28GHz MULTIPLE INPUT MULTIPLE OUTPUT PLANAR ANTENNA FOR 5G MOBILE COMMUNICATION

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Specially dedicated to my supervisor,

my dad, my mom, my wife and friends who encouraged

me throughout my journey of

education.

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ABSTRACT

Fifth generation (5G) is the next major phase of mobile telecommunications standards beyond the current 4G, which will operate at millimeter-wave frequency band. This thesis presents designs for MIMO planar antennas (single element and arrays at 28 GHz) Based on the best optimized single element patch, antenna array is designed at 28 GHz. An array theoretically offers higher gain compared to single antenna and offers more directive beam. The planar antennas are designed on Rogers RT Duroid with permittivity of 2.2 and the thickness of 0.381 mm. All structures are simulated and optimized using CST software. The performance are analyzed by means of the S parameters and the radiation pattern of the planar antenna. For single element antenna, are well matched at 28 GHz with S11 of -25.54 db in inset feed, and with S11 of -13.53 db in aperture coupled feed. The gain of single element antenna using inset feed is 7.721 db, while the gain of single element antenna using aperture coupled feed is 7.084 db. For 2x1 elements MIMO antenna using different two feeding techniques. The antenna is well matched at 28 GHz with S11 of -17.69 db, S21 of -34.78 db in inset feed, and with S11 of -17.3 db, S21 of -39.03 db in aperture coupled feed. The gain of single element antenna using inset feed is 8.169 db, while the gain of single element antenna using aperture coupled feed is 7.899 db. For 2x2 elements antenna array using aperture coupled feeding techniques. The antenna is well matched at 28 GHz with S11 of -10.2 db. The gain of 2x2 elements MIMO antenna using aperture coupled feed is 10.16 db.

ABSTRAK

Generasi kelima (5G) adalah fasa utama seterusnya bagi standard telekomunikasi mudah alih yang melebihi 4G semasa, yang akan beroperasi pada jalur frekuensi gelombang milimeter. Tesis ini membentangkan reka bentuk antena planar MIMO (elemen tunggal dan susunan pada 28 GHz), di mana 28GHz adalah salah satu daripada frekuensi standard komunikasi 5G. Berdasarkan patch elemen tunggal yang dioptimumkan, beberapa reka bentuk antena planar antena MIMO pada 28 GHz dicadangkan dengan bilangan unsur reka bentuk yang memenuhi keperluan antena 5G. Antena planar menggunakan substrat Rogers RT Duroid.Semua struktur antena disimulasi menggunakan perisian CST. Prestasi a dianalisis dengan menggunakan parameter S antena planar. Untuk antena unsur tunggal, dipadankan dengan baik pada 28 GHz dengan S11 daripada -25.54 db dalam inset feed, dan dengan S11 daripada -13.53 db dalam aperture ditambah suapan. Keuntungan antena elemen tunggal menggunakan umpan inset adalah 7.721 db, sedangkan keuntungan antena elemen tunggal menggunakan umpan ditambah aperture adalah 7.084 db. Untuk elemen 2x1 antena MIMO menggunakan dua teknik pemakanan yang berlainan. Antena ini dipadankan dengan baik pada 28 GHz dengan S11 daripada -17.69 db, S21 daripada -34.78 db dalam feed inset, dan dengan S11 daripada -17.3 db, S21 daripada -39.03 db dalam suapan aperture ditambah. Keuntungan antena elemen tunggal menggunakan umpan inset adalah 8.169 db, sedangkan keuntungan antena elemen tunggal menggunakan feed aperture ditambah 7.899 db. Untuk pelbagai elemen antena 2x2 menggunakan teknik makan aperture ditambah. Antena ini dipadankan dengan baik pada 28 GHz dengan S11 daripada -10.2 db. Keuntungan elemen antena MIMO 2x2 menggunakan feed aperture ditambah 10.16 db.

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LIST OF SYMBOLS

ε	-	Permittivity
ε_r	-	Relative Permittivity
c	-	Speed of Light
f	-	Frequency
$f_\circ$	-	Operating Frequency
W	-	Microstrip Patch Width
L	-	Microstrip Patch Length
h	-	Thickness
d	-	Distance between elements
S_{11}	-	Return Loss

LIST OF ABBREVIATIONS

PEC	-	Perfect Electric Conductor
CST	-	Computer Simulation Technology
BW	-	Bandwidth
FBW	-	Fractional Bandwidth

CHAPTER 1

INTRODUCTION

1.1 Introduction

The generations of mobile communication systems are presented in Table (1.1). Mobile phone network has been historically divided into four generations, each generation has specific characteristics that distinguish it from other, each generation is different from the other in terms of frequency, data rate, maximum number of users and the geographical area covered by the network. [3]

Table (1.1): summary of mobile communications generations [3]

Cellular phone generation	1G	2G	3G	4G	5G

1st year deployment	1981	1992	2001	2010	2020
Peak supported Data rate	2 Kbps	64 Kbps	2 Mbps	100 Mbps	10 Gbps
Frequency	900 MHz	900MHz and 1.8GHz	800/900 MHz 1.7 to 1.9 GHz 2100 MHz	800MHz 900MHz 1800MHz 2100MHz 2600MHz	28GHz 37 GHz 39 GHz 64 – 71 GHz
General functional description	Analogue cellular phones	Digital cellular phones (GSM/CDMA)	First mobile broadBand utilizing IP protocols (WCDMA2000)	The mobile broadBand on a unified standard (LTE)	Tactile internet – Enhance M2M communications network

5G (5th generation mobile network or 5th generation wireless system) is a term used in some research papers and projects to represent the next major phase of the mobile telecommunication standard beyond the current 4G. 5G is considered to be a mobile communication technology after 2020. [2]

5G is a new generation, it comes along each 10 years, from 1982, the 1st generation wireless network appears. These standards were formulated to meet the current and future needs of mobile users. However, global mobile traffic is growing exponentially every year, and the trend may continue into the future. [1]

In the next decade, global mobile data traffic will surely continue to grow rapidly. Naturally, people are increasingly concerned that the current 4G cellular network capacity will be unsustainable for a long time. In recent years, numerous research institutes and industry partners have been studying the concept of improvement in terms of capacity, delay and mobility of 5G (5G) mobile networks. Due to insufficient spectrum of the traditional microwave frequency band, as an additional frequency spectrum band of the 5G cellular network, the millimeter wave (mm-wave) frequency band has attracted people's attention. [2]

The main goal of 5G is to increase the coverage of wider network capacity at a lower cost. The common recognition among different research groups for future 5G technical work is that the static user's peak data rate is 10 Gb / s, the mobile user is 1 Gb / s, and the urban area is not less than 100 Mb / s. The technology being studied to meet these high data rate goals is Massive MIMO

Massive MIMO: The concept of extending multi-user MIMO to hundreds of antennas at a base station is a promising solution that can significantly increase user throughput and network capacity by allowing beamforming data transmission and interference management. The significant increase in path loss at very high frequencies must be compensated by a higher antenna gain, which can be achieved by increasing the number of antennas at the base station. The goal of 5G R&D is still to be 1 millisecond lower than the 4G device delay and lower battery consumption. [1]

In recent years, the demand for high-speed cellular data and the demand for more spectrum have prompted the use of millimeter-wave (millimeter-wave) carrier frequencies for future cellular networks, including high-gain adaptive antennas. Millimeter wavebands have attracted a lot of attention because of the large amount of bandwidth available. [3]

The millimeter-wave band is defined as the portion of the electromagnetic spectrum extending from 30 - 300 GHz with corresponding wavelengths range of 10 - 1 mm. Historically, mm-wave frequencies were used mostly for defense and radio astronomy applications mainly because of the high cost and limited availability of electronic devices at these frequencies. The recent advancement of silicon technology and the rapidly growing mm-wave applications markets (such as automotive radars, high-resolution imaging and high-definition video transfer requirements) necessitate the development of broadBand, highly integrated, low power and low cost wireless systems including high-efficiency planar antennas. [4]

Integrated planar antennas have gained a lot of interest in the past years for mm-wave applications due to their low cost, ease of fabrication and potential for high efficiency operation. The small wavelength at mm-wave frequencies is an advantage for the design of small and efficient antennas. The size of the antenna is determined by the laws of physics; and for efficient radiation, the antenna size should be of the order of half wavelength or larger. Therefore, for f = 30 - 300 GHz (λ = 10 - 1 mm), it is feasible to build antennas that are physically small and at the same time electrically large enough to radiate efficiently. However, at mm-wave frequencies the losses are generally higher than at lower frequencies; and the antenna designer needs to carefully design the antenna and choose the appropriate substrate to minimize losses and achieve high radiation efficiency. [6]

Due to its small wave length, mm-wave antenna size can be made smaller than conventional cellular frequency wave. The small antenna size enables sharp beamforming or massive MIMO technology.

In 5G requirements, the antenna should at least have a gain of 12 dB and bandwidth more than 1 GHz. [5]

1.2 Thesis motivation

In this research, a comprehensive study of different parameters that affect antenna performance, (such as antenna type, feeding technique, substrate dielectric constant, substrate thickness, substrate loss tangent, etc.…), was carried out. The outcome of this study serves as a design guide and is very useful for 5G mm-wave antenna designers. The usefulness of the study is illustrated through the design of a planar antenna optimized for 5G communication systems.

1.3 Problem Statement

Advances in wireless communication system technology have generated a strong demand for the development of new antenna structures. In the wireless communication system, the structure of the microstrip array antenna is very modern, and it is an interesting research. It is widely used in the field of mobile communication, mainly for increasing the range and reliability. Due to the increased attenuation of high frequencies, we need to design a high-gain, small-sized and directional beam antenna.

Other than that, most of the microstrip antenna array is also large in size. The major limitations of conventional microstrip antenna array to design is inter-element spacing requirement for minimizing mutual coupling.

1.4 Objectives

The objectives of this project are:

1.To design, simulate and analysis the square patch array antennas which operate at 28GHz.

2.To analyze the performance of the designed antenna at 28GHz to serve for 5G mobile communication.

1.5 Thesis Overview

The thesis consists of five chapters:

Chapter 1 is an introduction about 5G communications, and its frequency band. Several antennas designs for 5G antenna are introduced in the literature review.

Chapter 2 provides an overview of the theory of Antenna. Calculate the antenna parameters which describe the behavior of antenna, square patch antenna and its design procedures are presented.

Chapter 3, a parametric study is performed to choose the best design for 28GHz antenna.

Chapter 4, antenna array designs are presented, the array is constructed from the best design in chapter 3.

The last chapter presents the conclusions drawn from the current work and also future work.

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