Enhanced Monopulse Radar Tracking Using Empirical Mode Decomposition

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***Abstract*— Monopulse radar processors are used to track targets that appear in the look direction beamwidth. The target tracking information (range, azimuth angle, and elevation angle) are affected when manmade high power interference (jamming) is introduced to the radar processor through the radar antenna main lobe (main lobe interference) or antenna side lobe (side lobe interference). This interference changes the values of the error voltage which is responsible for directing the radar antenna towards the target. A monopulse radar structure that uses filtering in the empirical mode decomposition (EMD) domain is presented in this paper. EMD is carried out for the complex radar chirp signal with subsequent denoising and thresholding processes used to decrease the noise level in the radar processed data. The performance enhancement of the monopulse radar tracking system with EMD based filtering is included using the standard deviation angle estimation error (STDAE) for different jamming scenarios and different target SNRs.**

I. INTRODUCTION

Monopulse radars are commonly used in target tracking because of their angular accuracy. However, these radars are affected by different types of interference which affects the target tracking process and may lead to inaccurate tracking [1]. A high power interference (jamming) may be introduced to the radar processor through the radar antenna main lobe (main lobe interference) or antenna side lobe (side lobe interference). The resultant distortion due to this interference will affect the induced target error voltage and consequently the radar tracking ability. Seliktar et al. [2] suggests adding constraints to the monopulse processors steering vectors to decrease the effect of the noise interference before extracting the target information. In our work the radar signal is processed in the empirical mode decomposition (EMD) domain to reduce the interference noise before supplying the received radar data to the monopulse processor.

EMD based real signal denoising is described in [3] and [4]. In our work we propose the use of an EMD filter to cancel interference signal that appears in the main beam look direction without adding any more constraints to the monopulse processor. Following a brief introduction to the empirical mode decomposition (EMD) the paper will describe the structure of the new EMD based monopulse radar processor. The superior performance of the new monopulse algorithm will be demonstrated for different jamming scenarios.

II. MONOPULSE RADAR PROCESSORS

A. Monopulse Radar Processors

1) The conventional processor is a non adaptive configuration comprising two sets of weights set to the sum and difference steering vectors. These steering vectors are defined as [3]:

$$w_{\Sigma} = a(\nu_l)\,,\ w_{\Delta} = \left.\frac{\partial a(\nu)}{\partial \nu}\right|_{\nu_l} \tag{1}$$

where $a(\nu)$ is the centre phase normalized steering vector in the look direction, N is the number of antenna, ν is the spatial steering frequency, and ν_l is the spatial steering frequency snapshot at time instant l.

2) The spatial processor is an adaptive configuration in which an adaptive beam former is used for the sum and difference weights by applying unity gain constraints in the look direction (target look direction). These weights (sum and difference) may be written in the following form [3]:

$$w_{\Sigma} = \frac{R_x^{-1} v_{\Sigma}}{v_{\Sigma}^H R_x^{-1} v_{\Sigma}}\,,\ w_{\Delta} = \frac{R_x^{-1} v_{\Delta}}{v_{\Delta}^H R_x^{-1} v_{\Delta}} \tag{2}$$

where R_x is the covariance matrix of the input data, ν_{Σ} and ν_{Δ} are the spatial steering frequency for the sum and difference channel respectively and $_H$ indicates the Hermitian.

3) The sum and difference outputs are given in terms of the respective processors,

$$z_{\Sigma}(l) = w_{\Sigma}\mathbf{x}(l)\ ,\quad z_{\Delta}(l) = w_{\Delta}\mathbf{x}(l) \tag{3}$$

where $\mathbf{x}(l)$ is the $N \times 1$ spatial snapshot at time instant l.

4) The error voltage The real part of the ratio of difference to sum outputs defined as [2, 3]

$$\varepsilon_v(l) = \Re\left\{\frac{z_{\Delta}(l)}{z_{\Sigma}(l)}\right\} \tag{4}$$

This error voltage conveys purely directional information that must be converted to an angular form via a mapping [2].

5) The standard deviation of the angle error (STDAE) [2] is determined using a target that is injected randomly across the range and angle within the main beam. The corresponding angle error is then averaged over the range and is defined as:

$$\sigma_{\varepsilon_\phi} = \sqrt{E\{|\varepsilon_\phi|^2\}} \tag{5}$$