Range dependence in bistatic radars for STAP : problem formulation and proposed solutions

Fabian D. Lapierre

Signal Processing Group, Université de Liège (Belgium)

The problem of detection of slow moving targets by means of a moving pulsed radar has been of great interest for quite some time. Two geometrical configurations are considered : monostatic radars where the transmitter and the receiver are co-localized and bistatic radars where the transmitter and the receiver are physically separated and moving along possible distinct trajectories. The radar uses a linear antenna and transmits a train of coherent pulses. Detection of moving targets can then be improved by using simultaneously the spatial and temporal information, corresponding to the antenna and the train of pulses, respectively.

The most important challenge is the rejection of clutter, which is the Doppler intereference signal coming from the fixed background. Space-Time Adaptive Processing (STAP) is known to provide an optimum solution. From measurement of the signal received by the antenna, the spatial frequency of the field along the antenna can be extracted. It can be found by applying a Fourier transform of the signal along the space dimension (antenna). Analysis of the temporal information using Fourier transform allows us to estimate the Doppler frequency. Clutter Direction-Doppler trajectories can then be obtained by plotting the clutter Doppler frequency as a function of the clutter spatial frequency. These curves give an idea of the spatial distribution of the clutter Doppler frequency, which is called the clutter spectrum. For monostatic radars, the clutter spectrum has a simple form and the theory of STAP gives good results as explained below. For bistatic radars, the combined transmitter and receiver motions implies a complicated structure for the clutter spectrum, which complicates the rejection of clutter. The reasons for this are now explained.

The construction of the optimum processor implies the estimation of the clutter space-time covariance matrix. This matrix contains the correlation between samples corresponding to different pulses and different array elements. It should be noted that the returned signal comes from all the points on earth seen by the radar antenna. This signal resulting from reflections from the ground is analysed in a succesion of range gates (the bistatic range being the distance between the transmitter, the scatterer and the receiver). For each range gate, a new processor is estimated. It can be shown that applying a Fourier transform to the received space-time signal in a given range gate (which is called a snapshot) gives the clutter spectrum defined earlier. Practically, the estimation of the clutter covariance matrix is done based on the information contained in neighboring snapshots. Then, a non-biaised estimator can be obtained if the clutter spectrum is the same in all the range gates used to estimate the clutter covariance matrix. The clutter spectrum must then be range-independent, which is the case for monostatic radar in the case where the antenna orientation is aligned with the radar motion. This is why STAP gives good results for this particular configuration. For bistatic radars, there is no geometry for which the clutter spectrum is range independent. Therefore, the Direction-Doppler trajectories are range dependent. This is why the rejection of clutter is more difficult.

The goal of this research is to find methods to make the clutter spectrum independent of the bistatic range. A few solutions are currently being explored. The first solution is based on a distorsion of the clutter spectrum in order to fit this spectrum to that obtained for the range of interest. This is a simple scheme that can give good results. The second uses suboptimal methods (developed for monostatic radars), that capture the minimum number of degrees of freedom needed to reject clutter optimally. For these methods, the training set used to estimated the clutter covariance matrix can be significantly reduced.