Pseudo-Noise Waveform Synthesis for SAR Applications

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***Abstract*— The paper presents the research carried out at Warsaw University of Technology on area of waveform design for Noise Synthetic Aperture Radar (SAR). The aim of the article is to present the method of creating complex pseudo-noise waveform with reduced side lobes of autocorrelation function in observation area.**

I. Introduction

The Noise SAR is a technique which uses noise-like waveforms to image stationary objects. The advantage of the noise waveform is lack of ambiguity both in range (time delay) and velocity (Doppler domain). The Noise SAR image is formed by computing correlation between point-like scatterer theoretical return and the received signal, assuming a grid of possible scatterers positions. For slow antenna movement it is possible to neglect Doppler effect and Noise SAR image formation can be divided into range compression and cross-range processing. The range compression is performed by calculating cross-correlation function between transmitted and received signal, after converting both of them to the baseband.

The disadvantage of the application of the noise waveform for SAR radar is the presence of the masking effect [1]. A strong echo signal or a strong crosstalk signal between transmitting and receiving antenna produces high peak in the cross-correlation function, accompanied by sidelobes (known also as the processing noise floor or residual fluctuation). The peak to sidelobes level is equal to Bt product (signal bandwidth B multiplied by the correlation time t). The sidelobes of strong signals can completely mask weaker echoes, and thus limit the image dynamic range as well as the SAR imaging distance.

There are several methods to overcome this problem. The first is to provide high separation between antennas. The other possibility is to use the CLEAN method [2, 3, 4] for removal of dominant scatterer from the scene. The disadvantage of CLEAN type methods is its very high computational burden, since after removal of each scatterer the SAR image has to formed again.

In the paper the authors proposed an alternative approach – waveform design. The goal is to design noise waveform with reduced time sidelobes. While it is not possible to reduce the sidelobes for all possible delays the authors decided to reduce the time sidelobes in the area of formed image. In the research the cyclic signal was assumed and details are explained in paragraph III B.

II. Noise SAR

The classical Synthetic Aperture Radars (SAR) use pulse waveforms for scene sounding and image generation. The pulse waveforms have several advantages. The technology is mature and there is a lot of waveforms with very good properties – especially low range sidelobes. While working in pulse mode one transmit/receive antenna is sufficient. Near objects and far objects are usually separated in time and there is no overlap of their echoes, so medium dynamic range with range sensitivity control is adequate. Hoverer to provide adequate mean power it is necessary to generate high power (several kW) pulses. Nowadays, the scientists and engineers look for very simple, small, low power devices that could be mounted at UAV's and other small platforms, including ground-based scanners and vehicles. The solution is to use CW SAR systems. Most of them are based on FMCW concept, but such approach, similar to the pulse one, is not free from ambiguities. A promising waveform, which is free of range and Doppler ambiguities is the noise signal. To verify the concept of noise SAR systems, and to identify its limitation a ground-based SAR demonstrator was constructed at Warsaw University of Technology. It is a very simple system that consists of:

- Moving platform attached to balcony of the laboratory, equipped with Tx and Rx antennas
- Signal sources including Arbitrary Signal Generators
- Signal digitizers such as digital oscilloscopes and vector signal analysers.

The SAR acquisition is performed in a stop-and-go mode. Computer controlled step motor shifts the platform to required position, and then signal generation and signal recording is performed. The SAR image is created off-line using MATLAB software.

The stop-and-go mode simplify significantly the image formation, while it is possible to divide the processing into two parts: range compression and cross-range compression.