ANALYSIS OF WEARABLE ANTENNA USING ELECTROMAGNETIC BAND GAP UNDER BENDING CONDITIONS

AINI NOOR LIANA BINTI AZMI

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science in Electronic Engineering

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DECLARATION

I declare that this thesis entitle “Analysis of Wearable Antenna Using Electromagnetic Band Gap Under Bending Conditions” 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 : Aini Noor Liana binti Azmi

Date :……………………………………

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering

Signature : ……………………………………

Name : Dr. Mohd Sa'ari bin Mohamad Isa

Date : …………………………………...

DEDICATION

To my beloved mother, father, husband, our lovely twins and my family.

ABSTRACT

Wearable antenna caught many attentions among researchers due to its wide applications in the technology. The wearable antenna can be widely applied in military, medical, tracking, and many other fields due to its capability to function on the body and off the body. It is an advantage if the wearable antenna could operate with wide bandwidth. However, there are some drawbacks when designing wideband antenna. Backward radiation is one of the major drawbacks introduced by a wearable antenna. Therefore, it is crucial to reduce the backward radiation to avoid harm to the user. Hence, this thesis presents a wearable antenna integrated with Electromagnetic Band Gap (EBG) structure to perform at particular dual-band Wireless Local Area Network (WLAN) frequencies; 2.4 GHz and 5.2 GHz. EBG structure is a type of metamaterial which cannot be found in nature. This structure has become one of the interests due to its extraordinary response to electromagnetic waves. The wearable antenna is designed in the form of circular ring microstrip patch antenna. Jeans have been used as the medium of the substrate. Jeans fabric is selected due to its high permittivity and inelasticity compared to the other materials. The overall size of the antenna is 70x70mm. In order to improve the performance of the antenna, an EBG is then designed to be integrated with the proposed wearable antenna. Next, the designed structures have been fabricated and measured for return loss, gain, directivity, and radiation pattern. The integration of the wearable antenna with the EBG structure has improved the overall performance. The gain of 5.711 dB and 7.474 dB has been achieved for both high and low resonating frequencies respectively, which shows almost 63.7% improvement at low frequency and 121.4% at high frequency. As the designed antenna is designed to be worn on the body, the bending effect of the structure is studied. Cylindrical foams are used to replace human torso for this purpose. Three radiuses have been selected, representing adult's wrist, arm, and thigh. The overall structure is then been tested under bending conditions; resulting intangible effect to the antenna's performances compared to the flat antenna. The return loss for the antenna was found to be very little affected by the presence of body which makes the designed antenna to be suitable for the wearable communication system. Thus, this antenna is suitable for WLAN application purposed especially for medical, consumer electronics sectors and military field. The details of the measured and simulated are presented and discussed.

ABSTRAK

Antena boleh pakai menarik perhatian dalam kalangan penyelidik atas penggunaannya yang luas dalam teknologi. Antena boleh pakai boleh digunakan secara meluas dalam ketenteraan, perubatan, penjejakan, dan banyak bidang lain kerana keupayaannya berfungsi atas badan dan pada badan. Ia adalah kelebihan jika antena boleh pakai mampu beroperasi dengan jalur lebar. Walau bagaimanapun, terdapat beberapa kekurangan ketika mencipta antena jalur lebar. Sinaran ke belakang adalah salah satu kelemahan utama yang diperkenalkan oleh antenna boleh pakai. Oleh itu, adalah penting untuk mengurangkan sinaran ke belakang untuk mengelakkan kemudaratan kepada pengguna. Oleh itu, tesis ini memaparkan satu antenna boleh pakai yang disatukan dengan struktur Gerbang Jalur Elektromagnet (EBG) untuk melaksanakan frekuensi rangkaian tanpa wayar kawasan tempatan (WLAN) tertentu; 2.4 GHz dan 5.2 GHz. Struktur EBG adalah sejenis bahan metamaterial yang tidak dapat ditemui secara semulajadi. Struktur ini menjadi salah satu kepentingan kerana tindak balas luar biasa terhadap gelombang elektromagnetik. Antena boleh pakai direka bentuk dalam bentuk tampalan jalur mikro cincin bulat. Kain seluar jeans telah digunakan sebagai medium substrat. Kain seluar jeans dipilih kerana ketelusan yang tinggi dan keupayaannya berbanding dengan bahan lain. Saiz keseluruhan antena ialah 70 x 70 mm. Untuk meningkatkan prestasi antena, EBG kemudian direka untuk disepadukan dengan antenna boleh pakai yang dicadangkan. Seterusnya, struktur yang dirancang telah direka dan diukur untuk kehilangan pulangan, keuntungan, corak arah dan corak radiasi. Penyepaduan antenna boleh pakai dengan struktur EBG telah meningkatkan prestasi keseluruhan. Keuntungan 5.711 dB dan 7.474 dB masing-masing telah dicapai bagi kedua-dua kekerapan resonasi tinggi dan rendah, yang menunjukkan hampir 63.7% peningkatan pada frekuensi rendah dan 121.4% pada frekuensi tinggi. Oleh kerana antena yang direka adalah untuk dipakai pada badan, kesan lenturan struktur dikaji. Gabus silinder digunakan untuk menggantikan tubuh manusia untuk tujuan ini. Tiga radius telah dipilih, mewakili pergelangan tangan dewasa, lengan dan paha. Struktur keseluruhannya kemudian diuji di bawah keadaan lenturan; menghasilkan kesan tidak ketara kepada prestasi antena berbanding dengan antena datar. Kehilangan pulangan untuk antena itu didapati sangat sedikit terjejas oleh kehadiran badan yang menjadikan antena yang direka sesuai untuk sistem komunikasi yang boleh dipakai. Oleh itu, antena ini sesuai untuk aplikasi WLAN yang bertujuan terutama untuk medan, sektor elektronik pengguna dan bidang ketenteraan. Butiran yang diukur dan disimulasikan disampaikan dan dibincangkan.

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LIST OF ABBREVIATIONS

WLAN	-	Wireless Local Area Network
ISM	-	Industrial, Scientific and Medical
MPA	-	Microstrip Patch Antenna
RF	-	Radio Frequency
RL	-	Return Loss
BW	-	Bandwidth
Γ	-	Reflection Coefficient
P	-	Power
Z	-	Impedance
f	-	Frequency
E	-	Electrical Field
M	-	Magnetic Field
EBG	-	Electromagnetic Band Gap
CST	-	Computer Simulation Technology
IEEE	-	Institute of Electrical and Electronic Engineers
HIS	-	High Impedance Surface
SAR	-	Specific Absorption Rate
HPBW	-	Half Power Beamwidth
FNBW	-	First Null Beamwidth
DUT	-	Device Under Test
GHz	-	Giga Hertz

dB	-	Decibel
mm	-	Milimeter
MHz	-	Mega Hertz

LIST OF PUBLICATIONS

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

1. M.S.M. Isa, A.N.L. Azmi, A.A.M. Isa, M.S.I.M. Zin, M. Abu, Z. Zakaria, M.S.M. Saat, and A. Ahmad, 2014. Analysis on the Performance of Textile Circular Antenna under Bending Conditions, *Malaysian Technical Universities Conference Engineering & Technology (MUCET)*, Melaka, Malaysia, November 10-11.
2. M.S.M. Isa, A.N.L. Azmi, A.A.M. Isa, M.S.I.M. Zin, M. Abu, Z. Zakaria, M.S.M. Saat, and A. Ahmad, 2015. Comparative Study of Mutual Coupling on Microstrip Antennas for Wireless Local Area Network (WLAN) Application, Journal of Telecommunication, Electronic and Computer Engineering (JTEC),
3. M.S.M. Isa, A.N.L. Azmi, A.A.M. Isa, M.S.I.M. Zin, M. Abu, Z. Zakaria, M.S.M. Saat, and A. Ahmad, 2014.Wearable Textile Antenna on EBG for WLAN Applications, Journal of Telecommunication, Electronic and Computer Engineering (JTEC),Vol. 6, July 2014, pp 51-58.

CHAPTER 1

INTRODUCTION

This chapter presents an overview on the research background of the project and covers the problem statement, objectives, and work scopes of the research. This chapter also describes briefly the flow of the thesis.

1.1 Research Background

The technology of mobile communication has grown remarkably. The history of this communication starts with the operation of first generation (1G), followed by the second generation (2G), where the system is mainly voice application with digital technology. The technology then expanded to third generation (3G) which offers better technology with better data rate. Over the year, the latest technology is the fourth generation (4G). In recent years, body centric wireless communication becomes one of the important parts in the 4G mobile communication system.

Body centric communication takes place in between two networks, personal area networks (PANs) and body area networks (BANs). There are two concepts involved in this communication which are on-body communication and off-body communication (Wei et al., 2017). The on-body communication defines communication between wireless implants and body nodes while off-body communication takes place when the body worn device communicates with any mobile or base units located around the environment.

In the past several decades, major enhancements of off-body antenna designs have been identified. In supporting the increasing in antennas and propagation of the off-body centric communication system, numerous technologies have been introduced in the modern antenna design field (Agarwal et al., 2016; Paraskevopoulos et al., 2017). One of the dominant research topics in antennas for body centric communications is wearable, and fabric based antennas which are popularly called as textile antennas.

Much interest is currently focusing in body-worn communication systems especially for motion detection on the body. Other than that, there are numbers of applications of this technology which include paramedics, military and fire fighters. Hence, body worn antennas made by textile have been introduced which can be applied into clothing with ideal performance at low cost.

However, some drawbacks have been identified when applying the antenna on body such as the low power gain and the presence of backward radiation. Due to that, metamaterial studies are reported to find the solution to the challenges. Metamaterial technology is one of the most popular technology and becoming an interest in electromagnetic properties study. Metamaterials are attractive as they have the desired electromagnetic properties which cannot be found in natural materials. One of the metamaterial subset is electromagnetic band gap (EBG) structure. It has been reported by (Basit & Karu 2012) that a large variety of electromagnetic band gap (EBG) structures have been introduced in order to achieve directive radiation.

The discovery of these EBG structures has the promising solutions to solve the body worn antenna drawbacks. The production of EBG also able to suppress surface waves in the antenna ground plane besides reducing the backward radiation of antenna and improving the antenna gain. In addition, this structure will respond to another drawback which is the surface waves in the antenna ground plane by suppressing the amount of waves during propagation. Due to that, the deployment of EBG structure integrated with wearable antenna will prove the superiority of these structures by improving the antenna performances through this project.

1.2 Problem Statement

In modern antenna design, there is great attention in wearable antennas in both the civil and military domains. In the civil domain there is a move towards pervasive computing which utilizes various electronic devices placed around the body and new development in Green technology with the development towards RF energy harvesting. Flexible, conformal antennas are essential to provide an unobtrusive solution as continues RF energy can be generated when the module can be wearable (Langley and Shaozhen, 2009). Consequently, authors have introduced many antennas especially on network communication at 2.45 GHz and 5-6 GHz for on body applications. The development and assessment of the flexible wearable antennas which are integrated into clothing have become one of the interests to be analysed for these applications.

Furthermore, people tend to use more than one communication system at the same time. These are important as the capabilities of multiband with wide bandwidth are popular for most microwave region applications, such as Radio Frequency Identification (RFID), Wireless Local Area Network (WLAN), and Global Positioning System (GPS). Therefore, it is crucial to develop on body communication system, coinciding with the recent demand on high efficiency and high mobility technologies.

The problem has arisen with the bending effect to the antenna performances, as human will make movement in every single moment. The advantage of studying the bending effect is that the wearable antenna would be able to conform to the surface of the body; therefore they must be able to withstand a certain amount of structural deformation.

The method of bending is by placing the antenna on curved surface, such as foam with air permittivity to represent open surface. In this project, focus is given on the return loss, gain, efficiency, as well as the radiation pattern of the structure due to effect of providing additional resistance to the physical structure.

The other issue on the design of the antenna is the conformability for wearing on body in terms of health. In order to achieve wide bandwidth, the backward radiation of the antenna will be increased. The concern is to reduce the radiation as much as possible so that more power transmit is developed, and less power is absorbed by the body. Meanwhile, the are limitations of the proposed wearable antenna, as it should be designed by using inelastic fabric material with low permittivity, as well as low profile structure.

1.3 Objectives

The objectives of the research are as follows:

1. To design a wideband wearable antenna operating in WLAN frequency range; 2.4 GHz and 5.2 GHz.
2. To investigate and analyse the bending effect of the antenna on the antenna's performances.
3. To reduce the backward radiation of the wearable antenna using Electromagnetic Band Gap (EBG).