UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electronic and Computer Engineering

X-BAND SPANAR ANTENNA FOR HEART RATE MONITORING SYSTEM

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A thesis submitted
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DECLARATION

I declare that this thesis entitled "X-Band Spanar Antenna for Heart rate Monitoring System" is the result of my own research except as cited in the references. The thesis has not been accepted for the any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : HAZWANI BINTI AZMAN

Date : 15 /12/2016

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality as a partial fulfillment of Master of Electronic Engineering.

Signature	:..
Supervisor Name	: DATO' PROFESSOR DR. MOHD NOR BIN HUSAIN
Date	: 16/12/2016

DEDICATION

To my beloved mother and father Dedicated to ALLAH Almighty, my loving parents and my siblings for your infinite and unfading love, sacrifice, patience, encouragement and best wishes

ABSTRACT

The demands of Heart rate Monitoring Systems are getting more extensive rapidly in wireless communication application subjects as an important role in modern life for all practical purposes. The early stage of the system was heavy, bulky and costly, but the latest technology in wireless systems is smaller and cheaper. The touch-less technique or contact-less technique heart monitoring using microwave Doppler radar has been given more attention in the activities of detection of cardio-pulmonary since the 1970's. The antenna has become a critical attention in radar and space communication application since the radio link was first built in 1886 by Hertz, whereby the antenna had the function to allow people to stay connected and informed with each other. Due to the increase in demand of the detection monitoring system, Spanar Antenna for the Heart rate Monitoring System is introduced at X-Band frequency. The proposed antenna is designed 20.835mm x 8.9mm to operate at 10GHz, which suggested return loss, S_{11} less than -10dB and gain, G more than 3dB. The elements of antenna structure are referred from basic ice-cream cone, where the slit shape is added for a good antenna performance. The proposed antenna is simulated with Heart rate Monitoring System configuration at 10m distance with 10.002dBm minimum input power before implementation process. The elements of system configuration are referred from continuous-wave radar transceiver and homodyne receiver for a good system performance. A continuous-wave radar transceiver conversion has a simple topology. The homodyne or direct conversion receiver has simplicity, low power consumption and inexpensive.

ABSTRAK

Sistem pemantauan kadar jantung begitu penting dalam kehidupan masa kini, dimana sistem ini mendapat permintaan yang begitu meluas dalam aplikasi komunikasi tanpa wayar bagi tujuan praktikal. Pada peringkat awal, sistem ini dihasilkan dalam struktur yang berat dan besar dan harganya begitu mahal, tetapi dengan teknologi terkini yanh digunakan dalam sistem tanpa wayar, ianya dihasilkan dalam struktur yang lebih kecil dan ringan serta mampu dimiliki. Sejak tahun 1970-an, pemantauan jantung dengan teknik tanpa sentuhan yang menggunakan gelombang mikro Doppler radar telah diberi perhatian yang lebih dalam aktiviti pengesanan kardio-pulmonari manusia. Di samping itu, sejak hubungan radio yang pertama kali dibina pada tahun 1886 oleh Hertz, antena telah menjadi perhatian penting dalam radar dan ruang aplikasi komunikasi, dimana antena mempunyai fungsi bagi membolehkan manusia terus berhubung dan memaklumkan antara satu sama lain. Oleh kerana peningkatan dalam permintaan sistem pengesan pemantauan kadar jantung, Spanar Antena telah diperkenalkan dan seterusnya dihasilkan pada frekuensi yang lebih tinggi terutamanya dalam jalur-X. Rekaan antena yang dihasilkan mempunyai saiz 20.835mm x 8.9mm yang beroperasi pada frekuensi 10GHz, dimana S_{11} diperolehi kurang daripada -10dB dan G lebih daripada 3dB. Elemen antena yang dihasilkan berdasarkan bentuk asas aiskrim kon, dimana bentuk 'slit' ditambah pada rekaan tersebut untuk mencapai fungsi antenna yang dikehendaki dan lebih baik. Antena yang dihasilkan telah beroperasi dengan sistem pemantauan kadar jantung pada jarak 10m dengan kuasa input minimum sebanyak 10.002dBm sebelum proses pelaksanaan diteruskan. Untuk menghasilkan prestasi sistem yang baik, elemen dan komponen sistem ini direka berdasarkan penghantaran gelombang radar yang berterusan dan penerimaan gelombang radar secara terus kepada manusia. Penghantaran gelombang radar yang berterusan mempunyai topologi yang lebih mudah. Manakala penerimaan secara terus mempunyai kesederhanaan, penggunaan kuasa yang rendah dan mampu milik.

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LIST OF SYMBOLS ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

ADS	-	Advanced Designed System
CST	-	Computer Simulation Technology
Lab View	-	Laboratory Virtual Instrument Engineering Workbench
MATLAB	-	Matrix Laboratory
FKEKK	-	Faculty of Electronic and Computer Engineering
UTeM	-	Universiti Teknikal Malaysia Melaka
dB	-	Decibels
dBm	-	Decibel in miliwatts
dBi	-	Decibel over isotropic
mm	-	Milimeter
m	-	Meter
cm	-	Centimeter
mW	-	Miliwatts
μW	-	Microwatts
W	-	Watts
Hz	-	Hertz
kHz	-	Kilo Hertz
GHz	-	Giga Hertz
LO	-	Local Oscillator
RF	-	Radio Frequency
IF	-	Intermediate Frequency
S_{11}	-	Reflection coefficient
S_{21}	-	Transmission coefficient

BW	-	Bandwidth
VSWR	-	Voltage Standing Wave Ratio
G	-	Gain
NF	-	Noise Figure
Cs	-	Carrier spectrum
Bs	-	Baseband spectrum
RHP	-	Right Hand Polarization
DC	-	Direct Current
AC	-	Alternating Current
RCS	-	Radar Cross Section
RR	-	Respiration Rate
HR	-	Heart Rate
HRV	-	Heart Rate Variability
$\theta_{(t)}$	-	Phase variation
$x_{(t)}$	-	Periodic movement
f	-	Frequency
c	-	3 x 10 m / s
λ	-	Wavelength
s	-	Safe power density
G	-	Gain
p	-	Average radiating power
r	-	Distance antenna with human subject
P_t	-	Transmit power
P_r	-	Received power
R	-	Distance antenna with target
σ	-	Radar cross section
δ	-	Loss tangent
W	-	Width of patch
L	-	Length of patch
a	-	Actual or physical radius of patch
fr	-	Resonant frequency
a_1	-	Side length of patch
$\emptyset$	-	0.019

r_c	-	Radius of circle
l_r	-	Length of rectangle
w_r	-	Width of rectangle
l_t	-	Length of triangle
l_f	-	Length of feed line
w_f	-	Width of feed line
l_s	-	Length of substrate
w_s	-	Width of substrate
l_g	-	Length of ground
w_g	-	Width of ground
l_{sl}	-	Length of slit
w_{sl}	-	Width of slit
f_o	-	Operating frequency
ε_r	-	4.4
ε_{reff}	-	Effective dielectric constant
h	-	Thickness of substrate
L_{eff}	-	Effective length of patch
ΔL	-	Extra length of patch
a_e	-	Effective radius of patch
Z_o	-	50 Ω

LIST OF APPENDICES

LIST OF PUBLICATIONS

The research papers produced and published during the course of this research are as follows:

NO. **PAPER**

1. Othman, M. A., Azman, H., Nor Husain, M., Ismail, M. M., Sulaiman, H. A., Misran, M. H. and Motsidi, M. R. (2013). Heart Monitoring Systems at 10 GHz Using Microwave Doppler Techniques for theAthletes Fitness Monitoring System: A Review. *Australian Journal of Basic and Applied Sciences*, *7*(14).

2. Azlishah Othman, M., Azman, H., Nor Husain, M., Zoinol Abidin Abd Aziz, M., Abd Rahim, Y., Nairn Che Pee, A. and Fairuz Iskandar Othman, M. (2014, April). 10 GHz Microstrip Spanar Antennas: An Experimental Analysis. In *Journal of Physics Conference Series* (Vol. 495, No. 1, p. 2028).

CHAPTER 1

INTRODUCTION

1.1 Research Background

Generally, healthcare monitoring systems are used by people who really care about their current status or health level condition for future preferences. The early detection of abnormal heart rate can help to prevent from serious disease and of course, this is important in everyday life. The use of a healthcare monitoring systems is not merely only at the hospitals and at home. It is also used by people in the sports field, while driving, and many more.

The existing healthcare monitoring system for a person has two categories; either wired or wirelesses, to meet the demands of users. Most of the wearable systems are custom made with straps, which needs to attach directly to their surface body and may cause discomforts. Furthermore, body-mounted wireless portable sensor devices have limited radio range and wireless connectivity is dynamic due to extreme mobility which may cause difficulties to carry out certain movements and activities. In addition, wearable systems and wireless portable sensors have fixed distance and fixed movement, which require greater freedom of movement in joints.

For that reason, the wireless system was developed. Most of the wireless systems are custom made with a non-invasive method by using various types of antenna (Sadek *et al.* 2010). Since no sensor is required on the target body, the improvements focused on the antenna in terms of type, size and several performances at the Front-end of the Heart rate Monitoring System. Besides that, it has also become miniaturized in sizing and has minimum transmitted power before the implementation to the system (Dany Obeid *et al.* 2009).

1.2 Problem Statements

In Front-end of the wireless heart rate monitoring systems, many types of antennas were used such as horn antenna, parabolic and series-fed micro-strip array antennas. For example, a tunable system for contact-less heartbeat detection and a modeling approach is used a horn antenna (Dany Obeid *et al.* 2009). Then, noninvasive biosignal detection radar system using circular polarization was approach by using series-fed micro-strip array antenna (Lee *et al.* 2009). Latest, X-Band radar system for detecting heart and respiration rates is approach by using 2 separate circular polarized array antenna (Lee *et al.* 2011). Technically, those antenna types are large in size which requires a lot of space and cost.

Due to this reason, this research will focus on minimizing 20.835mm x 8.9mm, which has 68.85% compact size as compared to the previous one with 40mm x 25mm in the same structure of the Ice-Cream Cone at higher frequency (Othman *et al.* 2013). The patch of antenna is made from micro-strip, which makes it very attractive for the radar applications. In order to design a compact micro-strip patch antenna at a higher frequency, higher dielectric constants are used, which resulted to efficient and result in a narrower bandwidth.

Therefore, by adding the slit shape on the ground plane or patch of antenna, it helps to achieve better antenna results of the gain, bandwidth and capabilty to operate for several independent frequencies band such as C-Band and X-Band microwave communication system. By adding the slit shape, the reflection coefficient indicates 17.5% difference from the previous value which is -30.5dB (Othman *et al.* 2013). The gain also indicates 13.97% difference from the previous value which is -4.107dB (Othman *et al.* 2013).

Consequently, the simulation will be done in order to make sure the compatibility of antenna designed structure to the system configuration with minimum input power. The Heart rate Monitoring System configuration is referred from the Heart rate Monitoring System for the patients from past researcher (Lee *et al.* 2011).

1.3 Objectives

The objectives of this project as below:

1. To design and simulate a small size of Spanar antenna at 10GHz resonance frequency.
2. To fabricate the design and measure the performances of Spanar antenna at 10GHz resonance frequency.
3. To evaluate the Spanar antenna performances at the Front-end of Heart rate Monitoring System at 10m distance with 10.002dBm minimum input power before implementation process.

1.4 Scope of Research

The project was limited as stated in the following:

1. The antenna designs are based on basic shapes, such as circular, rectangular and triangular.
2. The antennas are designed and simulated at X-Band frequency response by using CST Microwave Simulation Studio software.
3. The antennas are fabricated on FR4 board by using chemical etching process.

4. The reflection coefficient of antennas are measured by Using Vector Network Analyzer in the open space lab, while the radiation pattern of antennas was measured by using Far-field Measurement System in anechoic chamber room.

1.5 Contributions

The project outcomes are stated as follows:

1. The small size Spanar antenna with 20.835mm x 8.9mm was designed at 10GHz of X-Band resonance frequency. The Spanar antenna size has 68.85% smaller compared to the previous with 40mm x 25mm (Othman *et al.* 2013).
2. The Spanar antenna was indicated the reflection coefficient 17.5% good from previous which is -30.5dB (Othman *et al.* 2013). The gain also indicates 13.97% good from previous which is 4.107dB (Othman *et al.* 2013).
3. Based on above results, the reflection coefficient, S_{11} was -20.15dB, transmission coefficient, S_{21} was 30.084dB, carrier spectrum, C_s was 68.516dB, baseband spectrum, B_s was 77.015dB, output power, P_{out} was 29.795dBm, transmit power P_t was 1.302dBm, receive power, P_r was -12.781dBm, gain, G was 7.96dB, noise figure, NF was 3.052dB has been figured out at 10GHz. Where the previous system has not stated in their experiment (Lee *et al.* 2011).
4. The input power, P_{in} was 10.002dBm reduced from previous with 11dBm (Lee *et al.* 2011) and safe power density was 6.767mW/cm^2 good from previous system with approximately 10mW/cm^2 (Park *et al.* 2003).