ANALYSIS OF INDOOR MIMO CHANNEL CAPACITY USING SPATIAL DIVERSITY TECHNIQUE

[1]M.Z.A. Abd Aziz, [1]Z. Daud, [1]M.K. Suaidi, [2]M.K.A. Rahim

[1]Faculty of Electronic and Computer Engineering,
Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka Malaysia

[2]Faculty of Electrical Engineering, Universiti Teknologi Malaysia,
81310 Skudai, Johor, Malaysia

mohamadzoinol@utem.edu.my, mkamal@fke.utm.my

Abstract

This paper focus on simulation and measurement of MIMO channel capacity for indoor propagation. A spatial diversity method is employed during measurement and simulation process. The investigation on the channel capacity for various distance and spacing of both transmitter and receiver antenna have been done. The investigations of channel capacity are included with difference distance between transmitter and receiver sides and different in element antenna spacing. For the simulation, the path loss for the free space and physical effect are been considered. The 2x2 rectangular microstrip patch array antenna is used in order to characterize channel parameter at 2.4GHz operating frequency. Measurement process for 4x4 antenna configuration is done in UTeM Microwave Laboratory. The capacities of MIMO channel also decrease by increasing the distance between transmit and receive antenna.

Keywords: *MIMO, MIMO Channel, Spatial Diversity and Wireless MIMO Capacity.*

I. INTRODUCTION

Wireless communication systems become more important as they provide a flexibility and user friendly of application. Because of broadband wireless systems benefit from accurate channel characterization, there is growing interest in broadband wireless multiple-input multiple-output (MIMO) channel models and channel characterization. MIMO systems offer significant increase data throughput without additional bandwidth or transmit power. MIMO system used multiple antennas at transmitter and receiver front end. The use of antenna arrays in wireless communication systems provides many advantages. For example channel capacity can be greatly increased with increasing antenna array at both link [1][2].

In Figure 1, source of the system will be voice or data transmitted from a computer while destination is a person listening or computer receiving data. The radio frequency (RF) component is included in the MIMO channel since they influence the end-to-end transfer function. Input data is converted to suitable signal for the transmitter and will distribute through the channel [3].

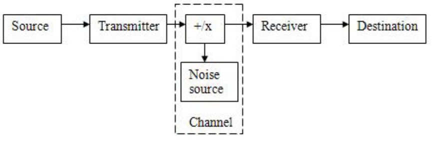

Figure1 : Classic Wireless Communication

MIMO channel describes the connection between the transmitters and receiver. The MIMO channel models can be divided into the non-physical and physical models [4][5].

This paper will discuss and analyzed the simulation of capacity effect to the wireless MIMO channel for different spatial diversity is applied at the both sides of transmitter and receiver. Then the measured channel capacity is compared to channel capacity obtain from Kronecker and Weischselberger model.

II. WIRELESS PROPAGATION

Wireless technology is rapidly evolving, and is playing an increasing role in lives of people throughout the world. The mechanism of wireless propagation is diverse, but can generally element to reflection, diffraction and scattering [6]. Environment of antenna position is one of the importance parts to describe channel in a system. Free space radio wave propagation is the most basic model of radio wave propagation and assumes the signal travelling through a straight path or line-of-sigh (LOS).

The power density of the system in free-space is $\frac{P_T}{4\pi d^2}$ W/m^2 where P_T is transmitted power and d is distance between transmitter and receiver antenna. If the transmitting antenna has gain in the direction of the receive antenna and effective area of antenna is involve, and then receive power P_R is given by.

$$P_r = \frac{P_T G_T G_r}{\left(\frac{4\pi d}{\lambda}\right)^2} \tag{1}$$

where λ is wavelength [7].

III. SYSTEM CONFIGURATION

The objective of this paper is to investigate the channel capacity effect by different distance of transmit and received and antenna element spacing for an indoor environment. Figure 2 shows the antenna configuration and measurement setup. This project assumes distance (d) much larger than antenna spacing (l). From geometrical arrangement, the different path length for LOS arrangement between transmitter and receiver is:

$$r_{n,m} = \sqrt{d^2 + \left(l(n-m)\right)^2} \tag{2}$$

where n and m is number of transmit and receive antenna respectively.

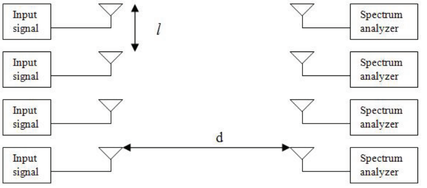

Figure 2 : Antenna configuration

The signal is transferred over several different propagation paths. In the case of wireless transmission, it can be achieved by using multiple transmitter antennas (transmit diversity) and/or multiple receiving antennas (diversity reception) [3]. This system is built up to combine the methods such as transmit and receive power correlation, and spatial diversity. The Matlab simulation tool is use to compare MIMO channel models based on the theoretical data and measured data. The measurement campaign is done to collect the data required to verify the MIMO channel model (Kronecker model and Weichelberger model) and to estimate the model parameters that characterize different configuration.

Channel correlation between transmitter and receiver is calculated. Correlation coefficient is a measured of the linear relationship between transmitter and receiver [8]. Strong LOS usually considered as low-rank channel matrix and it will provide correlation between transmitter and receiver [9].

IV. CHANNEL CAPACITY ANALYSIS

MIMO channel capacity depends heavily on the statistical properties and antenna element correlations of the channel [10]. MIMO channel capacity is quantifies the maximum bit rate allowed by channel without error transmission [11]. Channel capacity is define by

 ISSN: 2180 - 1843 Vol. 2 No. 2 July - December 2010

$$C_{MIMO} = E\left\{\log_2\left(\det\left(I_{Nt} + \frac{\rho}{Nt}\left(HH^H\right)\right)\right)\right\} \quad (3)$$

Where $(.)^H$ is the hermitian operator defined by transposed conjugate matrix, E{.} is the expectation, ϱ is signal to noise ratio (SNR) and I_{Nt} is is an n*m identity matrix. MIMO capacity increase by increasing angle spread factor for LOS and NLOS scenarios [12]. By calculating the eigenvalue of channel, capacity of the MIMO system is presented as:

$$C = \sum_{i=1}^{\min\{N,M\}} \log_2\left(1 + \frac{E_s}{N_0}.\frac{1}{N}.\lambda\right) \quad (4)$$

Where E_S/N_0 presents the ratio of signal energy to noise energy, n and m is transmitting and receiving antenna and λ is the eigenvalue

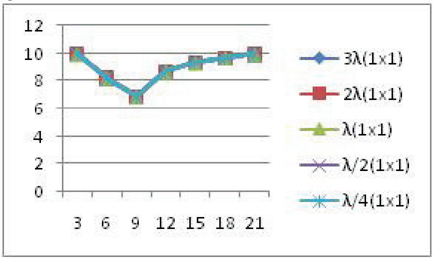

Figure 3: 1x1 configuration

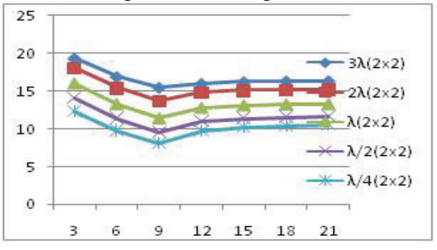

Figure 4: 2x2 configuration

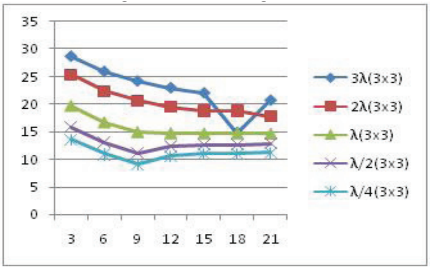

Figure 5: 3x3 configuration

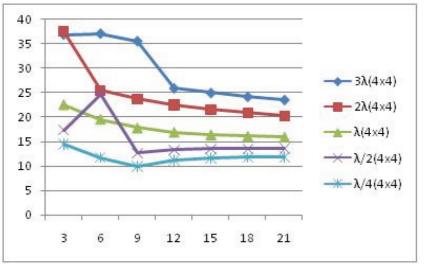

Figure 6: 4x4 configuration

Figure 3 to Figure 6 illustrates simulation result for channel capacity of SISO and MIMO configuration. From the simulation, the channel capacity of SISO configuration is the smallest (6.86 b/s/Hz – 9.934b/s/Hz) while capacity of 4x4 configuration antenna is highest (11.29 b/s/Hz – 37.06 b/s/Hz). The channel capacity for all configurations is increase by increasing the antenna spacing while the channel capacity is decrease by increasing transmitter and receiver distance.

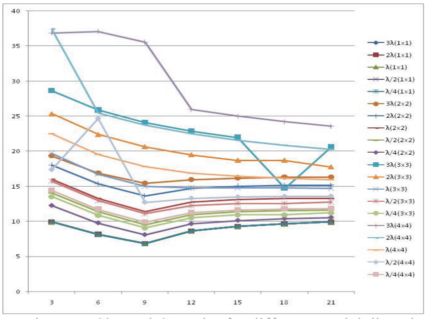

Figure 7: Channel Capacity for different spatial diversity

Figure 7 illustrate the spatial diversity effect for 1x1, 2x2, 3x3 and 4x4 antenna configuration. In Figure 7, the channel capacity for each configuration will increase by increasing the antenna spacing and will be decrease by increasing distance between transmitter and receiver.

The channel capacity for 4x4 MIMO configurations with 3λ antenna spacing is highest (37.067 b/s/Hz) while the lowest (6.86 b/s/Hz) channel capacity for SISO configuration. The channel capacity for 3x3 antenna configuration with 3λ spacing is higher than the channel capacity for 4x4 antenna configuration with λ spacing. This is because the mutual coupling between antennas will reduce by increasing antenna spacing and it will increase the channel capacity. The mutual coupling effect is discussed in [12].

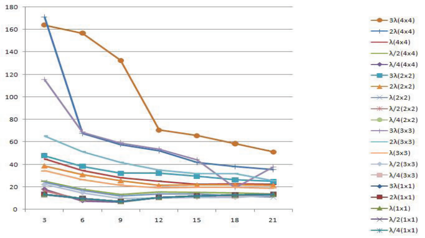

Figure 8: Kronecker model

Figure 8 shows the channel capacity for 1x1, 2x2, 3x3 and 4x4 antenna configuration with different antenna spacing. From the figure, the channel capacity for 4x4 is highest compare to 1x1 antenna configuration. The result shows the capacity for 4x4 antennas configuration are almost 160 b/s/Hz at distance 3m and will be decrease by increasing the distance from transmitter to receiver. The channel capacity almost closed when increasing the distance for all antenna configurations.

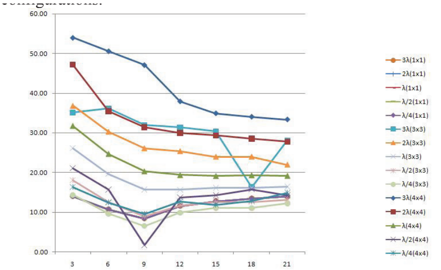

Figure 9: Weichselberger Model

Figure 9 shows the effect of spatial diversity on channel capacity for Weichselberger's model. The result is similar to other channel model which is the channel capacity is for 4x4 antenna configuration is higher (53.98 b/s/Hz) than 1x1 antenna configurations. The result also shows the channel capacity for 3λ antenna spacing is better than 1λ antenna spacing. This is because, the channel capacity for 3x3 antenna configuration with 3λ antenna spacing is higher than 4x4 antenna configuration with λ spacing. The channel capacity will decrease by increasing the transmitter and receiver distance.

Figure 10 show comparison the 4x4 antenna configuration of measured and simulation channel capacity. The line-of-sight (LOS) of Weichselberger model shows the capacity is approximate to the measured data while the channel capacity for Kronecker 's model is large differ to the measured data.

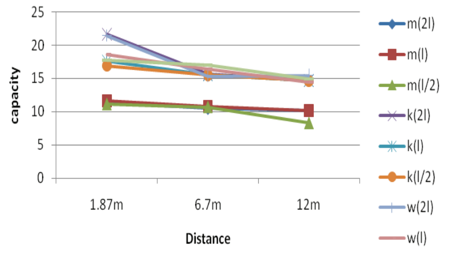

Figure 10: Measurement for different *d* and *l*

V. CONCLUSION

Spatial diversity technique is one of the methods to improve the channel capacity for MIMO wireless communication system. From the observation, capacity of propagation channel is slowly decrease by increasing the distance between transmitter and receiver for measured and simulation process. by increasing the spacing between antennas at both ends will increase the capacity of the channel propagation. The capacity of Weichelberger model is more suitable to the measured channel capacity compared to Kronecker model when physical effect is considered. The simulations prove that the Kronecker model is not suitable for more 2x2 antenna configuration [13].

REFERENCES

[1] G.J.Foschini and M.J. Gans, "On Limits of Wireless Communication in a Fading Environment", Wireless Personal Communications, vol. 6, pp.311-335,1998

[2] I. Emre Telatar, "Capacity of multi-antenna Gaussian Channels", European transactions on telecommunications, vol.10, no. 6, pp. 585-595, Nov./Dec 1999

[3] Peter Stavroulakis "Interference Analysis And Reduction For Wireless System", page 48, 2003

[4] Kai Yu and Björn Ottersten, "Models for MIMO Propagation Channels, A Review", in Wiely Journal on Wireless Communications and Mobile Computing Special Issue on Adaptive Antennas and MIMO Systems, 2002-07-08

[5] Aida Botonjiæ, "MIMO channel models", Diploma Thesis, Examensarbeteutförti Elektronikdesign vid Linköpings Tekniska Högskola, Campus Norrköping,

[6] Shahab Sanayei and Aria Nosratinia, "Antenna Selection in MIMO Systems", Adaptive antennas and MIMO system for wireless communications. IEEE Communications Magazine • October 2004

[7] Richard Jaramillo E, Oscar Fernandez and Rafael P. Torres, " Empirical Analysis of 2x2 MIMO channel in Outdoor-Indoor Scenarios for BFWA Applications", IEEE Antennas and Propagation Magazine, Vol. 48, No.6, December 2006

[8] Theodore S. Rappaport , 'Wireless communications (principle and Practice)', Second Edition, Prentice Hall of India, 2007

[9] J. G. Proakis, 2001 'Digital Communication', Fourth Edition, McGraw-Hill Higher Education

[10] James R. Schott, 1997 " Matrix Analysis for Statistics", page 24, New York: John Wiley & Sons.

[11] Leilei Liu, Wei Hong ," Characterization of line-of-sight MIMO channel for fixed wireless Communications."2007

[12] Andrea Goldsmith, Ali Jafar, Nihar Jindal, Sriram Vishwanath, " Capacity limits of MIMO channels", IEEE journal on selected Areas in communications, VOL. 21, NO.5, JUNE 2003

[13] C. Pereira, Y.Chartois, Y. Pousset, R. Vauzelle, " Impact Of Indoor Environtment Modelling on MIMO Channel Characterization," Proceedings of the 9th European Conference on Wireless technology, Manchester UK [Sept. 2006].

[14] Wallace J., Jensen M., "mutual coupling in mimo wireless systems: a rigorous network theory analysis", IEE Trans. Wireless Communication, 2004, pp.1130-1134.

[15] Claude Oestges " Validity of the Kronecker Model For MIMO Correllated Channels", 63rd IEEE Semi-annual Vehicular Technology Conference Spring, VTC-Spring '06 (Melbourne, Australia) pp, 2818-2822, May 2006.