MULTIPLE INPUT MULTIPLE OUTPUT DIELECTRIC RESONATOR ANTENNA FOR LONG TERM EVOLUTION APPLICATIONS

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To my beloved mother, **RAMLAH HASAN**
and father, **ROSLAN YA'ACOB**

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ABSTRACT

Wireless communications have been part of human life where people can communicate worldwide with very high speed through the use of new technology known as Long Term Evolution (LTE). LTE is an evolution in wireless communication system which is capable of providing high data rates and high speed transmission. In addition, a multiple input multiple output (MIMO) technology enables wireless communication systems to achieve high data rates and high quality of services by placing multiple antennas at transmitter and receiver. Multiple antennas should be designed to have good isolation even when closely spaced. A ceramic material with several attractive features which is called a dielectric resonator (DR) is used as a radiation element in this thesis. This thesis presents three designs of dielectric resonator antenna (DRA) that operate at 2.6 GHz for LTE applications. Firstly, a coplanar waveguide (CPW) rectangular DRA (RDRA) without and with metallic strip has been designed. The measured impedance bandwidths (BWs) for CPW RDRA without and with metallic strip for S_{11} < -6 dB are 45% and 66%, respectively. The gains obtained for CPW RDRA without and with a metallic strip are 2.92 dBi and 3.12 dBi, respectively. Secondly, an MIMO F-shaped DRA is designed. The measured impedance BWs for S_{11} < -6 dB are 36% for port 1 and 31% for port 2, respectively with S_{21} = 33 dB. The antenna provides gain of 1.99 dBi for port 1 and 1.85 dBi for port 2. Lastly, an MIMO RDRA is designed. Two orthogonal modes of the MIMO RDRA are excited by using two different feed mechanisms which is CPW and coaxial probe. The measured impedance BWs for S_{11} < -6 dB are 47% for port 1 and 25% for port 2, respectively with S_{21} = 33 dB. The antenna provides gain of 4.97 dBi for port 1 and 4.51 dBi for port 2. Then, the third design was extended by using higher relative permittivity value of DR in order to reduce the antenna size. It can be seen, both second and third designs produced correlation coefficient well below 0.5 with nearly 10 dB diversity gain. A reasonable agreement between the simulated and measured results has been achieved.

ABSTRAK

Komunikasi tanpa wayar telah menjadi sebahagian daripada kehidupan manusia di mana orang ramai boleh berkomunikasi ke seluruh dunia dengan kelajuan yang sangat tinggi melalui penggunaan teknologi baru yang dikenali sebagai Evolusi Jangka Panjang (LTE). LTE merupakan evolusi dalam sistem komunikasi tanpa wayar yang mampu menyediakan kadar data yang tinggi dan kelajuan penghantaran yang tinggi. Di samping itu, teknologi berbilang masukan berbilang keluaran (MIMO) membolehkan sistem komunikasi tanpa wayar untuk mencapai kadar data yang tinggi dan perkhidmatan berkualiti tinggi dengan meletakkan berbilang antena pada bahagian penghantar dan penerima. Berbilang antena perlu direkabentuk untuk mempunyai pengasingan baik walaupun jarak rapat. Bahan seramik dengan beberapa ciri-ciri menarik yang dipanggil resonator dielektrik (DR) digunakan sebagai elemen radiasi di dalam tesis ini. Tesis ini membentangkan tiga reka bentuk antena resonator dielektrik (DRA) yang beroperasi pada 2.6 GHz untuk aplikasi LTE. Pertama, daya sesatah pandu gelombang (CPW) DRA berbentuk segiempat tepat (RDRA) tanpa dan dengan jalur logam telah direka bentuk. Pengukuran jalur lebar bagi CPW RDRA tanpa dan dengan jalur logam untuk S_{11} <-6 dB adalah 45% dan 66%, setiap satu. Gandaan yang diperolehi untuk CPW RDRA tanpa dan dengan jalur logam adalah 2.92 dBi dan 3.12 dBi. Kedua, MIMO DRA berbentuk F telah direka bentuk. Pengukuran jalur lebar untuk S_{11} <-6 dB adalah 36% untuk port 1 dan 31% untuk port 2, dengan S_{21} = 33 dB. Antena ini menyediakan gandaan sebanyak 1.99 dBi untuk port 1 dan 1.85 dBi untuk port 2. Akhir sekali, MIMO RDRA telah direka bentuk. Dua mod ortogon daripada MIMO RDRA di teruja dengan menggunakan dua mekanisme masukan yang berbeza iaitu CPW dan kabel sepaksi. Pengukuran jalur lebar untuk S_{11} <-6 dB adalah 47% bagi port 1 dan 25% untuk port 2, dengan S_{21} = 33 dB. Antena ini menyediakan gandaan sebanyak 4.97 dBi untuk port 1 dan 4.51 dBi untuk port 2. Kemudian, reka bentuk ketiga telah dilanjutkan dengan menggunakan nilai ketelusan relatif DR yang lebih tinggi untuk mengurangkan saiz antena. Reka bentuk kedua dan ketiga memberikan pekali korelasi kurang daripada 0.5 dengan gandaan kepelbagaian menghampiri 10 dB. Kesetaraan di antara keputusan simulasi dan pengukuran telah dapat dicapai.

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LIST OF ABREVIATIONS

BW	-	Bandwidth
CP	-	Circular Polarization
CPW	-	Coplanar Waveguide
CST	-	Computer Simulation Technology
dB	-	Decibel
DR	-	Dielectric Resonator
DRA	-	Dielectric Resonator Antenna
DWM	-	Dielectric Waveguide Model
EDGE	-	Enhanced Data Rates for GSM Evolution
GPRS	-	General Packet Radio Service
GUI	-	Graphical User Interface
GSM	-	Global System for Mobile Communication
HSPA	-	High Speed Packet Access
HSPA+	-	High Speed Packet Access Plus
IEEE	-	Institute of Electrical and Electronics Engineers
LTE	-	Long Term Evolution
MIMO	-	Multiple Input Multiple Output
MISO	-	Multiple Input Single Output
PCS	-	Personal Communications Service
PIFA	-	Planar Inverted F Antenna
RDRA	-	Rectangular Dielectric Resonator Antenna
SMA	-	Sub Miniature Version A
SIMO	-	Single Input Multiple Output
SISO	-	Single Input Single Output
UMTS	-	Universal Mobile Telecommunications System
UV	-	Ultraviolet

VNA	-	Vector Network Analyzer
VoIP	-	Voice over Internet Protocol
WWAN	-	Wireless Wide Area Network
Wi-Fi	-	Wireless Fidelity
3GPP	-	3rd Generation Partnership Project

LIST OF SYMBOLS

S_{11} & S_{22}	-	Reflection coefficient magnitude
S_{21}	-	Isolation
%	-	Percentage
ε_r	-	Permittivity
δ	-	Loss tangent
≤	-	Less than or equal to
>	-	Greater than
Ω	-	Ohm
λ_g	-	Guided wavelength
$\lambda_\circ$	-	Free space wavelength
ρ_e	-	Correlation coefficient
G	-	Diversity gain
η	-	Total efficiency

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Imagine that Malaysian societies of tomorrow, which mobile users will be able to receive and send high quality videos, images, data along the highways, on the trains, in the parks, universities and anywhere with high speed data transmission. In order to have the high speed data transmission and amount of data received or transmitted, a new high performance of air interface is introduced which calls Long Term Evolution (LTE) and later on upgraded to LTE-Advanced. LTE standardized by the 3rd Generation Partnership Project (3GGP) in order to satisfy with the market demand [1]. LTE operates over different frequency bands from 400 MHz up to 4 GHz with impedance bandwidth (BW) from 1.4 to 20 MHz [2].

However, this evolution need major requirement especially on the user equipment and base station infrastructures. The high speed data transmission and high data rates of the proposed antenna can be achieved by applying multiple input multiple output (MIMO) technology. With the MIMO technology, multiple element of antennas are placed at the transmitter and receiver of the communication system to exploit multipath fading in order to improve the capacities of channel, data rates, link reliability, and network coverage [3-

4]. In order to fully exploit the aforementioned benefits of MIMO technology, the multiple antennas should be designed for good isolation even when closely spaced [5-6].

Much research on wireless communication used printed antenna to implement MIMO technology. Therefore, with the introduction of ceramic material with several attractive features in 1980s, it is a very much interesting candidates for LTE applications [7]. This antenna is called a dielectric resonator antenna (DRA). The antenna with the suitable size, simple structure and good performance are proposed in this thesis for LTE applications.

1.2 Problem Statement

The new era of mobile communication has been evolved moving forward from first-generation (1G) analogue voice communication to the second-generation (2G) which is digital voice communication. Then, mobile communication technology has been expanded to the 3G that provide video call, internet access, games and video or music download. Furthermore, the new coming of mobile communication technology fourth generation (4G) which is called LTE that increasing the speed and data rates of mobile telephone networks [8-9].

LTE is one of the key technologies in recent mobile wireless communication system that provides high quality service and coverage. One way to develop LTE technology is to fulfill the requirement by placing multiple of antennas is placed at both transmitter and receiver. This technique is called MIMO technology which is suitable method to improve performance of wireless communication system by reducing multipath fading and cross channel interference [5]. Also, the correlation coefficient and isolation need to be consider in improving uncorrelated signals between transmitter and receiver in MIMO technology.

Other than that, the antenna size should be practical or can be utilized in the devices such as tablet, laptop and mobile phone. The standard device has a maximum form factor of 100 mm × 55 mm × 13.5 mm include a plastic cover that houses the whole device, an LCD and a battery which has been discussed in [10-11]. The devices are shown in Figure 1.1. Therefore, a ceramic material with some attractive features and potentially useful antenna radiation element which is called a dielectric resonator (DR) is used in this research [12]. DRA has several potential to be implemented for wireless communication system such as high impedance BW, high radiation efficiency, small conductive loss and various of feeding mechanism [13-15]. DRA also have various shapes (i.e. spherical, cylindrical, trapezoid, split conical) [16-19]and feeding mechanism [20-23] with simple structure.

Figure 1.1: Portable communication devices [24-25].

Although many studies have been carried out in MIMO antenna, many are still focusing on printed antennas. Typically, printed antenna using two or more antenna elements to build MIMO antenna. However, DRAs have not received much attention in MIMO technology, especially for LTE at 2.6 GHz. This is because the 2.6 GHz is the new standard in Malaysia during these two years. Other than that, most of the previous studied conducted on MIMO DRA at low band of LTE (LTE 700MHz) or for circular polarized. In addition, DR can be used to reduce the size and improve the impedance bandwidth (BW) of antenna. Therefore, an MIMO DRA with good diversity performance for LTE applications at 2.6 GHz is presented in this thesis. In MIMO technology, high isolation and low correlation coefficient is main requirement to achieved good diversity performance. Therefore, several parameters such as current distribution, mode excitation and antenna configuration and distance are studied to improve the isolation and correlation coefficient. Other diversity performance (i.e. diversity gain, total efficiency) of MIMO antenna by using DRA has also been discussed in the following chapter.

1.3 Objectives of Research

The objectives of the thesis are:

1. To design and fabricate an MIMO dielectric resonator antennas for LTE applications at 2.6 GHz.

2. To investigate the performance of an MIMO dielectric resonator antenna in term of S-parameters (S_{11}, S_{22} and S_{21}), gain, radiation pattern, correlation coefficient, diversity gain and total efficiency.

1.4 Scope of Research

The scope of this research is to design, fabricate and measure an MIMO DRA for LTE applications. This research begins with designing an antenna that has a single port. Then, comparison will be made without and with metallic strip. After that, the research proceeds with an MIMO F-shaped DRA. This antenna design consist two antenna elements which is normally use by printed antenna. It can be seen that the printed antenna implement two or more antenna elements to develop MIMO technology. Several studies on the antenna configuration are conducted to ensure that MIMO F-shaped DRA can produce good diversity performance. Final design and also main contribution in this research which is an MIMO RDRA shows that only one resonator is needed to radiate two different modes at the same frequency.

The characteristics of the antennas will be analyzed and optimized to get the best performance. Then, the antenna will be fabricated and measured in term of S-parameters, gain, radiation pattern, correlation coefficient, diversity gain and total efficiency to ensure it is suitable to operate as MIMO antenna for LTE applications.

1.5 Layout of the Thesis

This thesis is organized with seven chapters. In Chapter 1, the research starts with the understanding of the problem statement and the objectives of this research. Chapter 2 of this thesis starts with the introduction of the modern wireless communication which is LTE and also the basic concept of MIMO technology and DRA. The technique and design consideration from the previous research that is related to this research are discussed and summarized in this chapter.

Chapter 3 reviews the methodology applied in this research. This chapter consists of flow chart, process of setting the general simulation using 3D-Software CST microwave studio, design specification, fabrication and measurement process of DRA. Then, a single port antenna with wide impedance BW is designed and presented in Chapter 4. The comparison of the antenna without and with metallic strip is discussed.

An MIMO F-shaped DRA with two antennas element is presented in Chapter 5. The various configurations of antenna with suitable distance and shape is studied in order to produce a good isolation (S_{21} < -20 dB). The performance of the proposed antenna is investigated in term of S-parameters, gain, radiation pattern, correlation coefficient, diversity gain and total efficiency.

The main contributions of this research are described in Chapter 6. In this chapter, the MIMO RDRA using single element of DR is proposed. This chapter provides the performance of the two similar antenna designs with different relative permittivity (ε_r) value of DR which is 10 and 30. The performance of the proposed antenna which is similar with Chapter 5 is investigated in order to ensure the proposed antenna can operate as MIMO antenna. Finally, Chapter 7 gives summary from all chapters and some recommendations for future work.

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APPENDIX A: List of Author's Publication

1. S. F. Roslan, M. R. Kamarudin, M. Khalily, and M. H. Jamaluddin, "An MIMO rectangular dielectric resonator antenna for 4G applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 13 pp. 321-324, 2014.