FLEXIBLE METASURFACE-ENABLED ANTENNA FOR WEARABLE MEDICAL BODY-AREA NETWORK APPLICATION

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Dedicate to my beloved family and supervisor, Dr. Mohd Saari bins Mohammad Isa.

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ABSTRACT

In our modern world, technologies have evolved in order to provide better facilities for human kind. Recently, engineers have introduced a wearable antenna that can be used in medical applications. Implementation of wearable antenna in medical applications will help to increase the effectiveness in term of communication between those machines. However, wearable antenna is quite dangerous for human because radiation from that antenna can affect human skin thus create a bigger chance for human to have cancer. This paper will discussed about design of Flexible Metasurface-Enabled Antenna for Wearable Medical Body Area Network Application. Federal Communication Commission have introduced new frequency band which known as Medical Body Area Network (MBAN). MBAN operate in frequency range from 2.36 GHz until 2.4 GHz. Main objective of this paper is to investigate ways to reduce back radiation from wearable antenna. Metasurface can act as surface that can prevent human from radiation thus will increase performances of wearable antenna. This antenna was design by using CST software. This prototype antenna shows a great improvement in term of gain, bandwidth and front to back ratio. Furthermore, this prototype shows that metal backed metasurface help to reduce 95.3% specific absorption rate. In other word, this design is really suitable to be use as wearable antenna in medical applications.

Keywords: MBAN band, Medical Applications, Wearable antenna, 2.4 GHz

ABSTRAK

Di dalam era dunia moden, teknologi telah berkembang dengan pesat bagi menyediakan kemudahan kepada semua manusia. Kebelakangan ini, para jurutera telah memperkenalkan antena yang boleh dipakai untuk kegunaan dalam bidang perubatan. Antenna ini akan meningkatkan tahap kecekapan dalam perhubungan yang berlaku diantara mesin yang sering digunakan. Walaubagaimanapun, antenna yang bole dipakai amat merbahayakan bagi manusia kerana kesan radiasi daripada antenna tersebut akan member kesan pada kulit manusia sekaligus meningkatkan peluang pengguna menghidap penyakit kanser. Laporan ini mengulas mengenai reka bentuk antenna yg mengunakan permukaan meta yang fleksibel dan digunakan dalam bidang perubatan. Suruhanjaya komunikasi persekutuan telah memperkenal satu frekuensi band baru yang dikenali sebagai “Medical Body Area Network”. Frekuensi band ini akan beroperasi dalam linkungan 2.36 GHz sehingga 2.4 GHz. Objektif utama penyelidikan ini adalah untuk mencari cara mngurangkan kesan radiasi belakang daripada antena yang bole dipakai. Permukaan meta mampu menghindarkan manusia daripada radiasi sekaligus akan meningkatkan keupayaan antenna tersebut. Antena ini telah direka mengunakan perisisan CST. Prototaip antena ini telah menunjukkan satu perubahan yang ketara dari segi perolehan, jalur lebar dan ratio depan. Selain itu, prototaip ini telah menunjukkan permukaan meta telah mengurangkan kadar serapan spesifik sebanyak 95.3%. Dalam erti lain antena ini sesuai digunakan sebagai antena yang boleh dipakai didalam bidang perubatan.

Kata kunci: MBAN band, peralatan perubatan, antenna pakaian, 2.4 GHz

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CHAPTER I

INTRODUCTION

This research focused on design, simulate, fabricate and measure of flexible metasurface enabled antenna for wearable medical body area network application that will operate in a frequency range 2.36 GHz until 2.4 GHz. All design and prototype of antenna in this research were constructed using CST software. Result of measurement in this research was focused on three main things which are reflection loss, gain and SAR value. In this chapter, all background and related facts regarding this research were discussed by detail. This chapter also includes objectives, scope, problem statement and methodology of this project. All chapters outline also were included in this chapter.

1.1 Introduction

Over the years, communication is one of important aspect in human life. Researchers around the world always make experiments in order to create new technology that can improve our communication systems. In 1886, Heinrich Hertz introduced the first wireless communication in human history. A system that he created was using a dipole antenna as transmitter and a loop antenna as receiver. This system was very success thus become inspiration to other engineers for creating more powerful systems.

Thirteen years later, an engineer namely as Marconi try to send information across the Atlantic. He attached several vertical wires to the ground to function as transmit antenna. Then, he attached the receiver antenna across the Atlantic by paste it on a kite. His action was successful. He managed to create history where he was a first person that can send information in 200 meter distance. Engineers believe this antenna technology can be use to improve our communication systems.

In a blink of eyes, technologies of antenna have evolved. World have seen introduction of several type of antenna such as Yagi-Uda, Horn, Arrays, Parabolic, Patch and Planar antenna. Most famous application that contain antenna is mobile phone. Function of antenna in mobile phone is to transmit signal when users make a call. Antenna in mobile phone also works as receiver when there is incoming call. In other words, antenna is crucial part in mobile phone because without them our phone will be useless.

Application of antennas also evolved based on new technologies. Today, antennas not only use in mobile phone but it also used in military and medical applications. We know that military will use antenna in their communication system. However, we still confuse about antenna in medical applications. What the function of antenna in medical applications?

Actually, antennas were use in medical applications for a long time ago. Other people maybe not know about this but antennas in medical applications are really important in order to transmit and receive signal from medical devices. There are lots of antenna types that were use in medical applications for example, implantable antenna and wearable antenna. In this paper, we will focus on wearable antenna for medical applications.

Wearable antenna brings lots benefit to medical sector. Wearable antenna was more easy for patient to wear thus make it better for nurse's works. Wearable antenna will allow two way communication systems between device and external data control unit or directly to nurse station. Other than that, wearable antenna will increase capability for close range and long range data exchange. So, all clinician works will become faster and more efficient.

Wearable monitoring system contain of an array of sensors that were paste into the fabric of the user to continuously monitor the physiological parameters and transmit wireless signal to a remote monitoring station. In the conventional wearable physiological monitoring system, the sensors are integrated at specific locations on the vest and are interconnected to the wearable data acquisition hardware by wires woven into the fabric. In medical sector, patient will wear this vest in order to make it easier for medical checkup.

However, wearable antenna can bring lots of harm to users. The drawback in sensor system is that the cables woven in the fabric pickup noise such as power line interference and signals from nearby radiating sources and thereby corrupting the physiological signals. As stated above, users will wear the vase that contain antenna. It is really dangerous because antenna will have strong back radiation. This radiation can affect human skin thus making human to have a bigger chance of cancer. In order to settle this problem, this research was conducted to find ways to reduce back radiations.

1.2 Overview Project

This project is all about design of flexible metasurface enable antenna for wearable medical body area network applications. This prototype antenna was expected to operate in a range frequency 2.36 GHz until 2.4 GHz. It is due to allocation of MBAN frequency by FCC. This project mainly focused on metasurface that can reduce back radiation thus produce better wearable antenna for medical applications.

An electromagnetic metasurface can be define as a kind of artificial sheet material that have sub-wavelength thickness and electromagnetic properties on demand. Metasurfaces could be either structured or not structured with sub wavelength-scaled patterns in the horizontal dimensions. In the electromagnetic theory, metasurfaces could modulate the behaviors of electromagnetic waves through the specific boundary conditions.

So, metasurface was the best solution for back radiation in wearable antenna. Electromagnetic properties of metasurface will modulate thus prevent all radiation from human skin. However, there are lots of metasurface techniques that can be use in antenna. Example of the technique is frequency selective surface, electronic band gap and split ring resonator. This project focused on frequency selective surface.

One of main key in this project is flexible and wearable antenna. In order to fulfill this target, prototype antenna must be design using textile. It is because; textile is comfortable and flexible so that it can perform a better result as wearable antenna. Textile that we use in this design must be suitable for wearable antenna. Permittivity and loss of tangent of this textile must be considered before it can be use in this prototype.

1.3 Objectives

This project focused on three main objectives. One of them is to find suitable textile that can be used as wearable antenna. Furthermore, this project focused to design and develop wearable antenna that operates medical body area network for medical applications which operate at 2.36 GHz until 2.4 GHz. Last objective is to research suitable metasurface that can be used to improve performances of this antenna.

1.4 Scope of Works

First of all, research on design and antenna type must be conducted. Then, all parameters and design specification must be stated as guidelines for our result. There are few design specification that needed to be concern such as center frequency, gain, bandwidth, directivity and SAR value. We need to conduct a research in order to know some technique that commonly use to improve specification that stated above.

Top priority in wearable antenna is about users' safety. As we know, wearable antenna will produce back radiation which is dangerous for human skin thus can cause cancer. In order to solve this problem, we need to find out ways to reduce or prevent back radiation of wearable antenna. We may review other's project to learn some technique that can decrease back radiation of antenna.

This project is focused on flexible antenna. So, we need to know effect of antenna performances under bending condition. In order to create a flexible antenna, suitable substrate must be use. In this project, textile is the best choice to act as substrate in our antenna. It is because, textile have lots of characteristic that will make users comfortable when they wear the antenna.

1.5 Problem Statement

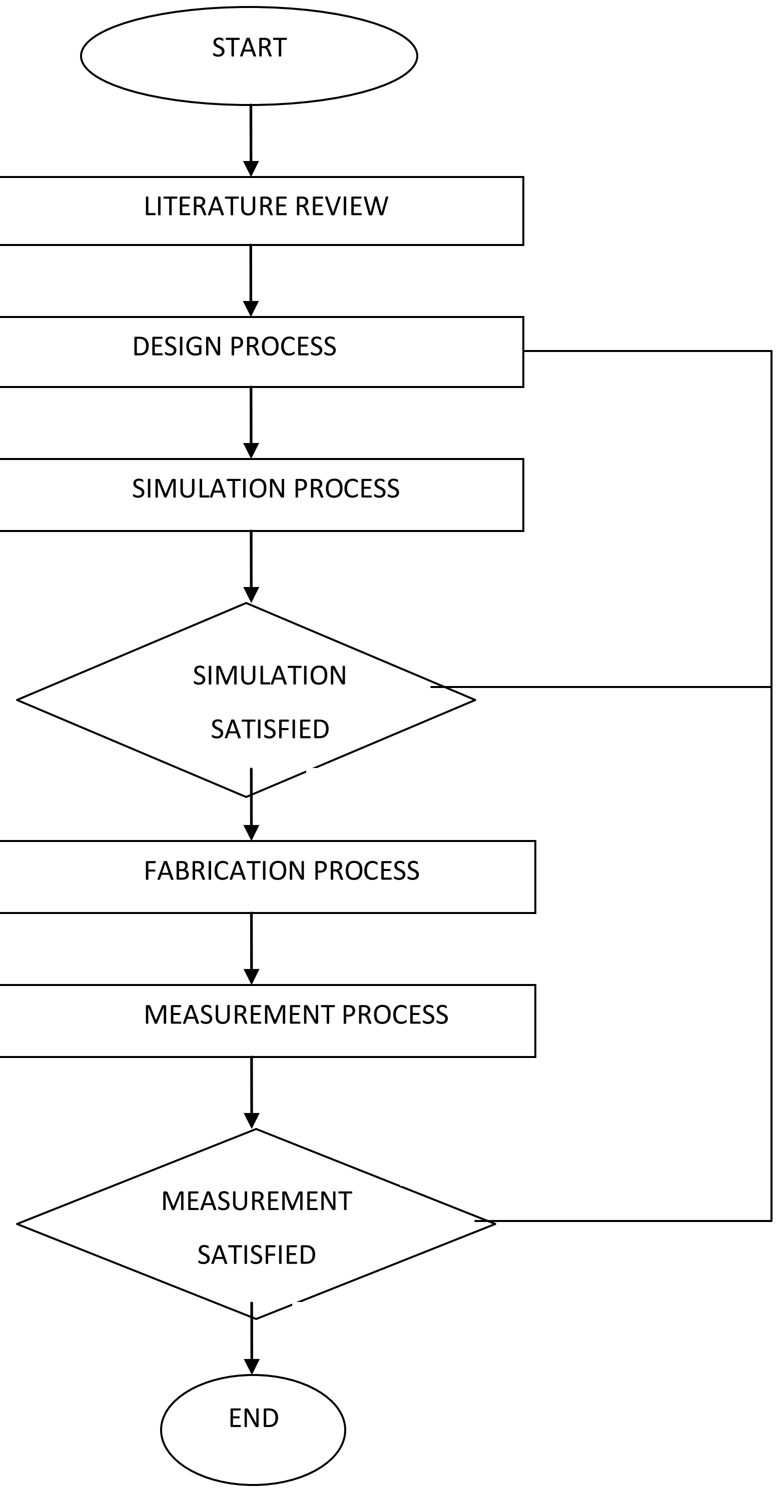
Wearable antenna has been used for many years in several applications. Wearable antenna brings lots of advantage to users. One of them is mobility. Users just need to wear the antenna, and then he can use the application everywhere he goes. Unfortunately, wearable antennas also have some negative part.

As discussed earlier, wearable antenna was worn on the human body. So, first problem statement in this project is the loading effect of due to lossy tissue makes the design of a high radiation efficiency antenna challenging. Lossy tissue can be defines as human body parts such as skin, muscle, fat and bone. Layers of human body are very thick thus making it difficult for signal to penetrate. So, wearable antenna will have low performance due to this problem.

Second problem statement is impact of wearable antenna on human tissue. As we know, an antenna have a front and back radiation. It become problem when wearable antennas have a back radiation. It is stated that wearable antenna will be worn by users. So, back radiation from that antenna will penetrate into human body. Radiation of antenna was known to be dangerous for human because it will a bigger risk for human to have cancers.

Lastly, effect of material and type of an antenna can be defined as third problem statement. This project mainly focused on flexible and wearable antenna. So, it is crucial task to find a suitable material that have a great flexibility thus efficient for antenna performances. We need to research on permittivity of several textiles in order to know which textile that can produce great wearable antenna. Weight of material also must be considered in order to make it as wearable antenna.

1.6 Methodology



First task in this project is to gain information about wearable antenna as much as we can. A literature review must be conduct in order to gain all information. Literature review in this project will focused on three main things. Firstly, we need to gather information about type of antenna that suitable to be use as wearable antenna. As we know, there are lots of antenna types in our technology. Each of them has their own advantages and disadvantages. So, we need to review every type of antenna so that we can identify which type will perform better as wearable antenna.

We also need to review about metasurface. As stated in the title of this project, metasurface will be main part of this antenna. There are lots of metasurface techniques that we learnt. So, we need to ensure which technique is suitable in our design. Lastly, we also need to have literature review regarding material that we will use in our design. This project is about wearable antenna, so textile will be a best choice for our substrate. We need to find suitable materials that have great performances for antenna. This textile must be lightweight and comfortable to be use by users.

After all information that we get in literature review, design process will be conducted. All design in this project will be done using CST software. Design process will include three phases. First phase is about shape of ground plane. It was really important because ground plane will affect antenna performances. Second phases are about design of substrate.

Substrate must be design carefully because it is crucial part for antenna. Last phase is about implementation of metasurface at ground plane. As stated in paragraph above, different shape of metasurface will affect the antenna performances. So, design process must be conducted carefully in order to get precise results.

Simulation process will take place as soon as design process complete. This process also will do by using CST software. During this process, all specification that stated in scope of work must be simulating. All result from simulation must be same from design specification. If our simulation result is precise, we can proceed with fabrication process. However, we need to undergo design process again if our simulation results are not accurate. If our simulation results are not satisfied, we must alter our design. There may be some changes that we can do in order to get an accurate simulation results.

If we are already satisfied with simulation results, we can proceed with fabrication process. Fabrication process is toughest in this project. One mistake in this process can create a big problem. In this project, fabrication process will be conducted by using copper paste technique. As we know, textile will be use as substrate in this project. So, design of this antenna will be paste on this textile using copper paste technique. This technique is quite difficult because it need some sort of skills. Fabrication process must be done in careful environment so that any errors can be prevented.

Measurement process is the last step in this project. Function of this step is to measure all result based on antenna prototype that we design. Measurement must be conducted in order to measure all design specification that we stated above such as resonance frequency, return loss, gain, and directivity and SAR value. If our measurement value is not like we expect, we must return to design process. There must be some errors in design process that lead to inaccurate measurement results. We can do parameter sweep in order to identify our design problem.

If there are no errors happen in measurement process, that’s mean our project have complete. We need to make sure our design can work as we want. So, we must carefully look at our antenna to find if there any errors in our design.

1.7 Chapter Outline

This report contains of five chapters and the details of this report will be outlined as:

Chapter I – This chapter will outline the introduction for the entire project. The fundamental explanations are mentioned in this chapter. Introduction and overview project is mainly focusing on project's background. Other than that, this chapter also will give an overview about the objectives of developing this project, work scope of the project, problem statement and lastly the process methodologies.

Chapter II – This chapter is described about the previous studies, researches and readings process that have been carried out and also to supported and understand the project. Literature Review explaining about the existing research method that has been used before for this project and also the advantageous and disadvantageous of the method used. Shape and material that can be used to design the wearable and flexible antenna also discussed in this chapter. This chapter also elaborates about suitable metasurface technique that can be used to reduce back radiation in antenna. Lastly, this chapter includes some discussion about material which is suitable for wearable antenna and can work as substrate in this antenna prototype.

Chapter III – This chapter concentrates on the methodology process of this project which is it will be explain on how the project is been carried. It also explains about the design method used for the metasurface on the ground plane. This chapter will explain in detail about step on how the development of both of this design by using the CST Microwave Software. The design process and design specification will be explained in details in this chapter.

Chapter IV – This chapter is about result and discussion. This section will explain about the finding of this project and analysis of result. The simulation results are presented. The comparison of reflection loss or S11 between before adding metasurface to the ground plane and after adding metasurface to the ground plane will be presenting and analyzed. Result for other specifications such as gain and SAR value also will be discussed in this chapter. The discussions for the whole research are related to finding and observation that had been made from the results.

Chapter V– This is the final stage for the overall process and performance of the project. This chapter concludes the entire project finding, improvement achieved and future works that can be improved for future studies based on this project. This chapter also will include some suggestion that can be done to improve the results.

CHAPTER II

LITERATURE REVIEW

This chapter will discussed about previous project regarding wearable antenna. All background and information were gathered in this chapter so that it can be use in this project. This chapter also will discuss about type of antennas that commonly use as wearable antenna. Furthermore, research about existing technique that was used to reduce back radiation will be explained in this chapter. Lastly, characteristic of suitable material will be defined in this chapter.

2.1 Review of Antenna Types

There are several antenna types in our modern world. For example Yagi Uda, Loop, parabolic and Microstrip Patch antenna. Each of them has their own advantages and disadvantages. Later, we will discuss about antenna types that suitable to be use as wearable antenna.

2.1.1 Planar Monopole Antenna

Planar monopole antenna is one of common type that always be used as wearable antenna. It is due their compact size and shape so that it is suitable to function as wearable antenna. Main factor that planar monopole were always be use as wearable antenna because they are beneficial for on body communications [1]. On body communications can be define as antenna were worn by users while transmit the data then receiver is in the environment.

Theoretically, planar monopole antenna can be defining as one half of a dipole antenna [2]. Planar monopole almost always mounted above some sort of ground plane. The case of a monopole antenna of length L mounted above an infinite ground plane is shown in Figure 1(a). Using image theory, the fields above the ground plane can be found by using the equivalent source (antenna) in free space as shown in Figure 1(b). This is simply a dipole antenna of twice the length.

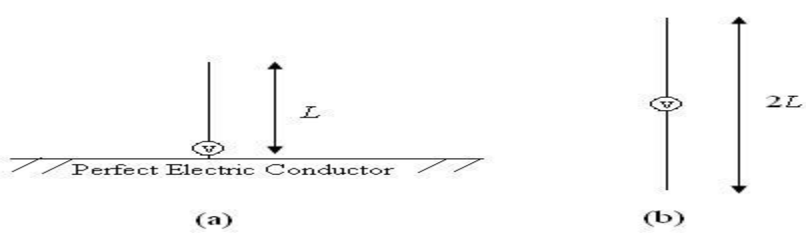


Figure 1: Planar monopole antenna [2]

Since planar monopole is quite same with dipole antenna, engineers always calculate the radiation patterns of monopole antennas based on dipole result. However, there are some changes in the formula. We need to remember that the impedance of a monopole antenna is one half of that of a full dipole antenna [3]. For a quarter-wave monopole the impedance is half of that of a half-wave dipole so,

$$Z_{IN} = 36.5 + j21.25 \text{ Ohms} \qquad (2.1)$$

We can understand because monopole only need half voltage compare to dipole antenna due to its size which is half from dipole. As we know, dipole will have two ends which each of them have positive voltage and negative voltage. This is totally different with monopole antenna because its only has one end that uses positive charge. The other end of monopole antenna will connect to ground. In other words, we can say that impedance of monopole antenna is halved from dipole [3].

The directivity of a monopole antenna is directly related to that of a dipole antenna. If the directivity of a dipole of length *2L* has a directivity of D1 [decibels], then the directivity of a monopole antenna of length *L* will have a directivity of D1+3 [decibels]. That is, the directivity (in linear units) of a monopole antenna is twice the directivity of a dipole antenna of twice the length [3]. The reason for this is simply because no radiation occurs below the ground plane; hence, the antenna is effectively twice as "directives".

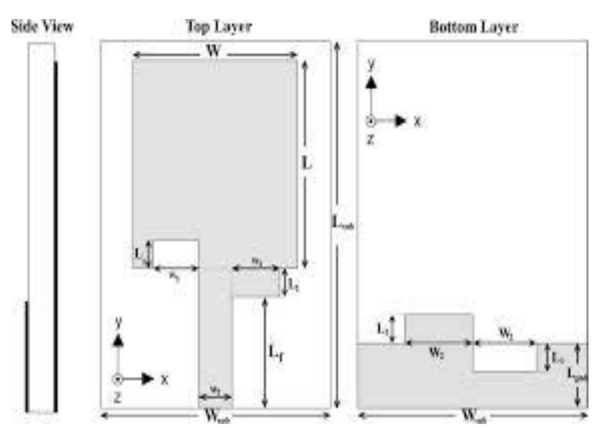


Figure 2: Parameters of planar monopole [3]