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Investigation of the Point Spread Function of MIMO SAS with Designed DFCW-LFM and FC Signals.

ABSTRACT - Masterthesis

In the past decades, considerable attention has been paid to Synthetic Aperture Sonar (SAS) as it provides rang-independent azimuthal resolution. By utilizing SAS, it is always desired to reconstruct an image with high resolution and Area Coverage Rate (ACR). However, there is a trade-off between high ACR and high along-track resolution as the achievement of a constant along-track resolution requires the step size between two pings should not be bigger than half of the element size. This problem is fully solved by using multiple transmitters and receivers at the same time, i.e. Multiple-Input Multiple-Output (MIMO) SAS. The orthogonal performance among signals from different transmitters is crucial for implementing MIMO SAS. Although various orthogonal waveforms are studied, there is no systematic approach telling us how to find orthogonal signal groups, thus this thesis focuses on studying different ways to find orthogonal signal groups.

This thesis firstly describes the fundamentals of MIMO synthetic aperture processing and derives the Point Spread Function (PSF) of MIMO SAS, based on which the auto-correlation functions of each transmitted signal and their cross-correlation functions are used as the performance measures when designing the transmitter waveforms. Waveform design can be divided into two parts: Discrete Frequency Coding waveforms (DFCW)-Linear Frequency Modulated (LFM) and Frequency Chain (FC) signals. The number of possible DFCW-LFM signal combinations explode as the number of sub-pulses increase and it is hard to analyze all of them in an acceptable time. A Block Design Method (BDM) is proposed to solve the problem of explosive growth of signal combinations. The experiment results show the auto-correlation sidelobe levels of DFCW-LFM signals are unsatisfactory although they provide acceptable cross-correlation peak levels, so DFCW-LFM signals cannot make up capable candidates for transmitted signals. FC signals have the similar structure as DFCW-LFM signals and the only difference between them is that FC signals have continuous instantaneous frequencies while DFCW-LFM signals not. Analyzing all the signal groups in an acceptable time remains as a problem for FC signals and the BDM does not apply for FC signals due to their different frequency structures. Therefore a Two Step Procedure (TSP) is proposed to solve the problem. The TSP analyzes the auto-correlation

and cross-correlation properties sequentially while they are combined in a cost function and used as a metric directly to find the optimal group in a Direct Approach (DA) typically. From the experiment results, FC signals have better auto-correlation performance and are more suitable candidates for transmit signals.