Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF GROUND TARGET DETECTION SOFTWARE SYSTEM FOR AREA MONITORING USING AN FMCW RADAR

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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Tarikh: **13/1/2023**

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DECLARATION

I declare this project report entitled “DEVELOPMENT OF GROUND TARGET DETECTION SOFTWARE SYSTEM FOR AREA MONITORING USING AN FMCW RADAR” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

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Date : 13/1/2023

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours.

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DEDICATION

I would like to dedicate my Bachelor Degree project to my parent Rohaizi Bin Hamid and Ruslina Binti AB Rahman who thought me to be an independent and determined person. Both of them give me inspiration for not giving up in life and also worked hard to give me some advice and financial support to finish my studies. They always supports me and always thought me that the best knowledge in life which is to learn from our experiences and take that as in positive side of every negative thing. Next to my kind supervisor that guide in this project Dr Suraya Binti Zainuddin that always taught some knowledge and fresh ideas to complete this project. To my friends and all people that had guided me throughout completion of this project. Besides, t the person that encourages me to persue electronic engineering fields. Lastly, to the person who give me an inspiration for not giving up studying in electronic engineering.

ABSTRACT

An area monitoring or surveillance system is crucial to ensure the area's privacy is not intruded. Various methods can be explored for monitoring, including the utilisation of radar. Radar is favoured due to its robustness against the weather. Thus, this project aims to design and develop a detection system to detect a ground target and its distance from the monitoring system by utilising a Frequency Modulated Continuous Waveform (FMCW). Radar is capable of detecting motion, measuring speed, distance, angle of arrival, and direction of movement. Motion sensors for anti-burglary security systems, whether indoor or outdoors, are low-cost components that take use of the Doppler effect. In this application, radar is gradually replacing the Passive Infrared Sensors, which gained popularity in the past due to their cheap cost. Reason of doing ground target detection is because radar it has ability to cover wide regions on the surface for genuine two-dimensional monitoring day and night in practically any weather, with minimal influence from air dust and/or haze. Firstly, the range estimation will be simulated by using MATLAB to prepare for the range estimation algorithm. Next, the project will utilised a Distance2Go module for transmitting FMCW signal and acquired the echoes. Received signal will be post-processed using MATLAB to obtain the target information using Fast-Fourier Transform (FFT) and Peak Detection algorithms. Upon the peak detection, beat frequency is obtained and target range is estimated. As a result, the system can locate the target and its range from the observing point. Furthermore, performance will be analysed in terms of accuracy of the radar detection of target range compared to actual condition. The signal frequency spectrum and time domain signal were also observed. Lastly, the finding may contribute to the knowledge of ground-target detection and can make deeper understanding about FMCW radar concept for this project.

ABSTRAK

Sistem pemantauan atau pengawasan kawasan adalah penting untuk memastikan privasi kawasan tidak dicerobohi. Pelbagai kaedah boleh diterokai untuk pemantauan, termasuk penggunaan radar. Radar digemari kerana keteguhannya terhadap cuaca. Oleh itu, projek ini bertujuan untuk mereka bentuk dan membangunkan sistem pengesanan untuk mengesan sasaran tanah dan jaraknya dari sistem pemantauan dengan menggunakan bentuk gelombang berterusan termodulat frekuensi (FMCW). Radar mampu mengesan gerakan, mengukur kelajuan, jarak, sudut ketibaan, dan arah pergerakan. Penderia gerakan untuk sistem keselamatan anti pecah rumah, sama ada di dalam atau di luar, adalah komponen kos rendah yang menggunakan kesan Doppler. Dalam aplikasi ini, radar secara beransur-ansur menggantikan Penderia Inframerah Pasif, yang mendapat populariti pada masa lalu kerana kosnya yang murah. Sebab melakukan pengesanan sasaran darat adalah kerana radar ia mempunyai keupayaan untuk meliputi kawasan yang luas di permukaan untuk pemantauan dua dimensi tulen siang dan malam dalam hampir semua cuaca, dengan pengaruh minimum daripada habuk udara dan/atau jerebu. Pertama, anggaran julat akan disimulasikan dengan menggunakan MATLAB untuk menyediakan algoritma anggaran julat. Seterusnya, projek itu akan menggunakan modul Distance2Go untuk menghantar isyarat FMCW dan memperoleh gema. Isyarat yang diterima akan diproses selepas menggunakan MATLAB untuk mendapatkan maklumat sasaran menggunakan algoritma Fast-Fourier Transform (FFT) dan Peak Detection. Selepas pengesanan puncak, kekerapan rentak diperoleh dan julat sasaran dianggarkan. Akibatnya, sistem boleh mengesan sasaran dan julatnya dari titik pemerhatian. Tambahan pula, prestasi akan dianalisis dari segi ketepatan pengesanan radar julat sasaran berbanding keadaan sebenar. Spektrum frekuensi isyarat dan isyarat domain masa juga diperhatikan. Akhir sekali, penemuan ini mungkin menyumbang kepada pengetahuan pengesanan sasaran darat dan boleh membuat pemahaman yang lebih mendalam tentang konsep radar FMCW untuk projek ini.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

FMCW	-	Frequency Modulated Continuous Waveform
FFT	-	Fast Fourier Transform
CW	-	Continuous Waveform
RF	-	Radio Frequency
D2G	-	Distance2Go
SDR	-	Software Defined Radio
RUT	-	Radar Under Test
AWGN	-	Additive White Gaussian Noise
SNR	-	Signal to Noise Ratio
MIMO	-	Multiple Input Multiple Output
D2G	-	Distance2Go

CHAPTER 1

INTRODUCTION

This chapter will discuss about the background of the project, problem statement, objective, scope of the project.

1.1 Research Background

In our world, radar technology is one of the most advanced technologies for measuring object distances. There have been many radar systems that have been utilised for diverse reasons. Radar systems are categorised into several groups based on their operations and uses. This list covers some of the most prevalent radar systems used for various roles and by various industries. They are many type of radar such as Bistatic radar, Frequency Modulated Continuos Waveform (FMCW) radar, Doppler radar and others[1].

FMCW radar is a special type of radar sensor which is it radiates continuous transmission power like a continuous wave radar. FMCW radar also can measure not only the distance from the target radar but also it can measure the speed of target. Unlike Continuous Waveform (CW) radar, FMCW radar may modify its operational frequency during measurement. The broadcast signal is frequency or in phase modulated. Radar measurements using runtime measurements are only physically possible with these frequency or phase variations[2].

The ability to measure very small distances to the target is one of the main properties of FMCW radar. Next, the ability to assess both the target range and its relative velocity simultaneously, as well as extremely high range measurement accuracy.

Radar performance is initially measured in terms of propagation efficiency in different mediums such as air, vegetation, and ground in relation to the desired detection range. The general rule is that the lower the frequency, the more efficiently radio waves propagate through the medium. Furthermore, in a condition of obscurant present, propagation is advantageous when the Radio Frequency (RF) wavelength is substantially greater than the particle size forming the propagation medium. This is why radars operate far better than optical systems in the presence of smoke, dust, fog, and rain[3].

In contrast to typical cameras, radar sensors can provide wide-area monitoring that expands more than a facility's perimeter and will work efficiently in all light circumstances. With wavelengths ranging from millimetres to centimetres, security radars can easily penetrate weather and obscurants and provide dependable detection capacity. Due to their inherent ranging and massive signal processing capabilities, Radars can instantly and continuously scan a vast region and extract moving objects with a very low false alarm rate with the deployment of modern algorithms. When networked and interfaced to an integrated surveillance system, radars' accurate range and bearing information on targets allow for prompt camera cueing for visual assessment of threats and pointing of dissuasion devices, either optical or aural.

1.2 Problem Statement

Recently, due to covid-19, our world is going through uncertain climate change that can affect the security system. It may influence the operated trustworthy electrical gadget, just like any other device. Different weather types have different effects on various components in the surveillance devices and electronics, such as monitoring equipment and cameras that operate at a specific operating temperature. For example, cold weather impacts outdoor security system cameras in terms of optics and mechanical interruptions.

Meanwhile, ice can destroy an unprotected camera. If there is moisture near an outdoor camera and the temperature drops below freezing, frost can form on the camera's lens and prevent the user from seeing anything outside but the crystalline patterns created by the snow. For a powered moving camera, such as an auto tracker, ice produced by previous moisture from rain or sleet might cause the camera to freeze in place, preventing movement.

On the contrary, hot weather can cause heated cameras that affect several conditions. For an extended amount of time, the heat may be insufficient to keep the camera from freezing and continuing to process and work, and several power failures may occur.

Thus, the FMCW radar is a potential option to tolerate issues arise in monitoring ground target. Radar is capable of detecting motion and determining speed, distance, angle of arrival, and movement direction. Besides, radar can operate in various weather situations, including rain, fog, and dust, and can cover both long and short distances. It works by sending electromagnetic radiation toward things known as targets and observing the echoes that return.

1.3 Objectives

With regards to the problem statement discussed in previous section, the project objectives are as follows:

1. To develop a ground target range detection algorithm for FMCW radar signal processing by using MATLAB.
2. To validate the range detection algorithm through the experimental data.
3. To analyse the software developed in terms of it functionality and accuracy.

1.4 Scope of Project

a) To study the function of FMCW radar for monitoring the ground area.

b) Using the MATLAB application, create software to simulate the range radar for ground detection.

c) Prelim – to simulate the concept of range detection using FMCW signal

d) To identify the range of target from the radar transmitter and receiver for actual experimental measurement.

e) To verify software developed on the measurement data gathered using Distance2go module.

1.5 Outline of report

This report comprises of five main chapters divided into several sections to provide a detail explanation of the research. The contents of each chapter are summarised below to lay an overview guide of the study.

Chapter one consists of research background, problem statement, objectives and scope of project.

Chapter two consist of the review of literature, basic waveform of FMCW and Concept of range detection using FMCW.

Chapter three outlines the overall research methodology that consist of all processes involved in this research. It present the proposed of conceptual diagram of the proposed model. This chapter also elaborated on workflows project and test processes of design simulation and hardware development which is Distance2Go (D2G).

After understanding how the study was conducted generally, chapter four focuses on analysis data from experiment simulation post processes and analysis data from outdoor experiment for post processing.

Finally, Chapter five present the final summarised in conclusion. A summary of the research is presented, and finding of the study are discussed and interpreted.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In radar system configuration, there are 3 basic configurations which are monostatic, bistatic, and multistatic. Monostatic radar is a radar arrangement where the transmitter and the receiver are all in the same location and usually form the same piece of radar equipment. This configuration allows the transmitter to be synchronised with the receiver, making the timing method for measuring the target range easier to implement[4]. Bistatic radar share a common antenna between the transmitter and receiver and consist of separately located transmitting and receiving sites. In a bistatic radar system, the distance between the transmitting and receiving units is greater, and the parallax is usually greater. This means that a signal can also be received when the geometry of the reflecting object reflects very little or no energy in the direction of the monostatic radar (stealth technology). It is primarily used for weather radar in practise[5].

A multistatic radar system consists of multiple spatially diverse monostatic radar or bistatic radar components that share a common coverage area. The requirement for some level of data fusion between component parts is an important distinction of systems based on these individual radar geometries. Multistatic systems spatial diversity enables multiple aspects of a target to be viewed at the same time. The ability to gain information can result in a number of advantages over traditional systems. Multistatic radar, also known as "multisite" or "netted" radar, is analogous to the concept of macrodiversity in communications[6].

In FMCW radar it also called altimeter. It transmits data at a low power level. Many solid-state devices, such as magnetrons and reflex klystrons, can provide this. The super-heterodyne architecture provides excellent sensitivity and stability and it offers higher bandwidth compare to CW radar.

2.2 Previous Recent Project

Previous recent project, which used nearly identical software to innovate and develop the new project, were chosen to develop a concept for improving and mitigating the disadvantages. Table 2.1 offers a comparison table for ten various studies relevant to this project, so that we may enhance or prevent the project's drawbacks after studying them.

Table 2.1: Summary of Related Previous Projects

No.	Author	Title	Year	Method	Parameter	Result
1.	[7]	A method for Multi-target Range and Velocity Detection in Automotive FMCW Radar	2009	A new technique is based on voting is presented to overcome difficult signal processing and find correlated beat frequencies from all conceivable combinations.	Matlab was used to simulate the proposed technique. The modulation period was 1ms, the transmission bandwidth was 300 MHz, and the centre frequency was 76.5 GHz.	After two-step voting, the results for possible pairs of beat frequencies are obtained, and the strongest correlative beat frequencies are coupled for the real target. This strategy will help to improve radar detection qualities.
2.	[8]	Design and Development of A FMCW Ground Based Imaging Radar System	2009	Ground-based high bandwidth linear FMCW, fully polarometric, real-time imaging radar system design and development	FM-CW system setup 5.3GHz is the operating frequency (C-band), transmit power, Pt = 20dBm, measurement range = 20 to 100m, dynamic range = +20dB to -30dB, Receive power, Pr, ranges from -41dBm to -107dBm, with an IF bandwidth of 100Khz.	A concept design for an FMCW, fully polarometric imaging radar system has been proposed. This radar device may be used for simple target monitoring and categorization. This low-cost system is possible due to the use of a basic RF subsystem, a commercial component for chirp production, and a PC-based data collecting and processing system.

3.	[9]	FMCW Radar System with Additional Phase Evaluation for High Acurracy Range Detection	2011	The blending of FMCW and CW radar concepts into a single system involves an examination of their performance in terms of critical metrics such as accuracy, range resolution, and unambiguous range. By using labview and Matlab	Frequency range fmin to fmax : 24Ghz to 25Ghz , Bandwidth B : 1Ghz , cycle duration time T : 400us, propagation velocity on the measurement line c : $2.34 \times 10^{8} ms^{-1}$	To evaluate the accuracy, the obtained frequency values are transformed into position using the FMCW sawtooth modulation technique. In addition to the ideal location, both zeropadding and interpolation approaches are discussed. Radar-based position detection sensor systems with high precision accuracy at ranges of a few metres provide a low-cost option for industrial applications. This research combines two popular radar techniques (FMCW and CW) to obtain great accuracy in location detection.
4.	[10]	Moving and Stationary Target Detection Scheme using	2017	Create a goal tracking stage that includes clustering, data association, track administration, and a track filter. Finally, based on the target track	With a range-bin size of 0.5 m, a velocity-bin size of 0.5 km/h, and observable velocities ranging from -15 to 15 km/h, the signal	Suggested moving target indicator to differentiate moving target components from stationary target components prior to Doppler processing This was done to avoid