ULTRA WIDEBAND ANTENNA WITH BAND NOTCH AT 5.8 GIGAHERTZ USING CONDUCTIVE SILVER COATED THIN FILM

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This thesis is dedicated to:

My beloved mother, RUBIAH BINTI IDRIS, my father, ABDUL RANI BIN ALI and all my siblings for their endless supports, loves and cares.

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ABSTRACT

Wireless communication technology is a fast developing technology which gives a huge impact on social life nowadays. Currently, thin film is one of the emerging technologies in the recent antenna technology and it has been rapidly adapted into the wireless communication system over these few years. It has attracted major attention to antenna designers due to its major advantage which is very low thickness. This thesis focuses on the design of the Ultra Wideand (UWB) antenna with a band notch at 5.8 GHz using the conventional FR-4 and the thin film as the main materials. The UWB antenna is capable of covering the 3.1-10.6 GHz frequencies, which includes the *IEEE 802.11.a* WLAN frequency of 5.8 GHz. A Split Ring Resonator/Complimentary Split Ring Resonator (SRR/CSRR) was introduced in the design to achieve band notch at 5.8 GHz and reduce interferences from WLAN applications. The effects of the SRR/CSRR on these UWB antennas are thoroughly analyzed in terms of their placements. The SRR/CSRR can be placed at both outside and inside of the radiating element when FR-4 is used. However, placing the SRR outside the radiating element of the transparent antenna produced a poor notch of only -9.61 dB reading on its reflection coefficient. Meanwhile, implementation of SRR inside the radiating element gave better reflection coefficient of -7.80 dB. The surface losses of AgHT-8 limit the possible position to place the SRR on the transparent antenna. Besides, it also significantly reduces transparent antenna's gain to -6 dBi. The proposed antenna is a new type of antenna that can be integrated with window glass and used for indoor monitoring system.

ABSTRAK

Teknologi komunikasi wayarles adalah satu teknologi yang pesat membangun yang memberi kesan yang besar terhadap kehidupan sosial pada masa kini. Teknologi filem nipis adalah salah satu teknologi baru dalam teknologi antena dan ia telah diadaptasi dengan cepat ke dalam sistem komunikasi tanpa wayar sejak beberapa tahun ini. Teknologi ini menarik perhatian pereka antena kerana kelebihan utamanya iaitu bahan-bahannya yang sangat nipis. Tesis ini memberi tumpuan kepada reka bentuk antena Jalur Lebar Luas (UWB) dengan frekuensi tolakan pada 5.8 GHz menggunakan bahan sedia ada FR-4 dan filem nipis sebagai bahan-bahan utama. Antena UWB ini mampu meliputi frekuensi UWB dari 3.1 GHz hingga 10.6 GHz yang merangkumi frekuensi IEEE 802.11.a WLAN pada 5.8 GHz. Satu Resonator Cincin Terpisah/Resonator Cincin Terpisah Slot (SRR/CSRR) telah digunakan untuk menghasilkan frekuensi tolakan pada 5.8 GHz dan mengurangkan interferens dari aplikasi-aplikasi WLAN. Kesan pengenalan SRR/CSRR pada antena UWB ini dikaji secara menyeluruh terutama daripada segi kedudukannya. SRR/CSRR boleh diletakkan di kedua-dua bahagian luar atau dalam unsur pemancar apabila FR-4 digunakan. Walau bagaimanapun, bacaan pekali pantulan adalah lemah (-9.61 dB) jika SRR/CSRR diletakkan di luar unsur pemancar antena filem nipis. Bacaan pekali pantulan akan bertambah baik (-7.8 dB) jika SRR/CSRR ini diletakkan di dalam unsur pemancar bagi antena filem nipis. Kedudukan SRR di dalam antena filem nipis adalah terhad kerana filem nipis ini mempunyai kehilangan permukaan yang tinggi. Selain itu, kehilangan permukaan itu juga mengehadkan nilai capaian antena ini dengan nilai maksimum hanya sebanyak -6 dBi. Antena yang dicadangkan ini merupakan antena jenis baru yang boleh digabungkan dengan cermin tingkap dan digunakan untuk sistem pengawasan dalam bangunan.

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LIST OF ABREVIATIONS

UWB	-	Ultra Wideband
CPW	-	Co-planar Waveguide
CST	-	Computer Simulation Technology
OLED	-	Organic Light Emitting Diode
FR-4	-	Flame Resistant 4
AgHT	-	Conductive Silver Coated Thin Film
PET	-	Polyethylene Terephthalate
RFID	-	Radio Frequency Identification
SRR	-	Split Ring Resonator
CSRR	-	Complementary Split Ring Resonator
FCC	-	Federal Communication Commission
PEC	-	Perfect Electric Conductor
EMI	-	Electromagnetic Interference
RFI	-	Radio Frequency Interference
WLAN	-	Wireless Local Area Network
WiMAX	-	Worldwide Interoperability for Microwave Access
dB	-	Decibel
dBi	-	Isotropic Decibel
S11	-	Reflection Coefficient

LIST OF SYMBOLS

σ - Surface resistivity

ρ - Conductivity

ε_r - Dielectric permittivity

ε_{reff} - Dielectric effective permittivity

f - Resonating frequency

f_L - Low resonating frequency

L - Inductance

C - Capacitance

R - Resistance

H - Height of cylindrical monopole antenna

r - Radius of cylindrical monopole antenna

p - Probe length

R - Radius of circular planar monopole antenna

R_{eff} - Effective radius of circular planar monopole antenna

c - Velocity of light in free space

k_{nm} - mth zero derivative of Bessel function based on nth order

W_s - Width of substrate

L_s - Length of substrate

W_f - Width of transmission line

L_{TL} - Length of transmission line

wr - width of ring resonator

$R1$ - Outer radius of split ring resonator

$R2$ - Inner radius of split ring resonator

D	-	Separation distance between rings of resonator
gr	-	Gap of ring resonator
Wg	-	Width of CPW ground
Lg	-	Length of CPW ground
g	-	Gap of CPW
Wtl	-	Width of CPW transmission line
d1	-	Distance of SRR in *y*-axis
d2	-	Distance of SRR in *x*-axis
d3	-	Distance of SRR from the center of radiating element
*r*3	-	Radius of circular slot in Antenna 3
Ω	-	Ohm

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CHAPTER 1

INTRODUCTION

1.0 Research Background

Planar monopole antenna is one of the antennas that have been widely used in the recent antenna technologies. This type of antenna has been rapidly developed over the past few decades and have become very popular among the researchers because of its properties such as its compact size, low profile, light weight, low cost and easiness in the fabrication process [1]. Planar monopole antenna can be described as a microstrip antenna with very thick air substrate and the ground is located at infinity [2]. The microstrip antennas have some major disadvantages such as low efficiency, low power, narrow bandwidth and poor polarization [3]. Many researches were conducted to further improved the disadvantages of these microstrip antennas and the outcome of these researches have produced various types of planar monopole antenna structure and shapes [4-8]. Further optimizations were also made on the shape of the ground plane of these planar monopole antennas [9-12]. These optimizations were targeted to overcome the previously mentioned disadvantages of the microstrip antennas. There have been too many researches conducted on the variation of the structures and shapes of the antenna making the field to become saturated. Thus, the current researchers are now looking into another angle of research; the possibility of implementing new materials in the antenna design.

Currently, thin film is one of the emerging technologies in the recent antenna technology and it has been rapidly adapted into the wireless communication system over these few years. It has attracted major attention to antenna designers due to its major advantage; very low thickness. Thin film technology has been implemented widely in product areas, such as in x-ray detectors, thin film photovoltaic and as well as smaller but possibly growing areas of OLED displays or e-book readers [13]. One of the popular thin film materials is the transparent conductive silver coating material (AgHT-8), which is almost transparent to the human eye with minimum of 82% visible transparency percentage. AgHT-8 consists of two layers; first layer is the substrate which is made of Polyethylene Terephthalate (PET) and the second layer is the conductive layer that consists of conductive silver coating.

Since the AgHT-8 structure is a single sided, where it consists of only a substrate and a conductive layer, the co-planar waveguide (CPW) feeding needs to be implemented. CPW feeding is a type of feeding where the ground and transmission line are both on the same surface. A lot of CPW-fed antennas have been designed over the few years and these show that these antennas can be used in both Ultra Wide Band (UWB) and single band frequency. These kinds of antennas has attracted a lot of attentions due to their advantages of low radiation losses, less dispersion and wider bandwidth compared to other type of microstrip feedings [14].

As for this research concerns, the CPW-fed antenna was used as it is easier to cover the 3.1 - 10.6 GHz, UWB band. It is desirable so that the antenna is transparent and less bulky compared to existing antennas. Since the transparent material used is new in this field, some properties and performances of the antenna designed using the material still need to be determined. Apart from the level of material transparency, the performances of the transparent antenna in terms of return loss, efficiency, gain and radiation pattern were verified and compared to the non-transparent antenna.

Lastly, the antenna made of the AgHT-8 improved the ease of antenna implementation in public areas. The transparent antenna should be able to be integrated to existing commercial window glass. These facts have motivated this research to design a simple transparent antenna operating at UWB frequencies, which can be integrated to the commercial window glass.

1.1 Problem Statement

The transparent antenna is a new antenna innovation that is very useful in the recent wireless communication. Recent development in antenna technology requires the development of an antenna that can be implemented in public areas without being apparent to the naked eyes. The conventional antenna are usually implemented to a system and high likely to be installed at an open space to obtain maximum performances. However, since the antenna is apparent, it is prone to vandalism and sometime, raising concerns to the users regarding the radiation effect of the antenna to the human body. This limitation can be overcome by using this thin film antenna which is more than 82% transparent. The transparent antenna can be installed at any place and provide the coverage needed. This transparent antenna can be integrated to the existing windows of a building or room to reduce the space required.

Recent UWB technologies have introduced a new tracking and monitoring system that operated within frequency range of 3.1 GHz to 10.6 GHz such as the patient monitoring system in a hospital. This monitoring system requires some sensors and antennas to establish a wireless transmission to collect and send data over the networks. The system requires many antennas to cover the whole hospital building areas. The problem of using conventional antenna is that the antenna is apparent and can be spotted by the patient, visitors and the staffs in the building, raising concerns on the radiation effects of the antenna to the users. Figure 1.1 shows an example of indoor position tracking created by a company in Hungary (Bluenion) [15]. They had conducted a case study and implemented an indoor positioning system inside a clinic in Shanghai, China. The system uses Wifi, Bluetooth and RFID technologies for the wireless transmission. However, the concept of the system can be used for UWB tracking system. Some sensors and wireless routers (with a built-in antenna) are required to cover the whole clinics, which are apparent to the visitors view. By using the proposed thin film transparent antenna, the antenna can be integrated to the windows and can hardly be spotted by common eyes. Thus, the transparent antenna can provide the coverage needed without losing the aesthetic values.

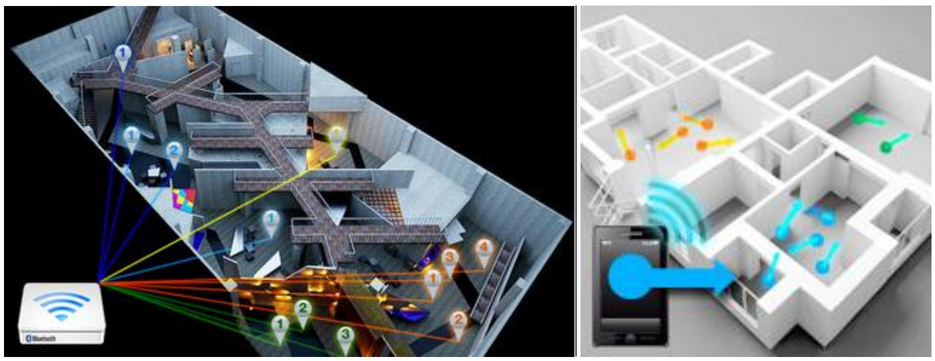

Figure 1.1: BLUENION indoor position tracking [15]

1.2 Objectives of Research

This research gives a positive impact to the development of wireless communication technology. The project introduced a new design of a transparent thin film antenna operating at UWB frequencies. The objectives of this project are:

i. To design and analyze the performances of SRR/CSRR.
ii. To design, simulate and fabricate an UWB antenna with band notch at 5.8 GHz using FR-4.
iii. To analyze the effects of using transparent material (AgHT) in UWB antenna design and SRR/CSRR performances.

1.3 Scope of Work

In order to achieve the objectives, several steps have been considered to accomplish the proposed reconfigurable antenna. This includes a comprehensive literature review, which is required to obtain a basic UWB antenna design. It is important to build basic knowledge on designing the proposed antenna and to identify all the expected result in designing an antenna. In this project, the focuses are on the design of UWB antenna using both non-transparent (FR-4) and transparent (AgHT-8) materials.

The first design is the UWB antenna using the FR-4 board. This antenna should cover the 3.1 - 10.6 GHz frequency range. After an UWB antenna is successfully designed, the effects of adding a metamaterial (SRR/CSRR) to the antenna are to be analyzed. This step involves determining the parameters and best location of the SRR/CSRRs. The second design is the UWB antenna using conductive silver coated thin film (AgHT), which is the transparent material. The same steps as in the first design was used to determine the effects of the metamaterial on the transparent antenna.

Since the purpose of the transparent antenna is to be integrated with commercial glass window, some analyses on the effects of the glass windows on the antennas' performances were carried out. In this project, some common clear substrates of different properties in terms of permittivity were analyzed to represent the various types of windows glass available in the market. The effects of sizes and thickness of the clear substrate were analyzed. In the process of designing the antennas, electromagnetic software such as Computer Simulation Technology (CST) is required to verify the performance of the proposed antennas.

After all the optimization has been done, a prototype of the proposed design was fabricated. There are some limitations on the fabrication processes that affect the performances of the prototype antennas. First limitation is the size of the transparent antenna that is very small. The precision of the tools used is low, which may results to some shifting in the overall geometries of the prototypes. The second limitation is the glass used for the fabrication. The tools used to measure the permittivity of the glass can only provide the estimated permittivity. Thus, the permittivity of the glass integrated to the antenna is not accurate and the measured results were slightly different from the simulations. The fabricated antenna undergone the return loss and radiation pattern measurements. These tested results were compared to the simulation results and the results of the comparison will identify whether the antenna is successfully designed or not.

1.4 Thesis Outline

This thesis consists of 5 chapters which involve every step used to complete the proposed reconfigurable antenna. The thesis outline is organized as follows:

Chapter 2 is more toward the basic literature review on planar monopole antenna and some overviews about the development of the planar monopole antenna technology which is very popular in current research field. This includes the designs of UWB antennas and implementation of SRR/CSRR for band notch purposes. The metamaterial properties of the SRR/CSRR are one of the subchapters, where it explains their function in creating the band notch. Also, some basic information on the transparent thin film material is also included in another subchapter; explaining the concept of thin film and its implementation in other fields. These theoretical knowledge helped to proceed with next subchapter as this subchapter is mainly about the motivation of previous researches on the proposed transparent thin film antenna. In this chapter, all the previous researches related to UWB antennas, band-notched antennas, and transparent thin film antennas are discussed. This reading provided basic knowledge on the development of the proposed antenna structure.

In Chapter 3, the steps taken to complete the design were discussed. This-chapter focuses on the design stage using appropriate software. Then, the discussions were stretched out on the fabrication stage which involves software part, printing and hardware part. The final stage of this chapter includes the measurement stage. This final stage can be used to determine either the fabricated antenna is working at proposed frequency band or not.

Chapter 4 highlighted the steps taken to design the proposed UWB transparent antenna. This chapter was separated into two sections. The first section focuses on the development of the UWB antenna using FR-4 board, followed by an introduction of SRR/CSRR to create a band notch. This first subchapter of the first section discussed on the development of the SRR/CSRR. The effect of each parameters in the SRR/CSRR was discussed throughout obtaining the 5.8 GHz band notch. The next subchapter discusses in details the proposed non-transparent UWB antenna with band notch at 5.8 GHz, including all the proposed geometries and performances.

The second section of Chapter 4 discusses on the development of the transparent thin film antenna using AgHT. The first subchapter in this section discusses the parameters involved in designing the UWB transparent antenna. The next subchapter is on the effects of introducing the metametarial, SRR/CSRR on the transparent antenna. As the final step in completing proposed antenna design, some analyses on the effect of integration between the proposed UWB transparent antenna with the clear substrate (glass) were conducted. The geometry of the glass was varied to represent the various type of glass existed in the market. These discussions were on the return loss data, gain, efficiency and radiation pattern data for each part. Finally, conclusion and suggestions for future work were discussed in Chapter 5.

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