8-PORT 5G MASSIVE MIMO IN SUB-6 GHz BASE STATION FOR LTE BANDS 43/46 APPLICATION

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DEDICATION

Specially dedicated

to my parents, my wife and friends who

encouraged me throughout my journey

of education.

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ABSTRACT

The 5G (fifth generation) communication system is the next major phase of mobile telecommunications standards beyond the current 4G, which means new antenna design for 5G base station and mobile station will be in great demand in the near future. At present, it is well known that the 2 x 2 Multiple-Input-Multiple-Output (MIMO) or 4 x 4 MIMO is mainly used in 4G Long-Term-Evolution (LTE) wireless communication. However, neither the 2 x 2 MIMO or 4 x 4 MIMO can meet the needs of 5G. So in order to meet the needs of 5G, this thesis proposes a 6 x 6 MIMO integrated into a base station for 5G massive MIMO to provide good diversity gain and multiplexing gain. This thesis proposes an 8-port antenna MIMO structure operating in the LTE band 43 (3600-3800MHz), and LTE band 46 (5150-5925 MHz) for 5G MIMO application in base station. The proposed MIMO antenna is composed of a novel dual-band antenna element that can cover both the 3600-3800 MHz (LTE bands 43) and 5150-5925 MHz (LTE band 46) for future 5G mobile station. The proposed antenna was designed, simulated and optimized using CST software. The performance was analyzed by means of the S parameters of the planar antenna. This antenna achieved a high gain, its return loss well below -10 dB, the isolation between antennas around -20 dB, and a good total radiation efficiency.

ABSTRAK

Sistem komunikasi 5G (generasi kelima) merupakan fasa utama dalam standard telekomunikasi mudah alih yang melampaui 4G semasa, dimana permintaan untuk reka bentuk antena baru bagi stesen pangkalan 5G dan stesen bergerak akan meningkat dalam masa terdekat. Pada masa ini, diketahui bahawa 2 x 2 Berbilang-Input-Berbilang-Output (MIMO) atau 4 x 4 MIMO banyak digunakan dalam komunikasi wayarles evolusi-jangka-panjang 4G (LTE). Walaubagaimanapun, kedua-dua 2 x 2 MIMO dan 4 x 4 MIMO tidak dapat memenuhi keperluan 5G. Oleh itu bagi memenuhi keperluan 5G, tesis ini mencadangkan 6 x 6 MIMO diintegrasikan ke stesen pangkalan untuk MIMO 5G besar agar memberikan gandaan kepelbagaian dan gandaan pemultipleksan yang lebih baik. Tesis ini mencadangkan struktur MIMO antena 8 port yang beroperasi di jalur LTE 43 (3600-3800MHz), dan jalur LTE 46 (5150-5925 MHz) untuk aplikasi 5G MIMO di stesen pangkalan. MIMO yang dicadangkan terdiri daripada elemen antena dwi-jalur baru yang boleh meliputi kedua-dua 3600-3800 MHz (jalur LTE 43) dan 5150-5925 MHz (jalur LTE 46) untuk stesen bergerak 5G masa depan. Antena yang dicadangkan direka, disimulasikan dan dioptimumkan menggunakan perisian CST. Prestasi dianalisis dengan menggunakan parameter S antena planar. Antena ini mencapai gandaan yang tinggi, kehilangan pulangannya di bawah -10 dB, pengasingan antara antena sekitar -20 dB, dan jumlah kecekapan radiasi yang baik.

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LIST OF ABBREVIATIONS

MIMO	-	Multi-Input, multi-Output
FR4	-	Flame resistant 4
WLAN	-	Wireless Local Area Network
CST	-	Computer Simulation Technology
BW	-	Bandwidth
EBG	-	Electromagnetic band Gap
WiMAX	-	Worldwide Interoperability for Microwave Access

LIST OF SYMBOLS

E	-	Electric Field
H	-	Magnetic Field
ε	-	Permittivity
εr	-	Relative Permittivity
C	-	Speed of Light
f	-	Frequency
$f_{\circ}$	-	Operating Frequency
Wp	-	Width of Microstrip Patch
Lp	-	Length of Microstrip Patch
Wg	-	Width of Ground
Lg	-	Length og Ground
g	-	Width of Inset Notch
yo	-	Length of Inset Notch
L1	-	Length of Slot
W1	-	Width of Slot
Rin	-	Input Impedance
S11	-	Return Loss

CHAPTER 1

INTRODUCTION

1.1 Introduction

We all know, as people's expectations and demands, mobile communication are getting higher and higher, the development of mobile communication has entered a new era. At present, the most mainstream voice is that 5G (fifth generation) will come in 2020. The arrival of 5G is not our imagination of so simple, because 5G in both transmission speed and reliability are more powerful than the current 4G wireless communication, therefore, before 5G really coming, we have a lot of work and research needs to be done, for example, in order to meet the various features of 5G, we need to design a new type of antenna. At present, MIMO (multiple-input multiple output) is regarded as a very important part of the future 5G antenna design, but we also know that the current widely used MIMO design is still 2 x 2 MIMO and 4 x 4 MIMO. Obviously, the current design cannot meet the requirements of future 5G [1-2].

At present, 2x2 MIMO is the most commonly used communication system in 4G and its predecessor, of course, 4x4 MIMO has been widely used in recent years. But for 5G base stations, these two difference MIMO systems are far from enough. Massive MIMO has at least four antenna elements if we want to reach 5G demand [3]. For 5G mobile base stations, at least six or more antenna components are required to achieve faster and more stable transmission [4]. Because with more antennas, space can be reused more efficiently, allowing MIMO systems to achieve greater channel capacity, therefore, this MIMO system can have better anti-fading ability and improve data throughput [5-6].

As the international standard of 5G communication is still under study, this international standard has not been officially released. At the 2015 world radio communication conference (WRC-15) [7], the conference determined that 3400-3600 MHz in the C band was allocated as a new IMT band for future 5G wireless communication. Therefore, the frequency band below 6GHz, also known as sub-6GHz frequency band, has aroused the interest of many countries at present. Today, there are many countries that have started the research work related to 5G.

Among these countries, most of them focus their research on 3400-3600 MHz (LTE band 42) and 3600-3800 MHz (LTE band 43). For example, Germany announced its national 5G strategy on July 13, 2017 and released more 5G spectrum planning, at present, downlink frequency band of satellite communication uses 3.4-4.2 GHz. Many developed countries plan to compress the frequency of satellite communication and divide it into mobile communication. So Germany uses half of that, 3.4-3.8 GHz, for mobile communications. On July 31, 2017, Ofcom, the UK regulator, released a new consultation report on the future use of mobile spectrum, seeking advice on the expansion of 3.6-3.8 GHz frequency band for mobile business. On August 3, 2017, American FCC (Federal Communications Commission) launched a public consultation on 5G medium frequency band, the FCC considers the middle frequency band including 3.7-4.2 GHz, 5.925-6.425 GHz and 6.425-7.12 5GHz. But only LTE band 42 and LTE band 43 are not enough, so LTE band 46 (5.15-5.925 GHz) is also considered for future 5G frequency applications.

With the introduction of 5G strategy in various countries, there are higher requirements for the design of new antenna for 5G mobile communications. Because all electronic devices want to have smaller size and lighter weight, in the antenna design, we also want to minimize its size and weight without affecting the performance of the antenna. Based on this situation, finding a suitable antenna has become the key to meet the future needs. Microstrip patch antenna is an antenna with small size, light weight and good performance. At the same time, because of its low cost and ease of fabricate, it has also been widely used in the design of 5G antenna in recent years [9].

A traditional microstrip antenna would be placed on a dielectric substrate of Lp x Wp size, and on the other side of that dielectric substrate, we would normally place a ground of the same size. In general, relative permittivity and thickness of dieletric substrate are important, which should be determined at the beginning of design. The microstrp patch antenna can also be designed into any possible shape to meet the design needs.

Dual-band operations can be implemented by loading a slot or stacking microstrip antennas from a feed slot or by sharing a single aperture between two separate feed antennas. When the former design is used in array, there are limitations such as complex beamforming and complex duplex network, which make it difficult to achieve a good radiation pattern of two bands. The other method provides us with a separate feed system, in which each frequency band in the beam can be independently controlled, so it is more flexible. Another advantage of dual frequency antenna is that we can adjust the frequency according to our own needs.

When we review the development of wireless communication, it is not difficult for us to find that the progress of each generation of wireless communication will be accompanied by huge technological reforms [10]. Figure 1.1 shows the differences between 1G and 5G wireless communication technologies.

Technology	1G	2G/2.5G	3G	4G	5G
Deployment	1970/1984	1980/1999	1990/2002	2000/2010	2014/2015
Bandwidth	2kbps	14-64kbps	2mbps	200mbps	>1gbps
Technology	Analog cellular	Digital cellular	Broadbandwidth/ cdma/ip technology	Unified ip & seamless combo of LAN/WAN/WLAN/PAN	4G+WWWW
Service	Mobile telephony	Digital voice,short messaging	Integrated high quality audio, video & data	Dynamic information access, variable devices	Dynamic information access, variable devices with AI capabilities
Multiplexing	FDMA	TDMA/CDMA	CDMA	CDMA	CDMA
Switching	Circuit	Circuit/circuit for access network&air interface	Packet except for air interface	All packet	All packet
Core network	PSTN	PSTN	Packet network	Internet	Internet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal&Vertical	Horizontal&Vertical

Figure 1.1 Comparison of 1G to 5G technology [1]

Based on the above research background, in this study, we focused on how to design a dual-frequency antenna, so that it can meet the requirements of 5G, and based on MIMO technology, so that it can get better stability and transmission speed.

1.2 Problem Statement

The structure and characteristics of 2 x 2 MIMO and 4 x 4 MIMO cannot meet the requirements of future 5G communication.

The conventional MIMO antenna is usually single band which is insufficient for the usage of 5G applications.

At present, most of the bandwidth of 5G antenna design is relatively narrow. We know that the frequency of LTE band 46 is very wide, but most of the designs cannot cover it. Even if there are designs with wide bandwidth, their return loss is relatively low.

1.3 Research Objectives

This paper mainly studies how to design a dual frequency microstrip patch antenna by adding a slot on the basis of single band antenna. By adding a slot structure to microstrip patch antenna, the dual band antenna design can be basically achieved. We used this dual band antenna to design a MIMO with 8 ports. Therefore, our research objectives are:

To design, simulate and fabricate an 8-port antenna for 5G massive MIMO application in mobile base station.

To analyse the performance of the designed antenna operating in the LTE (long term evolution) band 43 (3600-3800MHz) and LTE band 46 (5150-5925 MHz) to serve for 5G mobile communication.

1.4 Scope of Research

Our research focuses on the design and analysis of a microstrip patch antenna that can meet our needs for future 5G mobile base station. Therefore, the scope of this research are:

Design a single dual-band patch antenna that can cover both the 3.6-3.8 GHz and 5.1-5.9 GHz. First, we use FR-4 as our dielectric substrate, because it's very common in the market and it's not very expensive and it's widely used in antenna design. However, later we found it difficult to fabricate the design results, so we chose RT 5870 as our substrate. The relative permittivity and thickness of RT 5870 dieletric substrate are 2.33 and 1.6 mm.

Secondly, design an 8-port massive MIMO antenna by using the single dual-band patch antenna. In the design process, we first studied the distance between two antennas in the horizontal and vertical directions. When this distance is determined, we use this distance to arrange the placement of 4 antennas and 8 antennas.

Moreover, using CST studio suit software to simulate the proposed design. Analyze the parameters in the simulation results such as reflection coefficient, radiation pattern, bandwidth, isolation. Through the analysis of these parameters, the performance of the antenna is studied and how to optimize the design.

Finally, the proposed MIMO antenna will be fabricated and measured.

1.5 Organisation of The Project Report

This project report consists of 5 chapters. The first chapter briefly introduces the research background of 5G and MIMO antennas, problem statement, research purpose and scope, and the organizational structure of the project report.

The second chapter explains the basic concepts and fundamental of the dual frequency microstrip slotted antenna and MIMO. Some of previous work on dual-band microstrip antenna regarding its size and its performance and MIMO techniques and design with difference methods were discussed in this part.

The third chapter describes in detail of project methodology, the design process of MIMO and antenna, and how to use CST software for simulation. In this chapter, we also explain in detail the steps of antenna design and the formulas that will be used in the design process. At the same time we also put forward an estimate of the design results.

The fourth chapter introduces the final design and Specific design parameters of the single dual-band microstrip patch antenna and 8-port MIMO, as well as the parametric study of the proposed antenna and MIMO. The single dual-band patch antenna and the MIMO's performance such as reflection coefficient, bandwidth, realized gain, polar plot radiation pattern are presented. Besides, the comparison between 2-port MIMO, 4-port MIMO and 8-port MIMO are briefly discussed.

Chapter 5 summarizes our design, and puts forward the research direction in the future research work for some problems in the design.

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