Chapter 10
Simulation of a Frequency-Modulated Continuous-Wave (FMCW) Radar Using Fast Fourier Transforms (FFT)

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ABSTRACT

Frequency-modulated continuous-wave (FMCW) radar systems send known frequency signals to moving targets and receive the signal back to detectors. FMCW systems can be used to measure exact heights of landing aircrafts. In addition, they are used in early warning radar systems and in proximity sensors. The advantage of using these radar signals is that the object target velocity and range can be quickly calculated using fast Fourier transforms (FFT). Taking the row-wise FFT of the signal matrix gives range information in form of range bins. Then taking column-wise FFT enables displaying the velocity for each range bin. The three-dimensional graph of the resulting matrix gives a signal power plot with respect to both the range bin numbers and their velocity.

INTRODUCTION

This chapter details the steps taken to simulate the FMCW radar system using FFT. One should be able to follow these steps with the specified set of hardware and software to get the same configuration. This project was implemented under the supervision of NASA scientists and faculty advisors in dedicated NASA labs.

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Following lessons learned here and authors' previous experiences in data visualization and signal processing research and training relevant labs were designed to enhance the Engineering programs at the Virginia State University (VSU) and Elizabeth City State University (ECSU) (Sheybani, 1992, 2002, 2006, 2007, 2008, 2010, 2011, 2012, 2013, 2017; Javidi, 2008, 2010, 2014, 2015, 2017; Ouyang, 2010; Garcia-Otero, 2011; Badombena-Wanta, 2010; Ettus, 2014, 2015; Luttamaguzi, 2017; Mathworks, 2014).

Some of the most recent advances in applications of microwave radiometry and specialty radar systems are due to the new developments in high-speed integrated circuits developed in digital signal processing as well as radio frequency (RF) and microwave technologies. As an example, the FMCW (frequency modulated continuous wave) maritime radar transmits a continuous radio frequency that varies gradually with time. When an object reflects the signal, the received waveform will build up a delayed replica of the transmitted waveform, with the time delay as a measure of the target range. If the target is moving, the radar system will register a Doppler shift within the received signal. The amount of Doppler shift is directly proportional to the radial speed of the target and can be determined after performing the range fast Fourier transform (range FFT). Performing a second FFT gives a two dimensional complex valued matrix, whose spectral peak corresponds to the Doppler shift of the moving target (Sediono, 2013).

Microwave radiometry and specialty radar systems are also used in weather radars that are used to monitor the precipitation events in atmosphere by estimating reflectivity from received power signals on receiver. Since received signals are contaminated by noise, such techniques are developed to calculate reflectivity accurately (Maurizka, 2016).

Another application is in finding the altitude information for the safety of aircraft that employs the FMCW radar as an altimeter. Although classical Fast Fourier Transform (FFT) method has been successfully used in short range measurement for Radar Altimeter, the problem of altitude estimation in long distance for Radar Altimeter is still an issue. Main problem of the existing methods for long range measurement is that they easily lose the current altitude or require the long searching time (Kuang, 2013).

BACKGROUND

Radar is an instrument that sends out a frequency pulse that hits an object which sends a pulse back to the instrument. The pulse that is sent back after hitting the object can be processed and analyzed to gain information on the object (i.e. range,