Target Detection and Positioning in Correlated Scattering Using Widely Distributed MIMO Radar

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***Abstract*—Multiple-input multiple-output (MIMO) radars use different sources of diversity to improve the performance of the radar. A MIMO radar in which angular diversity is achieved by using widely distributed antennas has been proposed to reduce the impact of the fluctuations of the target radar cross-section. This type of system is also known as the statistical MIMO radar. Typically, it has been assumed that the scattering amplitudes of the signals received by different antennas are either fully correlated or independent depending on the configuration. However, the antennas may see similar aspects of the target in some situations leading to correlation in the scattering. In this paper, we show how the correlation of the scattering can be exploited to improve the probability of detection and positioning. This is achieved by using a parametric model for the correlation of the scattering. We also investigate how the correlation can be used for estimating the direction of arrival with an uncalibrated MIMO radar system.**

***Index Terms*—MIMO radar, diversity methods, target detection, maximum likelihood estimation**

I. Introduction

In a multiple-input multiple-output radar, multiple waveforms are used to improve the performance of the radar. There exist several different approaches to take advantage of the diversity provided by such systems. In colocated MIMO radars, the transmitters or receivers operate as a coherent array. This approach is taken for example in [1]. An entirely different approach is the MIMO radar with widely separated antennas[2], which is also referred to as the statistical MIMO radar[3]. Using widely distributed transmitters or receivers provides angular diversity, as the target is seen from several different angles.

Target detection using widely distributed MIMO radar was initially studied in [3]. It was assumed that the noise is spatially white and that the scattering from the target is an independent process for each transmitter–receiver pair. It was also assumed that the propagation delay is approximately the same for all the transmitter–receiver pairs, although the signal model has since then been expanded to include different propagation delays[4]. Equal time delays require the antennas to be relatively closely spaced, which can cause the scattering to be correlated. Furthermore, when the time delays are approximately the same, it is not possible to use the delays to estimate the position of the target. We investigate how the correlation can be exploited in target detection and positioning.

The optimal detector in Neyman–Pearson sense was derived for the different statistical MIMO radar configurations in [3] assuming independent scattering amplitudes. This result was extended to the commonly used Swerling cases in [5]. We derived the optimal likelihood ratio test for correlated scattering in spatially colored noise in [6]. However, using the LRT requires the covariance matrix of the scattering amplitudes to be known, which seldom is known exactly. In order to overcome this problem, the use the generalized likelihood ratio test (GLRT) was proposed in [7]. The covariance matrix was assumed to have a Toeplitz structure, which required the antennas to be positioned on a line with uniform spacing. In this paper, we use a more generic correlation model that does not constrain the antennas to any particular configuration.

The generalized likelihood ratio test can be formed using the maximum likelihood estimates for the unknown parameters. Using the GLRT derived in [6] for target detection would thus require estimation of the covariance matrix of the scattering amplitudes. Estimating it is problematic as typically there is only very limited number of pulses (samples) available to obtain a reliable estimate. Hence, the sample estimate of the covariance matrix is not accurate enough to improve the probability of detecting the target.

In order to achieve better performance, the structure of the covariance matrix of the scattering amplitudes should be exploited. This is possible because the positions or relative displacements of the antennas can be assumed to be known, so the correlation of scattering is a function of the target position. We assume the scattering can be modeled by using an exponential model in which the correlation depends on the difference in the angle to the target. It will be seen that the Kronecker model for the covariance matrix results form this simple exponential model. It is demonstrated that the position of the target can be estimated with a distributed MIMO radar system using the correlation model even when it is not possible to use the time delays.

This paper is organized as follows: The signal model is discussed in Section II and the target direction estimation in Section III. Target detection using GLRT is considered in Section IV. Numerical results will be provided in Section V. Finally, Section VI gives the concluding remarks.

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