Evaluation of Adaptive Filter Algorithms for Clutter Cancellation in Passive Bistatic Radar

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***Abstract*—Passive Bistatic Radar exploits the illumination of a scene by a local communications transmitter in order to perform radar processing without dedicated transmitter hardware. The direct transmission and strong stationary clutter are often present in the surveillance signal, reducing dynamic range and masking returns from targets. In this study various adaptive filters are used to estimate the direct path and clutter components and cancel them from the signal. Performance metrics particular to radar processing are defined, and the investigated filters are evaluated by application to Passive Bistatic Radar with real DVB–T data.**

I. Introduction

Passive Bistatic Radar (PBR) systems perform radar processing without dedicated transmitter hardware, instead using an illuminator of opportunity such as a television or radio broadcast signal. The lack of a transmitter results in significantly reduced hardware costs and the ability to operate entirely covertly while enjoying continuous illumination [1], [2], [3]. Exploiting communications transmissions enables otherwise reserved frequencies to be used for radar [2], [1].

Communications signals are not designed for use in radar. PBR processing output can thus exhibit many ambiguities due to signal structure [3], [4], [5], [2]. PBR is complicated by the lack of control over the transmitted signal and is operationally constrained to regions where suitable signals are available [3], [6]. A PBR system obtains a reference signal for radar processing by directing a beam at the transmitter, resulting in a template which suffers from additive noise and possible short–delay clutter due to reflectors within the beam [7], [3], [8]. The Direct Path Interference (DPI) is typically the largest component in the PBR's surveillance signal(s), which may also contain strong returns due to stationary clutter. This causes serious degradation of dynamic range [7], [9], and masking of weak targets by sidelobes [8].

In recent years PBR studies have used various types of transmission, including analogue FM [10], [11], [5], digital radio (DAB) [1], [10], [9] and digital TV (DVB–T) [7], [11], [4], [3], [8]. DVB–T signals have sufficient bandwidth for range resolution of a few tens of metres [11] and are noise–like, resulting in thumbtack–like ambiguity surfaces independent of signal content [12].The presence of redundant data and pilot information in the DVB–T frames produces some ambiguities which can be ameliorated via mismatched filtering [2], [4].

In this article we are concerned chiefly with the removal of DPI and zero–Doppler clutter (ZDC) in the data signal. Some studies suggest analogue null–steering to mitigate DPI [9], [10]. Post–digitisation the DPI & ZDC may still dominate the target returns and thus digital processing is needed to completely remove it [5]. For a static receiver, the majority of interference distinguishes itself from the targets of interest by having no significant Doppler shift. Clearly this interference will not directly obliterate target returns of high Doppler [10], however it will still constrain the dynamic range of the system and thereby mask weak targets. Interference has been removed by application of a modified CLEAN technique [7] however it is most often cancelled with an adaptive filter [1], [8].

An adaptive filter has a transfer function which evolves over time. A recursive algorithm continuously adapts filter weights which converge to optimal values without complete *a priori* knowledge of the signal characteristics [13]. Adaptive filters have a limited ability to alter their weights over time in order to track changes in nonstationary signals. However adaptive filters can be slow and computationally cumbersome [10].

Adaptive filters have been successfully used for removal of unwanted components of a signal, for example echo suppression in acoustic signals [14]. Evaluation of the performance of adaptive filters for interference cancellation has been performed in general contexts. However in the PBR scenario the interference (DPI & ZDC) is of the same form as the desired components (target returns), being delayed and weighted copies of the transmitted DVB–T signal. Furthermore error values are not readily computed since in PBR one does not have precise knowledge of the transmitted signal. The purpose of this study is to evaluate several methods of clutter cancellation in the context of DPI & ZDC, with metrics that are applicable specifically to PBR.

In the remainder of this paper we introduce and discuss various adaptive means of DPI & ZDC removal. We define some metrics by which one can evaluate how well a given algorithm has suppressed DPI & ZDC in the PBR scenario. We then apply the introduced methods to some real DVB–T data, forming radar range–Doppler maps and evaluating performance.

II. Clutter Removal Filters

A. Generalities

Given a Coherent Processing Interval (CPI) of N samples, and data signal vector $\underline{x} = [x_1, \dots x_N]^T$ containing returns

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