MODEL ORDER ESTIMATION FOR ADAPTIVE RADAR CLUTTER CANCELLATION

Muralidhar Rangaswamy[1], *Steven Kay*[2], *Cuichun Xu*[2], *and Freeman C. Lin*[3]

[1]Air Force Research Laboratory, Sensors Directorate, 80 Scott Drive, Hanscom AFB, MA, 01731
[2]Department of Electrical and Computer Engineering, University of Rhode Island,
Kelly Hall, 4 East Alumni Ave. Kingston, RI 02881
[3]ARCON Corporation, 260 Bear Hill Road, Waltham, MA, 02451

ABSTRACT

Adaptive waveform design for radar clutter cancellation requires knowledge of the rank of the clutter subspace. In this paper, we compare the computed clutter subspace rank, r, using three methods: (i) the exponentially embedded family (EEF) estimator, (ii) Rissanen's minimum description length (MDL) estimator, and (iii) the statistical ranking and selection method (CWA).

1. INTRODUCTION

Successful application of the space-time adaptive processing (STAP) for airborne radar systems to detect moving targets depends on the effective use of the available degrees of freedom to ameliorate the problems of training data support and computational cost. These considerations become particularly important in heterogeneous clutter scenarios. One solution to determine the required number of degrees of freedom is to correctly estimate the number of target signals. Under ideal conditions when the power spectrum density (PSD) of the clutter has a sharp locus (clutter ridge) in the angle-Doppler space and PSDs of all targets are away from the clutter ridge, it is simple to obtain the correct number of targets. In practice, the clutter PSD has a wide spread in the angle-Doppler space and some of target PSDs remain buried in the clutter spectrum. This often prohibits the correct estimation of the number of targets. Therefore, another approach is to adaptively design a proper waveform in order to null the clutter. Consequently, adaptive waveform design for radar clutter cancellation requires $a\ priori$ knowledge of rank of the clutter subspace. For airborne radar applications, the clutter rank is a function of two fundamental factors, i.e., the spatio-temporal non-stationarity of the clutter and system parameters such as platform speed, inter-element array spacing, and pulse repetition interval. The KASSPER data sets [1, 2], which are simulated data for airborne linear phased radar system with precisely the above-mentioned system parameters, are used for the estimation of clutter rank.

Designing a model order estimator to compute the clutter rank is essential for waveform design to mitigate clutter and to enhance target detection performance of adaptive detectors, e.g., the normalized low-rank adaptive filter [3]. Since the problem is one of composite hypothesis testing, for which no optimal solution exists, there is no consensus on its solution. One common approach employs a Bayesian philosophy which assumes a noninformative prior in an effort to "integrate out" the unknown model parameters. Then, the effect of the prior is ignored. Along these lines the minimum description length (MDL) has been proposed based on coding arguments [4]. Another approach, based on differential geometric statistical models, is the exponentially embedded family (EEF) [5]. In this paper, we compare EEF and MDL estimators for clutter rank estimation.

The CWA method [6] is based on ranking and a variation of the subset selection approach [7] to develop a screening procedure to select secondary data for radar signal processing. With some effort, the CWA method can be modified for the estimation of clutter rank provided that the clutter covariance matrix is given. In other words, one can reformulate the CWA procedure by replacing δ^* and c with the clutter-to-noise ratio, CNR (in the case of signals embedded in white noise, it will be signal-to-noise ratio, SNR), where δ^* is a preassigned real number to differentiate between good and bad eigenvalues and c is the real number chosen to satisfy the condition that the probability of a correct selection is optimal. After this replacement, the computed clutter rank during each Monte Carlo simulation step is equal to the total number of eigenvectors V_i having the ratio of eigenvalues $\lambda_i/\lambda_p > CNR\,(i = 1, 2, \cdots, p-1)$ where p is the total number of eigenvalues for the clutter covariance matrix and λ_p is the smallest eigenvalue .

In Section 2, we describe radar parameters used to generate simulated L-band and X-band KASSPER data sets and present eigenspectra computed for both data sets. Then, the EEF formulation for covariance rank estimation is given in Section 3. Computed clutter ranks using EEF, MDL, and CWA methods for both data sets are illustrated in the Sections 4 and 5, respectively. Section 6 presents conclusions.