The range-dependence problem of clutter spectrum for non-sidelooking monostatic STAP radars

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Problem formulation

The problem of slow moving targets detection by means of a moving pulsed radar is examined for monostatic radars, where the transmitter and the receiver are co-localized. The radar uses a linear antenna and transmits a train of coherent pulses. Combining this space (antenna) and time (train of pulses) informations can enhance target detection.

The signal received from reflexions on the ground is divided in range gates. For a given range gate, the signal is a space-time snapshot. Applying a 2D FOURIER transform to the snapshot allows us to determine the spatial and DOPPLER frequencies f_s and f_d of the scatterer under interest.

The most important challenge is the rejection of interferences coming from the fixed background (clutter). The space-time repartition of the clutter power is found by plotting the clutter DOPPLER frequency as a function of the clutter spatial frequency. (direction-DOPPLER trajectories).

The optimum clutter rejection is provided using Space-Time Adaptive Processing (STAP) [1, 3]. For each range gate r, a new processor is applied. The optimum processor (OP) for a given r is [1]

$$\underline{\boldsymbol{w}}_{opt}(r)(f_s, f_d) = \underline{\underline{\boldsymbol{Q}}}^{-1}(r)\underline{\boldsymbol{v}}(r)(f_s, f_d),$$

where $\underline{\underline{\boldsymbol{Q}}}$ is the space-time clutter-plus-noise covariance matrix and $\underline{\boldsymbol{v}}$, the space-time steering vector. The construction of the OP implies the estimation of $\underline{\underline{\boldsymbol{Q}}}$, based on information contained in neighboring snapshots [3]. The estimator $\underline{\underline{\widehat{\boldsymbol{Q}}}}(r)$ for the range gate r is obtained by using N_r snapshots centered about r, i.e.,

$$\underline{\underline{\widehat{\boldsymbol{Q}}}}(r) = \frac{1}{N_r}\sum_k \underline{\boldsymbol{y}}(r_k)\underline{\boldsymbol{y}}^{\dagger}(r_k)$$

for $r - \frac{N_r-1}{2} \leq k \leq r + \frac{N_r-1}{2}$and $k \neq r$. $\underline{\boldsymbol{y}}(r_k)$ is the received snapshot for the r_kth range gate.

$\underline{\boldsymbol{y}}(r_k)$ being a random process, the clutter spectrum is the 2D FOURIER transform of $\underline{\underline{\widehat{\boldsymbol{Q}}}}(r)$ (or $\underline{\boldsymbol{y}}(r_k)\underline{\boldsymbol{y}}^{\dagger}(r_k)$) for a given r. An accurate estimator is found by applying the MVE to $\underline{\boldsymbol{y}}(r_k)\underline{\boldsymbol{y}}^{\dagger}(r_k)$ [1]. The resulting clutter spectrum is composed of a clutter ridge that has the same shape as the corresponding direction-DOPPLER trajectory. A non-biaised estimator is obtained only if the clutter spectrum is range-independant in the N_r range gates. This is not the case for non-sidelooking monostatic radars. The only existing method to compensate for this range-dependence is the DOPPLER warping [2]. However, the performance decreases as the crab angle of the antenna increases.

Proposed solution

This method appies to each $\underline{\boldsymbol{y}}(r_k)\underline{\boldsymbol{y}}^{\dagger}(r_k)$ a non-linear transformation that fit the clutter ridge of each $\underline{\boldsymbol{y}}(r_k)\underline{\boldsymbol{y}}^{\dagger}(r_k)$ to that of the range gate of interest, before application of STAP. The deformation studied here is a 2D dilatation.

After estimation of $\underline{\underline{\boldsymbol{Q}}}$, the OP must be applied in the space-time domain. However, the clutter spectrum is found by a non-linear power spectrum estimator that has no inverse transformation. The dilatation must then be done in the space-time domain. Working with discrete snapshots, 2D replicas of the clutter spectrum must first be suppressed in the space-time domain by applying a 2D interpolation filter to $\underline{\boldsymbol{y}}(r_k)\underline{\boldsymbol{y}}^{\dagger}(r_k)$.

The optimum trade-off between low sidelobes and reduction of high frequencies amplitudes is the 2D-KAISER window. This solution is examined and compared to the DOPPLER warping technique.

References

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