THE DESIGN OF DUAL-BAND AND BROAD BAND ANTENNA USING DOUBLE-SIDED AND U-SLOTTED PARASITICALLY COUPLED ARRAY STRUCTURE FOR LTE AND WLAN APPLICATIONS

by

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Dedication

To

My lovely mother.

Her support, encouragement, and constant love have sustained me throughout my life.

To

My dear father.

His words of inspiration and encouragement in pursuit of excellence, still linger on.

To

My wife, brothers, My daughter and friends

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TABLE OF CONTENTS

`

LIST OF FIGURES

`

`

`

`

LIST OF TABLES

LIST OF SYMBOLS

Ω	Ohm
η	Efficiency
ε	Permittivity
ω	Angular Frequency
σ	Conductivity
f	Frequency
Γ	Reflection Coefficient
C	Light Speed in Free Space
λ	Wavelength
Z	Impedance
W	Width of antenna

ABBREVIATIONS

WLAN	Wireless Local Area Network
LTE	Long Term Evolution
CST	Computer Simulation Technology
dB	Decibel
dBm	Decibel of Measured power referenced to 1 milli watt (mW)
GHz	Gigahertz
mm	Millimeter
VSWR	Voltage Standing Wave Ratio
BTs	Base Transceiver Station
3GPP	Third Generation Partnership Project
WCDMA	Wideband Code Division Multiple Access
UHF	Ultra High Frequency
RFID	Radio Frequency Identification
ESPAR	Electrically Steerable Parasitic Array Radiator

Analisis dua bulan belah jajaran antena dan ditambah pula parasitik bentuk ruang U untuk aplikasi LTE dan WLAN

ABSTRAK

Tesis ini membentangkan pembangunan antena untuk Evolution (LTE) dan Wireless Local Area Network aplikasi jangka panjang (WLAN). Tambahan pula, dalam generasi komunikasi tanpa wayar akan datang seperti 3G atau 4G, ia adalah sangat penting untuk meningkatkan kawasan liputan dan kecekapan rangkaian WLAN untuk menggunakan bagi kawasan lama. LTE boleh menjadi satu penyelesaian yang bagus bertindak sebagai tulang belakang tanpa wayar untuk meningkatkan rangkaian WLAN. Dalam tesis ini, dua jenis antena iaitu tidak seragam L slotted antena bermuka dua dan U-slotted antena dengan parasitik akan dikaji untuk LTE dan aplikasi WLAN. Bermuka dua antena telah dibentuk dengan 4 × 2 patch terpancar oleh talian penghantaran suku panjang gelombang terdaapt di kedua-dua belah FR-4 substrat. Dimensi yang berbeza daripada L-slot telah dimasukkan di kedua-dua patch sebelah terpancar. Ia dikaji dimana sebelah atas array dengan L-slot yang lebih kecil mampu untuk membangkitkan pada frekuensi atas (5.8 GHz) dan pada bahagian bawah dengan L-slot lebih besar mampu untuk membangkitkan pada frekuensi yang lebih rendah (2.6 GHz). Selain daripada itu, ia mencapai keuntungan yang tinggi di kedua-dua frekuensi. U-slotted antena dengan parasitik ditambah pula telah direka untuk peningkatan jalur lebar dan operasi dual-band untuk aplikasi LTE dan WLAN. Pelbagai yang dibentuk oleh dua patch U-slotted didorong oleh talian penghantaran suku panjang gelombang sementara empat tompok Uslotted digandingkan dengan parasitik dengan pelbagai didorong. Ia dikaji bahawa apabila talian penghantaran direka di sebelah yang sama dengan patch terpancar ia menghasilkan operasi band yang luas pada 5.8 GHz manakala apabila parasitik ditambah patch U-slotted ketara meningkatkan jalur lebar daripada 11.2% kepada 21.37% pada 5.8 GHz manakala 7 dBi keuntungan. Seterusnya talian penghantaran beralih di bahagian belakang substrat dan menghubungkan dengan patch didorong oleh melaui tembaga, ia menghasilkan keuntungan yang tinggi operasi dual-band 2.6 GHz (LTE) dan 5.8 GHz (WLAN). Selain itu, parasitic yang ditambah pada patch U-slotted berfungsi sebagai penapis takuk band untuk menghapuskan frekuensi yang tidak diingini 4.26 GHz kepada 4.9 GHz dan manjadi antena ke dalam dual-band radiator. Prototaip yang dicadangkan mencapai keuntungan yang tinggi sebanyak 9.5 dBi pada 2.6 GHz manakala 7.2 dBi pada 5.8 GHz. Fleksibiliti pelbagai gandingan parasit telah disiasat dengan mereka bentuk orientasi yang berbeza untuk U-slot dan mendapati keuntungan operasi yang tinggi untuk dual-band dalam setiap prototaip. Dalam semua antena prototaip, struktur ruang udara dikekalkan di antara substrat dan lapisan bawah. Pelbagai jenis parameter seperti pekali pantulan, corak sinaran, keuntungan dan pengedaran semasa telah dianalisis.

The design of Dual-Band and Broad Band Antenna Using Double-Sided and U-slotted Parasitically Coupled Array Structure for LTE and WLAN Applications

ABSTRACT

This thesis presents the development of array antenna for Long term Evolution (LTE) and Wireless Local Area Network (WLAN) applications. In next generation wireless communication it is very essential to improve the coverage area and efficiency of WLAN networks in order to use for long area. LTE can be a great solution acted as wireless backhaul to improve WLAN network. In this thesis two types of antenna as double-sided array antenna and U-slotted parasitically coupled antenna array have been investigated for LTE and WLAN applications. Double-sided array antenna are formed using 4×2 radiating patches by quarter wavelength transmission line contains at the both side of FR-4 substrate. Different dimension of L-slot has been inserted at both side radiating patches. It is found out that the upper side of the array with smaller L-slot capable to excite at upper frequency (5.8 GHz) while at the lower side with bigger L-slot capable to excite at lower frequency (2.6 GHz). Moreover it achieved high gain at both frequencies. U-slotted parasitically coupled antenna array has been designed for bandwidth enhancement and dual-band operation for LTE and WLAN applications. The array is formed by using two driven U-slotted patches feed by quarter wavelength transmission line while another four U-slotted patches are coupled parasitically with driven array. It is found out that when transmission line designed at the same side with radiating patches it produced a broad band operation at 5.8 GHz. Parasitically coupled U-slotted patches significantly improved the bandwidth from 11.2% to 21.357% at 5.8 GHz while it obtained 6.98 dBi gain. Next the transmission line shifted at the back side of substrate and connects with driven patches by copper via, it produces high gain dual-band operation at 2.6 GHz (LTE) and 5.8 GHz (WLAN). Moreover it is realized that, parasitically coupled U-slotted patches work as a band notch filter to eliminate unwanted frequency of 4.26 GHz to 4.9 GHz and turned the antenna into dual-band radiator. The proposed prototype has achieved high gain of 9.5 dBi at 2.6 GHz while 7.2 dBi at 5.8 GHz. The flexibility of parasitic coupling array has been investigated by designing different orientation of U-slot and has found high gain dual-band operation in every prototype. In all proposed antenna prototypes, an air gap structure is maintained between substrate and ground plane. Different type of parameters as reflection coefficient, radiation pattern, gain and current distribution have been analyzed.

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, with rapid development in new generation wireless communication it is highly demanded to develop and improve array antennas. Moreover those antennas needs to operate for Wireless Local Area Network (WLAN), Worldwide Interoperability for Microwave Access (WIMAX), Second Generation (2G), Third Generation (3G) and Fourth Generation (4G) communications. Furthermore, in long or medium range point-to-point communication developing multi-band or dual- or triple-band array antenna can be a great solution compare to single band antennas. Specially high speed data transfer communication promotes multi-band or broadband array antenna to reduce space installation problem in Base Transceiver Station (BTs) . Thus the portability of integrating one more applications in a single antenna can be increased (Lui, Chu and Wu, 2011). In some circumstances developing dual-band antenna array is more preferable compared to broadband antenna since it has a lower profile (Wang et.al.,2012).

Wireless Local Area Network (WLAN) is established as a widely recognized application for its attractive feature of viable, cost effective high speed data connectivity solution which enables user mobility. This demand makes attractive to develop array antenna for WLAN application. According to IEEE 802.11 WLAN standards, the demanded allocated frequencies are 2.4 GHz, 5.2 GHz and 5.8 GHz (Raj

et al.,2006). Recently Long Term Evolution (LTE) has arisen a great concern for next generation communication such as-3G and 4G which is developed by Third Generation Partnership Project (3GPP) (Huiqing Zhai et al., 2015). Moreover LTE is widely organized by various operators depend on the specific regions. In Malaysia LTE Band 7 known as 2.6 GHz is one of the most useful frequency band used for this technology. Furthermore developing dual-band array antenna for WLAN and LTE applications can be a great solution to improve WLAN network (Nayan M.K et al.,2015). LTE can be wireless backhaul to comprises all high speed WLAN network in big area.

Since 1950s (James, Hall and Wood.,1981) microstrip patch antenna has been taken a great attention in wireless communication because of conformal and simple planar structure compare to other's antenna. Moreover it is more economical for commercialization since it can be adaptable to use in the fabrication for radio frequency (RF) and microwave frequencies. They also allow the advantages of printed circuit technology. It achieved the conformability to the curved surface (Bancroft.,2004). Traditional microstrip patch antenna can be formed in a microwave substrate where patch can be rectangular, circular and many other's shape (Huang,J.,2008). Furthermore, microstrip patch antenna can be easily analyzed using different types of model like transmission line circuit model, the multimode cavity model and different numerical method as FTDT and moment (Milligan.,2005).

In high range or medium range indoor or outdoor or backhaul wireless communication, it is extremely desired to transmit data from one point to another point. It is highly required to develop directional antenna for backhaul communication (Gardelli, La cono and Albani.,2004; Medeiros, Lima, Costa et al.,2010). Furthermore,

for transmitting data in long or medium range communication system, lower gain antenna cannot be successfully implemented. It is highly demanded to design array antenna to achieve high gain at specific frequency (Zedong Wang, Zhang, Yangzeng et al.,2014). In recent years, lots of microstrip array antenna has been investigated for wide band and dual-band applications. Different techniques are developed for wide-band application as- aperture coupled antenna (Yun and Yoon.,2005), L-probe feed antenna (Wong and Luk.,2003), slot antenna (Wang, Huang and Fang.,2007 ; Huyun and Lee.,1995; Lee, Luk, Tong et al.,1996 ; Lau, Luk and Lee.,2001) etc. Different types of technique such as: Fractal antenna, Dielectric resonator antennas and dipole array antennas have been investigated to develop dual-band base station array antenna (Huiqing .Zhai et al.,2014). Furthermore, multilayer structure is also widely used to develop array antenna structure (Y.B.Jung et al.,2010). However, the main challenge for designing array antennas is to avoid complexity and high fabrication cost . In this thesis, a simple structure of antenna array will be proposed. In order to accomplish the goal, a comprehensive analysis will be provided.

The aim of this thesis is to develop dual band and broadband array antenna which will be simple in structure, compact size compare to other's array antenna and can provide high gain. The proposed antenna structure of this thesis can be highly suitable for dual-band LTE and WLAN applications and broad band WLAN applications. The frequency chosen for LTE application is 2.6 GHz (LTE 7 band) and for WLAN application is 5.8 GHz.

The antenna is designed using Computer Simulation Technology (CST) Microwave Studio Suite Software. The proposed antennas are fabricated using FR-4

substrate of thickness 1.6 mm and dielectric constant 4.7. It is measured in a anechoic chamber using Agilent ENA8051C. The fabricated antenna results are compared with the simulated antenna and found out a similar result which validate the antenna array is capable to achieve high gain dual-band operation at LTE and WLAN applications. The broadband operation of the proposed antenna for WLAN application has numerically studied.

1.2 Problem Statement

IEEE 802.11 standards Wireless Local Area Network (WLAN) provides a high speed network to transmit data. However the coverage capability and efficiency of WLAN system is comparatively lower in the using of next generation wireless communication system. Furthermore it is very essential to increase the coverage capability and efficiency of WLAN standards to ensure a flexible network system. Long Term Evolution (LTE) brings a fastest growing wireless communication technology. However in order to increase the coverage area and efficiency of WLAN network, LTE can be a great solution (Vijayalakshmy and Sivaradje.,2014). LTE can be acted as a wireless backhaul to provide seamless convergence for WLAN network. Furthermore, it is essential to develop WLAN and LTE to create Everything over IP Capability (EoIP) .

In order to design a dual-band array antenna various methods have been explored in recent years. Fractal array antenna, dipole array antenna, multi layer structure and using different types of slot as- V-shaped, E-shaped, U-slot, U-shaped strip are used to develop dual-band array antenna. Multi layer antenna as like aperture

coupled antenna is very hard to fabricate and very costly (Jyoti, R.P and Kshetrimayum, R.S.,2011) . However different types of transmission line has already developed and investigated for dual-band array antenna. Furthermore, this transmission line brings constructional complexity and the antenna size become larger (Zhai Huiqing et al.,2014). In order to achieve broad band and dual-band operation U-slot in the radiating patch is one of technique. Inserting U-slot in radiating patch has already investigated for bandwidth enhancement 20% for micro wave substrate and 30% for air substrate. Furthermore, in U-slot dual-band or triple band operation can be achieved using suitable dimension cut from U-slot for small frequency ratio of less than 1.5 between two centre frequencies (Lee, K,F et al.,2010; Mok, W,C et al.,2013). In this thesis, firstly a double-sided array antenna for LTE and WLAN applications has been explored. Secondly, a U-slotted parasitically coupled antenna array has been investigated for bandwidth improvement and dual band operation. The effect of parasitic coupling has been briefly analyzed. Moreover, the orientation flexibility of U-slot has been investigated by different orientation of U-slot. A comprehensive analysis will be investigated compare with other's array antenna.

1.3 Thesis Objectives

The main purposes of this thesis is to develop and design dual-band array antenna for LTE and WLAN applications. The investigation will be done by designing double-sided array antenna and parasitically coupled U-slotted antenna array. Moreover bandwidth improvement characteristics of parasitically coupled array antenna will be highlighted. The main objectives of this study includes:

i. To design, fabricate double-sided array antenna for LTE and WLAN applications and validate the performance in terms reflection coefficient, radiation pattern and gain.

ii. To design a wideband and dual-band U-slotted parasitically coupled antenna array and validate the performance using parasitic coupling .

iii. To design, fabricate different orientation of U-slot in parasitically coupled antenna array and validate the flexibility using parasitic coupling.

1.4 Scope of Work

The scope of this research work has started with the information of wideband and dual-band array antenna. It was gathering via a lot of sources such as IEEE Explorer, journals, conference papers and books. The issues and problems related to the array antenna have been considered. Several techniques have been used to enhance the bandwidth. Moreover in order to obtain dual-band operation different approaches are developed such as slot technique, stacked antenna structure, different types of feed like single or dual feed, using stub etc. Furthermore, transmission line concept has widely studied to build up array antenna. However, U-slot in the radiating patch can provide broad band and dual-band array antenna. The electrical length of U-slot has been widely studied.

A good antenna has considered in terms of performance as- reflection coefficient, gain, radiation pattern for E-plane and H-plane. The targeted designed