Signal Detection in Multi-Frequency Forward Scatter Radar

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Abstract — **The peculiarity of Forward Scatter Radar (FSR) is the absence of range resolution. As a consequence, possible low signal-to-clutter ratio is the most limiting factor in FSR detection. In this paper we will discuss non-coherent and coherent FSR Doppler signal processing and consider an alternative cross-correlation approach, which could be called 'quasi-coherent' processing. Multi-frequency radar enables correlation of Doppler output of one of the channels with another which can be considered as the matching waveform, or the reference signal, to the first signal. This leads to a compression of the FSR return by cross-correlation with enhanced processing gain, and, consequently, enhanced detection.**

I. Introduction

Two traditional approaches are used in radar for automatic targets detection (ATD). These are the coherent signal processing (CSP) and the non-coherent (post-detector) signal processing (NCSP). If radar is fundamentally coherent, the CSP is the optimal processing that provides a maximum signal-to-noise ratio (SNR) at least in the case of Gaussian noise. For the CSP, the reference signal (i.e. the copy of the transmitting signal) must be known and compared with the received signal. NCSP is usually technically simpler and rather effective in terms of ATD if the signal dominates above the noise. However, the efficiency of NCSP dramatically reduces as soon as SNR becomes less than 0 dB. In this paper we propose a new approach for signal detection in FSR. This approach will provide signal compression which is no more than 3dB worse than in CSP for any SNR, and is technically achievable. The method is based on cross-correlation of signals from two coherent frequency separated channels. The description and justification of this method is the subject of this paper.

The concept of a forward scatter micro-sensors radar network for situational awareness in ground operations was described in [1]. The network consists of a number of nodes (separated short-range transmitter/receiver pairs) operating in forward scatter configuration with a continuous wave and intended for detection and recognition of moving ground targets such as personnel and cars intruding the protected area. Vegetation may surround radar position and be presented in close proximity to Tx/Rx and directly on the baseline. Fundamentally, FSR does not have the range resolution, and clutter is picked up from a large volume where spatially distributed clutter sources may form backscattering, bistatic and forward scattering signal interference. As a result, the clutter component may entirely mask the target component in FSR return in the time domain and we can expect poor performance of non-coherent detection. In this case coherent detection is expected to give conclusive results.

The essence of coherent detection is signal compression due to matching filtering of radar return when the acquired signal correlates with a reference waveform. In contrast to conventional radar, where the reference function is the delayed and frequency-shifted transmitted waveform, the received signal in FSR depends on the target's speed, RCS and trajectory and is a priori unknown. Thus, the optimal filtering process represents the problem of sequential correlation of the received signal with a set of pre-defined reference waveforms. Maximisation of correlation is a criterion for a particular reference function to be a matching waveform. Hence coherent detection is accompanied by target trajectory and speed estimation.

Despite its advantages, coherent detection processing for FSR is both time and resource consuming. We can expect to require thousands of reference functions to cover all the possible trajectories and velocities of targets within a 3 dB loss criterion of the compressed signal gain.

Use of multi-channel equipment, however, enables a 'lite' version of coherent processing, where FSR returns from one channel is used as a reference function to the other. Returns may consist of either a composition of signal and clutter/noise or just clutter and, again,, clutter power may exceed the target power. However, if we assume that clutter signals at different channels are de-correlated while target signatures are correlated after re-sampling, we can expect compression gain in the presence of a target and, therefore, detection in the background of low-correlated clutter.