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Performance Analysis of the Modified Versions of CFAR Detectors in Multiple-Target and Nonuniform Clutter

Mohamed B. El Mashade
Al-Azhar University, Cairo, Egypt
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Abstract—A constant false alarm rate (CFAR) in the presence of variable levels of noise is usually a requirement placed on any modern radar. The CA- and OS-CFAR detectors are the most widely used ones in the CFAR world. The cell-averaging (CA) is the optimum CFAR detector in terms of detection probability in homogeneous background when the reference cells have identical, independent and exponentially distributed signals. The ordered-statistic (OS) is an alternative to the CA processor, which trades a small loss in detection performance, relative to the CA scheme, in ideal conditions for much less performance degradation in nonideal background environments. To benefice the merits of these well-known schemes, two modified versions (MX- and MN-CFAR) have been recently suggested.
This paper is devoted to the detection performance evaluation of these modified versions as well as a novel one (ML-CFAR). Exact formulas for their false alarm and detection performances are derived, in the absence as well as in the presence of spurious targets. The results of these performances obtained for Rayleigh clutter and Rayleigh target indicate that the MN-CFAR scheme performs nearly as good as OS detector in the presence of outlying targets and all the developed versions perform much better than that processor when the background environment is homogeneous. When compared to CA-CFAR, the modified schemes perform better in ideal conditions, and behave much better in the presence of interfering targets.

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I. INTRODUCTION

Detection of the radar's signal becomes a complex task when its returns are nonstationary background noise (or noise-plus-clutter). Many radar systems operate in environments where noise generated within the receiver is not the dominant source of interference. Undesired echoes from rain and unwanted signals from other radiating sources often exceed the receiver noise level. These sources of interference may completely obliterate the radar display, or may overload the computer which is making Yes/No decisions as to which echoes are valid.

To reduce this problem, radar detection processing can use an algorithm to estimate the clutter energy in the target test cell and then adjust the detection threshold to reflect changes in this energy at different test cell positions. As the clutter-plus-noise power is not known a priori, a fixed threshold detection scheme cannot be applied to the radar return if the false alarm is to be controlled. In other words, the false alarm probability increases intolerably if a fixed threshold is used as a detection scheme. Therefore, adaptive threshold techniques are required in order to maintain a nearly constant false alarm rate.

Because of the diversity of radar search environments, such as multiple targets and abrupt change in clutter, there exists no universal CFAR scheme. As a consequence, much attention has been paid to the task of designing and assessing these adaptive detection schemes [1–4].

A variety of CFAR techniques are developed according to the logic used to estimate the unknown noise power level. An attractive class of such schemes, which set the threshold adaptively based on local information of total noise power, includes cell-averaging (CA), ordered-statistic (OS) and their modified versions. The threshold in a CFAR detector is set on a cell basis using estimated noise power by processing a group of reference cells surrounding the cell under investigation.

The CA is an adaptive processor that can play an effective part in much noise and clutter environments, and provide nearly the best ability of signal detection while reserving the enough constant false alarm rate. This algorithm has the best performance in homogeneous background since it uses the maximum likelihood estimate of noise power to set the adaptive threshold. However, the existence of heterogeneities in practical operating environments renders this processor ineffective [5].