AN ANALYSIS OF HEARTBEAT MONITORING USING MICROWAVE DOPPLER TECHNIQUE

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This project and research work is dedicated to any beloved parents for their devoted caring throughout my life, my loving brother and sister, also my friends for their encouragement and love.

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ABSTRACT

This Final Year Project (FYP) refers to technical work and report writing experience that is relevant to professional development prior to graduation. One of the Universiti Teknikal Malaysia Melaka requirements for the award of Bachelor of Electronic Engineering (Wireless Communication) is that a student should complete his/her Final Year Project (FYP) and report. In order to that, my Final Year Project (FYP) titled "An Analysis of Heartbeat Monitoring Using Microwave Doppler Technique". This thesis discussed the possibility of detecting heartbeats using Doppler radar technique. The previous technology in detecting heartbeat like ECG is obstructive and not effective in certain situation where the subject doesn't cooperate. To overcome this problem, the Doppler radar technique is used. This technique works by transmitting continuous wave to targeted subject chest using one antenna and measure the reflecting signal using a vector network analyzer (VNA). The received reflected signal and transmitted signal is measured in term of the differentiation of the signal phase, the phase variation of the signal containing information about respiration activity and heartbeat signal. To separate these two signal, wavelet method and simple filter for filtering unnecessary signal have been used. The experiment is conducted using 2.4GHz frequency and several transmitted power. The results show that using wavelet methods from MATLAB software prove that the heartbeat signal can be detected using a single antenna. The results also show that the reduction of transmitting power significantly reduces the ability to detect a heartbeat signal. The significance of this research gives information about the minimal power needed to accurately detect the heartbeat signal.

ABSTRAK

Projeck Sarjana Muda (PSM) adalah satu usaha dalam menanaman dan pembagunan sifat professional yang berasaakan kerja-kerja teknikal dan softskill secara menyeluruh. Salah satu syarat untuk melengkapkan penganugerahan Ijazah Sarjana Muda Kejuruteraan Elektronik (Komunikasi Wayar), Universiti Teknikal Malaysia Melaka, seseorang mahasiswa perlu melengkapkan secara menyeluruh berkaitan Projek Sarjana Muda dengan sempurna. Berasaskan tujuan dan matlamat itu, Projeck Sarjana Muda (PSM) saya bertajuk "Analisis Pemantauan Degupan Jantung Menggunakan Teknik Gelombang Mikro Doppler". Tesis ini membincangkan kemungkinan mengesan degupan jantung yang menggunakan teknik radar Doppler. Teknologi sebelumnya dalam mengesan denyutan jantung seperti ECG adalah obstruktif dan tidak berkesan dalam keadaan tertentu di mana subjek tidak bekerjasama. Untuk mengatasi masalah ini, teknik radar Doppler digunakan. Teknik ini berfungsi dengan menghantar gelombang berterusan ke dada tertakluk disasarkan menggunakan satu antena dan mengukur isyarat mencerminkan menggunakan penganalisis rangkaian vektor (VNA). Menerima isyarat yang ditunjukkan dan isyarat dihantar diukur dari segi pembezaan fasa isyarat, perubahan fasa isyarat yang mengandungi maklumat mengenai aktiviti pernafasan dan isyarat denyutan jantung. Untuk memisahkan kedua-dua isyarat, kaedah ombak dan penapis mudah untuk menapis isyarat yang tidak perlu telah digunakan. Eksperimen ini dijalankan dengan menggunakan frekuensi 2.4GHz dan kuasa yang dihantar berbeza-beza. Keputusan menunjukkan bahawa menggunakan kaedah ombak dari MATLAB perisian membuktikan bahawa isyarat denyutan jantung boleh dikesan menggunakan antena tunggal. Keputusan juga menunjukkan bahawa pengurangan menghantar kuasa ketara mengurangkan keupayaan untuk mengesan isyarat denyutan jantung. Kepentingan kajian ini memberikan maklumat tentang kuasa minimum yang diperlukan untuk mengesan dengan tepat isyarat denyutan jantung.

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LIST OF ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
FYP	-	Final Year Project
IEEE	-	Institute of Electrical and Electronics Engineers
VNA	-	Vector Network Analyzer
FCC	-	Federal Communications Commission
CW	-	Continuous Wave
ISM	-	Industry, Science and Medical
BPM	-	beat per minute
ADS	-	Advance Design System
RF	-	Radio Frequency
EM	-	Electromagnetic
GUI	-	Graphic User Interfaces
ECG	-	Electrocardiogram

CHAPTER 1

INTRODUCTION

1.1 Background

Microwave Doppler radar has been used for wireless sensing applications for many years. Beginning from 1970s, microwave Doppler radar found new applications in human healthcare monitoring and detection. It offers new opportunities, such as physiological movement and volume change sensing [1], human vital signal detection for finding trapped people under earthquake rubble [2]. First works were done with heavy and bulky waveguides, but recent advances in microwave and radar technologies made it possible to integrate such a system on a single chip [3,4], which is compact, light-weight and low cost. With inexpensive and compact design, microwave Doppler

radar could be used in home healthcare monitoring, particularly for detecting sleep apnea [5,6].

Microwave Doppler radar was first used for sensing of respiration rate and the detection of apnea in 1975 [1]. Since 1980s, similar systems were developed for finding victims trapped in earthquake rubble and an avalanche [7] and sensing human presence behind wall or other barriers [8]. All these systems were designed for using in diagnostic institutions, but are impractical for home healthcare monitoring. Alternatives to this for heart and respiration on home monitoring are polar straps [9], chest expansion measuring straps [10] for respiration monitoring, acoustic monitors, nasal and oral sensors. All these method required contact with body and careful placement.

Doppler-type motion-sensing radar systems typically transmit continuous-wave (CW) signal, which is reflected off the target and received by the receiver. According to Doppler theory, a moving target will cause frequency shift in transmitted signal, which can be detected by detector. A stationary person has chest movement, and, therefore, Doppler radar with chest as target will received transmitted signal with Doppler shift caused by movement of the chest, which contains information about heartbeat and respiration.

In this thesis, the propose system is to use single receive and transmit antenna in order to provide simplicity in measurement setup and the recorded of S11 parameter data from Vector Network Analyzer (VNA).

1.2 Problem Statement

According to statistics, cardiovascular disease is the leading cause of death for both men and women in Malaysia. Latest studies even show that Malaysians are developing heart problems at a younger age of around 58, compared to the Thais who

develop heart disease at 65, Chinese at 63, and western nations who tend to get heart problems at the average age of 66. Early detection and treatment of symptoms and abnormalities can significantly decrease this rate. Therefore, the heart-related signals are the most important vital signals to monitor.

1.3 Objectives

This study embarks on the following objectives:

i. To study Microwave Doppler Radar Technique

ii. To experiment heartbeat signal using existing equipment

iii. To analyze the heartbeat signal

1.4 Scope

The scope of this study will cover the analysis of Microwave Doppler Radar technique. The experiment was conducted in 2.4GHz frequency which was under the unlicensed frequency spectrum, the chosen of this frequency because it widely used and falls in Wi-Fi application frequency.

With the fixed frequency, therefore the measurement was conducted with different transmitted power generated by VNA. Transmitted power was varied from 10dbm, 0dbm, -10dbm, -15dbm, and -25dbm. This transmitted power chooses under the FCC considers which cannot exceed 1Watt power for human safety.

1.5 Report Structure

The report structure is the detail of the report ingredients or the layout that divided into few chapters. In this reports, there are six chapter were it is introduction, literature review, methodology, results, discussion and conclusion chapters.

First of first, introduction chapter is chapter one. This introduction chapter will cover briefly describe about the background and overview of this project. Besides that, this chapter covers problems statement, objectives, scope of the project, expected outcome and methodology.

Following that, second chapter contains the literature review or research to get information about this project. In order to get the information which is related, there will have many resources can gained from, such as internet, journals, books and etc. Those facts, figure and information that found from the resources will use as references and informative data. This information will used in this project by comparing info and founds the best method and technique that can implement or add in this project.

In chapter three, mainly focuses on the methodology of the way the project is carried out. In here, the step, methods and process of the experiment and planning schedules of projects will discuss more detail. Follow this methodology will get a better view, proper planed work scope and better understanding on project flow.

In chapter four, all the results are observed and all the measurement is recorded. Beside that this chapter will cover the simulation parts by using the proper software.

Based on simulation and experiment results, all the data are well recorded in table form. By that, all the comparison study and analyzing is carried out. The well presentable graph, figure and chart will produce in order to summarized the result part overall. Based on the outcome of all table, graph and chart will be briefly discussed. All testing results are attached with the proper aid of figure and table.

Chapter five is the discussion chapter. In this chapter, the results based discussion will carry out. All the fact and figure is declared with giving proper reasons based on theoretical fact. The interrelationship between the theoretical and practical will detailed. The observed, analyzed, and measured fact is well detailed and declared.

The chapter six is the conclusion chapter. This chapter will conclude the whole procedures of the project that including project finding, achievement analysis and conclusion of the research implementation that had been used. If necessary, this chapter can discuss about the suggestion for enhancement in future of the project.

By compile all listed six chapter above will produced a proper full report of Final Year Project. This report structure is based on the fixed rule in UTeM for final year project report. Further related chapter can be added, by approved of supervisor specified but all listed chapter above is necessary included.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature reviews is a progress in read and collect all the informative material such as journal, magazine, article, bulletin and many more, where it used to relate all theoretically, fact and figure which is true and recognize by a specific organization or institute or bodies. Besides that, it all so mean about literature we review regarding project overall. For this project, I was review some IEEE journals, bulletin, books and internet websites.

2.2 Microwave Doppler Radar Theory

Basically, microwave Doppler radar is a technique being used in detecting heartbeat signal referring to this thesis itself. Before furthering discuss about how this project being conducted and experiment, it's appropriate to define each term that's being described in this technique.

Microwaves are electromagnetic waves with wavelengths shorter than one meter and longer than one millimeter, or frequencies between 300 megahertz and 300 gigahertz. A major advantage of radio and microwave frequency radar systems is that these waves can penetrate through some objects that light cannot penetrate, allowing detection of objects that cannot be seen [11].

Radar can be categories depending on their various applications. For example there are pulsed radar, primary radar, secondary radar, imaging radar and non imaging radar, and continuous wave radar (CW) . In this thesis will focus on continuous wave radar. Continuous wave radar systems transmit a continuous wave radio signal to detect information for a target. In this type of system, a known frequency signal is transmitted and the reflected signal from the target is received. Referring to previous works for extracting heartbeat signal, mostly by the author used CW radar to transmit signal. It is because the CW radar is not pulsed, and has no minimum or maximum range, and maximizes the power incident on the target. CW radar also has the disadvantage that they cannot measure distance, because there is no time reference in the continuous wave.

Doppler radar can be measured when the target is moving perpendicularly to the radar, it does not make any Doppler shift. So, the radar cannot distinguish movement and in that case the Doppler radar can only detect one dimensionally [12], according to Doppler theory, when a target with periodic movement but zero velocity, the reflected signal is modulated with its phase by the time-varying position. When the target is person breath normally, the modulation of the reflected signal contains information

about chest displacement due to heartbeats and respiration. However, when holding breath, the chest displacement due only to heartbeats [13-14].

Hence, the measurement of this small displacement is the concerns for extracting the heartbeat signal. Equation (1) shows the relation between the chest displacement $\Delta x(t)$ and the phase variation $\Delta\Theta(t)$. Where λ is the wavelength of the transmitted signal.

$$\Delta\theta(t) = \frac{4\pi\Delta x(t)}{\lambda} \qquad (2.1)$$

2.3 S – Parameter

Scattering Parameters, also called S-parameters, belong to the group to two port parameters used in two port theory. Like the Y or Z parameter, they describe the performance of a two port completely. Different to Y and Z, however, they relate to the traveling waves that are scattered or reflected when a network is inserted into a transmission line of a certain characteristic impedance Z_L. Therefore, S-parameters can be compared to reflection and through pass of pair spectacles [15].

S-parameter is important in microwave design because they are easier to measure and to work with at high frequencies than other kinds of two port parameter. They are conceptually simple, analytically convenient and capable of providing detailed insight into a measurement and modeling problem. However, it must keep in mind that like all other two port parameters, S-parameters are linear by default [15].

Related works tend to extract the average heartbeat rate for a specific window. The heartbeat rate is measured using two different schemes. The first scheme is based on measuring the phase of S_{11} where the single antenna is used for both transmitting and receiving. The second scheme is based on measuring the phase S_{21} where two antennas are used to respectively transmit and receive signals. Studies show that both S_{11} and S_{21} parameters can detect the heartbeat signals with relative errors slightly different where S_{21} measured lower percentage of relative errors. The paper compared the S_{11} and S_{21} parameter with different output power. The experiment is performed at 16GHz frequency [16].

On the other hand, in this thesis the proposed systems use single-antenna microwave system for heartbeat detection. The reflected signal computes in S_{11} parameter. The proposed system is tested for one frequency and several transmitted powers. The frequency used is 2.4 GHz as it's belong to the ISM free unlicensed band [13].

2.4 Radar Theory

Radar, an acronym for Radio Detection and Ranging, describes a system that transmits an electromagnetic signal and senses the echo from reflecting objects, thereby gaining information about those objects. The time delay between the transmitted and received signals indicate the distance to the target, the frequency shift of the received signal enables calculation of the target's velocity, and the strength of the signal gives information about the target's radar cross section, which provides information about its size, geometry, and composition.