Adaptive Radar Detection and Localization of a Point-Like Target

Danilo Orlando and Giuseppe Ricci, *Senior Member, IEEE*

***Abstract*—In the present paper, we focus on the design of adaptive decision schemes for point-like targets; the proposed algorithms can take advantage of the possible spillover of target energy between consecutive matched filter samples. To this end, we assume that the received useful signal is known up to a complex factor modeled as a deterministic parameter; moreover, it is embedded in correlated Gaussian noise with unknown covariance matrix. Finally, for estimation purposes we assume that a set of secondary data, free of signal components, but sharing the same covariance matrix of the noise in the cells containing signal returns, up to a possibly different scale factor, is available. Remarkably, the proposed decision schemes can provide accurate estimates of the target position within the cell under test and ensure the desirable constant false alarm rate property with respect to the unknown noise parameters.**

***Index Terms*—Adaptive radar detection, constant false alarm rate (CFAR), generalized likelihood ratio test (GLRT), localization.**

I. Introduction

In the last decades design of adaptive decision schemes capable of detecting targets buried in Gaussian and non-Gaussian noise has raised a great interest in the signal processing community. The seminal paper by Kelly [1] and the technical report [2] are considered points of reference in this research field. Indeed, most recent papers rely on the results contained in the above works. In [1], the generalized likelihood ratio test (GLRT) is used to design an adaptive decision scheme capable of detecting coherent pulse trains in presence of Gaussian disturbance with unknown covariance matrix. Moreover, it is assumed that a set of secondary data free of signal components, but sharing the same spectral properties of the noise in the cell under test (CUT), is available (homogeneous environment). In [3], the authors derive the so-called adaptive matched filter (AMF), whose design relies on the so-called two-step GLRT-based design procedure. In fact, its design is split into two steps: first a non adaptive GLRT for known covariance matrix is derived; then, the fully adaptive version of the GLRT is obtained by replacing the unknown matrix with a proper estimate. Again, the homogeneous environment is assumed at the design stage.

A slightly general noise model assumes that the covariance matrix of the CUT and that of secondary data coincide only up to a scale factor. This scenario is referred to as partially homogeneous environment and has been first proposed in [4], where the authors apply the GLRT to derive a fully adaptive detector, referred to as the adaptive coherence estimator (ACE) but also as adaptive normalized matched filter (ANMF) [5]. The reader is referred to [6] for a list of papers concerning detection of radar targets against ground and sea clutter, clustered according to several related issues.

Most detectors considered so far assume that the target is located exactly "where the matched filter is sampled" and, hence, that there is no spillover of target energy to adjacent matched filter returns. Actually, there are reports of algorithms that consider the spillover between two adjacent sampling points and use practical centroiding to associate pairs of targets from one matched filter sample to those in another [7]. While this is a reasonable approach, it does not fully use the information provided by the measurements from the two sampling points and is hence suboptimal [8]. In [8], it is assumed that several closely spaced targets fall within the same beam of a monopulse radar and among three or more adjacent matched filter samples in range; for the considered scenario a maximum likelihood (ML) extractor is developed that makes use of monopulse information from the above samples to estimate the angles and ranges of the targets. This idea is further investigated in order to estimate the angles and ranges of multiple unresolved extended targets in [9]. Remarkably, decision schemes conceived to detect distributed targets, see [2], [10]–[12], can be used to account for the spillover of a point-like target.

In the present paper, we process space-time data to detect a possible point-like target with known Doppler frequency shift and direction of arrival. More precisely, we design adaptive decision schemes that take advantage of the possible spillover of target energy by exploiting the relationship between the amplitude of the target in the cell where it is located and that in one of the two adjacent cells. The novelty of the present paper with respect to [8] is that we exploit a closed-form solution to the ML estimation of the radar cross section (RCS) of the target conditioned on its position; second, we attack detection in homogeneous and partially homogeneous environment with unknown covariance matrix. A set of secondary data, free of signal components, but sharing the same covariance matrix of the noise in the cells containing signal returns, up to a possibly different scale factor (for partially homogeneous noise), is available. Remarkably, the proposed decision schemes can provide accurate estimates of the target position within the CUT and ensure the desirable constant false alarm rate (CFAR) property with respect to the unknown noise parameters.

The remainder of the paper is organized as follows: the next section is devoted to the problem formulation and describes the discrete-time signal and noise models. Section III focuses on

Manuscript received November 29, 2010; revised March 28, 2011 and June 02, 2011; accepted June 04, 2011. Date of publication June 16, 2011; date of current version August 10, 2011. The associate editor coordinating the review of this manuscript and approving it for publication was Dr. Lawrence Carin.

The authors are with the Dipartimento di Ingegneria dell'Innovazione, Università del Salento, 73100 Lecce (LE), Italy (e-mail: danilo.orlando@unisalento.it; giuseppe.ricci@unisalento.it).

Digital Object Identifier 10.1109/TSP.2011.2159602