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A Robust Multiple Signal Detector Based On Amc For Radar Signals

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Abstract: *Flexibility and versatility of digital techniques grew in the front-end signal processing and with the advent of integrated digital circuitry, high speed signal processors were developed and realized. Radar continued to grow in the recent years by keeping the future developments in mind and with better digital capability. Significant contributions in DSP in Radar have been in MTI processing, Automatic Detection and extraction of signal, Image reconstruction, etc An automatic modulation classifier (AMC) based on low-complexity signal features and a hierarchical decision tree is presented for pulsed radar applications. This AMC is implemented on a field-programmable gate array (FPGA) platform. The algorithm has been designed to minimize the computational burden to achieve real-time operation. The novelty of the paper consists of the development of a low-computational-complexity radar AMC suitable for real-time FPGA implementation.*

Keywords: *Pulsed radar, Automatic Modulation Classifier, FPGA, Digital Signal Processing, Moving Target Indicator Processing*

I. INTRODUCTION

Pulsed-Doppler radar is advanced signal processing techniques, many techniques suggests, to deals with techniques, from a very low level point of view, that allow a radar to detect a target, estimate its parameters and track it in a noisy environment. Nowadays, any military force has a set of various radars that perform several strategic and tactical missions. Radar systems are used in both civilian and military domains. Airports use radar systems to track landing aircrafts. Weather forecasts are mostly based on radar maps taken from satellites. Police forces use handed-Doppler radars to check car speed. the main difference between the civilian and the military domains is the fact that in war context, targets try to escape from radar coverage whereas in civilian domain, the security of an aircraft is partly ensured by the radar coverage in case of dense air traffic. Moreover, in the civilian domain aircrafts do have similar shapes and volume; it strongly eases system design as all targets have similar characteristics (mainly speed and shape). Pulsed-Doppler Radar is advanced Signal Processing Techniques, Many techniques suggests, to deals with techniques, from a very low level point of view, that allow a radar to detect a target, estimate its parameters and track it in a noisy environment. Nowadays, any military force has a set of various radars that perform several strategic and tactical missions. Radar systems are used in both civilian and military domains. Airports use radar systems to track landing aircrafts. Weather forecasts are mostly based on radar maps taken from satellites. Police forces use handed-Doppler radars to check car speed. The main difference between the civilian and the military domains is the fact that in war context, targets try to escape from radar coverage whereas in civilian domain, the security of an aircraft is partly ensured by the radar coverage in case of dense air traffic. Moreover, in the civilian domain aircrafts do have similar shapes and volume; it strongly eases system design as all targets have similar characteristics (mainly speed and shape).

However, in the military domain, each side tries to have furtive vehicles that can get close to the opponent forces without being detected. This involves very complex architecture and structure designs. Each target has a so-called radar signature. Targets are classified according to specific (sometimes secret) criteria. Basically, it defines how a given target will respond to pre-defined specific electromagnetic signals. Materials used and body shape are of high importance in designing a furtive vehicle Radar Signal Processing involves mathematical function analysis and fundamental theory in several scientific fields (waves propagation, digital filtering...). A strong background in these areas is required in order to design such system. However, this paper will only explore the signal processing aspects of radar designing. It assumes that the reader has basic knowledge in electromagnetic wave theory, antenna theory and signal processing. The measurements are thus relative to the radar own position in the 3D space and to its own speed. Embedded radars encounter fast changing operation conditions as ship/frigate or aircraft are not strictly stable. The second question also strongly affects signal processing techniques as ground and water does not have the same impact and effects on.

II. SYSTEM MODEL

A. Automatic Modulation Classifier

In general, an automatic modulation classifier (AMC) consists of two parts: the signal pre processing and the classification algorithm. The first part can estimate the time of arrival (TOA), pulse width (PW), signal power, signal-to-noise ratio (SNR), carrier frequency, etc. Classification algorithms can be divided into two types: likelihood-based (LB) algorithms (also known as decision-theoretic algorithms) and feature-based (FB) algorithms. In contrast to LB algorithms, FB approaches are not optimal, but they are more suitable for real-time implementation. The process of designing an FB classifier can be separated into three steps. The first step (in common with LB classifiers) is to determine the modulations or groups of modulations of interest. Our AMC is designed for pulsed radar signals.

1. MODULATIONS AND SIGNAL MODEL

The input signal is classified into four possible modulations: non intra pulse modulation (NM), linear frequency modulation (LFM, ascending or descending), frequency modulation (FM) different from LFM, and phase shift keying (PSK). PSK modulations are sub classified as 2PSK (such as Barker, Barker-squared, or pseudo-Barker signals), 4PSK, or MPSK (M > 4, such as the chirp like poly phase codes Frank, P1, P2, etc.). The signals to be detected are pulsed with random TOA

In our signal model, signals are complex (I + jQ). The preprocessing part is responsible for refining the time gating to introduce the PW signal samples into the classifier and to estimate the SNR.

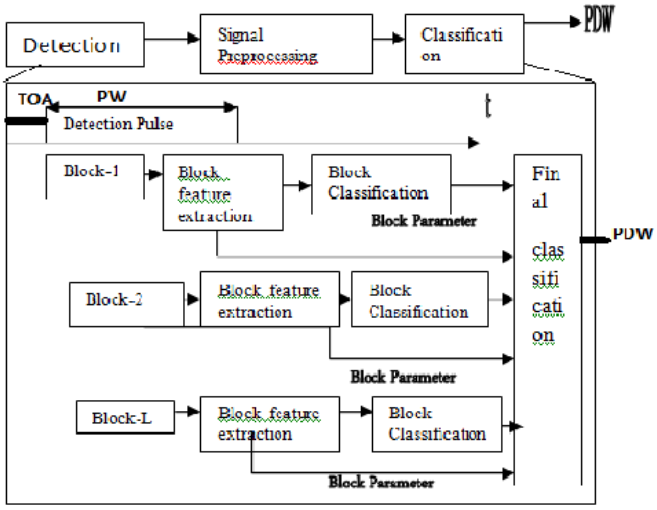

Fig.1 Block Based Modulation Classification

An overall view of the designed AMC is shown in Fig.1. The detected signal is passed through the preprocessing part in which TOA, PW, SNR, and residual carrier frequency are estimated. The signal preprocessing part and the AMC are described in this Sections respectively. The PW range of pulsed radar signals to be classified can be broad.

TABLE I Typical PRF, PRI, and PW Values in L band for Primary and Airborne Early Warning and Control (AEW&C) Radars

Radar	**PRF (Hz)**	**PRI (ms)**	**PW (µs)**
Primary radars	[400, 1000]	[1, 2.5]	[1, 250]
AEW&C (high PRF)	[10000, 50000]	[0.02, 0.1]	
AEW&C (low PRF)	[250, 4000]	[0.25, 4]	[0.25, 200]

2. Signal Pre-processing

For a pulsed radar signal, the TOA and PW must be estimated by the signal pre-processing part to avoid the insertion of noise samples in the classification algorithm. Only signal samples within the PW are passed through the classifier. Under these conditions, TOA and PW estimation errors could modify the correct classification probability (CCP) of the classifier. TOA and PW are estimated using an adaptive thresholding. Once the TOA and PW are obtained, the SNR is estimated. The noise is estimated with samples up to TOA, and the signal power is estimated with samples from TOA to TOA+PW.

3. Final Classification

The classifier makes the final decision by gathering all block classifications and the block chirp rate estimates. This classification needs the following: the number of total blocks L and the number of blocks classified as NM (LNM), LFM (LLFM), FM (LFM), and PSK (LPSK). In addition, the number of blocks sub classified as 2PSK (L2PSK), 4PSK (L4PSK), and MPSK (LMPSK) is needed.

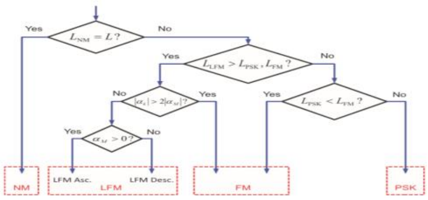

Fig 2 Final classification based on HDT.

B. HIERARCHICAL DECISION TREE

Separation of NM: The unwrapped instantaneous phase of a NM signal is a linear function of time with the expression φu[n]=2π fcn, where fc is the residual carrier frequency error. The MSE of the instantaneous phase and its linear fitting (γNM) must be lower for NMs than for the others. Thus, γNM feature can be used to separate NM from the rest of signals (fig.2).

The distance between NM and LFM increases with the chirp rate |α|, taking into account that an NM signal is a particular case of LFM with α =0, i.e., NM is a member of the LFM class. Similarly, the gap between NM and PSK/FSK modulations increases with the symbol rate (decreases with Ts) and SNR.

1.Separation of PSK

The kurtosis is related to the tail length of the probability density function (PDF), so higher kurtosis implies that the variance is the result of more sporadic high values. Hence, γK is greater for PSK signals than for the rest of modulations because of high spikes in the instantaneous frequency of the PSK signals. As shown in, γK and γV are two key features to identify the PSK signals. For PSK signals, γV increases with symbol rate (decreases with Ts), yet γK decreases with symbol rate (increases with Ts).

2. Separation of LFM and FM

Given that the instantaneous frequency is described by a linear function of time, then the unwrapped instantaneous phase follows a quadratic function. To reduce the computational complexity of curve fitting, the decimated form of the instantaneous phase (φu,R[n]) is used. Therefore, the γLFM,R feature allows us to separate NM/LFM signals from others whose instantaneous frequency is not a linear function of time, as shown in The separation between NM/LFM and PSK/FSK modulations increases with symbol rate (decreases with Ts) and SNR

3. PSK Sub classification

If a block is classified as PSK, the algorithm sub classifies it as 2PSK, 4PSK, or MPSK (M > 4). 1) Separation of 2PSK: When the instantaneous phase of a 2PSK signal is multiplied by 2, phase transitions of π are converted to 2π, and then the unwrap function should remove these phase shifts. Consequently, the unwrapped instantaneous phase must be a linear function of time, φu,2[n]=2 (2π fc)n, where fc is the residual carrier frequency error. Under these premises, the MSE of φu,2[n] and its linear fitting (γ2PSK feature) for a 2PSK signal should be lower than γ2PSK for an MPSK (M > 2). shows a clear separation between 2PSK and 4PSK/8PSK.

4. Separation of 4PSK**:**

In a similar manner to 2PSK, when the instantaneous phase of a 4PSK signal is multiplied by 4, phase jumps of π and π/2 are transformed into jumps greater than or equal to 2π and the unwrap function removes these phase shifts, obtaining a linear function of the form φu,4[n]=4 (2π fc)n. Hence, the MSE of φu,4[n] and its least squares linear fitting (γ2PSK) for a 4PSK (and 2PSK) signal is smaller than γ4PSK for a MPSK (M > 4). This procedure can be extended to separate M1PSK from M2PSK (M2 > M1) using φu,M1. However, separation performance decreases with M in a similar manner to other PSK classifiers.

III. SOFTWARE IMPLEMENTATION

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Math and computation, Algorithm development, Data acquisition, Modeling, simulation,prototyping, Data analysis, exploration, and visualization, Scientific and engineering graphics, Application development, including graphical user interface building.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows formulating solutions to many technical computing problems, especially those involving matrix representations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or Fortran. The name MATLAB stands for matrix laboratory. MATLAB was written originally to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, constituting the state of the art in software for matrix computation. In university environments, MATLAB is the standard computational tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the computational tool of choice for research, development, and analysis. MATLAB is complemented by a family of application specific solutions called toolboxes.

A. NUMERICAL COMPUTING

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, and Fortran.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems. In 2004, MATLAB had around one million users across industry and academia. MATLAB users come from various backgrounds of engineering, science, and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprises.

B. INTERFACING WITH OTHER LANGUAGES

MATLAB can call functions and subroutines written in the C programming language or Fortran. A wrapper function is created allowing MATLAB data types to be passed and returned. The dynamically loadable object files created by compiling such functions are termed "MEX-files" (for MATLAB executable).

Libraries written in Java, ActiveX or .NET can be directly called from MATLAB and many MATLAB libraries (for example XML or SQL support) are implemented as wrappers around Java or ActiveX libraries.

Calling MATLAB from Java is more complicated, but can be done with MATLAB extension, which is sold separately by MathWorks, or using an undocumented mechanism called JMI (Java-to-Matlab Interface), which should not be confused with the unrelated Java Metadata Interface that is also called JMI.

As alternatives to the MuPAD based Symbolic Math Toolbox available from MathWorks, MATLAB can be connected to Maple or Mathematica. MATLAB has a direct node with modeFRONTIER, a multidisciplinary and multi-objective optimization and design environment, written to allow coupling to almost any computer aided engineering (CAE) tool. Once obtained a certain result using Matlab, data can be transferred and stored in a modeFRONTIER workflow and viceversa.

C. TECHNICAL COMPUTING

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB features a family of application-specific solutions called toolboxes.

Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

IV. RESULT AND DISCUSSION

This section presence the performance of AMC as a functional block diagrams using Matlab. The AMC is an halfway path between signal detection and demodulation. For classifying any signal modulation place a main role. This modulation is done by pre processing and selection of the classification algorithm. To pre process the input pulsed radar signal using TOA and PW. For detecting the unknown signal it is necessary to generate the unknown signal. Initially the radar signal will be generated by applying continuous waveform.

A. CONTINUOUS WAVEFORM

Continuous wave radar is a type of radar system where known stable frequency continuous wave radio energy is transmitted and then received from any reflecting object CW radar sets transmit a high-frequency signal continuously as shown in Fig 5.1. Most modern air combat radar, even pulse Doppler have a continuous function as missile guidance purposes. Here also we following same process . In CW amplitude and modulation is likewise conceived and would lead to pulse radar with a modulation depth of 100%.

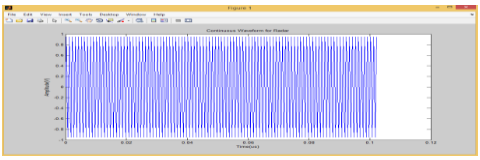

Fig.6 Continuous Waveform for Radar signal

CW (Continuous Wave) radar system can able to perform only basic target detection. To determine the of CW radar system unified sinusoidal waveform will be used with fixed pulse width duration and sampling frequency.The magnitude of this CW will be changed based on distance requirements.

B. PULSED WAVEFORM

In this case, pulsed radar a signal appears will perform with the best compared to a CW radar system. In this case, one has to choose between a mono-pulse radar (MPR) and a train pulsed radar system by defining interval period. Such a choice will be based on the maximum range the radar is expected to reach, the 3D area it has to cover but also on other specific aspects. Increasing the duration of a transmitted pulse increases its energy and improves target detection capability. Conversely, reducing the duration of a pulse improves the range resolution of the radar.

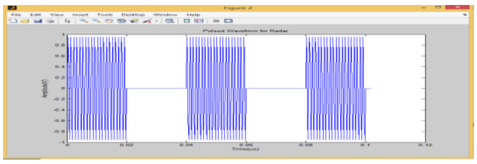

Fig 7 pulsed Radar signal

The pulsed waveform is modulated to classify the signals (LFM, NLFM, IM, 2PSK, 4PSK, 8PSK). In modulation the preprocessing takes place. TOA, PW and SNR must be estimated to avoid the insertion of noise samples in the classification algorithm.

C. ALGORITHM

The pulsed signal is modulated and transmitted to the Automatic modulation classifier. The pulsed signal is represented in the form of symbols. To determine the phase and magnitude of the symbol which is present in the signal we are using the Cordic algorithm. In Cordic algorithm the rotate vector (1,0) by ϕ is used to get cos ϕ and sin ϕ . Rotation reduces to shift add operation. Features are extracted from CORDIC output & its size will be reduced through logarithmic computation with base 2. In computing, $\log_2$ is often used. One reason is that the number of bits needed to represent an integer n is given by rounding down $\log_2(n)$ and then adding 1. For example $\log_2(100)$ is about 6.643856. Rounding this down and then adding 1, we see that we need 7 bits to represent 100. Similarly, in order to have 100 leaves, a binary tree needs $\log_2(100)$ levels. In the game where you have to guess a number between 1 and 100 based on whether it's higher or lower than your current guess, the average number of guesses required is $\log_2(100)$ if you use a halving strategy to bracket the answer.

D.CLASSIFICATION OF SIGNALS

Obtaining the value by the process of $\log_2(n)$ the threshold value is manipulated. This will set a particular threshold value to each range of signal and this ranges set as pre coded truth table. This is the main source used to classify the signals (LFM, NLFM, NM, PSK, 2PSK, 4PSK). Partial classification is carried out by addressing pre-coded truth table over features extracted after thresholding. Some of the obtained signals are discussed following below.

1. LFM MODULATED OUTPUT

Here we examine the Linear Frequency Modulation (LFM) for pulse radar technique on a generic signal model. Pulse radar signal allows achieving the performance of a shorter pulse using a longer pulse and hence gain of a large spectral bandwidth.By customizing following characteristics of the pulsed waveform LFM signal is generated.Sample rate,Duration of a single pulse, Pulse repetition frequency, Sweep bandwidth

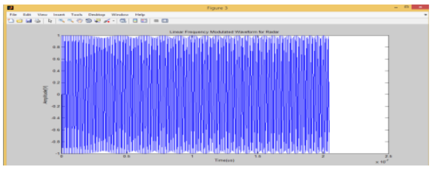

Fig 8 LFM modulated output

2. NLFM MODULATED OUTPUT

For non linear FM modulation pulse with a fixed sample rate, a pulse duration with an increasing instantaneous frequency, and a sweep bandwidth is used. The amplitude modulation is rectangular.The complex envelope of a Non linear FM pulse waveform increase with increasing instantaneous frequency.

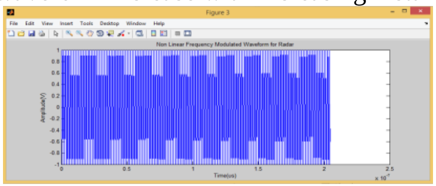

Fig 9 NLFM modulated output

3.AMC CLASSIFIED OUTPUT

After preprocessing the signal is converted into symbols and using cordic algorithm phase and magnitude is separated. Features are extracted from CORDIC output & its size will be reduced through logarithmic computation with base 2.Partial classification is carried out by addressing pre-coded truth table over features extracted after thresholding. Then this modulated signal is transmitted to the AMC for determine the classification as shown in Fig 5.5 as classified output.

Fig 10 classified output

Other AMCs present a significant lower sensitivity obtained by filtering in the time–frequency domain at the cost of using more complex algorithms. Summarizing, our AMC uses simple signal features and a simple classification technique (HDT) with no time–frequency processing at the cost of presenting higher sensitivity than other classifier\

V. CONCLUSION

In this paper, we analyze the performance of signal features based automatic modulation classifier (AMC) for pulsed radar system. Initially we pre-process the pulsed radar signal with various ,modulation schemes over parametric metrics .The proposed algorithm is based logorthemeic based dimention recution after feature extraction that exploits the sparsity of the estimated signal. We also perform tree based symbol selection in each iteration to prove the fast convergence. We illustrated the performance of our algorithm in numerical simulations, and our algorithm shows a significant performance in signal detection method.

VI. FUTURE SCOPE OF THE WORK

To carry out real time FPGA hardware implementation of AMC with low power and area efficient hardware architecture. To prove the efficiency of CORDIC based approach for complex signal processing and to carry out FSM based final classification. And finally FFT transformation will be used to compute frequency components and used it as additional feature for better accuracy.

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