Effects of the SNR of the Signal Replica in LMMSE-based Filtering

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***Abstract*— A general issue in radar processing is amongst other ones to separate targets. Several advanced techniques have been developed to fulfill this objective, such as linear minimum mean square error based processing (LMMSE). Nevertheless they depend heavily on the signal replica known at the receiver, and exhibit degraded performance when this reference is not noise-free. And this is also true for the classic matched filter (MF). As such the replica used for correlation receiver can be described with a signal to noise ratio (SNR). The analysis of the effects is done for a multi-target scenario where targets are close enough for the sidelobes of a target to interfere with the main lobe of another target, and close-by weaker echos are also present. This paper shows some experimental and simulation results illustrating the effects when there is such a discrepancy between the echoing signal and the signal reference used in the processing. Also shown is the improvement when countermeasures to this problem are taken.**

I. Introduction

Traditionally, in radar, the desired targets behaved as point objects and were separated by more than the radar resolution. On the other hand modern radar systems have to detect closely spaced targets with large ratios between strong and weak reflections. In particular in cases where some form of compression of long modulated pulses is implemented, the closely spaced targets interfere with each other, and applying standard matched filtering technique causes masking of the weaker close targets by the sidelobes. Most recently several strategies are under investigation for applying orthogonal frequency division multiplexing (OFDM) waveforms, widely used in communication standards, as radar signals for various purposes, [1], [2]. Multi-carrier signals such as OFDM allow flexibility and efficient use of the spectral resources, [3]. Furthermore, then enable to embed a communication message in the radar signal and achieve high data rates [2].

Several coding schemes [4] have been analyzed to counteract the inherent high sidelobe level of OFDM when processed by a matched filter. Nevertheless the desire for communication data embedded in the OFDM radar waveform precludes the adoption of rigid coding schemes to lower the sidelobes. Consequently the task of lowering the sidelobes is shifted to the receiving filtering scheme. Often used in several fields of science for unmasking of hidden objects is the CLEAN algorithm: a subtraction technique used to unmask weaker targets. Recently other filtering techniques, [5], [6], were proposed to solve closely spaced targets, based on LMMSE, linear minimum mean square error. These last techniques, in particular the so called Adaptive Pulse Compression scheme, have shown good performance under several perspectives [7]. Nevertheless they present a strong dependence on the transmitted signal reference known at the receiver [8].

The objective of this paper is to evaluate the effects and degradation of performance of the LMMSE-based filter as in [5] when the transmitted signal replica at the receiver is not noise free. The analysis is done using actual recorded measurements in a radar laboratory set-up and supported by simulation. Furthermore this analysis is performed for two signals, linear frequency modulation (LFM) and the OFDM radar-communication signal, in the case in which the transmitted signals replica are not noise free, as it is often the case in actual radar systems.

This paper is structured as follows. In Section II the processing scheme is recalled, including the signal model and the filter generation scheme. Section III provides the description of the experimental setup and pre-processing, which includes the setup of the anechoic chamber and simulated targets, signal chain, and pre-processing. In Section IV the results are shown and discussed. Conclusions are presented in section V.

II. Processing

Some alternative techniques to the traditional matched filtering belong to the least squares type. When placing the latter techniques in a statistical approach, the aim is to estimate the filter obtaining the minimum mean square error (MMSE) between the filter output and the desired parameter. To improve its analytical tractability, the assumption of a linear model for the received signal (linear estimator) can be applied, leading to an LMMSE technique [9], [10]. The method highlighted in [5] applies such an LMMSE scheme in a reiterative way on a reducing subset of the same sequence of samples of the received signal, with no fresh samples added.

A. Signal model

The signal model describes the received signal in terms of its components due the echoes of the transmitted signal and