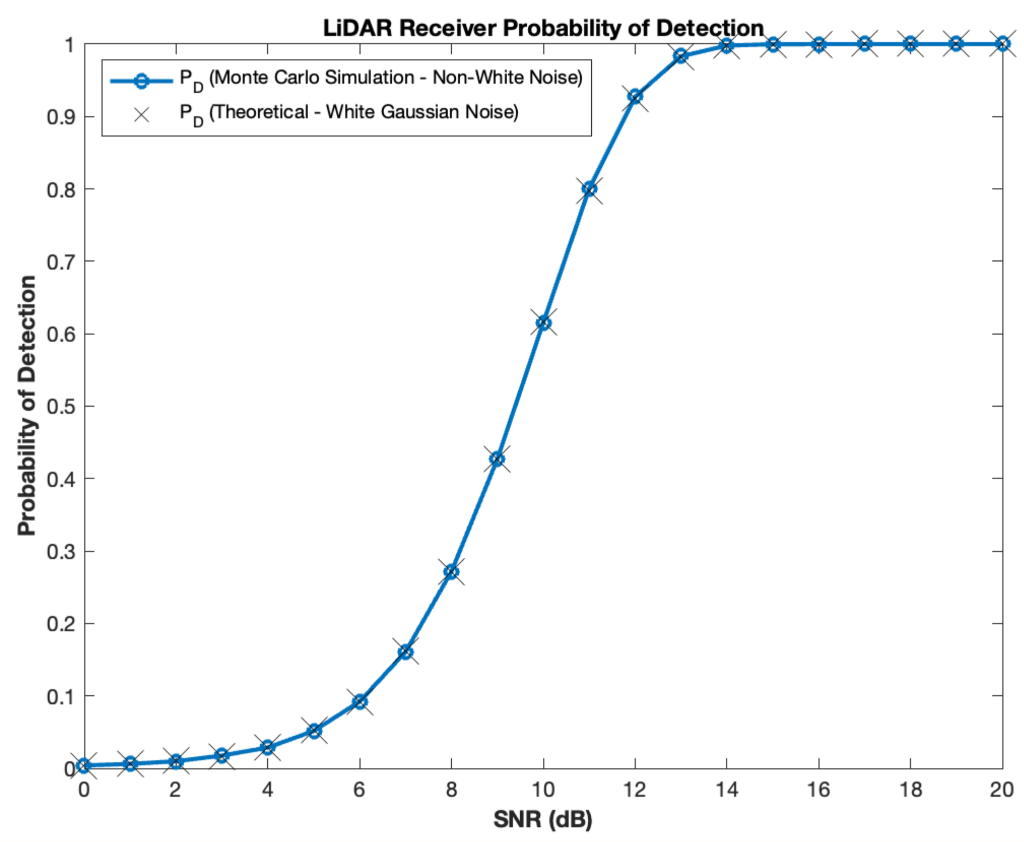
Unlike receivers operating in the radio and microwave frequency spectrum, Johnson noise is not the dominant noise source for NIR receivers. Therefore, studies into LiDAR receivers should not hastily assume that the total LiDAR receiver noise characteristics can be approximated as white Gaussian noise since shot noise is a significant noise source that does not follow a Gaussian statistical distribution

$$SNR_{NIR\,(APD)} = \sqrt{\frac{NR^2P_s^2M^2R_f^2}{2eB_N(RP_S + RP_B + I_d)FM^2R_f^2 + B_N(4kTR_f) + \langle V_{amp}^2 \rangle}}$$

Shot Noise Background Noise Dark Current Johnson Noise Amplifier Noise

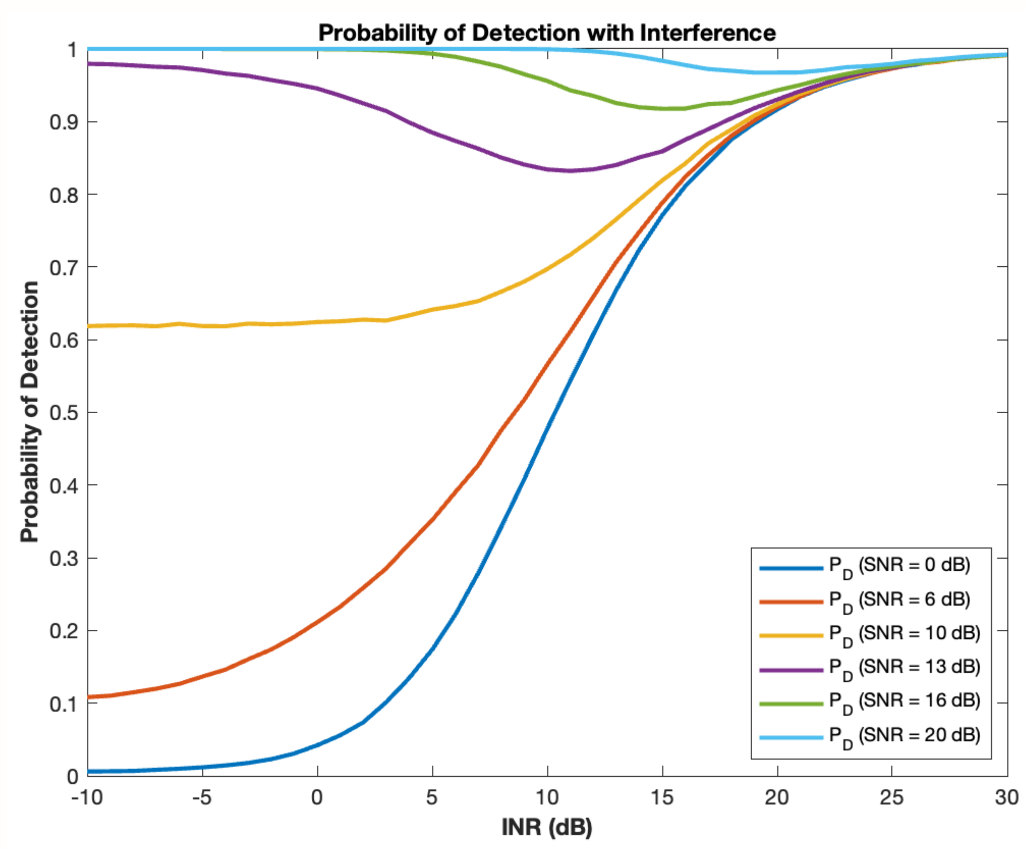
Simulation

The probability of detection (PD) performance curves (y axis) as a function of signal-to-noise-ratio (SNR) (x axis) with the probability of false alarm (PFA) set at 0.0001. The detection curve utilizing correlated noise from the Monte Carlo simulation is shown by the blue line. The theoretical PD with white Gaussian noise assumption is shown by the black crosses. The resulting PD curve from the Monte Carlo simulation and the theoretical PD with white noise are very close to one another.



This further supports the common use of Gaussian distribution as a first-order approximation of LiDAR receiver noise profile, even though the LiDAR receiver has non-linear SNR characteristics.

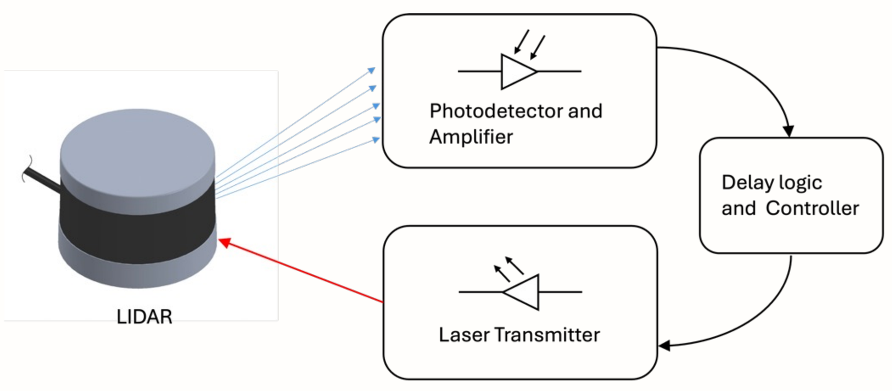
As most LiDAR system currently employ non-coherent detection, the simulation assumes that the envelope of the interference pulses perfectly overlap with the genuine reflected laser pulses at the detector, The PD curves include the effect of the interference adding more energy to the actual reflected laser pulse energy, causing the total power received by the LiDAR detector to increase. This increased total received power exceeds the detection threshold which creates the false perception that the PD curves seems to have improved.



However, in reality, it is the interferences that artificially increase the percentage of measurements crossing the detection threshold. The simulation result shows the LiDAR PD (y axis) as a function of incrementing interference-noise-ratio (INR) (x axis) with fixed (SNR).

Experimentation

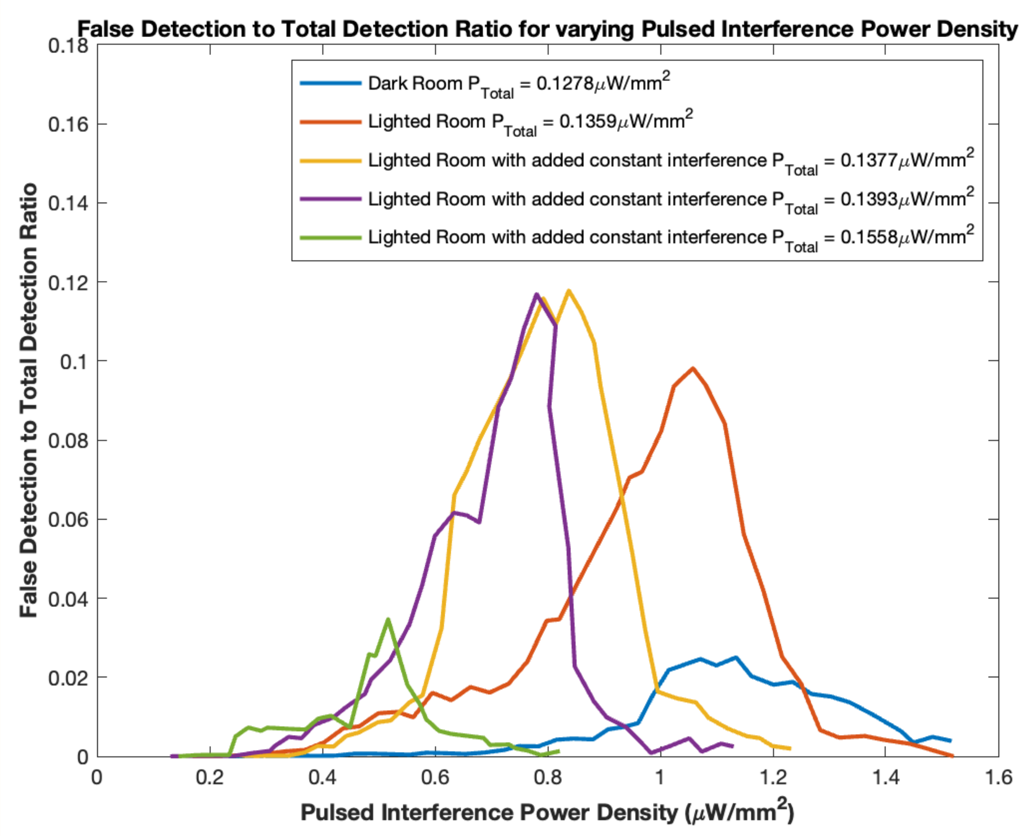
Laser pulses from the LiDAR are intercepted by the photo detector. The controller controls the laser diode to transmit synchronized interference towards the LiDAR to interfere with the LiDAR's normal operation.



Because the LiDAR receiver is a non-coherent detector, it is unable to differentiate between interferences and genuine reflected laser pulse from its own transmitter, the LiDAR receiver processes the sum of genuine reflected laser pulse and interference power; and generates a point cloud output feed to a computer for false detection measurement.

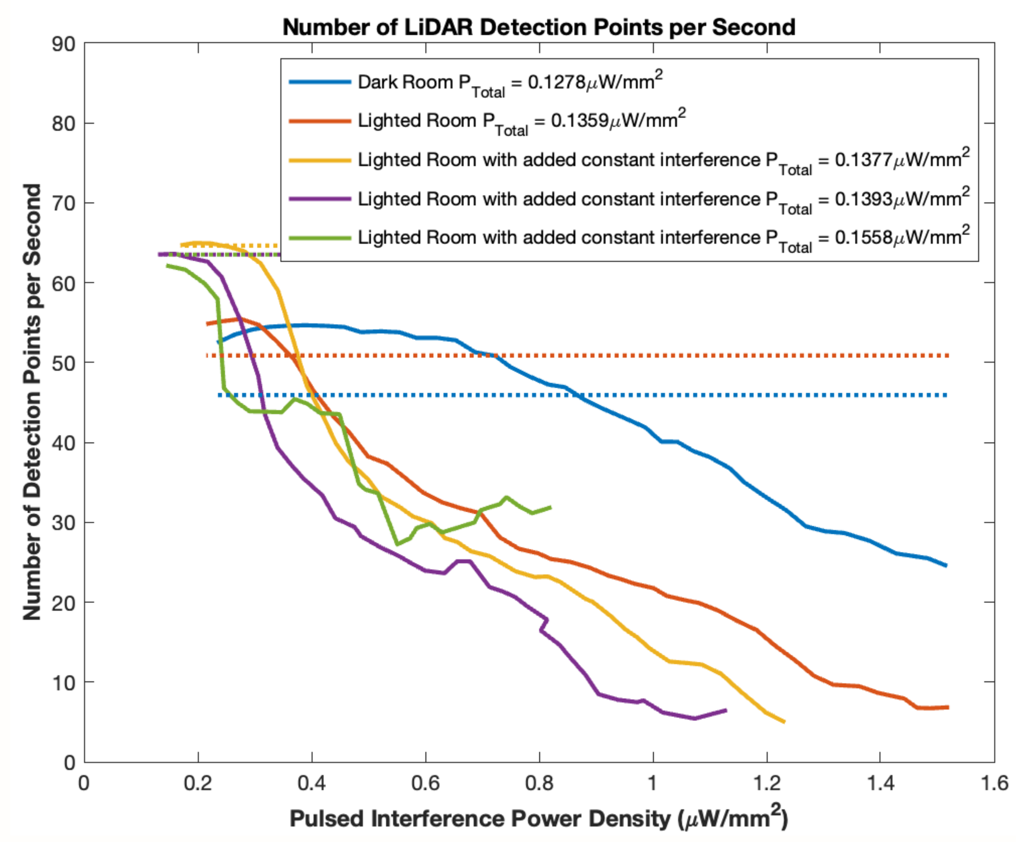
The false detection measurements reveal that the VLP-16 (LiDAR used for experiment) is more susceptible to false detection in environments with higher average noise power (e.g. lighted Room) compared to environments with lower average noise power (e.g. dark room).

The experimentation results reveal that peak false detection rate is achieved with a combination of pulsed and constant interference transmitted towards the LiDAR. The measurements shows that the maximum achievable false detection rate is obtained when pulsed interference power density is 0.8 μWmm² with a constant interference power density is 0.1377 μWmm².



The measurements demonstrate that the detection performance of a LiDAR is susceptible to interference from its environment. However, modern LiDARs have post detection processing scheme to help reduce the number of false detections generated.

The experiment findings suggest that the schemes are designed to help the LiDAR manage the different interference profiles that the device may encounter during its operation, to impede the effects that interference have on the detection performance of the LiDAR.



Conclusion

1. It is possible for low-powered pulsed and constant interference (less than 1 μWmm²) to noticeably affect the detection performance of the LiDAR.
2. The peak false detection to total detection ratio is achieved with a combination of pulsed interference and constant interference power transmitted towards the LiDAR. The relationship between false detection pixel generation rate, pulse interference power and constant interference power is similar to the signal-to-inference-plus-noise-ratio (SINR) relationship found in radar systems.
3. The detection performance of the LiDAR is more resistant to false detection from interference when the LiDAR is operating in environments with lower average noise power (e.g. night time).
4. Modern LiDAR systems likely have post detection processing capabilities to help suppress false detections.

The prevalence of LiDAR systems in autonomous platforms is anticipated to continue becoming more pervasive in both civilian and military domains. As these autonomous platforms are heavily reliant on sensory information from LiDAR systems and tend to have multiple LiDARs operating in close proximity with one another, platform designers have to ensure reliable interoperability of multiple LiDARs and prevent the likelihood of LiDAR systems mutually interfering with one another.

In parallel, research into methods to further minimize the effects that external interference have on the detection performance of the LiDAR is essential to ensure continued reliable LiDAR sensing and operation.

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