INCORPORATION OF TEXTILE ARTIFICIAL MAGNETIC CONDUCTOR INTO DIPOLE ANTENNA

MUHAMMAD AZFAR BIN ABDULLAH

UNIVERSITI TEKNOLOGI MALAYSIA

INCORPORATION OF TEXTILE ARTIFICIAL MAGNETIC CONDUCTOR INTO DIPOLE ANTENNA

MUHAMMAD AZFAR BIN ABDULLAH

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I declare that this thesis entitled *"Incorporation of Textile Artificial Magnetic Conductor into Dipole Antenna"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	MUHAMMAD AZFAR BIN ABDULLAH
Date	:	JULAI 2014

Specially dedicated to my mom and dad,

Norani binti Ibrahim and Abdullah bin Dohat,

My siblings and family, for their encouragement and support;

As well as all my friends who always inspired and motivated me along my excellent Journey of education

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ABSTRACT

The radiation and gain characteristics of wearable dipole antenna which are omni-radiation pattern and low gain are not sufficient to support the wearable on-body system. So, to overcome these problems, the incorporation of textile dipole antenna with Artificial Magnetic Conductor (AMC) are designed and analysed. The purpose of implementing the dipole antenna with AMC is to reduce the antenna backward radiation towards the human body and to increase the antenna’s gain. By implementing this concept, the dipole antenna’s beam direction is shifted outward from the human body and the antenna’s gain is increased. In this thesis, the dipole antenna with AMC is investigated and analysed. The antenna's substrate is made of denim jeans. It has ε_r = 1.7, tan σ = 0.025 and 1mm thickness. The radiating materials are made of two different conducting fabrics which are *Shieldit Super fabric* and copper fabric. A flexible dipole antenna with 3 by 3 arrays flexible AMC, operating at 2.4GHz is designed. In order to have better performance of the integrated antennas, the properties of the fabric such as bending effect, wetness effect and on-body measurement are investigated. The possibility of different positions of the dipole antenna above the AMC which may alter the performance of the antenna is also discussed. *Computer Simulation Technology* (CST) software is used for the antenna and AMC simulation. The performances of the dipole antenna with and without AMC are compared. It shows that the performance of the antenna with AMC increases the gain by 5 dB and the antenna’s radiation is more directive. Furthermore, the resonant frequency of the antenna with AMC shifted due to the bending effect. The best location to put the dipole antenna with AMC is at the back of the human body.

ABSTRAK

Ciri-ciri sinaran radiasi dan gandaan antenna dwikutub boleh-pakai iaitu corak sinaran kesemua arah dan gandaan rendah tidak mencukupi untuk menyokong system yang dipakai atas badan. Jadi, untuk mengatasi masalah ini, gabungan tekstil antena dwikutub dengan pengalir magnet tiruan (AMC) direka dan dianalisa. Tekstil AMC digunakan pada antenna dwikutub bertujuan bagi melindungi tubuh manusia daripada sinaran antenna dari belakang dan meningkatkan gandaan antena. Dengan melaksanakan konsep ini, arah sinaran radiasi antena dwikutub dialih keluar menjauhi tubuh badan dan gandaan antena ditingkatkan. Dalam tesis ini, antena dwikutub boleh-pakai dengan AMC disiasat dan dikaji. Substratum antena diperbuat daripada kain jeans denim nilai $\varepsilon r = 1.7$, tan $\sigma = 0.025$ dan ketebalan 1.0 mm. Bahan-bahan terpancar diperbuat daripada dua fabrik yang berbeza iaitu fabrik Super Shieldit dan fabric kuprum. Antena dwikutub yang fleksibel dengan 3 x 3 tatasusun fleksibel AMC beroperasi pada frekuensi 2.4 GHz direka. Bagi mendapatkan prestasi yang lebih baik daripada antena dwikutub beritegrasi AMC, sifat-sifat fabric : seperti kesan lenturan, kelembapan dan pengukuran kuasa pada badan disiasat. Kedudukan antena dwikutub yang berbeza atas AMC yang boleh mengubah prestasi antenna juga turut dibincangkan. Technologi Simulasi Komputer (CST) perisian digunakan untuk simulasi antena dan AMC. Prestasi antena dwikutub dengan dan tanpa AMC dibandingkan. Ia menunjukkan bahawa prestasi antena dengan AMC meningkatkan gandaan sebanyak 5 dB dan radiasi antena adalah lebih terarah. Tambahan pula, frekuensi salunan antena dengan AMC telah beranjak disebabkan oleh kesan lenturan. Lokasi terbaik untuk meletakkan antena dwikutub dengan AMC adalah di belakang tubuh badan manusia.

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LIST OF SYMBOLS

Z_s	-	Surface impedance
ε_r	-	Substrate permittivity
h	-	Substrate thickness
δ	-	Tangent loss
d	-	Separation distance between dipole antenna and AMC
λ	-	Operating wavelength
Z_o	-	Characteristic impedance
l	-	Length of the dipole
τ	-	Power transmission coefficient
Γ	-	Reflection coefficient
$G_{realized}$	-	Realized gain
f_r	-	Operating frequency
L	-	Inductance
C	-	Capacitance
W	-	Patch width
g	-	Gap between the patches
f_U	-	Upper frequency
f_L	-	Lower frequency
ε_o	-	Free-space permittivity
μ_o	-	Free-space permeability
η_o	-	Free-space impedance
λ_o	-	Free-space wavelength
λ_g	-	Guided wavelength

LIST OF ABBREVIATIONS

HIS	-	High Impedance Surface
AMC	-	Artificial Magnetic Conductor
RF	-	Radio Frequency
PMC	-	Perfect Magnetic Conductor
PEC	-	Perfect Electric Conductor
CST	-	Computer Simulation Technology
RL	-	Return Loss

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CHAPTER 1

INTRODUCTION

1.0 Research Background

Recently, there has been much interest in body-centric communication [1, 2]. Future clothing may have a variety of consumer electronics built into the fabric such as radio tagging, and remote camera [3]. They are purely made of textile or fabric material. So, the antenna becomes flexible and easier for users to wear. Needless to say, the textile material which cannot constantly be in a flat condition is the problem for flexible, body worn antennas. The effect of the bending antenna may alter the performance of the antenna [4-7]. Thus, one of the purposes of this research is to suggest improvements to the existing body-worn wireless communication system.

Antennas function as the collector and converter of electromagnetic waves to electronic signals. Thus, it is vital to choose the appropriate antenna especially for on-body wireless communication. Modern wireless applications like telemedical and military communication systems have put enormous attention in developing low profile antennas that can be integrated with compact systems [8]. As an example, telemedical communication provides clinical healthcare at a distance to improve medical services especially in an emergency situation. These technologies offer communication between patient and medical staff or among medical staffs in a hospital. However, any metal plate which is in the hospital may disturb the performance of the communication. In technical terms, a very small gain is obtained when the low profile antennas are placed above a perfect electrical conducting surface due to destructive interference between the antenna and its image [8]. This was the motivation in introducing the idea of using artificial magnetic conductor (AMC) surfaces as supporting structure for such low profile antennas. Besides, the AMC reduced backward radiation from the antenna and hence a reduction in the radiation absorbed by the body [9, 10].

Due to the drawbacks mentioned, this research involves the design and development of textile antenna with AMC at 2.45 GHz in order to minimize the radiation absorbed by users and at the same time increase the gain of the antenna. The designed antenna and AMC are fabricated based on the optimum simulation results obtained. Experimental validations with and without the AMC is carried out to verify the performance of the designs.

1.1 Problem Statements

In recent years, fabric or textile antenna has been rigorously studied by researchers around the world to comply with wireless body-centric communication system. For a small omni-directional flexible dipole antenna, the highest gain achievable is about 2.0 dBi which is considered low. This antenna cannot fulfill the acceptable gain for new technologies with different frequency bands. Furthermore, a person who wears the antenna would be exposed to the antenna’s radiation. To overcome this problem, a flexible artificial magnetic conductor is introduced and presented.

Under on-body environment, it is difficult to keep the fabric material in a flat condition [7]. The position of the fabric materials such as bending and crumpling may influence the performance of the antenna. The properties of fabric material such as bendable, crumpling and washable have to be taken into consideration to ensure the good performance of the antenna.

1.2 Research Objectives

The main purposes of this research are:

1) To investigate and compare the performance of two textile dipole antennas. The conducting fabrics used are purely copper fabric and *Shieldit Super* fabric while the substrate used is denim jeans.
2) To design and analyze the dipole antenna with and without Artificial Magnetic Conductor.
3) To analyze and compare the performance of the antenna with and without AMC on bending condition and on-body movement.

1.3 Scope of Research and Limitations

Firstly, study and understand the concept of the dipole antennas and artificial magnetic conductor. After understanding the concept of the antenna and the AMC are done, the designs are simulated using CST software. The main parameters such as return loss, radiation pattern, and reflection phase are achieved from the simulation results. The optimization works of the simulated designs are done before integrating the antenna with the AMC structure. Parametric study of position of the dipole antenna above the AMC structure is done to choose the best position of the antenna placement above the AMC. Thus, the performances of the antenna with and without AMC are compared with each other.

Next, the antenna and the AMC are fabricated using fabric materials. The denim is used as the substrate of the antenna and the AMC while pure copper fabric and *Shieldit Super* fabric are used as the radiating patch. The fabricated designs are measured in three different conditions which are bending condition, wet condition and on human body. They are measured and compared in terms of return loss, radiation pattern and realized gain.

1.4 Research Contributions

The research contributions are:

i. The AMC offers high gain to the antenna. The reflected wave of the antenna is in-phase with the incident wave of the antenna consequently high gain is increased.
ii. The degradation of antenna’s performance caused by human body can be minimized by introducing the AMC structure.

1.5 Thesis Organization

Chapter 1 presents the research background, research benefits, problem statements, objectives and scope of research and limitations. The research background talks about the preview of the study in our life. The problem statements are created from the research background. Then, the objectives of the research are determined. The scopes of work are done to describe the limit or focus the research's objectives.

Chapter 2 reviews the characteristic of dipole antenna and artificial magnetic conductor. The previous authors described and explained the main parameters involved in studying the dipole antenna and AMC. This chapter also presents previous studies on textile antenna and textile AMC. Variable textiles have been used in designing the antenna and the AMC.

Chapter 3 offers the overall research methodology about the experiments. Firstly, the dipole antennas are designed and fabricated. Three conditions of the antennas are analyzed and compared in terms of radiation pattern and reflection coefficient. Then, a unit cell of AMC is designed. 3 x 3 arrays of the AMC are fabricated. The performance of the dipole antenna is investigated by incorporating the AMC into the dipole antenna. The measurements are done by using network analyzer and anechoic chamber.

Chapter 4 presents the design specifications and performance of textile dipole antenna. All simulation and measurement results of textile dipole antenna are compared and discussed. Then, the fabricated designs are measured in three conditions which are bending condition, wetness condition and on human body. The parameters results in terms of return loss and bandwidth are compared.

Chapter 5 gives the detailed explanations of simulation setup in designing AMC. There are three conditions that need to be simulated to obtain the reflection phase diagram. The zero reflection phase is achieved at desired resonant frequency. Then parametric study on position dipole antenna above the AMC is investigated to determine the optimum condition result. The antenna with AMC is measured in two conditions. The study parameters which include return loss, realized gain and radiation pattern of the antenna are analyzed.

Finally, Chapter 6 draws some conclusions including the findings of the research, key contributions and recommendations for future research work.

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