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Review

Performance analysis of dual automatic censoring and detection in heterogeneous Weibull clutter: A comparison through extensive simulations

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ABSTRACT

In this paper, we address the problem of lower and upper automatic censoring of unwanted samples from a rank ordered data of reference cells, i.e., dual automatic censoring, and target detection with constant false censoring and alarm rates (CFCAR). Assuming a non-stationary background with no prior knowledge about the presence or not of any clutter edge and/or interfering targets, we propose and analyze the censoring and detection performances of the dual automatic censoring best linear unbiased (DACBLU) CFCAR detector in homogeneous and heterogeneous Weibull clutter. The cfcarness of both censoring and detection algorithms are guaranteed by use of linear biparametric adaptive thresholds. That is, we introduce a logarithmic amplifier, and determine the transformed Gumbel distribution parameters through the Best Linear Unbiased Estimators (BLUEs). The Censoring algorithm starts up by considering the two most left ranked cells and proceeds forward. The selected homogeneous set is used to estimate the unknown background level. Extensive Monte Carlo simulations show that the performances of the proposed automatic censoring method used in conjunction with various CFAR detectors are similar to those exhibited by their respective fixed-point(s) censoring detectors. Moreover, its performances are even better than those related to automatic censoring methods based on the assumption of initial homogeneous population.

Contents

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1. Introduction

In signal detection, the basic goal is to derive the optimum receiver structure based on some criterion that is determined by the application. Such optimal detectors require an essentially complete statistical description of the input signals and clutter. In practice, this information may not be available *a priori*, and the statistics of the input data may also vary with time. These constraints lead to the consideration of sub-optimal detectors. In practical radar signal detection systems, the aim is to automatically detect a target in clutter. Clutter is the term applied to any unwanted radar signals from scatters that are not of interest to the radar user. Since the environment in which the radar operates depends on factors such as weather conditions and physical location of operation, the returned signals are statistically non-stationary, with un-known variance at the receiver input. Target detection is commonly performed by comparing the radar return to a threshold. Ideal detectors, using a fixed threshold, are extremely sensitive to the clutter variance. In fact, a small increase in the clutter power results in a corresponding increase of several orders of magnitude in the probability of false alarm (P_{fa}), which is intolerable. Thus, one of the main tasks of radar detection is to maintain the constant false alarm rate (CFAR) constant. This can be achieved by adaptive thresholdding techniques, which are known to have the capacity to acquire immunity against all kind of background heterogeneities caused by the presence of precipitations and/or interferences and reflections from other various undesirable objects. They may appear as an extended clutter edge and/or as unwanted interfering targets with unknown power levels surrounding the cell being tested [1].

In order to guarantee CFAR detection, when the received samples present in reference cells are neither independent nor identically distributed, i.e., a heterogeneous environment, a class of detectors based on order statistics has been developed in the literature. In these detectors, the samples are first ranked in an ascending order according to their amplitude. Then, among the ordered reference cells, those containing unwanted echoes are discarded. The remaining homogeneous set of samples is used to estimate the unknown background level [2–20].

Some well-known detectors based on rank order statistics of sample data in a Gaussian background and censoring of interfering targets are given in [2–5], and where the number of interfering targets is assumed known *a priori*, which may not be available in many applications. Consequently, Barkat et al. [6] introduced the concept of automatic censoring and proposed the generalized censored mean level detector (GCMLD) CFAR, where the number of unknown interfering targets is estimated and censored automatically. The position of the clutter edge may not be available as well, and thus the concept of automatic censoring was considered further by Himonas and Barkat [7] and proposed the automatic CMLD (ACMLD) and the generalized two-level CMLD (GTL-CMLD) CFAR, which do not require any *a priori* information about the environment. They considered and studied cases where both a clutter edge and/or multiple target situations is (are) present in the reference window. These detectors estimate and censor automatically the highest unwanted cells without any *a priori* information about the presence or not of interfering targets, which is based on forward iterative cell-by-cell censoring procedure for rejecting the unwanted cells.

In [8–12] some detectors based on rank order statistics for non-Gaussian background were considered. In [8] Weber and Haykin proposed the WH-CFAR detector whose adaptive detection threshold does not rely on any distribution parameters' estimation. In [9] Levanon and Shor analyzed the performance of the order statistics (OS-CFAR) detector proposed in [4] for a Weibull clutter and for a known shape parameter. They also considered the WH-CFAR detector for an unknown shape parameter. For a homogeneous clutter, Ravid and Levanon [10] introduced the maximum likelihood (ML) CFAR detector based on the ML estimators of the Weibull distribution parameters. In multiple target situations, they also introduced the censored ML (CML) CFAR. Guida et al. [11] considered the best linear unbiased (BLU) CFAR detector in Weibull clutter; where a logarithmic amplifier is introduced to transform the Weibull distribution into a Gumbel distribution. That is, the location-scale (LS) type family allows the use of BLU estimators of the Gumbel parameters to adjust the linear biparametric detection threshold through a fixed number of ranked cells taken from a reference window whose lower and upper ends are trimmed. They also considered the BLU-CFAR detector in [12] for a lognormal clutter distribution whose transformation yielded the Gaussian distribution.

Automatic censoring for non-Gaussian clutter was introduced in [13,14] by Almarshad et al. In [13] they proposed the forward automatic censored cell averaging detector (F-ACCAD) CFAR for the case of lognormal clutter and multiple target situations. This detector uses ranked transformed normal samples to censor automatically the highest unwanted cells. It starts up the heterogeneity tests from a set of ranked reference cells assumed to be homogeneous and proceeds forward. Both censoring and detection algorithms are based on a biparametric linear thresholds for which the parameters of the normal distribution are estimated using a simple linear approach. In [14], they considered the forward/backward automatic censoring order statistics detectors (F/B-ACOSD) CFAR by use of the Weber–Haykin adaptive threshold introduced in [8]. Chabbi et al. [15,16] considered the forward/backward order statistics automatic censoring and detection (F/B-OSACD) CFCAR in Weibull clutter and multiple target situations. In [15], they considered a biparametric linear threshold where the parameters of the transformed