Faculty of Electronics and Computer Engineering

PERFORMANCE ENHANCEMENT WITH TRIANGULAR LOOP FREQUENCY SELECTIVE SURFACE ON MICROSTRIP ARRAY ANTENNA FOR 5G APPLICATION

Muhamad Akliff bin Abd Rahim

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MUHAMAD AKLIFF BIN ABD RAHIM

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DECLARATION

I declare that this thesis entitled "Performance Enhancement With Triangular Loop Frequency Selective Surface on Microstrip Array Antenna For 5G Application" is the result of my own research except as cited in the references. The thesis has not been accepted for any masters or degree and is not concurrently submitted in candidature of any other degree.

Signature	:	…………………………………………………………..
Name	:	MUHAMAD AKLIFF BIN ABD RAHIM
Date	:	…………………………………………………………..

APPROVAL

I hereby declare that I have read this thesis and in my opinion the thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature	:	………………………………………
Supervisor Name:	:	DR IMRAN BIN MOHD IBRAHIM
Date	:	………………………………………

DEDICATION

To my beloved late Mother,

To my Father for unconditional love,

To my Siblings and Friends for the big supportive.

And yeah to my beloved RanjauRunners and GengCaruts!!

ABSTRACT

The Fifth generation communication offers many benefits such as massive system capacity, very high data rate and low latency. Microstrip array antenna were popular due to the easiness of design and fabrication process. Besides, the microstrip array antenna is also popular for backhaul application. To enhance the performance of microstrip array antenna, the FSS has been integrated to the antenna structure. The Frequency Selective Surface (FSS) is based on metamaterial are the substitute to the fixed frequency metamaterials with static geometry and spacing in the unit cells used to find out the frequency response of a given metamaterial. FSS with specific geometrical shapes can be made-up as periodic arrays with elements of two dimensional. Antenna specification for return loss is below than -10 dB, but in practical field, the reflection coefficient of the signal always fluctuates, so it is giving unstable value for return loss. The directivity of the antenna depends on the antenna design. Since this antenna element is microstrip array antenna, the antenna performance will change by the additional patch. The integration with the FSS will be affected towards the return loss of the antenna. The design of antenna and Frequency Selective Surface is at 28 GHz on the Rogers Duroid RT5880 board with the thickness of substrate is 0.254 mm and copper thickness is 0.017 mm with dielectric constant of 2.2 and the tangent loss is 0.0009. The antennas was design from single patch antenna until 32-element patch array antenna by using the quarter wave theory to feed at 50 Ω, 70 Ω and 100 Ω. The FSS design on this research was held on three designs which are triangular loop, hexagonal loop and rectangular loop. From the simulation the triangular loop had the best result on return loss is -30.832 dB at 28 GHz. The rectangular antenna has been choosen due to the best result on single design which is -49.48 dB, next the single design has evolved to 32-element patch array antenna and the result is decreased to -37.62 dB. The 32 -element patch array antenna are integrated with triangular loop FSS, the return loss is better which is -64.67 dB. The simulation is done using microwave CST software. The fabrication process involves the photo etching technique. The return loss measurement on integrated antenna with FSS gives a minimum resonant -43.55 dB at 28.45 GHz, slightly shifted from the simulation result. The antenna directivity was recorded of 21.7 dBi.

ABSTRAK

Komunikasi generasi kelima menawarkan banyak kelebihan seperti kapasiti sistem yang besar, kadar data yang sangat tinggi dan latensi yang rendah. Antena jalur mikro tatasusunan popular kerana mudah untuk direka bentuk dan fabrikasi. Selain itu, antena jalur mikro tatasusunan juga popular digunakan pada aplikasi "backhaul". Permukaan Selektif Frekuensi (FSS) berasaskan bahan "metamaterial" adalah pengganti kepada metamaterial berfrekuensi tetap dengan geometri statik pada jarak dalam sel unit yang digunakan untuk mengetahui tindak balas frekuensi dari metamaterial yang diberikan. FSS dengan bentuk geometri yang tertentu boleh dibuat sebagai tatasusunan berkala dengan elemen dua dimensi. Spesifikasi antena untuk kehilangan balikan adalah kurang dari -10 dB, tetapi pada praktik lapangan, isyarat dari koefisien refleksi sentiasa berubah-ubah sehingga memberikan nilai tidak stabil untuk kehilangan balikan. Pengarahan antena bergantung pada reka bentuk antenna. Oleh kerana elemen antena adalah antena jalur mikro tatasusunan prestasi antena berubah dengan tambahan elemen tampalan. Integrasi dengan FSS akan memberikan kesan kepada kehilangan balikan antena. Reka bentuk antena dan (FSS) pada 28 GHz direka bentuk diatas papan Rogers Duroid RT5880 dengan ketebalan substratum 0.254 mm dan ketebalan tembaga 0.017 mm dengan pemalar dielektrik 2.2 dan kehilangan tangen 0.0009. Antena direkabentuk dari penampalan tunggal hingga tatasusunan tampal 32 elemen menggunakan teori gelombang suku untuk menyuap pada 50 Ω, 70 Ω dan 100 Ω. Reka bentuk FSS dalam kajian ini telah dibahagikan kepada tiga reka bentuk iaitu gelang segitiga, gelung heksagon dan gelung segi empat tepat. Dari simulasi gelung segi tiga memberi hasil terbaik untuk kehilangan kembali adalah -30.832 dB pada 28 GHz. Antena segiempat tepat telah dipilih kerana hasil terbaik pada reka bentuk tunggal iaitu -49.48 dB, seterusnya reka bentuk tunggal berevolusi kepada tampalan 32 elemen jajaran antena dan hasilnya berkurangan kepada -37.62 dB. Antena jalur mikro tatasusunan tampalan 32 elemen disepadukan dengan gelung segitiga FSS, kehilangan balikan didapati lebih baik iaitu -64.67 dB. Simulasi ini dilakukan dengan menggunakan perisian gelombang mikro CST. Proses fabrikasi melibatkan teknik etsa punaran. Pengukuran kehilangan balikan pada antena bersepadu dengan FSS memberikan titik resonan minimum -43.55 dB pada 28.45 GHz, sedikit berganjak dari hasil simulasi. Kearahan antena yang telah dicatatkan adalah 21.7 dBi.

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LIST OF ABBREVIATIONS

1G	-	First Generation
2G	-	Second Generation
3G	-	Third Generation
4G	-	Fourth Generation
5G	-	Fifth Generation
3D	-	Three Dimensional
2D	-	Two Dimensional
1D	-	One Dimensional
IOT	-	Internet of Things
WCDMA	-	Wideband Code Division Multiple Access
UMTS	-	Universal Mobile Telecommunications System
WiMAX	-	Worldwide Interoperability for Microwave Access
LTE	-	Long Term Evolution
VoIP	-	Voice over Internet Protocol
IP	-	Internet Protocol
ETSI	-	European Telecommunication Standardize
CST	-	Computer Simulation Tool software
HPBW	-	Half Power Beam Width
VSWR	-	Voltage Standing Wave Ratio
DNG	-	Double Negative Material
NRI	-	Negative Refractive Index
AMC	-	Artificial magnetic conductor

EBG	-	Electromagnetic Bandgap
FSS	-	Frequency Selective Surface
SRR	-	Structure of split ring resonator
RL	-	Return loss
RP	-	Radiation pattern
PCB	-	Printed Circuit Board
LTCC	-	Low Temperature Cofired Ceramic
SIW	-	Substrate Integrated Waveguide

LIST OF PUBLICATIONS

Rahim, M.A.A., Ibrahim, I.M., Kamaruddin, R.A.A., Zakaria, Z., and Hassim, N., 2017. Characterization of microstrip patch array antenna at 28 GHz. Journal of Telecommunication, Electronic and Computer Engineering, 9 (2-8), pp.137–141.

Rahim, M.A.A., Ibrahim, I.M., Zakaria, Z., Aziz, S. A. C., Hassim, N and Saadon, A.S., The Study on the Effect of Electromagnetic Band Gap on Microstrip Array Antenna At 28 GHz. Journal of Telecommunication, Electronic and Computer Engineering, 10 (2-6), pp. 125-128.

CHAPTER 1

INTRODUCTION

1.1 Research Background

The wireless technologies had advance and led to the evolution of radio, television, mobile telephone, and communication satellites. Nowadays, the information can be shared to almost every corner of the world. The first generation 1G of the network appeared in the 1980s and started with the advanced mobile phone services (AMPS) which are provided features like analogue communications, support only voice transmissions, using frequency division multiple access (FDMA) with 30 KHz for each channel and the frequency is ranging from 824 MHz to 894 MHz. Second generation of the network appeared in 1990s, from here the digital communication are started to be explored and the voice calls are becoming clearer and the communications are encrypted. Other than that, it is supported better voice and text transmissions. The frequency band are 900 MHz and 1800 MHz (Aravamudhan et al., 2015)

Next the third generation (3G) has greatly helped in the development of wireless services, which included voice telephony, mobile internet access, fixed wireless internet access, video calls and mobile TV. 3G uses services and networks that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications. The first 3G network was launched in May 2001 in a test release as Wideband Code Division Multiple Access (WCDMA) technology in Japan. The first Universal Mobile Telecommunications System (UMTS) (based WCDMA) network was launched in Europe in December 2001. 3G network has the features example as wider coverage area, improve spectral efficiency, greater network capacity, more services include video calls and broadband wireless data and data rate reached 14.4 Mbps on downlink and 5.8 Mbps on uplink.

The fourth generation (4G) communication (Zacharopoulou, 2015) were pre-release appeared in 2006 using worldwide Interoperability for Microwave Access (WiMAX) technology, and the first release appeared in 2009 with Long Term Evolution (LTE) technology with the features of data rate up to 100 Mbps s for mobile users and up to 1Gbps for fixed stations. Support Voice over Internet Protocol (VoIP) and data, maximum 2G/3G spectrum reusability, high quality audio/video streaming over Internet Protocol (IP). The newest generation which is fifth generation (5G) will also provide wireless connectivity for a wide range of new applications and use cases, including wearables, smart homes, traffic safety/control, and critical infrastructure and industry applications, as well as for very- high-speed media delivery (Dahariya et al., 2015; Andrews et al., 2014).

According to (Vendik, 2013), the electromagnetic wave can be controlled by using metamaterial. Usually the metamaterial increase their properties from design structure instead of from their composition. Metamaterial is a composite that depend more on the periodic structure, which mean the periodic structure can modify the permittivity and permeability. Thus, the designer of metamaterial can control the parameters, such as sizes, shape and orientation of the structure. In addition, (Tie and Hui, 2013) studied that metamaterial can be design as passband and stopband characteristic in various bands of wave number which is determined by the nature of the structure.

1.2 Problem Statement

The fourth generation (4G) communication becoming the medium to communicate the devices and it has becoming more congested by day because of there are so many of devices including the new technology nowadays (Ahmad, 2012; Bergren, 2017). The fifth generation (5G) are working only on millimetre-wave frequency which is a very high frequency (28 GHz). Therefore it is important to have a good return loss (< -10 dB) because the return loss are needed to be very low, because of the sensitivity signal of reflection coefficient always fluctuate so its giving unstable value for return loss and a good directivity which is more than 21 dBi. The microstrip array antenna is good characteristic such as reducing the cost of production, low profile and ease of installation.

According to Masnade the array were evolve until four element with a return loss of -21.44 dB with a gain is 11.21 dBi (Masnade et. al 2018). The directivity of the antenna was based on the antenna design, since the antenna design is microstrip array antenna, therefore it will evolve by the additional of the patch, from 9 dBi to 24.4 dBi,but the evolve of antenna effected toward the return loss (Ishfaq et. al., 2017). The antenna with FSS are integrated together and improvement on gain and return loss (Wang and Piao 2017).

In this research, The FSS are introduced as filter to the antenna. It will be attached in front of the antenna with a separation of air. The main objective is to overcome the other signal interrupt the return loss from fluctuate and increase the directivity of the antenna.

1.3 Objectives

1. Design and development microstrip antenna array with FSS structure at 28 GHz to improve the return loss and the directivity.
2. To study the performance of various Frequency Selective Surface design based on shapes and layers.