Faculty Of Electronic and Computer Engineering

POLARIZATION DIVERSITY IN MULTIPLE INPUT MULTIPLE OUTPUT WIRELESS COMMUNICATION SYSTEM

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
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2011

DECLARATION

I declare that this thesis entitled "Polarization Diversity In Mutliple Input Multiple Output Wireless Communication System" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....
Name : MUHAMMAD FAIZ BIN ABDUL KADIR
Date : 6/10/11

DEDICATION

To my beloved mother and father

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ABSTRACT

Telecommunication and wireless local area network (WLAN) technologies are increasing rapidly within this few decades. The technology revolution occurred due to wireless communication is more and more commonly used in everyday life for user and customers. Due to that, multiple antennas system was been developed in order to cope the high demand from users and customers. The multiple antennas known as multiple input multiple output (MIMO) system can enhance the channel capacity and increased the output performance of the system. Therefore, this system does not require an extra bandwidth or increasing the transmit power. Based on that, the objective of this project was to predict the MIMO performance at operating frequency was 2.4 GHz. The beamforming network and microstrip array antenna was designed, fabricated and measured at desired operating frequency. In this project, Microwave Office software was used to design the beamforming network, while Computer Simulation Technology (CST) software was used to design the microstrip array antenna. Both designed has been fabricated using etching technique and the Advantest Network Analyzer was used to measure the performance of the designs. The simulation and measurement data were been compared and discussed. The fabricated beamforming network and microstrip antenna were used to develop the Radio Frequency (RF) MIMO test bed system. The system measurement was been conducted in Microwave Laboratory at Faculty of Electronic and Computer Engineering, UTeM with the operating frequency 2.4 GHz. The spatial diversity, polarization diversity and beamforming network were been applied in measurement campaign to investigate the performance of wireless MIMO channel. The data that obtain from the measurement will be post-process using MATLAB software in order to calculate the MIMO channel capacity. The analysis will be focused on the effect of the MIMO channel capacity due to the proposed measurement setup configurations.

ABSTRAK

Teknologi telekomunikasi dan rakaian wireles setempat (WLAN) telah meningkat dengan begitu pantas dalam tempoh beberapa dekad kebelakangan ini. Revolusi teknologi ini berlaku disebabkan oleh komunikasi wayarles yang semakin digunakan secara meluas oleh para pengguna dan pelanggan dalam kehidupan seharian. Oleh yang demikian, sistem masukan antenna berbilang dibangunkan agar dapat memenuhi peningkatan kehendak dari para pengguna dan pelanggan. Sistem masukan antenna berbilang dikenali juga sebagai sistem masukan berbilang keluaran berbilang (MIMO) mampu untuk meningkatkan keupayaan saluran dan meningkatkan prestasi sistem. Sehubungan dengan itu, sistem ini tidak memerlukan penambahan dari segi lebar jalur atau peningkatan kuasa penghantar. Oleh yang demikian, objektif projek ini adalah untuk meramalkan prestasi keluaran sistem MIMO pada frekuensi operasi 2.4 GHz. Rangkaian pembentuk alur dan antena tatasusunan mikrojalur telah direkabentuk, difabrikasi dan diukur pada frekuensi operasi yang telah ditetapkan. Di dalam projek ini, rangkaian pembentuk alur direkabentuk menggunakan perisian Microwave Offce, sementara antena tatasusunan mikrojalur direkabentuk menggunakan perisian Computer Simulation Technology (CST). Kedua – dua rekabentuk difabrikasikan menggunakkan teknik punaran dan diukur menggunakan peralatan Advantest Network Analyzer. Data hasil daripada simulasi dan pengukuran tersebut akan digunakan untuk proses perbandingan dan perbincangan di dalam projek ini. Rangkaian pembentuk alur dan antena tatasusunan mikrojalur yang telah difabrikasi akan diguna untuk membangunkan sistem tapak ujian radio frekuensi MIMO. Sistem pengukuran telah dijalankan di makmal Gelombang Mikro, Fakulti Kejuruteraan Elektrik dan Kejuruteraan Komputer, UTeM pada frekuensi operasi 2.4 GHz. Teknik kepelbagaian ruang, kepelbagaian pengutuban dan rangkaian pembentuk alur telah diapplikasikan dalam proses pengukuran untuk mengkaji prestasi saluran sistem wayarles MIMO. Data yang diperolehi daripada pengukuran akan diproses menggunakan perisian MATLAB untuk mengira keupayaan saluran MIMO. Penganalisaan lebih tertumpu kepada kesan ke atas keupayaan saluran MIMO yang disebabkan oleh penyediaan konfigurasi pengukuran.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The technology of mobile communication and wireless local network (WLAN) were expanding at a very fast rate. From the first generation (1G) system that can only provide analogue voice communication to second generation (2G), where the system has been upgraded to digital voice communication. Third generation (3G) mobile communication can provide digital voice communication, internet access and download service. The current mobile was also having seen the rapid expansion where the mobile phone can access the internet, provide high resolution camera, video conference, which requires more bandwidth and high data transfer (Zheng Shaoyong, 2008).

The local area network (LAN) technology was also advancing, from wired to the wireless system (WLAN). One of the products of WLAN was WiFi, which enables the end users to be connected to the internet irrespective of their location. The WiMax (Worldwide Interoperability for Microwave Access) technology was been introduced based on IEEE 802.16 specifications which the aim of this technology was to provide high speed wireless the internet over long distance. The demand for wireless and multimedia application pushes the WLAN and mobile communication future service to provide high data throughput and transmission range (Zheng Shaoyong, 2008).

The need for more throughputs and transmission range, the engineer has introduced the multiple array antennas at both receiver and transmitter also known as multiple input multiple output (MIMO) system. Previously, single input single output (SISO) channel

was introduced where a single antenna at the transmitter and single antenna at the receiver. Then, single input multiple output (SIMO) was developed which at the receiver multiple antenna were located. Different from multiple input single output (MISO), where the multiple antenna was located at the transmitter side and single antenna at the receiver side (Zheng Shaoyong, 2008).

The MIMO system can provide more channel capacity without adding more transmit power or having a large bandwidth. The MIMO system can be divided into digital signal processing (DSP) and RF section. In this thesis, more focus is given towards the RF section where the beamforming and array antenna is used to perform MIMO system. Furthermore, the MIMO channel was been characterized to estimate the channel capacity.

1.2 Problem Statement

The issued regarding to the wireless communication was the multipath propagation mechanism that can reduced or degraded the wireless system performance. Besides that, in order to increase the system performance by increased the channel bandwidth also was a big issued because it will be required the new spectrum planning and service. The MIMO system was invented to make the multipath propagation mechanism as an advantage in order to increase the channel capacity. This system was characterized of multiple antennas that used at the transmitter and receiver sides and can increase the channel capacity (b/s/Hz) without increased the bandwidth and transmit power (Duman, Tolga M., & Ghrayeb, Ali, 2007 & Masuda, K., 2005).

The used of diversity was to increase the probability at the receiver end where at least one of the signals were received correctly (Duman, Tolga M., & Ghrayeb, Ali, *2007*). The spatial diversity was one of the diversity techniques. It can be done by space apart between the antennas but when used at the limited volume or space. It can be hard to be

implemented. Regarding to (Anreddy, V. R & Ingram, M. A., 2006), for realizing MIMO architecture in the compact device, polarization diversity presents an attractive alternative.

The beamforming network was used to comprehend the angle domain processing instead of using the digital angle domain processing (Innok, A. *et. al.*, 2009a). The results show that, by using the beamforming network it can improve the channel capacity of the MIMO system.

1.3 Objective

The objective of this project was to predict the wireless MIMO system performance at unlicensed Industrial, Science and Medical (ISM) frequency band (2.4 GHz). The effects of polarization diversity in term of vertical and horizontal polarization principal plane and different spacing of spatial diversity will be investigated in typical MIMO system.

1.4 Methodology

Regarding to the Figure 1.1 research methodology, the project starts with gathering the reading materials which were covers topic about MIMO system, MIMO channel characterization, microstrip antenna and beamforming network. The papers, journals and books were examples of the reading materials that have been gathered.

Then, the next process was developing the RF front end components. Butler matrix and array antenna were the RF front end components. The Butler matrix was been design and simulated using the Microwave Office software while the array antenna was been design and simulated using the computer simulation technology (CST). The CST software was used to design the array antenna because it can generated the three dimensional (3D) structure and it is also a popular software nowadays to simulate the 3D structure. Both RF

component, Butler matrix and array antenna were fabricated using etching technique and these component were fabricated using FR-4 board.

The RF front end test bed system was developed by using the fabricated Butler matrix and array antennas. The measurement was conducted in Faculty of Electronic Engineering and Computer Engineering laboratory.

The measurement campaign begins with employed the spatial diversity to the typical MIMO system. It can be realized by ranging the distance of transmitter and receiver for typical MIMO system. Then, the typical MIMO system was equipped with the beamforming network at transmitter and receiver to perform the MIMO beamforming network system. After that, the typical MIMO system with polarization diversity has been measured followed by integration with beamforming network. Based on the measurement data that obtain from the measurement campaign, the MIMO channel capacity can be calculated. The analysis was focused to the effect of the measurement campaign due to the polarization diversity and spatial diversity.

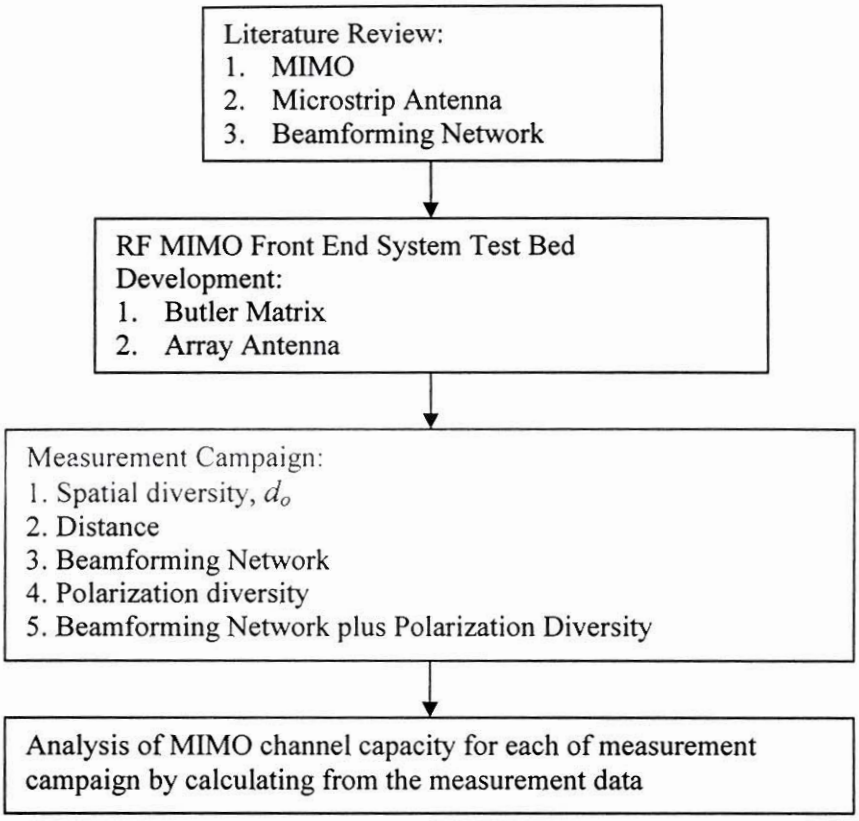

Figure 1.1 Research Methodology

1.5 Scope of Works

The RF MIMO front end system test bed was developed by using the Butler matrix and microstrip array antenna. The Butler matrix has been designed up to 4×4 numbers of orders. Meanwhile the microstrip array antenna was designed up to 2x2 rectangular microstrip patch array antenna. Both designs will be simulate and fabricate.

The measurement campaigns begin by setup the measurement test bed. The fabricated array antenna and beamforming network were used in order to develop the system. Hence that, the distance between transmitter and receiver sides was set at 15λ, 54λ and 96λ. For the measurement period, the spatial and polarization diversity also been occupied into the system.

For the spatial diversity, d_o, it was varied from $\lambda/2$ to 2λ. Meanwhile, the polarization diversity has three classes, which were applied at the transmitter, receiver and both sides. The spectrum analyzer was used to measure the receive power at the receiver. By using the measured data, the channel capacity of MIMO can be calculated. Therefore, the analysis was more focused to the channel capacity in order to analyze the effect of the measurement campaign.

1.6 Contribution of Research

The RF MIMO front end test bed was been developed by using 2×2 rectangular microstrip patch array antenna and 4×4 Butler matrix for indoor channel. The polarization diversity has been applied during the measurement period. The MIMO channel capacity for all the polarization diversity setup was been characterized and investigated. The channel capacity also been investigated for combination of polarization diversity and beamforming network.

1.7 Organization of Thesis

Chapter 1 is an introduction of this thesis. It included with research scope, the problem statement, research objective, research methodology and the contribution of this research.

Chapter 2 is highlighted the literature reviews about MIMO system. Under the MIMO system sub-topic also reviews on channel capacity, MIMO measurement setup and types of the diversity in MIMO system. Besides that, this chapter as included literature reviews on beamforming network.

Chapter 3 was focused on the methodology of this research. The methodology starts with constructed the RF MIMO front end system by using the fabricated

beamforming network and array antennas. The measurement campaign also is also including in this chapter.

Meanwhile, Chapter 4 is discussed and analyzed the results of the RF MIMO channel capacity. In addition, the results of simulation and fabrication of beamforming network and array antenna also was included in this chapter. The Chapter 5 was the conclusion and future work of the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 MIMO System

MIMO system capable of improving the data transmission reliability and increased the channel capacity (b/s/Hz) because of it can utilize the multipath propagation radio waves (Duman, Tolga M., Ghrayeb, Ali, 2007 & Masuda, K., 2005). In addition, this improvement can be achieved without increasing the bandwidth or increasing the transmitted power (Jaramillo, R.E *et. al.*, 2006).

Figure 2.1 was general MIMO system and can divide into Part A and Part B. Part A was the digital signal processing (DSP) section and Part B was the RF components (Jensen, M.A & Wallace, J.W, 2004). The input signals were encoded at the DSP section. The encoded signals were transmitted to the wireless channel by antennas after passing through the RF components. The encoded signals were received by an antenna at the receiver side. Then, the signals were decoded at DSP part after bypass the RF components part.

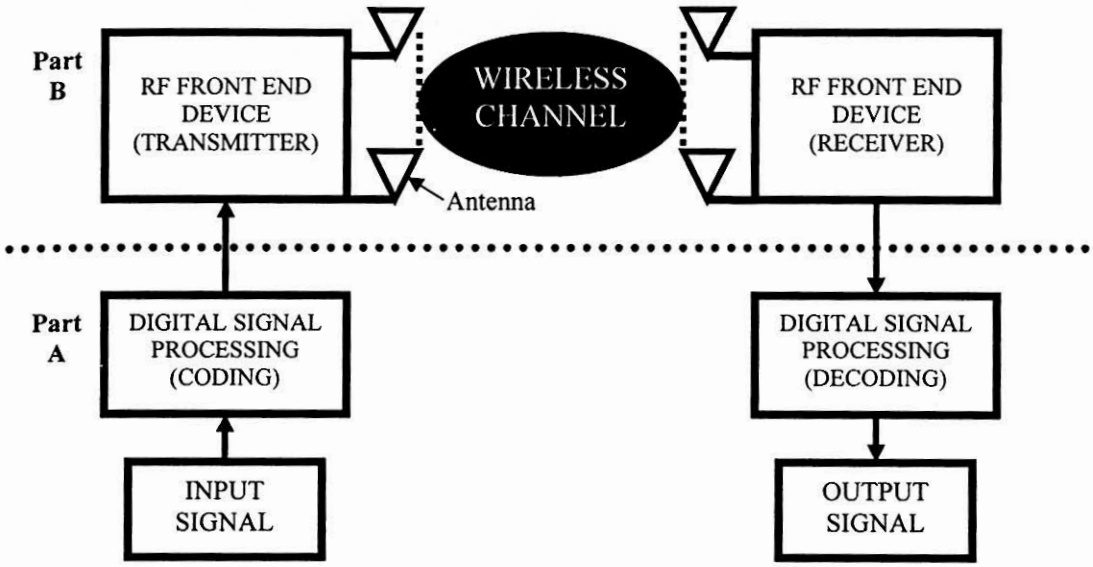

Figure 2.1 General MIMO Wireless System Block Diagram

Thus, the mathematical equation that described the MIMO system can be expressed as Equation (2.1). x represent as the input signal and y represent as the output signal.

$$y = Hx + n \tag{2.1}$$

where H in Equation (2.1) symbolized for the MIMO channel matrix and n was the noise in the system. The size of the MIMO channel matrix was depending on the number of transmits and receives antenna. Therefore, the Equation (2.2) shows the MIMO channel matrix, H. N represented as the number of transmitting antennas and M represent as the number of receiving antennas.

$$H = \begin{pmatrix} \rho_{11} & \rho_{12} & \rho_{13} & \rho_{11} \\ \rho_{21} & \rho_{22} & \rho_{23} & \rho_{24} \\ \rho_{31} & \rho_{32} & \rho_{33} & \rho_{34} \\ \rho_{41} & \rho_{42} & \rho_{43} & \rho_{yx} \end{pmatrix}_{M \times N} \tag{2.2}$$