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Introducing excision switching-CFAR in *K* distributed sea clutter

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ABSTRACT

In this paper a new Constant False Alarm Rate detector which is composed of an excision processor and a switching-CFAR detector, in sea environment with *K* distribution, has been introduced. The new detector is named excision switching CFAR. Performance of EXS-CFAR is derived and compared with a few other detectors such as CA-CFAR, GO-CFAR and SO-CFAR for the Swerling I target model in homogeneous and non-homogenous noise environments such as those with multiple interferences and clutter edges. The results show that EXS-CFAR detectors considerably reduce the problem of excessive false alarm probability near clutter edges while maintaining good performance in other environments. Also, simulation results confirm the gaining an optimum detection threshold in homogenous and non-homogenous radar environments by the mentioned processor.

1. Introduction

In a radar receiver, after amplitude detection, backscattered signal is sampled in Range and/or Doppler or both of them and a one or two dimensional reference window is formed. Detection in radar means existence or non-existence a target in the middle cell or cell under test (CUT) of a reference window. Estimated noise can be found based on samples surrounding CUT and different CFAR algorithms. A well-known class of processors are mean-level detectors such as cell averaging CFAR (CA) [1]. Unfortunately due to differences in environmental conditions such as changes in clutter edge, multiple targets or jamming, the target detection will be corrupted. As solutions for these problems, various CFAR schemes are proposed. Some examples are greatest of CFAR (GO-CFAR), smallest of CFAR (SO-CFAR), order-statistics CFAR (OS-CFAR) [2–5]. These schemes have advantages and disadvantages but none of them show considerably good performance in all types of environments. In [6,7], the concept of the variability index (VI) detection has been presented. The VI-CFAR dynamically switches to the CA-, SO- or GO-CFAR, depending on the outcomes of the VI and the mean ratio hypothesis tests. The VI processor exhibits a low loss CFAR in a homogeneous background and performs robustly in non-homogeneous environments [8].

An EXCA-CFAR is different from other types in that it assumes existence of the situation that a priori knowledge of the maximum clutter level is available [9,10]. Before averaging cells for noise level estimation, EXCA discards large samples exceeding a predetermined threshold called the excision threshold, with the intention of removing the samples due to interferers. The method of discarding large samples can compose with GO-CFAR and it will result excision greatest of CFAR (EXGO-CFAR) [11].

In this paper, referring to the switching processor in [12,13], we are focusing on its excision type in an environment of sea clutter with *K* distribution to enhance the previous CFAR detectors' performance in non-homogeneous environments (existence of clutter edge and multiple targets). In fact, by adjusting the parameters of this new algorithm, it will be shown that good performance in environment with clutter edge could be achieved. Many researches show that *K*-distribution has arisen mainly to represent radar sea clutter

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[14,15]. In this paper, the performance of excision switching CFAR (EXS-CFAR) is analyzed in comparison to conventional CFAR processors in the presence of clutter edge and multiple targets. Also, with the help of simulation, it can be confirmed that the threshold obtained by EXS is optimized. After describing the algorithm of EXS in Section 2, mathematical and related probabilities of detection and false alarm are presented in Section 3. In Section 4 the performance and simulation of the EXS processor in homogenous and non-homogenous environments will be analyzed and in the last section, the results are presented.

2. Description of EXS-CFAR method

The K distribution has arisen mainly to represent radar sea clutter [14]. A random variable X with probability density function:

$$f_X(x) = \begin{cases} \dfrac{2c}{\Gamma(v)}\left(\dfrac{c}{2}v\right)^{v} K_{v-1}(cx), & x \geqslant 0 \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

is said to have a K distribution. $K_v(x)$ is the modified Bessel function, v is a shape parameter, c is a scale parameter and Γ is the gamma function. For a K-distributed dataset with arbitrary shape parameter v, the distribution of the sum of N samples of this dataset cannot in general be expressed in closed form and has to be calculated numerically using the convolution method. For the special cases of the shape parameter $v = 0.5$, $v = 1.5$ and $v = m+3/2$, $m = 1, 2, \ldots$ closed-form expressions have been found in [15,16]. For $v = 0.5$, the K distribution (1) could be written as:

$$f(x) = c\mathrm{e}^{-cx} \tag{2}$$

which is a special case of the gamma distribution of (3) shown below with the shape parameter $v = 1$.

$$f(x) = \frac{c^v}{\Gamma(v)} x^{v-1}\mathrm{e}^{-cx} \tag{3}$$

where $\Gamma(v)$ denotes the usual gamma function which has value $(v-1)!$ for integer v.

For $v = 1.5$, we can derive:

$$f(x) = c^2 x\mathrm{e}^{-cx} \tag{4}$$

which is a case of the gamma distribution with the shape parameter $v = 2$.

For $v = m+3/2$, $m = 1, 2, \ldots$, the PDF of the sum of N samples is given by:

$$f(x) = \gamma^N \mathrm{e}^{-cx} \sum_{j_0=0}^{N}\sum_{j_1=0}^{j_0}\sum_{j_2=0}^{j_1}\cdots\sum_{j_{m-1}=0}^{j_{m-2}} \binom{N}{j_0}\binom{j_0}{j_1}\binom{j_1}{j_2}\cdots\binom{j_{m-2}}{j_{m-1}} \times \frac{\beta_m^{N-j_0}\beta_{m-1}^{j_0-j_1}\cdots\beta_0^{j_{m-1}}}{\Gamma(2N+j_0+j_1+\cdots+j_{m-1})}(cx)^{2N-1+j_0+j_1+\cdots+j_{m-1}} \tag{5}$$

where

$$\gamma = \frac{c\sqrt{\pi}}{2^{m-1}\Gamma(v)}$$

$$\beta_i = \frac{(m+i)!(m+1-i)}{2^i i!}$$

In this paper, it is assumed that the CFAR processor's input are range samples (range cells) which are received from a square law detector. Considering the sea clutter background and target change of Swerling I, the output samples will be iid (independent and identically distributed) K PDF as (6) (considering shape parameter equal to 1.5 based on (4)):

$$f_{X_i}(x_i) = \frac{1}{\lambda^2} x_i \mathrm{e}^{-x_i/\lambda}, \quad x_i \geqslant 0,\ \lambda \geqslant 0,\ 1 \leqslant i \leqslant 2N \tag{6}$$

which X_is are $2N$ windows samples (excluding CUT) and $\lambda = c^{-1}$ is the total background clutter-plus-thermal noise power. If a cell contains only thermal noise then $\lambda = \lambda_0 = 2\eta$ and if a cell also contains clutter then $\lambda = \lambda_c = 2\eta(1+\sigma_c)$. If a cell consists of multiple (not primary) targets then in (7) we have $\lambda = \lambda_I = 2\eta(1+\sigma_I)$. Also σ_c is the ratio of clutter power to the noise power and

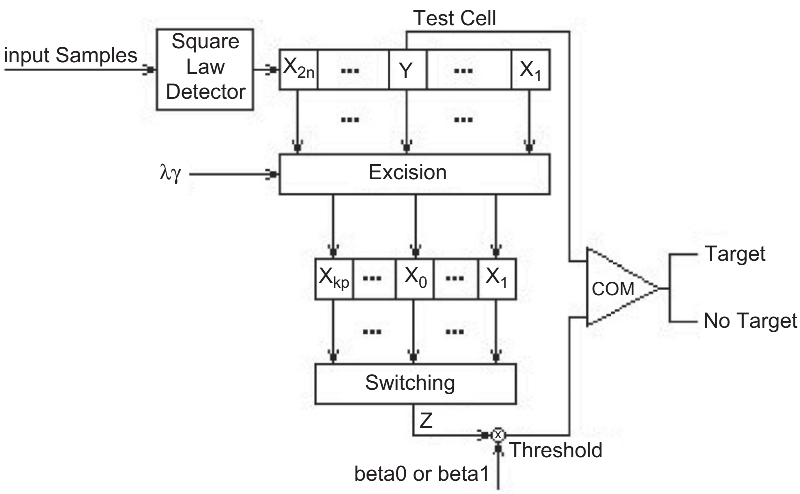

Fig. 1. Block diagram of EXS-CFAR.