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Analytical Performance Evaluation of Adaptive Detection of Fluctuating Radar Targets

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Abstract—A radar target whose return varies up and down in amplitude as a function of time represents the basis of a large number of real targets. This paper is intended to provide a complete analysis of CFAR detection of fluctuating targets when the radar receiver post-detection integrates M returned pulses from χ^2 fluctuating targets with two and four degrees of freedom and operates in a non-ideal environment. Owing to the importance of Swerling models in representing a large number of such type of radar targets, we are interested here in adaptive detection of this class of fluctuation models. Swerling cases I and III represent scan-to-scan fluctuating targets, while cases II and IV represent fast pulse-to-pulse fluctuation. Exact expressions of detection probability are derived for all of these models. A simple and an effective procedure for calculating the detection performance of both fixed-threshold and adaptive-threshold algorithms is obtained. In the CFAR case, the estimation of the noise power levels from the leading and the trailing reference windows is based on the CA technique. The performance of this detector is analyzed in the cases when the operating environment is ideal and when it includes some of spurious targets along with the target of interest. The primary and the secondary interfering targets are assumed to be fluctuating in accordance with the four Swerling's models cited above. The numerical results show that for strength target return the processor detection performance is highest in the case of SWIV model while it attains its minimum level of detection in the case of SWI model. Moreover, SWII model has higher performance than the SWIII representation of fluctuating targets. For weak target return, on the other hand, the reverse of this behavior is occurred. This observation is common for both fixed-threshold or for adaptive-threshold algorithms.

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I. INTRODUCTION

Radar is basically a means of gathering information about distant objects, or targets, by sending electromagnetic waves at them and analyzing the echoes.

There are two aspects to the radar statistical problem. The first is concerned with the background noise, which is random in character. In the absence of this background noise, detection poses no difficulty which means that however small the reflected signal from a target is, it may be detected with sufficient gain in the receiver. Background noise interference, however, imposes a limit on the minimum detectable signal. The question of target existence is, in fact, a choice of deciding between noise alone or signal-plus-noise mixture.

Random noise interference arises from many sources including radiation from the external environment and internal thermal noise. Generally, this noise is wideband with a uniform (white) or nearly uniform spectral density.

In addition, there is another major background noise source, which is referred to as clutter. This type of noise represents the aggregate radar return from a collection of many small scatterers, e.g., ground return, sea return, reflection from rain, chaff, and decay clouds. Detection and estimation in a clutter environment is a major problem in modern radars [1, 4, 11].

The second statistical aspect of the radar problem stems from the reflective properties of radar targets. If the radar cross section of an aircraft, or other complex target structures, is observed as a function of the aspect angle, the resulting pattern is characterized by rapid fluctuations in amplitude with minute changes in the aspect angle value. In a typical radar situation, the target is observed many times. The aspect angle at a particular time will govern the target cross section observed by the radar.

Since many targets have relative motion with respect to the radar, aspect angle changes on successive observations alter the radio frequency phase relationships, thereby modifying the radar target's cross section. This change may be a slow variation and occur on a scan-to-scan basis (on successive antenna scans