MILLIMETER-WAVE GRID ARRAY ANTENNA FOR 5G MOBILE COMMUNICATION NETWORKS

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Dedication to my beloved parents, my Brothers and my fiancée for their support and care.

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ABSTRACT

A single feed grid array antenna for *28 GHz* for 5G Mobile Communication Networks is proposed. It is designed on *1.52 mm* thick substrate made of Rogers Duroid 5880LZ (ε_r= 1.96 and *tan δ = 0.0019*) with *0.035 mm* copper claddings. Dimension of the antenna is *80 mm* × *80 mm* × *1.52 mm*. The grid array antenna is fed by a SSMA coaxial probe feed connector with Teflon (ε_r*=2.1*) with inner diameter *p = 0.5 mm* and outer diameter *d = 2 mm*, is drilled through the ground and the substrate to feed the radiating element and to achieve the characteristic impedance of *50 Ω*. The measured antenna exhibits 2.6 % impedance bandwidth from *27.576* to *28.312 GHz* at *27.944 GHz* with *1.74% 3dB* impedance bandwidth of *27.724* to *28.212 GHz* at *27.986 GHz*. The simulated antenna exhibits *41 %* impedance bandwidth from *22* to *33.38 GHz* at *27.694 GHz,* and *10.3%* 3dB impedance bandwidth from *26.58* to *29.765 GHz* at *28.1 GHz,* and *15.2dB* gain at *28 GHz*, with a 3dB gain bandwidth from *25.159* to *31.192 GHz*. The comparison between simulation and measurement results indicate that good agreement between measured and simulated results. The discrepancy between the measured and simulated results may be due to the effects of the RF cable, the SSMA to SMA adapter configurations and KEYSGHT N5234A PNA-L Microwave Network Analyser calibration process.

ABSTRAK

Sebuah grid pelbagai antena suapan tunggal bagi 28 GHz untuk 5G rangkaian komunikasi mudah alih adalah dicadangkan. Ia direka pada 1.52 mm substrat tebal diperbuat daripada Rogers Duroid 5880LZ (εr = 1.96 dan tan δ = 0,0019) dengan claddings tembaga 0,035 mm. Dimensi antena ialah 80 mm × 80 mm × 1.52 mm. Antena tatasusunan grid disuap oleh SSMA sepaksi penyambung probe dengan Teflon (εr = 2.1) dengan diameter dalaman p = 0.5 mm dan diameter luar d = 2 mm, digerudi melalui Tanah dan substrat untuk memberi makan elemen terpancar dan mencapai galangan ciri 50 Ω. Antena diukur menunjukkan 2.6% impedans bandwidth 27,576-28,312 GHz di 27,944 GHz dengan 1.74% 3dB impedans bandwidth daripada 27,724-28,212 GHz di 27,986 GHz. Antena simulasi menunjukkan 41% impedans bandwidth 22-33,38 GHz di 27,694 GHz, dan 10.3% 3dB impedans bandwidth 26,58-29,765 GHz pada 28.1 GHz, dan 15.2dB keuntungan pada 28 GHz, dengan 3dB keuntungan bandwidth 25,159-31,192 GHz . Perbandingan antara keputusan simulasi dan pengukuran menunjukkan bahawa perjanjian yang baik antara keputusan diukur dan simulasi. Perbezaan antara keputusan diukur dan simulasi mungkin disebabkan oleh kesan kabel RF, yang SSMA untuk SMA konfigurasi dan penyesuai KEYSGHT N5234A PNA-L Microwave Penganalisis Rangkaian proses penentukuran.

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LIST OF ABBREVIATIONS

5G - Fifth Generation
4G - Fourth Generation
LTE-A - Long Term Evolution Advanced
WiMAX - Worldwide interoperability for Microwave Access
MIMO - Multiple Input Multiple Output
MMIC - Monolithic Microwave Integrated Circuits
AiP - Antenna in Package
FCC - Federal Communication Commission
CPW - Coplanar Wave Guide
LTCC - Low Temperature Cofired Ceramic
MGAA - Microstrip Grid Array Antenna
MCAA - Microstrip Comb Array Antenna
VSWR - Voltage Standing Wave Ratio
HFSS - High Frequency Structural Simulator
CST - Computer Simulation Software
RFIC - Radio Frequency Integrated Circuit
dB - Decibel
BW - Bandwidth
Hz - Hertz
MHz - Mega Hertz
GHz - Giga Hertz
RF - Radio Frequency
mm - Millimeter
GA - Genetic Algorithm
Km - Kilometer
m - meter

dBi - decibels-isotropic

LIST OF SYMBOLS

ε_r - Relative permittivity

ε_{eff} - Effective permittivity

δ - Tangent loss

a - Substrate length

b - Substrate width

h - Substrate thickness

L - Length of the long side of the mesh

w_l - Width of the long side of the mesh

S - Length of the short side of the mesh

w_s - Width of the short side of the mesh

λ_g - Guided wave length

p - feeding-pin diameter

d - Aperture diameter

Ω - ohm

S_{11} - reflection coefficient

$|S_{11}|$ - Magnitude of the reflection coefficient

λ_0 - Wave length in free space

c - Speed of light

f_0 - Frequency in free space

z_{0l} - characteristic impedance of the long side

z_{0s} - characteristic impedance of the short side

R_r - radiation resistance

ξ - empirical factor

n - number of meshes

L_b - minor axis length

L_a - major axis length

W_t - sinusoid lines width

L_t - sinusoid lines length

A_m - sinusoid lines amplitude

N_p - number of periodicities in a section of a sinusoid line

η - area reduction factor

CHAPTER 1

INTRODUCTION

1.1 Introduction

Today there is a variety of multimedia services arises with the evolution of the mobile devices industry and raped development in the mobile communication sector and the use of mobile communication at these days does not depend on voice communication only it is include also broadband and multimedia services that the mobile communication infrastructure can support, but on top of that there is always a user demand for high mobility, high data rate and high availability with good quality of service guarantee. All these user requirements push the mobile communication industry for looking to a new technology and new frequency spectrum to support their infrastructure to meet the user requirements.

Qualcomm expects that the mobile traffic in 2020 will be 1000 times more than that of the current mobile traffic. To handle all of current mobile communication traffic the (4G) mobile communication system, (LTE-A) long term evolution advanced and (WiMAX) worldwide interoperability for microwave access uses advanced technologies such as (MIMO) multiple input multiple output, carrier aggregation and multicarrier transmission[1]. Also all that technologies, frequency band from 3GHz and below used in recent mobile communication are expected to be consumed due to the more demand in mobile communication data traffic. There for, accommodate the new data traffic requirements and user demands the frequency band should be enlarge, thus a new frequency band will be considered in (5G) mobile communication systems. The band in the 30GHz – 300GHz range at millimeter wave band is being considered as a good candidate for new mobile communication system (5G)[2], thus the system capacity of (5G) mobile communication system will be improved and mobile devices served by base station can experience better service environment with high speed broadband transmission with low latency when compared with the current mobile communication systems. Therefore the use of millimeter wave band for (5G) mobile communication system will provide novel multimedia services.

The transceivers in (5G) must guarantee a secure communication with reliable link speed of Gigabit per second everywhere any time. Around all the transceiver components for millimeter wave (30GHz – 300GHz) for (5G) mobile communication the antenna design required significant changes. This is because all the mobile communication standards up to (4G) has operate in the range of the microwave spectrum 300MHz-3GHz.

1.2 Problem Statement

The development of 5G mobile communication networks focuses on providing higher bandwidth and longer range. Thus the spectrum available in the millimeter-wave frequency bands provides multi-gigabit-per second data rates, but the realized communication range will be constrained based on several factors. These incorporate the higher atmospheric attenuation at these frequencies, furthermore the limited output power of monolithic microwave integrated circuits (MMIC) due to physical constraints. Therefore, the performance of the mobile millimeter-wave networks requires enhancement by using high gain antenna arrays.

1.3 Objectives of the Study

The objective of this project focus on design, simulate and fabricate a microstrip grid array antenna at millimeter-wave frequencies for (5G) mobile communications with an operating frequency of 28GHz, Moreover the proposed microstrip grid array antenna must provide a high gain and high radiation efficiency in order to overcome the drawback of the low gain of millimeter-wave.

1.4 Scope of the Study

The scope of this project is to gain an experience in designing and simulating a microstrip grid array antenna in millimetre wave frequencies for 5G mobile communication network through the literature review and the proposed microstrip grid array antenna must offer high gain and high radiation efficiency, the simulation of the proposed microstrip grid array antenna will be conducted to get the simulated results of the return Loss, Radiation Pattern and the Gain of the antenna by using CST Microwave Studio software. Finally the optimized microstrip grid array antenna will be fabricated and measured to compare the measured result with the simulated result.

1.5 Thesis Outlines

This project report is divided into five chapters, each chapter will explain the stages of the project design, and these four chapters constituent the project report was formatted as follows:

Chapter 1 introduces an introduction of why we need to move looking for a new frequency spectrum specifically millimeter wave frequency spectrum for 5G mobile communication networks, furthermore this chapter incorporates some view about the problem statements, objective, and scope of this research project.

Chapter 2 describes the propagation of the millimeter wave at 28GHz and 38GHz and summarizes the work that has been done to investigate the propagation of the millimeter wave in various environments, and what is the key change that is required for antenna design to be operating at the new millimeter wave frequency spectrum, followed by the evolution and the enhancements of the grid array antenna since it was proposed by John D. Kraus in 1964 up to Zhang & Sun, who received the microstrip grid array antenna on millimeter wave application and the proposed to use it for antenna in package application (AiP). Also the principle of operation of microstrip grid-array antennas at millimeter-wave frequencies will be explained in this chapter including the design parameters (Gain, impedance bandwidth, gain bandwidth, Half-Power Beam-width and microstrip grid array resonant frequency for the microstrip grid array antenna. Toward the end of this chapter the Microstrip grid array antenna Synthesis was introduced flowed by two types of microstrip grid array antennas (Wideband and Compact, Capacitive Slot feeding).

Chapter 3 the methodology which has been used for the entire project will be discussed and presented in this chapter in addition, the steps for the proposed microstrip grid array antenna fabrication process and measurement procedures will be demonstrated.

Chapter 4 depicts simulated and measurement results. Discussions about comparisons between simulated and measured result through the diagram are illustrated.

Chapter 5 concludes this project and indicates some future works.

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