DESIGN OF MONOPOLES ANTENNA FOR ON-BODY COMMUNICATION LINKS AT 2.45 GHZ

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To my beloved father (Zainudin Deraman) and mother (Norizan Lomman)
my lovely siblings
(Suhana, Atikah, Zehan, Mohd Zulaili, Mohd Nor Azman, Mohd Nor Aiman)
and my darling soulmate Mohd Haiza bin Mohd Nor

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ABSTRACT

Numerous researches have been devoted to the development of the wearable antenna for its functionalities in on-body communications. The printed monopole antenna fulfils the requirements as well as having wideband matching characteristics, omnidirectional radiation patterns and compact size. Transforming wearable antennas into a compact antenna for wireless on-body communication which operates at 2.45 GHz and to investigate their performances on the body are the objectives of the research. In this research, three types of printed monopole antennas with different configurations are proposed. A microstrip patch antenna is selected as the basic design and modifications on the radiating patch for these three antennas were tested on movements of normal activities of a human in an office environment using Computer System Technology (CST). To verify the performance of the proposed antenna, return loss was simulated using CST and measured with network analyser. Path loss measurement for five on-body channels which are belt-to-chest, belt-to-wrist, belt-to-head, belt-to-back and belt-to-ankle was measured with vector network analyser. For the antenna performance on the body, the belt-to-head body channels gave the best result for the path loss measurement with highest path loss mean values about -30 dB. It was also found that the developed antennas can perform well at 2.45 GHz with good return loss below than -10 dB, and both simulated and measured results were in agreement. These proposed antennas worked well with wide operating bandwidth about 17~32%. However, each of these antennas has its own superior feature based on the configuration that could enhance the compactness of the antenna.

ABSTRAK

Banyak penyelidikan telah dijalankan untuk membangunkan antena boleh pakai yang berfungsi pada komunikasi pada badan. Antena ekakutub tercetak memenuhi keperluan-keperluan tersebut disamping mempunyai sifat lebarjalur terpadan, corak radiasi semua arah dan saiz yang padat. Objektif penyelidikan ini adalah untuk mengubah antena boleh pakai kepada antena padat untuk kegunaan wayarles pada badan yang beroperasi pada 2.45 GHz dan untuk mengkaji kebolehan antena tersebut pada badan manusia. Dalam kajian ini, tiga jenis antena ekakutub tercetak dengan konfigurasi yang berlainan telah dicadangkan. Antena mikrojalur tampal dipilih sebagai reka bentuk asas dan pengubahsuaian pada unsur tampalan untuk tiga antena ini telah dijalankan dan diuji pada pergerakan normal aktiviti manusia di dalam persekitaran pejabat dengan menggunakan perisian "*Computer System Technology*" (CST). Untuk menguji kebolehan antena yang dicadangkan, kehilangan kembali telah disimulasi menggunakan CST dan diukur dengan menggunakan penganalisa rangkaian. Pengukuran kehilangan jarak untuk lima saluran komunikasi badan iaitu pinggang-ke-dada, pinggang-ke-pergelangan tangan, pinggang-ke-kepala, pinggang-ke-belakang dan pinggang-ke-buku lali telah dijalankan menggunakan penganalisa rangkaian. Saluran komunikasi badan pinggang-ke-kepala menunjukkan keputusan terbaik untuk kehilangan jarak dengan nilai min kehilangan jarak paling tinggi iaitu kira-kira -30 dB. Ia juga menunjukkan antena yang dibangunkan boleh beroperasi dengan baik pada 2.45 GHz dengan kehilangan kembali dibawah -10 dB, dan keputusan simulasi dan pengukuran saling menyetujui antara satu sama lain. Antena yang dibangunkan ini beroperasi dengan baik dengan lebarjalur kendalian kira-kira 17-32%. Walau bagaimanapun, setiap antena ini mempunyai kelebihan tersendiri berdasarkan konfigurasi masing-masing yang memenuhi kepadatan antena.

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LIST OF SYMBOLS

ε_{eff}	-	Effective Dielectric Constant
ε_r	-	Dielectric Constant
h	-	Substrate Thickness
W	-	Width
L	-	Length
f_r	-	Resonant Frequency
υ_0	-	Free-space Velocity of Light; 3 x 10^8
ΔL	-	Length extension
λ_o	-	Wavelength
f_H	-	Higher Operating Frequency
f_L	-	Lower Operating Frequency
a	-	Radius of sphere
ηa	-	Efficiency of ESA
Rr	-	Radiation Resistance
Rm	-	Material Loss Resistance
η_s	-	efficiency of system
η_m	-	efficiency of matching network
Tx	-	Transmitter
Rx	-	Receiver

LIST OF ABBREVIATIONS

WLAN	-	Wireless Local Area Network
PAN	-	Personal Area Network
GHz	-	Giga Hertz
ISM	-	Industrial Scientific Medical
BAN	-	Body Area Network
WBAN	-	Wireless Body Area Network
MICS	-	Medical Implantable Communication Services
MHz	-	Mega Hertz
RF	-	Radio Frequency
BW	-	Bandwidth
VSWR	-	Voltage Standing Wave Ratio
CPW	-	Co-planar Waveguide
PRMA	-	Printed Rectangular Monopole Antenna
PSMA	-	Printed Semicircular Monopole Antenna
UWB	-	Ultra Wide Band
dB	-	Decibel
PIFA	-	Planar Inverted-F Antenna
SAR	-	Specific Absorption Rate
ESA	-	Electrically Small Antenna
CST	-	Computer Simulation Technology
VNA	-	Vector Network Analyzer
SMA	-	SubMiniature version A
BMI	-	Body Mass Index
FDTD	-	Finite Different Time Domain
HFSS	-	High Frequency Structure Simulator

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CHAPTER 1

INTRODUCTION

This chapter presents the project background, problem statement, objective of the project, scopes of the project and organization of thesis.

1.1 Background

Recently, a massive amount of researches have been devoted to the development of the wearable antenna for its functionalities in on-body communications. In recent mobile technology and other technologies such as WLAN, WIFI, Bluetooth, and Personal Area Network (PAN), the use of wireless communication and other wireless applications, antenna design become more and more important in recent years. Due to increasing of the applications in the personal communications systems, body-centric wireless communication has become a major field of interest for researchers and will be part of the forthcoming convergence and personalization across the various domain applications [1].

Wireless data transmission is also getting very popular in medical applications such as wireless monitoring of vital functions. The key element in this kind of system is the utilization of small and efficient antennas that are working near human body [1]. In many cases the size of the antenna will determine the size of the overall device. The increasing availability of Bluetooth in mobile technologies has

led to the use of the 2.45 GHz ISM band to communicate among devices wirelessly. This band has become the most important in supporting several wireless communication standards as well as on-body wireless communication.

Many works have been done to establish optimum antenna types for on-body communication [2-6]. Research in [2] investigates the design of antennas for use in BANs at 2.45 GHz. Two on-body channels (belt-to-chest and belt-to-wrist) have been investigated by placing several types of antennas on the body, namely monopole, patch, loop and patch array. The combination of two monopole antennas was found to give the best path gain for both channels.

The printed monopole antennas [7-11] have been received much attention due to their unique advantages such as wideband matching characteristics, omnidirectional radiation patterns, high radiation efficiency and compact size. Printed monopole antenna also has many advantages such as small size, low-profile, simple structure and easy to fabricate. However, the conventional monopole antennas are practically bulky and protruding. Antennas with multi-band, small size and low profile are in great demand in on-body communications. Hence, concentrating on designing small and practical antennas (printed antennas) for on-body application is crucial. This project therefore concentrates on designing small and more practical antennas for on-body application as well as to investigate their performance on the body.

1.2 Problem Statement

In modern mobile and wireless communications systems, there is an increasing demand for smaller low-cost antennas that can be easily integrated with packaging structures. However, in some mobile or wireless applications in the 2.4 GHz ISM band, their physical size may be too large for wearability. Wearable devices for on-body application should be designed in term of functionality and human comfort. The previous works and designs on this application utilized

monopole antenna which were bulky and protruding. Hence, there is need to design a compact antenna for on-body communication.

1.3 Objective

The objectives of this project are:

i. To study and investigate the suitable antenna candidates for on-body communication.
ii. To design compact antennas that suitable for on-body communication at 2.45 GHz.
iii. To study the performance of the designed antennas for various part of body communication channels.
iv. To determine an optimum body channel for body centric wireless communication.

1.4 Scopes of Works

The scopes of this project are as follows:

i. Study on literature review and understanding the concept of printed monopole antenna.
ii. Design and simulate three printed monopole antennas with different configurations
iii. Perform numerical simulations on all the designed antennas.
iv. Fabrication process using etching technique on FR4 board.
v. Analyse the performances of the antennas such as return loss and radiation pattern.
vi. Perform on-body measurement (Path Loss, S21).
vii. Data analysis for path loss and documentation.

1.5 Thesis outline

The thesis consists of five chapters. The first chapter describes brief description of the project background, problem statement, the project objectives and scopes of project.

Chapter two briefly discussed the theory on patch antenna and antenna properties. Literature review from previous researches related to antenna on-body communications is given concentration in this chapter.

In chapter three, the methodology of this research is presented. The overall project activities are shown in a simple flow chart consist the design consideration, simulation tools and measurement process.

Chapter four presents the results obtained. Return loss and path loss results is recorded in detail in this chapter. Analyses of the findings are then discussed. These include parametric investigations and its effect on the antenna performance.

The final chapter concludes the thesis. Recommendations for future work are also given.

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