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Medium-PRF Detection by Non-coherent Integration

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Abstract— **The document describes a detection and inherent ambiguity resolution scheme for Medium-PRF waveforms. Medium-PRF waveforms are characterized by ambiguous measurements of both range and doppler. Ambiguities are resolved by changing the pulse repetition frequency (PRF) from burst to burst and by combining the ambiguous results of adjacent bursts. The classical binary integration procedure applies a detection threshold on burst level and combines detections from burst to burst including unfolding of the ambiguities. In this paper the more optimum method of non-coherent integration from burst to burst with inherent ambiguity resolution is discussed. The method provides a significantly improved detection performance. Of particular interest for non-coherent integration is the appearance of ghost targets. The paper proposes a method for deghosting.**

I. INTRODUCTION

In radar operation with Medium-PRF waveforms typically pulse groups (bursts) of constant pulse repetition frequency (PRF) are used, leading to target measurements with ambiguities both in target range and doppler (or radial velocity). For resolving the ambiguities the PRF is varied from burst to burst during target illumination.

The classical processing scheme is the filtering of the received signal in a doppler filter bank, followed by CFAR (constant false alarm rate) processing. Signals crossing the CFAR threshold represent ambiguous detections both in range and doppler. By unfolding the detections in range and doppler and correlating the unfolded detections from burst to burst the ambiguities can be resolved. For correlation a M out of N criteria is applied, e. g. with a 3 out of 5 criteria at least 3 correlated detections in the unfolded range and doppler area are required in a target illumination of 5 bursts to declare a final target detection. The detection scheme is thus a two-stage detector – a detector at burst level followed by the M out of N criteria. This detection scheme is called "binary integration". The CFAR threshold is selected to produce an acceptable false alarm rate at the output of the binary integrator. The binary integrator can be interpreted as a sub-optimum detector.

In the paper an alternative processing scheme with non-coherent integration and inherent ambiguity resolution is presented. After non-coherent integration a detection threshold is applied, resulting in detections in the unfolded range/doppler area. The non-coherent integration provides an improved detection performance compared to binary integration. Under some conditions the non-coherent integrator is an optimum detector. This is discussed in more detail below.

Target signal returns typically cause in the non-coherent integrator multiple detections in the unfolded range/doppler area. These unwanted multiple detections are called "ghost targets". In non-coherent integration applied in combination with Medium-PRF waveforms a deghosting procedure is necessary. The paper proposes a deghosting scheme, that is discussed in a similar principle in [1] and [2], but given here in a variant with less operational complexity. Further, an extension of non-coherent integration to a situation with clutter background instead of noise-only background is indicated.

II. NON-COHERENT INTEGRATION

A. Signal Model

A burst waveform of pulses transmitted with pulse repetition interval *PRI* is assumed. For a target appearing at doppler frequency $f_D = 2v_r / \lambda$ the receive signal in complex baseband in pulse period m is given by

$$\begin{aligned} x(m) &= \alpha_t \cdot s(f_D, \phi) + r(m) \\ &= \alpha_t \cdot \exp[j(2\pi f_D m \cdot PRI + \phi)] + r(m) \end{aligned} \qquad (1)$$

Here, α_t is the target amplitude, ϕ a signal phase as nuisance parameter and $r(m)$ an interference signal that may be composed by noise and clutter. The target signal appears in a range gate corresponding to the target range. Note that in Medium-PRF for a target outside the ambiguous range the target echo starts at the second, third etc. radar period. This is not included in the signal model above.

Writing the receive signal as vector $\mathbf{x} = [x_1,\ldots,x_M]^T$, the receive signal is

$$\mathbf{x} = \alpha_t \mathbf{s}(f_D, \phi) + \mathbf{r} \qquad (2)$$

The interference signal is characterized by the covariance matrix $\mathbf{R} = E\{\mathbf{r}\,\mathbf{r}^H\}$. This describes the signal model inside one burst. Below, the signal model and processing is extended to a target illumination consisting of a group of bursts.

B. Target Detection

For detection each range and radial velocity (or doppler) under test is tested for the hypothesis H_1 (target present) or H_0 (target not present):

$$\begin{aligned} H_1 &: \quad \mathbf{x} = \alpha_t \mathbf{s} + \mathbf{r} \\ H_0 &: \quad \mathbf{x} = \mathbf{r} \end{aligned} \qquad (3)$$

Given the probability density function (pdf) of the signal the target decision is formulated by comparing the likelihood

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