DUAL-WIDEBAND MIMO ANTENNA FOR LONG TERM EVOLUTION AND WIRELESS LOCAL AREA NETWORK INDOOR APPLICATIONS

by

MOHANNAD OBAID KATIE
(1340811137)

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School of Computer and Communication Engineering
UNIVERSITI MALAYSIA PERLIS

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DEDICATION

To my parents
Who taught me the value of study and perseverance ethic and have given me endless support

To my wife, sons, and daughter
Who encouraged me through the work of this thesis

To my brothers and sisters

To my friends

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Mohannad Obaid Katie
University Malaysia Perlis (UniMAP)

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LIST OF ABBREVIATIONS

3D	Three-Dimensional
4G	Fourth-Generation
ADG	Apparent Diversity Gain
C	Channel capacity
CDF	Cumulative Distribution Function
CST	Computer Simulation Technology
DG	Diversity Gain
dB	Decibel
EDG	Effective Diversity Gain
ECC	Envelope Correlation Coefficient
E_{θ}	Elevation electric field component
E_{φ}	Azimuth electric field component
E field	Electric field
G_{h}	Horizontally polarized gain component
GHz	Giga Hertz
G_{v}	Vertically polarized gain component
H field	Magnetic field
IEEE	Institute of Electrical and Electronics Engineers
ISM	Industrial, Scientific and Medical
LTE	Long Term Evolution
MA	Monopole Antenna
MIMO	Multi-Input Multi-Output
mh	Mean elevation angle of horizontally polarized wave distribution

m_V	Mean elevation angle of vertically polarized wave distribution
MEG	Mean Effective Gain
P	Power
P_{avs}	Available power from a source
P_{rad}	Radiated power
P_{θ}	Elevation power component
P_{φ}	Azimuth power component
PCB	Printed Circuit Board
PCS	Personal Communication Service
RF	Radio Frequency
SISO	Single-Input Single-Output
SNR	Signal to Noise Ratio
S_{jj}	Input reflection coefficient (input from *j*-th element)
S_{jk}	Transmission coefficient (from *k*-th to *j*-th element)
UMTS	Universal Mobile Telecommunications System
VSWR	Voltage Standing Wave Ratio
WCDMA	Wide band Code Division Multiple Access
WiMAX	World Interoperability for Microwave Access
WLAN	Wireless Local Area Network
XPD	Cross-polarization discrimination
XPR	Cross-polarization ratio

LIST OF SYMBOLS

Γ	Reflection Coefficient
Ω	Ohm
η	Efficiency
ε	Permittivity
μ	Permeability
α	Step in azimuth angle
β	Step in elevation angle
γ	Probability level
θ	Elevation angle
θ_0	Peak of elevation angle
λ	Wavelength
ξ	Eigenvalue of covariance matrix
ρe	Envelope correlation
σ	Angular spread
σ_h	Angular spread of horizontally polarized wave distribution
σ_v	Angular spread of vertically polarized wave distribution
φ	Azimuth angle
Ω	Solid angle

Dual-Wideband MIMO Antenna Untuk Evolusi Jangka Panjang dan Wireless Local Area Network Aplikasi Dalaman

ABSTRAK

Masukar berganda keluaran berganda (MIMO) teknik menggunakan pelbagai antena di kedua-dua penghantar dan penerima untuk meningkatkan prestasi sistem komunikasi tanpa wayar lebih pelbagai arah saluran pudar. A padat dwi-jalur lebar MIMO antena dengan saiz 36 × 22 mm^2 telah dicadangkan untuk sistem tanpa wayar mudah alih tertutup untuk berkhidmat LTE dan WLAN aplikasi, yang tidak boleh beroperasi dengan padat UWB MIMO antena. Oleh kerana teknologi UWB yang tidak dapat untuk membuat liputan LTE 2500 (2,5-2,7 GHz) standard, dan julat frekuensi UWB bertindih dengan standard 802.11a IEEE untuk rangkaian kawasan tempatan wayarles (WLAN). dicadangkan dwi-jalur lebar MIMO antena terdiri daripada dua unsur yang serupa Monopole antena (MA) dan mikrostrip talian suapan bagi setiap, yang diletakkan di sebelah substrat. The pesawat tanah dengan puntung berbentuk T diletakkan di sisi lain substrat untuk mengurangkan gandingan bersama dan meningkatkan pengasingan antara elemen antena. antena yang dicadangkan memperuntukkan dua band operasi 2.5- 2.85 GHz dan 4.85- 6.1 GHz berpusat di 2.64 dan 5.3 GHz masing-masing, dengan menggunakan teknik jalur dan berbelah di pinggir atas pesawat tanah. Kompak UWB MIMO antena mempunyai saiz 32 × 20 mm^2 juga terdiri daripada dua unsur MA bersimetri dan pesawat tanah dengan cerun separa termasuk menonjol puntung untuk penambahbaikan pengasingan dan meliputi band 3-11,52 GHz. Untuk mereka bentuk dan mengoptimumkan prestasi kedua-dua antena MIMO dicadangkan, perisian simulasi CST digunakan untuk mencapai keputusan yang boleh dipercayai dari segi S-parameter (pekali pantulan dengan gandingan bersama antara kedua-dua pelabuhan), dan (corak sinaran dengan pekali korelasi) dalam jangka corak kepelbagaian. Kedua-dua antena MIMO telah direka dan diuji, dan terdapat korelasi yang kuat antara keputusan simulasi dan diukur antena keperluan dalam parameter seperti kehilangan pulangan, VSWR, dan corak radiasi. Oleh itu, keputusan yang diperolehi menunjukkan bahawa kedua-dua antena MIMO cadangan boleh beroperasi dengan baik 2: 1 VSWR impedans bandwidth, pengasingan yang baik lebih baik daripada 18 dB antara antena unsur-unsur, pekali korelasi sampul surat (ECC) kira-kira 0.05 seluruh band dikehendaki, dan keuntungan kepelbagaian (DG) daripada 9,992 dB. keputusan pengukuran bersetuju dengan baik dengan keputusan simulasi membuat antena ini sesuai untuk aplikasi mudah alih.

Dual-Wideband MIMO Antenna for Long Term Evolution and Wireless Local Area Network Indoor Applications

ABSTRACT

Multiple-input multiple-output (MIMO) technique use multiple antennas at both transmitter and receiver to improve the performance of wireless communications system over multipath fading channels. A compact dual-wideband MIMO antenna with a size of 36 × 22 mm^2 was proposed for indoor portable wireless systems to serve the LTE and WLAN applications, which cannot operate with the compact UWB MIMO antenna. Due to the UWB technology unable of covering the LTE 2500 (2.5-2.7 GHz) standard, and the UWB frequency range overlaps with the IEEE 802.11a standard for wireless local area networks (WLANs). The proposed dual-wideband MIMO antenna consists of two identical monopole antenna elements (MA) and microstrip feed line for each, which are placed on one side of the substrate. The ground plane with T-shaped stub is placed on the other side of the substrate to reduce mutual coupling and enhance the isolation between the antenna elements. The proposed antenna provides two operating bands of 2.5- 2.85 GHz and 4.85- 6.1 GHz are centered at 2.64 and 5.3 GHz respectively, by using the technique of strips and slits on the upper edge of the ground plane. The compact UWB MIMO antenna has a size of 32 × 20 mm^2 also consists of two symmetrical MA elements and a ground plane with partial slope including protruding stub for isolation improvement and covers band of 3-11.52 GHz. To design and optimize the performance of the two proposed MIMO antennas, CST simulation software used to achieve the reliable results in term of S-parameters (reflection coefficient with mutual coupling between the two ports), and (radiation pattern with correlation coefficient) in term of diversity pattern. The two MIMO antennas were fabricated and tested, and there was a strong correlation between simulated and measured results of antennas indoor applications parameters such as return loss, VSWR, and radiation patterns. Therefore, the obtained results show that the two proposed MIMO antennas can operate with good 2:1 VSWR impedance bandwidth, good isolation better than 18 dB between antennas elements, envelope correlation coefficient (ECC) about 0.05 across desired bands, and diversity gain (DG) of 9.992 dB. Measurement results agree well with simulation results making these antennas suitable for portable applications.

CHAPTER 1

INTRODUCTION

1.1 Background

In recent times, the demand for portable terminal stations required orientation towards small size terminals, growing number of operating frequency bands, and enhanced radio link performance (Zhi Ning Chen, 2007). Thus, in various wireless applications for portable devices like laptops, cordless phones, wireless local area networks, and PDA terminal, etc. size reduction and bandwidth enhancement are becoming the essential design requirements for printed antennas. Wireless applications particularly may suffer problems such as multipath propagation and fading. Recently, the attention for multiband multiple antenna systems has been increasing with multi-standard wireless applications to overcome these problems (Zhi Ning Chen, 2007; Jensen & Wallace, 2004).

Moreover, Multiple-input multiple-output (MIMO) wireless systems have been among the most significant achievements at recent wireless applications, through overcoming the limitation of the channel capacity and improve the reliability of radio links. Multiple antennas system is capable of transmitting multiple signals simultaneously through parallel spatial channels between multiple isolated antennas (Najam, Tedjini, & Duroc, 2012). By introduction of spatial multiplexing, the data throughput is increased substantially, while the multipath fading reduction is achieved by providing the diversity. This is primary because MIMO systems, it can increase channel capacity with an increase in the number of antennas, without additional bandwidth or transmit power. Therefore, MIMO is considered as significant component of modern wireless communication standards. due to these helpful features, recently appeared the communication mobile standards related with worldwide interoperability for microwave access (WiMAX), long-term evolution (LTE), and IEEE 802.11a concerning wireless local area networks (WLANs), which have been combined into MIMO systems technology as well as adapted to portable applications (Zhi Ning Chen, 2007; Fujimoto, 2008).

In addition, the design of compact MIMO/diversity antenna is fundamental to as such multi-bands terminals (See, Abd-Alhameed, & Abidin, 2012). Thus, the mobile device needs multiband antennas can simultaneously operate in multiple frequencies, covering all the required wireless communication frequencies (R. Waterhouse, 2008), (Karaboikis, Papamichael, & Tsachtsiris, 2008).

Another option is an antenna with wideband characteristics, which using of tunable frequency or antennas with multiple wideband. However, one option is to use multi wideband antennas when a multiple-input multiple-output (MIMO) antenna is applied in a multifunctional portable device. A wideband antenna is specified accordingly to matched the relative bandwidth over 10% or more with respect to center frequency, while the antenna of narrow band is matched through less than dual operating bandwidths (Allen, Dohler, & Okon, 2006; Ebrahimi, 2011). However, the desired antenna bandwidth depend on applications as demand, and the wideband expression means various frequency ranges for various applications.

When applied the MIMO antenna in multi-standards portable devices, the demand is growing on multi wideband and high isolation (Zhi Ning Chen, 2007). Therefore, the design of a small size compact multi wideband MIMO antenna with high isolation is an open issue. For small devices, a typical MIMO antenna array should have a compact structure, good radiation patterns, and low-envelop correlation, good radiation efficiency and high isolation between the ports. The design of such high-performance antennas with the additional requirement of multiband behavior is an important engineering challenge (Fujimoto, 2008).

The wireless system faces a problem of capacity reduction, because of increasing number of users. The possibility of increasing data rate in mobile wireless applications is employing the techniques of diversity or multiple-input multiple-output system. In general, the reliability of wireless channel links can be improved by using diversity techniques and can be used in the MIMO systems, whilst MIMO multiplexing technique is utilized to enhancement the spectrum frequency efficiency. Therefore, enhancement in integrated technology made it possible for engineers' to fit multiple applications operating at different frequencies in very small size wireless devices. Due to which a need for multiple antennas supporting different wireless communication bands on the same platform increased tremendously (R. Waterhouse, 2008).

1.2 Problem Statement

Recently, and a result of high density in the government and commercial buildings, the personal and office wireless devices have been increased such as the keyboard, mouse, printers, remote control, sensors, wireless USB, and so on. So it became necessary to be used a broadband frequency range to covers all these devices. UWB technology enables a wide variety of applications in wireless communications under the FCC guidelines and has a wide range of indoor applications. On other hand, the wireless devices that used LTE and WLAN applications can not's be served through UWB technology, Due to the LTE2500 frequency band is out-of-band the UWB frequency band, and the signals that come from 802.11a systems represent in-band interference to the front-end receiver for UWB systems. Therefore, through modifying the ground plane by adding strips and slits at the upper edge, it can be made band notch over the broadband frequencies to achieve the LTE and WLAN bands (Ghavami, Michael, & Kohno, 2005).

Wireless applications may suffer problems such as multipath propagation and fading. Therefore, recently attention for the multiband multi-antenna systems has been increasing with multiple standard wireless applications to overcome these problems. When a multiple-input multiple-output (MIMO) antenna is applied in a multifunctional compact system, the demand is rising on multi-wideband and high isolation. MIMO'S antenna channel capacity is jeopardized by the low isolation due to the mutual coupling. Therefore, the design of a small size multi-wideband MIMO antenna with high isolation is an open issue (R. Waterhouse, 2008).

A wide bandwidth and multi-radio frequency are required when increasing the data rates, at the same time, this lead to a system of multiple antennas. Due to the limited space of the compact wireless devices, instead of employ singular antennas for various radio frequencies, an alternative trend is to employ singular or multiple antennas with multiple operating frequencies or with a wide bandwidth features. However, an issue arises with interaction between singular elements of the antenna in term of mutual coupling, when multi-elements of the antenna are packed closely. Due to a high coupling of antenna elements to each other and to the ground plane by participation the surface currents on them, this leads to growing the signal correlation between channels and reduce the antenna radiation efficiency due to the dissipated power in the coupled antenna ports (Karaboikis et al., 2008). In addition, unwanted frequencies cause more surface currents and this leads degradation in isolation, so an important procedure should be doing to reject or remove these undesired frequencies.