ESTIMATING TIME PARAMETERS FOR RADAR PULSE DESCRIPTOR WORDS USING FPGA

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DEDICATION

To my lovely mother, who gave me endless love, trust, constant encouragement over the years, and for her prayers.

To my family, for their patience, support, love, and for enduring the ups and downs during the completion of this thesis.

To my cousin, for his special support, trust, engorgement to accomplish this work and standing beside me in every step.

This work is dedicated to them.

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ABSTRACT

Electronic warfare (EW) system is an important capability that can advance desired military or, conversely, impede undesired ones. In a military application, EW provides the means to counter, in all battle phases, hostile actions that involve the electromagnetic (EM) spectrum. An electronic support (ES) system is used by the military for intelligence gathering, threat detection, and as a support to electronic attack system. Its main feature is to determine the Pulse Descriptor Words (PDWs) which consists of: 1. Frequency. 2. Time of Arrival (TOA). 3. Pulse Width (PW). 4. Direction of Arrival (DOA). Then, PDW signal will be applied on deinterleaver to determine Pulse Repetition Interval (PRI) and it could be a simple pulse, staggered or jittered pulse. The estimated signal parameters are then used as input to a classifier network to determine the identity of the received signal. This project investigates on the hardware implementation on FPGA (Field Programmable Gate Array) of the time parameters of radar signals after the signal is demodulated. A set of test signals representing different types of radar is first generated which is then used to estimate pulse word descriptors from the time parameters. Using histogram analysis, the estimated pulse word descriptors is then classified with a set of known data base. The performance is evaluated at various signal-to-noise ratio conditions. In this work, 128 clock cycles are used to complete the signal analysing with various values of latency depending on the PRP type. The design is more efficient in term of FPGA resources utilization comparing with previous work. The proposed design can be used for the purpose of auto-measure of time parameters in many EW applications which have physical limitations in size, weight and power consumption (SWaP) such as in an aircraft.

ABSTRAK

Sistem Peperangan Elektronik (EW) adalah sebuah sistem keupayaan penting yang boleh memajukan tentera yang dikehendaki atau sebaliknya menghalang orang yang tidak diingini. Dalam aplikasi ketenteraan, peperangan elektronik menyediakan cara untuk menghalang semua fasa pertempuran, aksi permusuhan yang melibatkan spektrum elektromagnetik (EM). Sistem sokongan elektronik (ES) digunakan oleh tentera untuk mengumpul maklumat perisikan, mengesan ancaman dan sebagai sokongan kepada sistem serangan elektronik. Ciri utamanya adalah untuk menentukan Pulse Descriptor Words (PDWs) yang terdiri daripada: 1. Kekerapan. 2. Masa ketibaan (TOA). 3. Lebar denyutan (PW). 4. Arah kedatangan (DOA). Kemudian, signal PDW akan diaplikasikan ke atas deinterleaver untuk menentukan Pulse Repetition Interval (PRI) dan ia juga boleh menjadi nadi mudah atau nadi denyutan. Isyarat parameter yang dianggarkan kemudiannya digunakan sebagai input kepada rangkaian pengelas untuk menentukan identiti isyarat yang diterima. Projek ini menyiasat pelaksanaan perkakasan ke atas isyarat radar iaitu masa parameter FPGA (Field Programmable Gate Array) selepas isyarat demodulasi. Satu set ujian isyarat yang mewakili pelbagai jenis radar dijana untuk pertama kali yang kemudiannya digunakan untuk menganggarkan deskriptor kata denyut daripada parameter masa. Dengan menggunakan analisis histogram, anggaran deskriptor kata denyut kemudiannya diklasifikasikan dengan satu set pangkalan data yang diketahui. Prestasi ini dinilai dengan pelbagai keadaan nisbah bunyi-ke-bunyi. Dalam projek ini, 128 kitaran jam digunakan untuk melengkapkan analisis isyarat dengan pelbagai nilai latensi bergantung kepada jenis PRP. Reka bentuk ini lebih cekap dari segi penggunaan sumber FPGA berbanding kerja sebelumnya. Reka bentuk yang dicadangkan boleh digunakan untuk tujuan pengukuran auto parameter masa dalam kebanyakan aplikasi EW yang mempunyai batasan fizikal dari segi saiz, berat dan penggunaan kuasa (SWAP) seperti dalam pesawat.

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LIST OF ABBREVIATIONS

ARM	-	Antiradiation Missile
ART	-	Adaptive Resonance Theory
AWGN	-	Additive White Gaussian Noise
COMSEC	-	Conflict Removal and Communications security
DEW	-	Direct Energy Weapon
DOA	-	Direction of Arrival
EA	-	Electronic Attack
ECM	-	Electronic Countermeasure
ECCM	-	Electronic Counter-Countermeasure
ELINT	-	Electronic Intelligence
EMP	-	Electromagnetic Pulse
EMCON	-	Electromagnetic Emissions Control
EMS	-	Electromagnetic Spectrum
EP	-	Electronic Protection
ES	-	Electronic Support
EW	-	Electronic Warfare
FBD	-	Functional Block Diagram
FPGA	-	Field Programmable Gate Arrays
HDL	-	Hardware Description Language
IP	-	Instantaneous Power
NEMP	-	Nuclear Pulse
PRI	-	Pulse Repetition Interval
PRT	-	Pulse Repetition Time
PRF	-	Pulse Repetition Frequency
PRP	-	Pulse Repetition Period
PDW	-	Pulse Descriptor Word
RTL	-	Register Transfer Level

CHAPTER 1

INTRODUCTION

1.1 Background

Electronic warfare system uses focused energy, usually radio waves or laser light, to confuse or disable an enemy's electronics. It can also involve listening collecting an enemy's radio signals or sensing the emitters.

1.1.1 Definition of Electronic Warfare (EW)

The official military terminology describes electronic warfare (EW) shown in Figure 1.1 as a military action aims to control the electromagnetic spectrum (EMS). This purpose is accomplished through offensive electronic attack (EA), defensive electronic protection (EP), intelligence gathering and threat recognition electronic warfare support (ES) actions. These current definitions give each function a broader scope with respect to terminology used previously, which was, respectively, electronic countermeasures (ECM), electronic counter-countermeasures (ECCM), and electronic warfare support measures (ESM). Another definition for EA function, in addition to the last ECM function, the use of direct energy weapons (DEWs), antiradiation missiles (ARM), and electromagnetic and nuclear pulses (EMP and NEMP) to destroy enemy electronic equipment. The new EP function definition includes, in addition to the previous ECCM function, the use of electromagnetic emissions control (EMCON), the electromagnetic hardening of electronic equipment, EW frequency conflict removal, and communications security (COMSEC) actions. The new ES function definition is not very different from the previous ESM definition as both include nearreal-time threat recognition in support of immediate decisions relevant to EA, EP, weapon avoidance, and targeting actions [1].

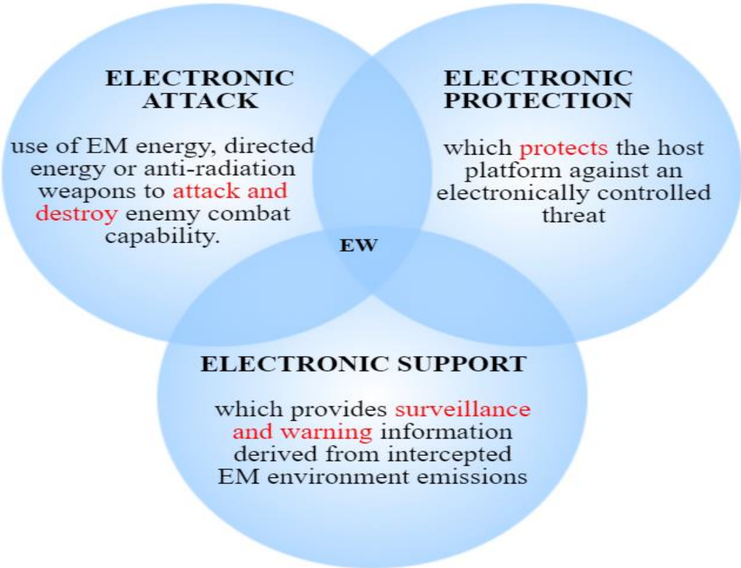

Figure 1.1: EW subsystems [2]

1.1.2 ES Receiving System

Modern radars can usually extract much more information from the target than just the range. They can extract angle, radial velocity, pointwise or distributed extension, aspect changes, jet engine vs. propeller modulation, and so forth. However, the measurement of range (i.e., the distance to a target) is still the most important radar function. The basic radar principle is shown in Figure 1.2.

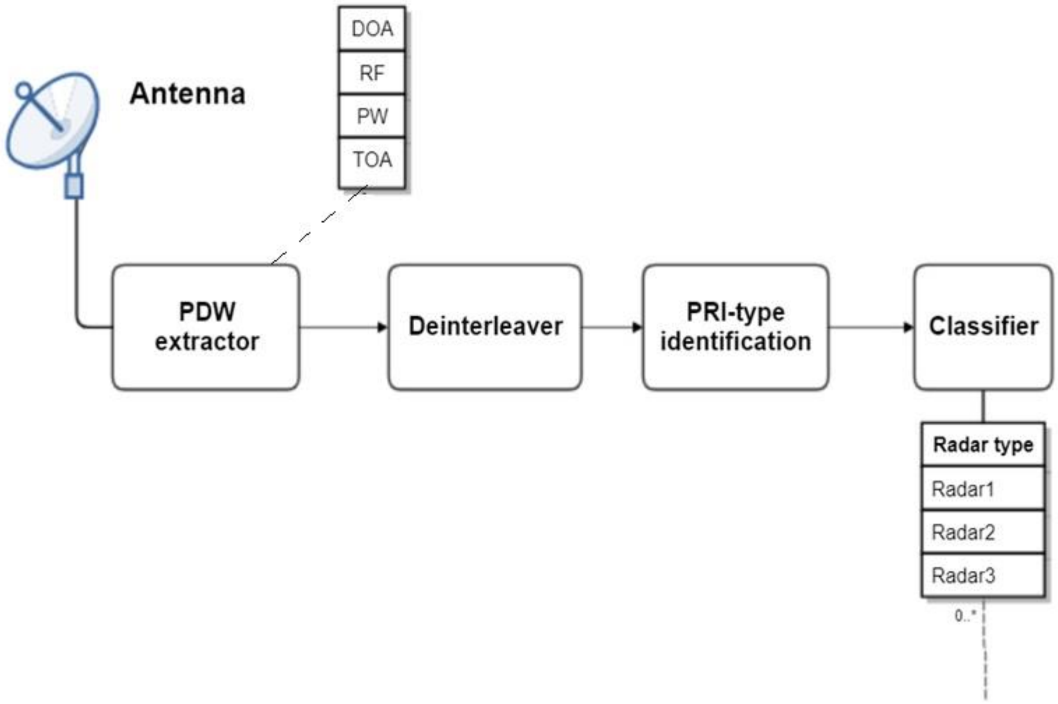

Figure 1.2: Block diagram of an ES receiving system [3]

1.2 Problem Statement

- Estimating an accurate pulse repetition interval (PRI) in noisy environment leads to missing pulses.

- The slower PRI analyzing leads to slower ES system response.

- Many of electronic support (ES) system applications have physical limitations in size, weight and power consumption (SWaP) such as in an aircraft.

1.3 Objective

- The PRI Estimation Algorithm is used to determine the PRIs of the received pulse train.

- To increase the system response speed, the received signal is analysed using FPGA.

- To increase the respond speed, the PRI estimation system is implemented on the FPGA.

1.4 Scope of Work

- MATLAB mathematical software is used to carry out all the simulation of algorithms.

- The noise in signal is assumed to be additive white Gaussian noise (AWGN).

- Threshold is chosen using Neyman-Pearson theorem.

- Radar PRI types used in this work are simple, 2-level staggered, 3-level staggered and jitter pulses.

- The received signal data is down sampled by 150, thus makes the PRI shorter to be used in the design and simulation.

- Quartus II software is used to design and implement algorithm on FPGA.

- ModelSim is used to simulate the Verilog code.

- Algorithm verified based on data captured at DSP Lab UTM.

1.5 Research Flow

Figure 1.3 shows the flow of tasks will be performed in this project. Existing algorithm for PRI estimation will be adjusted and tested for different PRI types in Matlab. Then algorithm will be converted to RTL and adjusted. Later, Verilog code will be written using Verilog HDL. Finally, algorithm will implement on FPGA in order to test it.

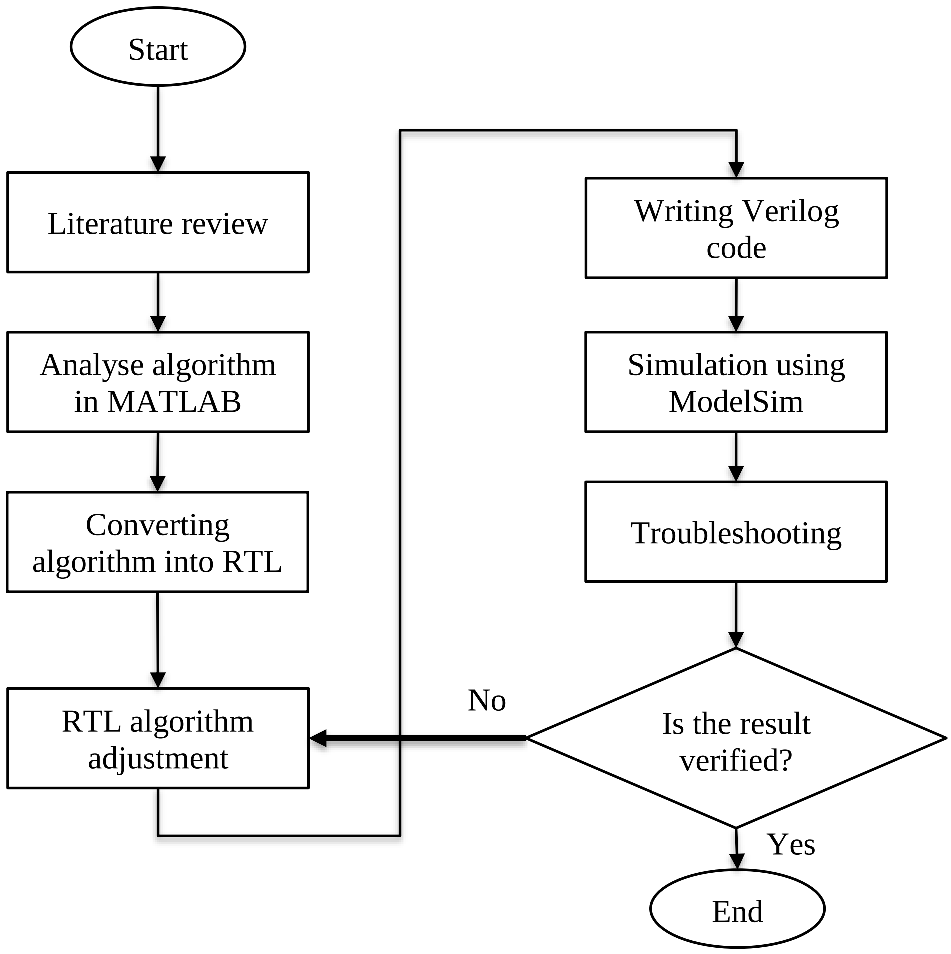

Figure 1.3: Project Flow Chart

1.6 Summary

This chapter discussed the introduction of this project, shadowed by brief explanation on electronic warfare and electronic support system. Problems were stated, objectives and scope of this project were presented.

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