A COMPLICATED AND IMPRESSIVE SOUNDING TITLE THAT IS TOO LONG FOR A SINGLE LINE WHILE INCLUDING EVERYTHING

by

David B. Chester

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Approved:

Scott E. Budge, PhD Major Professor	Jacob Gunther, PhD Committee Member

Charles M. Swenson, PhD
Committee Member

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CHAPTER 1

INTRODUCTION

LadarSIM is a robust parametrized simulation tool for time of flight lidar developed at Utah State University's Center for Advanced Imaging Ladar over the past decade and a half [2, 3]. LadarSIM has the flexibility to simulate a wide range of time of flight lidar systems with varying beam and scanner patterns and parametrized transmitt ers and receivers. These simulated systems can be evaluated using scenarios consisting of user specified terrain, targets, and flight paths. Taking full advantage of the significant work that has gone into creating the LadarSIM software, a simulation of a parametrized FMCW Doppler transmitter and receiver will be added to LadarSIM to evaluate the performance of Doppler lidar systems. Utilizing this Doppler lidar simulation capability a trade-off study will be performed to determine the effects of varying laser transmission power, beam divergence, aperture diameter, and FFT size on a Doppler lidar system. These parameters have been selected because of the significant effect they can have on the performance, cost, size, and power consumption of a Doppler lidar system.

It is anticipated that the results of this research will present a clear demonstration of the effects of these parameters on a Doppler lidar system. For each of these parameters it is expected that performance will increase as the value of the parameter is improved but diminishing returns will be evident. Using this data, a designer would have strong guidance in designing the parameters of a Doppler lidar system to meet mission requirements while expending the minimum necessary resources.

CHAPTER 2
LITERATURE REVIEW

Adany et al. describe the operation and performance of a simplified homodyne detection scheme. In this scheme a waveform generator drives an electro-optic modulator which modulates an optical signal from a laser. The resulting signal is split into two parts. One part is amplified and sent to the telescope and the other is used as the local oscillator. The returning signal from the telescope is optically mixed with the local oscillator signal and detected by a balanced photodetector. An FFT is then performed on the detected signal to determine detected range and speed. [1]. This scheme is implemented NASA's Morphious test vehicle in order to demonstrate its utility as a potential instrument for planetary landing missions. [4–7]. Because of its use by NASA the simplified homodyne detection scheme has been selected as the basis of the doppler lidar simulation in LadarSIM.

Adany et al. tested their lidar at ground level at ranges of 50 m and 370 m [1]. The NASA instrument has been tested mounted on a helicopter and the morpheus test vehicle to demonstrate its performance. In the altitude tests the altidue varried from approximately 50 m to 1700 m [8, 9]. The Morpheus test vehicle was launched to a 250 m altitude then descended along a 30 degree path to a simulated landing field [7]. These tests provide useful data to compare with simulated results. The results of Adany et al. are particularly interesting because they include a return spectrum from the 370m experiment. The experiments of Adany et al. fall short in that the targets all had relatively good reflectivity and an approximately 90 degree angle incidence therefore there is little to be learn about spectra resulting from non-ideal conditions. The expiriments performed by NASA accurately mimic real world circumstances but no data on the resulting spectra is provided and no information on the performance of the system at long ranges.The simulation proposed will therefore provide insight on data which is not readily available, performance information and spectra from non-ideal scenarios. This data will be useful in making decisions about doppler lidar system characteristics as well as improving detection algorithms for doppler lidar.

A key step in the detection of FMCW lidar or radar is obtaining the frequency spectrum of the returned signal. This is typically done with an FFT. Resolution of range and speed is inextricably tied to the resolution in frequency domain. Hence obtaining many samples of the returned signal and performing a large FFT that signal allows for the improved resolution. While it is necessary that the FFT be large only a relatively small number of the bins will contain peaks of the return signal. In order to reduce computational complexity alternative methods can be used to obtain the return spectrum. Al-Qudsi et al. demonstrate how a Zoom FFT (ZFFT) can be used to significantly decrease the computational complexity fo FMCW radar. The ZFFT basically works by determining what portion of the total signal is of interest then filtering the signal to isolate the signal of interest so that a smaller FFT can be performed [10]. A second approach is the Chirp Z-transform. In short the Chirp Z-transform differs from the FFT in that the spacing of frequency bins does not need to be uniform. Using the Chirp Z-transform frequency bins can be placed densely where high resolution is required and sparsely where it is not, potentially resulting in better resolution on important details with less computational complexity [11, 12].

Two very important metrics in evaluating the performance of a Doppler lidar system are probability of detection and false alarm rate. Probability of detection describes the probability that a detection will not be missed and the probability of false alarm describes the probability that something will be detected which is not the true return signal. Both of these phenomena are cause by noise in the signal either pulling a returned signal below the detection threshold or simply peaking above the detection threshold. In order to simulate this behavior it is necessary to simulate the FFT of noise. Mark A. Richards provides an in depth derrivation of this [13]. Wang et al. also examine the effects of noise on an FMCW radar's performance along with picket fence effect and derive the detection probability and false alarm probability as well as propose an improved threshold detection method [12].

CHAPTER 3
RESEARCH AND DESIGN METHODS

The goal of this research project is to ascertain and demonstrate the effects of particular parameters on the performance of a Doppler lidar system by developing a robust parameterized simulation of FMCW Doppler lidar. The parameters to be studied are laser transmission power, beam divergence, aperture diameter, and FFT size. These parameters have been selected because of their potential effect on the overall performance, cost, power consumption, weight, and computational power of a system. The results of this research will simplify the task of designing or selecting a Doppler lidar system by providing information about where to best allocate resources to achieve performance requirements.

In order to simulate the effects of these characteristics on a Doppler lidar system, a detailed parametrized simulation of Doppler lidar will be added to the LadarSIM lidar simulation software. The updated LadarSIM software will then be used to simulate various Doppler lidar systems with varying transmission power, beam divergence, aperture diameter, and FFT size then the performance of these instruments will be evaluated in a variety of simulated scenarios by calculating and recording the probabilities of detection and false alarm. LadarSIM is a robust and realistic simulator which accurately simulates the real world behavior of a lidar system [2, 3]. After simulating the true measurements of range and velocity of a scenario, LadarSIM simulates the transmission and return of a beam by modeling the interactions of the beam with the atmourned signal. Using this returned signal and models of the noise in the system the probability of detection and false alarm are calculated. For each simulated beam, the probability of detection and false alarm will be recorded with information about the range and angle of incident to the target. This data will be used to compare the performance of Doppler lidar systems with different parameters. The information about the range and angle of incident will be used to compare performance under different conditions.

In order to make the effect of each parameter as evident as possible, each parameter will be varied and measured while holding the other parameters constant. This will also cut down on the number of simulations because it will not be necessary to simulate every possible combination of parameters to determine the effects of each parameter. However, the parameters of aperture diameter and laser transmission power are directly related. An increase in one will proportionally offset a decrease in the other. This relationship will be studied and the resulting trade-offs presented.

CHAPTER 4
CONCLUSION

Doppler lidar is can contribute useful data in determining altitude, speed, and position of a space craft during the landing phase of a mission. Under the Autonomous Landing and Hazard Avoidance Technology (ALHAT) project, NASA has been developing doppler lidar systems to provide this data [6]. It is clear that Doppler lidar will play a role in forthcoming space exploration missions.

In selecting or designing a Doppler lidar an engineer must determine what parameters the system must have in order to meet mission performance requirements. This task will be simplified by the development of the proposed Doppler lidar simulation. This simulation will be added to the existing LadarSIM software. The result will be a robust parametric simulation tool which will be able to simulate the performance of Doppler lidar systems with arbitrary parameters in arbitrary scenarios.

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