A Fit-to-Sine based Processing Chain to handle Multiple-Target Scenarios

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Abstract— **The full coherent processing of non-equidistant sampled data has been the topic of many research activities. In this paper we propose a processing chain based on such an algorithm, the Fit-to-Sine function, which is able to handle multi-target and target/clutter radar signals. Starting from the computation of a least squares cost function in dependency of frequency, followed by a feature extraction method and the suppression of unwanted sidelobes, we conduct a simple noise/target distinction by utilizing basic fuzzy logic characteristics and operations. Finally we exemplify our processing chain and the achievable results on a real radar scenario with a target moving in strong clutter.**

I. INTRODUCTION

The Fit-to-Sine algorithm was first introduced in [1]. It is an efficient and reliable tool for the full coherent processing of non-equidistant sampled data. In [2] the algorithm was optimized and adapted for an implementation on a Field Programmable Gate Array (FPGA). One of the most important assumptions in these publications was that there is only one target present, or more precisely formulated, the target is always found by finding the Maximum. In this paper this assumption is abandoned, i.e. it is allowed that one or more targets are present, which demands a new form of defining targets, or regions of interest, hence called features. By utilizing the quintessential properties of the Fit-to-Sine algorithm, this can be done in a very efficient way, shown in Section II and III. Section IV illustrates how this reduced feature-space is used to establish a rating whether or not there is a target present. In Section V the described processing steps were applied to real world Radar data supplied by CSIR Defence, Peace, Safety and Security institution, confirming the capabilities of the proposed processing.

II. FIT-TO-SINE

In this section we will give a short introduction of the Fit-to-Sine algorithm. For the genuine publication please refer to [1].

A. Basic Algorithm

The Fit-to-Sine algorithm is a Maximum Likelihood (ML) estimator, which is minimizing the deviation to a harmonic oscillation in the least squares sense. With the given sample points $x_n = x(t_n)$, $n = 1, 2, \ldots N; x_n \in C$ of a complex harmonic oscillation the goal is to find the most appropriate complex sinusoidal oscillation

$$y(t) = ae^{j(2\pi ft+\alpha)} \tag{1}$$

with amplitude a, frequency f and phase α. This is done by minimizing the cost function

$$Q = \sum_{n=1}^{N} (y(t_n) - x_n)(y(t_n) - x_n)^\star \tag{2}$$

where "$\star$" denotes complex conjugation. Therefore Q is a measure how good an oscillation fits into the sample points. One approach would be to set the partial derivations $\partial Q/\partial a$, $\partial Q/\partial \alpha$, $\partial Q/\partial f$ to zero, respectively. In the Fit-to-Sine approach f is kept constant at first and only $\partial Q/\partial a$ and $\partial Q/\partial \alpha$ are set to zero. This leads to a system of convenient equations in a and α. The cost functions calculates to [2].

$$Q - Q_0 = \sqrt{\beta^2 + \gamma^2} \tag{3}$$

with

$$\beta = \sum_{n=1}^{N} \Re(x_n)\cos(\omega\ t_n)\ +\ \Im(x_n)\sin(\omega\ t_n) \tag{4}$$

$$\gamma = \sum_{n=1}^{N} \Im(x_n)\cos(\omega\ t_n)\ -\ \Re(x_n)\sin(\omega\ t_n) \tag{5}$$

$$Q_0 := \sum_{n=1}^{N} x_n \cdot x_n^\star \tag{6}$$

and $\omega = 2\pi f$.

This procedure can now be repeated for different frequencies out of a reasonable interval, which leads to a function of Q over f. The maximum delivers the most likely sine wave for the given sample points with frequency f, amplitude a and phase α[1].