DESIGN OF ULTRA WIDEBAND MICROSTRIP PATCH ANTENNA WITH BAND NOTCHED CHARACTERISTICS

BY

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ABSTRACT

Fifth generation cellular technology (5G) forums in ASEAN countries has been proposed lower frequency bands for 5G applications at 4.5 – 5.5 GHz and also the fixed-satellite service (FSS) is using 3.3 – 3.8 GHz for C-band. In this project, a single band notched (SBN), a double band notched (DBN) and two variable band notched (VBN) antennas are designed, simulated, fabricated and tested to create notched bands for 5G lower band from 4.5 GHz to 5.5 GHz (1 GHz), C-band 3.3 GHz to 4.2 GHz, (0.9 GHz) and Wi-MAX 3.2 GHz to 3.8 GHz (0.6 GHz) applications in UWB spectrum. Two types of UWB antenna have been designed and proposed by using low cost substrate FR-4 with partial grounding on rectangular patch and tuning fork shaped patch antenna. A single band and dual band notched UWB antennas were designed for 5G lower band by using a slot at the top of the radiating patch and by adding an arc shape open loop (ASOL) on UWB antenna. Two variable band notched UWB antennas were also designed by introducing a semi-circular slot (SCS) on the upper part and by inserting ring shape slits (RSS) in ground plane of UWB respectively. Simulated return losses, patterns, radiation efficiencies, directivities and gains are correlation and compared with available similar antennas and found good agreement. The peak radiation efficiency of 90% and maximum gain of 8.0 dBi are achieved with as low as 28% efficiency and -2.0 dBi gain in rejection bands. All antennas are fabricated using FR-4 substrate and tested using Vector Network Analyzer (VNA). The voltage standing wave ratio (VSWR) and return loss of test results prove that all antennas have excellent performance in notched band and UWB band frequencies by showing good agreement with simulation results, except the measured return loss is slightly different from the simulated result in the notched bandwidth in dual band notched and poor performance from 6 GHz – 8 GHz of UWB in variable band notch antenna. Therefore, designed single notch, dual notch and variable notch ultra-wideband antennas are proposed as a good candidate for 5G lower bands, C-bands and Wi-MAX bands notched applications environment.

خلاصة البحث

اقترحت منتديات الجيل الخامس في دول رابطة جنوب شرق آسيا نطاقات ترددية أقل لتطبيقات الجيل الخامس عند تردد يتراوح بين ٤,٥ و٥,٥ جيجاهيرتز وأيضا تستخدم خدمة الأقمار الصناعية الثابتة ٣,٣ إلى ٣,٨ جيجاهيرتز في النطاق C. في هذا المشروع، تم تصميم ومحاكاة وتصنيع واختبار نطاق أحادي مسنن (SBN) ونطاق مزدوج مسنن (DBN) واثنين من الهوائيات ذات النطاق المتغير (VBN) لإنشاء نطاقات محززة لنطاق الجيل الخامس أقل من 4,5 جيجاهرتز إلى 5,5 جيجاهرتز و C-band (3.3 GHz - 4.2 GHz) و Wi-MAX (3.2 GHz - 3.8 GHz) - في طيف UWB. تم تصميم نوعين من هوائي النطاق الترددي العريض (UWB) واقتراح إستخدامهما بركيزة منخفضة التكلفة FR-٤ مع تأريض جزئي على رقعة مستطيلة مع ضبط هوائي رقعة على شكل شوكة. تم تصميم هوائيات (UWB) ذات نطاق واحد وثنائي النطاقات للجيل الخامس نطاق أقل باستخدام فتحة في أعلى الحزمة المشعة وإضافة حلقة مفتوحة على هوائي UWB. وأيضا تم تصميم هوائيات UWB متغيرة النطاق عن طريق إدخال فتحة نصف دائرية (SCS) على الجزء العلوي ومن خلال إدخال شرائح على شكل حلقات (RSS) في المستوى الأرضي من النطاق الترددي العريض. وقد تم تحليل الخسائر العائدة والأنماط والكفاءات الإشعاعية والتوجهات والمكاسب ومقارنتها بهوائيات مماثلة متاحة وتم التوصل إلى توافق جيد . ويتم تحقيق أقصى كفاءة إشعاعية تبلغ ٩٠٪ وأقصى ربح يبلغ ٨. ٠ ديسيبل في حدود كفاءة منخفضة تصل إلى ٢٨٪ و - ٢ ديسيبل في نطاقات الرفض. جميع الهوائيات يتم تصنيعها باستخدام ركيزة FR-٤ ويتم اختبارها بإستخدام محلل شبكة المتجهات (VNA). ويثبت الاختبار(VSWR) وتعويض خسائر نتائج الإختبارات أن جميع الهوائيات لها أداء ممتاز في الترددات المحفورة في الحزمة الموجية والرزمة (UWB) بإظهار توافق جيد مع نتائج المحاكاة ، بإستثناء أن الخسارة المحسوبة في العائد تختلف إختلافا طفيفا عن النتيجة المحاكية التي تنتج عن عرض النطاق الترددي في الشريط المزدوج وبأداء ضعيف من ٦ جيجاهيرتز - ٨ جيجاهيرتز من (UWB) في هوائي متغير النطاق. لذلك ، فإن الهوائيات المصممة أحادية الدرجة ومزدوجة الدرجة والمتغيرة ذات الحواف المتناهية الصغر قد تم اقتراحها كمرشح جيد لبيئة التطبيقات للجيل الخامس ذات النطاقات المنخفضة ونطاق C، ونطاق Wi-Max.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Communication Engineering).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Mahfuz Md Mahmudul Hasan

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LIST OF SYMBOLS

ε_r	Relative Permittivity of the substrate
t	Trace thickness
h	Dielectric thickness of substrate
ε_{eff}	Effective Permittivity
$tan\ \delta$	Loss Tangent
f_r	Resonant Frequency
c	Speed of light
Z_0	Input Impedance
D	Antenna Directivity
G	Antenna Gain
Γ	Reflection Coefficient
φ	Azimuth Angle
θ	Elevation Angle

LIST OF ABBREVIATIONS

ASOL	Arc shape open loop
CST MWS	Computer Simulation Technology Microwave Studio
CPW	Coplanar Waveguide
DBN	Dual Band Notched
FCC	Federal Communication Commission
RSS	Ring Shape Slits
RPA	Rectangular Patch Antenna
SBN	Single Band Notched
SCS	Semi-Circular Slot
PG	Partial Ground
UWB	Ultra-Wideband
VSWR	Voltage Standing Wave Ratio
VBN	Variable Band Notched
5G	Fifth Generation

CHAPTER ONE

INTRODUCTION

1.1 RESEARCH BACKGROUND

An antenna is a very basic element for wireless communication. Antenna convert the electrical signal into the electromagnetic wave for propagation in space. Eventually, it's used for transmitting and receiving the signal. In 1950s microstrip patch antenna was first introduced and after development of the Printed Circuit Board (PCB) technology this concept was realized. Recently, many researchers are interested in research on microstrip patch antenna. Because it has huge application with some excellent advantages such as low cost, light weight, low power, suitability for portable devices and ease of fabrication. Due to its advantages, microstrip patch antennas became suitable for many mobile applications, satellites, missiles, aircrafts and handheld devices. However, microstrip patch antennas suffer from low gain and narrow bandwidth when the substrate used has high dielectric constant (Kshetrimayum, 2009;Y. Zhou et al., 2012).

In the 1980s, the USA Defense Department used the term Ultra-Wideband (UWB). The FCC allocated the ultra-wideband spectrum and approved UWB for public uses in February 2002 (FCC Commission, 2002). UWB systems have several advantages such as huge bandwidth from 3.1 GHz – 10.6 GHZ (7.5 GHz), low power usage, incorporation into low power ICs and prevention of jamming and extremely secure. There are several applications of UWB such as imaging systems, vehicular radar and communication systems (Heidari, 2008; Marko Bundalo, n.d.; Marko Bundalo, n.d.). Thus, UWB has large bandwidth and in this bandwidth many narrow bands wireless applications lie on it.

Wireless networking systems are increasing exponentially, and new strategies are developed daily to meet this technology's needs. Researchers have also concentrated on improving the existing antennas because of the importance of these instruments for evaluating communication efficiency and speed. The need to upgrade the current antennas has always been the primary objective of researchers, because of the importance of these instruments for evaluating communication efficiency and speed. The antennas are designed to include the antenna size, expense, structure simplicity and functionality. Many applications are introducing day by day and 5G lower band from 4.5 GHz to 5.5 GHz is one of the recent additions. Since, many applications fall within large band width of UWB, the researcher needs to avoid the interference of 5G lower band (4.5 GHz – 5.5 GHz), C-band (3.3 GHz – 4.2 GHz) and Wi-MAX (3.2 GHz – 3.8 GHz) application in UWB spectrum. In that case band notched characteristics is arisen up.

1.2 PROBLEM STATEMENT

The recent recommendation of lower frequency band in fifth generation (5G) cellular mobile communication for tropical countries include a part of C-band. Hence this band and the Coexistence of Worldwide Interoperability for Microwave Access (Wi-MAX) services within the UWB causes interference with the signals of Ultra-Wideband systems. In order to prevent signal leakage and unnecessary noise, it is very important that a communication system avoid conflict with other systems. It is therefore necessary to build a band-notched antenna in order to overcome unwanted bands. Hence an UWB antenna with fixed and variable band notched characteristics with above bands are required to be designed.

1.3 RESEARCH OBJECTIVES

The objectives of this research are as follows:

1. To design a microstrip patch antenna which operates in UWB (3.1 GHz – 10.6 GHz) with fixed and variable band notched at 5G lower band, C-band and Wi-MAX band.
2. To simulate, optimize, analyze and compare the characteristics of designed UWB antenna with and without band notched.
3. To fabricate the designed antenna, test and validate the results.

1.4 SCOPE OF RESEARCH

The focus of the research is to propose an antenna which covers the UWB bandwidth with band rejection application. This band notched criteria cover the 5G lower band (4.5 – 5.5 GHz) for application in ASEAN countries, Wi-MAX (3.2 – 3.8 GHz), C-Band (3.3 – 4.2 GHz) for satellite application ASEAN countries, 5G lower band (4.5 – 5.5 GHz) and variable band notched for of ring shape slits (RSS) (4.3 – 7 GHz), semi-circular slot (SCS) (2.75 – 4.4 GHz) cover those frequency bands for wireless application.

1.5 RESEARCH METHODOLOGY FLOW CHART

All parameters are calculated using mathematical equations developed by transmission line model of rectangular patch antenna. Optimization of parameters are done through simulation, the flow chart of block diagram of which is shown in Figure 1.1

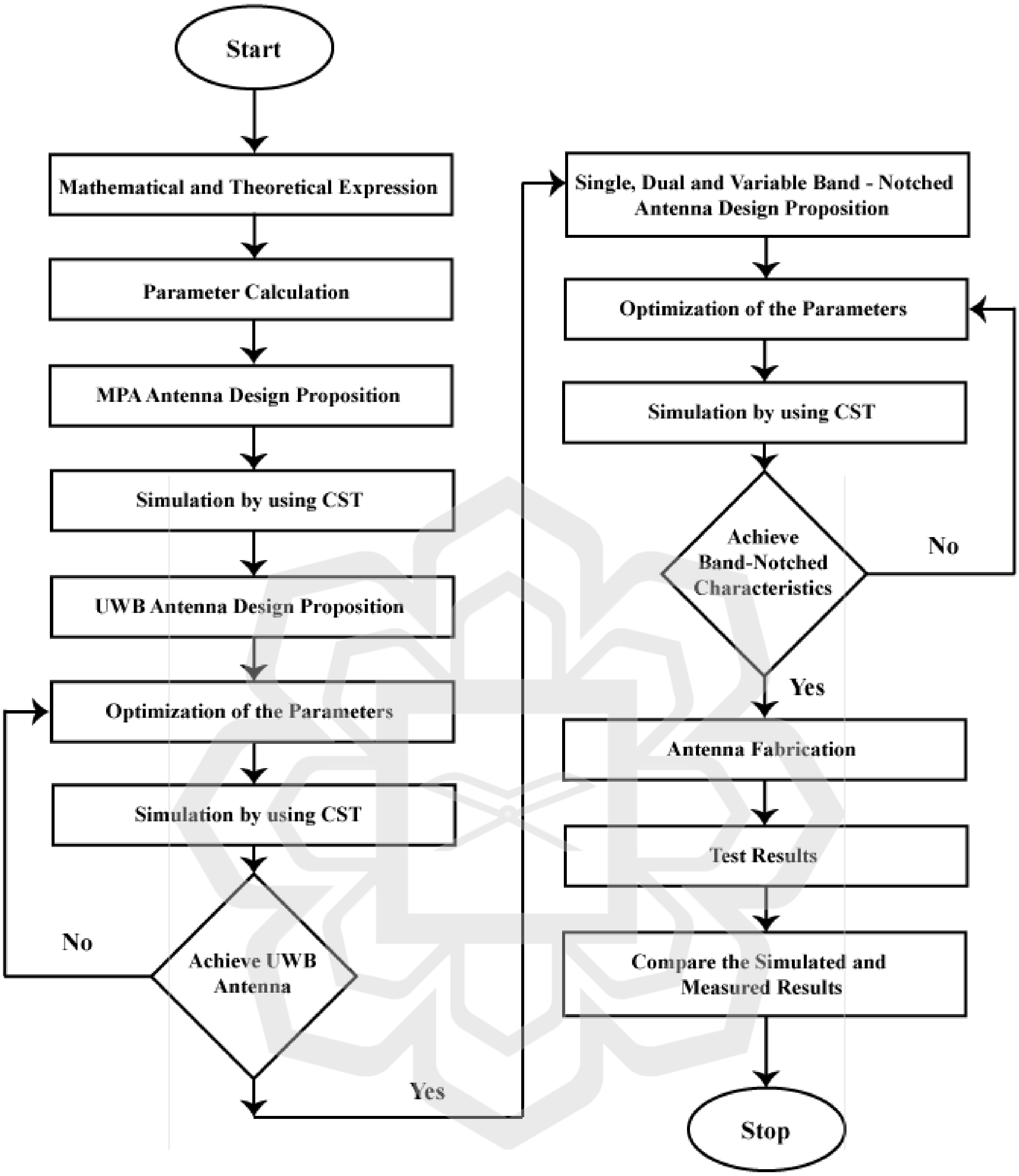

Figure 1.1 Step by step design procedure of the desired antenna

1.6 DISSERTATION OUTLINE

This thesis is divided up into five chapters:

1. Chapter one is the research introductive part. It provides a general overview of the study followed by the problem statement and objectives.
2. Chapter two gives a quick introduction to patch antennas coupled with a short description of the past. It also discusses the mathematical equations and UWB applications. It also discusses many methods to achieve UWB antenna and previous work in UWB antenna with band notched function. Finally, a short comparison with past years paper.
3. Chapter three discusses the methodology flow chart, simulation software, proposed designs and shows the parametric analysis. Then the optimum dimensions are justifying for each antenna with return loss and surface current distributions.
4. Chapter four presents the obtained simulated results for the VSWR, 2-D radiation patterns, efficiency, directivity and gain of the antenna. Finally, the chapter concludes by comparing the measured and simulated return loss, VSWR of each antenna.
5. The final remarks and suggestions for future research are given in Chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter describes the general mathematical and theoretical expression of microstrip patch antenna (MPA). The previous work related to UWB antenna and band notched antenna is also discussed in this chapter.

2.2 MICROSTRIP PATCH ANTENNA (MPA)

Microstrip patch antennas have a vast area of commercial and military applications such as satellite communication, mobile communication, Global Positing System (GPS), radio broadcast, Radio Frequency Identification (RFID), Multiple Input Multiple Output (MIMO), integrated phased array system, Direct Broadcast Satellite (DBS) system, remote sensing, wireless LAN's aircraft, spacecraft, missiles, telemetry, radar application, biomedical application, medical hyperthermia, automotive industry and so on (Fang et al., 2020). Under other conditions MPA has some detriments primarily known as poor efficiency and constitutional low bandwidth (Sanchez-Hernandez & Robertson, 1996). In the last four decades MPA have excellent demand due to its huge advantages taken a consideration of researchers and developers. The researches relevant to MPA have increased around the years and goes to maximum level, it's about 22% and almost 15% in last four decade consist of publications similar to an antenna and wave propagation in IEEE at 2003 (Peixeiro, 2011).

Microstrip patch antenna has some characteristics of UWB application, hence MPA have huge advantages for the wireless communication purpose and antenna is the basic elements for wireless applications. The physical structure of MPA reposes mainly