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Channel Capacity of Indoor MIMO Systems in the Presence of Spatial Diversity

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ABSTRACT

The capacity of Multiple Input Multiple Output (MIMO) systems has received much attention in recent years. This paper analyze the capacities of MIMO channel model for indoor propagation with increasing the distance between transmit and receive antenna through simulation and measurement. 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. The system measurement was been conducted in UTeM Microwave Laboratory, according to the real situation in indoor environment.

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INTRODUCTION

Today, demand for high data rate and channel bandwidth is increasing due to the modern and future application requirement in wireless communication systems. The Multiple-input-multiple-output (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 (Jensen, 2004; Foschini, 1998). The used of diversity was to increase the probability at the receiver end where at least one of the signals were received correctly (Duman, 2007). The spatial diversity was one of the diversity techniques (Poon, 2004; Molina-Garcia-Pardo, 2007). It can be done by space apart between the antennas but when used at the limited volume or space.

In WLAN technology, the signal will propagate through numerous paths which effected from the indoor environment. This phenomenon is call multipath propagation. So the MIMO channel system is introduced to solve this problem by exploiting the richness of multipath propagation. Additionally, the use of multiple antennas at both the transmitter and receiver provides significant increase in wireless channel capacity.

The MIMO channel models can be divided into the non-physical and physical models (Almers, 2007; Yu, 2002), in order to characterize the channel performance, the statistical model is used to find the channel capacity for every scenario. The MIMO channel model can be characterized by modelling the channel with consideration of physical parameter such as distance and scattering for every scenario.

This paper will discuss and analyzed the simulation of capacity effect to the wireless MIMO communication channel model 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.

1. *Channel Model and Channel Capacity:*

1.1 *MIMO Channel Model for LOS Scenario:*

Wireless propagation is dominated by the daily changes by environment features such as reflection, diffraction and transmission depending on the location of transmitter and receiver.

In this project, reflection is avoid because LOS is considered as a major signal. Since no reflection between n-th transmitter and m-th receiver, the channel coefficient h, only consists a direct path between these antennas.

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Because of the operation in free-space condition, the power receive of Friis free-space equation is considered (Richard Jaramillo, 2006).

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 r_{mn}^2 L} \tag{1}$$

Where is the transmitted power, and are transmitter and receiver antenna gain and is the wavelength in meters. The system loss, , such as cable loss or antenna efficiency are not related to free-space propagation.

1.2 MIMO Channel Model for LOS Scenario:

In this paper, parameters of MIMO channel model identified with construct a different configuration in indoor environment. Fig. 1 shows the antenna configuration and measurement setup. The development of algorithm is starting by calculating pathloss of the system. Then the correlation coefficient and eigen analysis are calculated sequentially to find the channel capacity of MIMO wireless communication system.

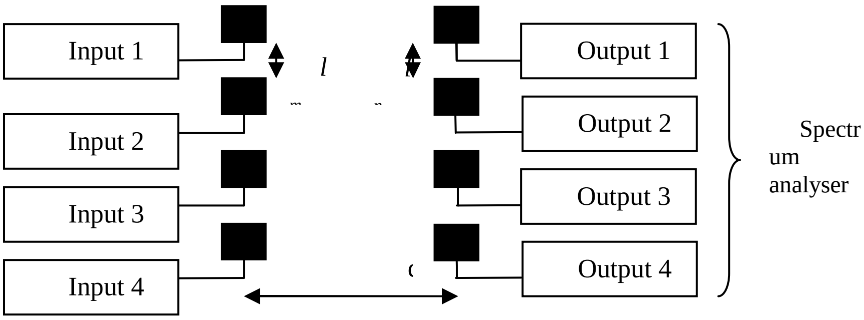

Fig. 1: Antenna configuration.

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 charaterize different configuration.

For this project, fixed wireless system is more to line-of-sight environment while the distance (d) is assumed much higher than antenna spacing (l). From geometrical arrangement, the different path length ( ) for LOS arrangement between transmitter nth and receiver mth is calculate such as equation 2 (Theodore, 2007; James, 1997).

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

For the second scenario, both transmitter and receiver antenna is placed with different antenna spacing (l). Thus, the path length ( ) is depending on the shifting of the antenna spacing. The paths length ( ) for different antenna spacing at transmitter (lm) and receiver (ln) is given by:

$$r_{n,m} = \sqrt{d^2 + \left(l_m - l_n\right)^2} \tag{3}$$

The third configuration is a multiple altitude antenna configuration which is the uniform antenna spacing is placed at both transmitters and receiver antenna front end but with different altitude.

1.3 MIMO Channel Model for LOS Scenario:

The data collected from the measurement are analyzed for every configuration. Equation (6) show the MIMO channel matrix H where N and M representing the number of transmitting and receiving antennas (Leilei Liu, 2007).

$$H = \begin{bmatrix} \rho_{11} & \rho_{12} & \rho_{13} & \rho_{14} \\ \rho_{21} & \rho_{22} & \rho_{23} & \rho_{24} \\ \rho_{31} & \rho_{32} & \rho_{33} & \rho_{34} \\ \rho_{41} & \rho_{42} & \rho_{43} & \rho_{44} \end{bmatrix}_{MxN} \tag{6}$$

The channel capacity is calculate by using equation (7) (Pérez Fontán, 2008).

$$C_{MIMO} = \sum_{i=1}^{i} \log_2\left(1 + \frac{SNR}{N}\lambda_i\right) b/s/Hz \tag{7}$$

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RESULTS AND DISCUSSIONS

Experimental work has been done by collecting data with configurations of typical and spatial diversity technique. The different measurement tools are helping in characterizing MIMO channel parameter.

1.4 Typical and Spatial Diversity:

The measurement work was started by collecting the data from the typical setup. Table 1 show thesimulation and measurement for typical and spatial diversity setup with lm and ln is antenna spacing at transmitter (lm = ln = □).

Table 1: Comparison of MIMO Channel Capacity for Simulation and Measured Data.

Simulation		Measurement
Kronecker	Weichselberger	
42.3868 b/s/Hz	30.3454 b/s/Hz	7.86 b/s/Hz

From the table, the Kronecker and Weichselberger model shows huge different compared to the measured data. However the Weichselberger model is closer to the measured data because this model uses joint correlation at both ends. It also prove the (Hüseyin Özcelik, 2004) work that Kronecker model is fail to predict the channel capacity for the system used more than 2x2 antenna.

1.5 MIMO System with Spatial Diversity Technique:

Measurement for spatial diversity setup has been done by varying the spacing (l) between antennas at transmitter by fixing antenna spacing at receiver and vice versa. From the observation, by changing the spacing between the antennas, it will change the value of eigenvalue and capacity.

Table 2 shows the MIMO channel capacity for configuration by changing l at receiver with fixed antenna spacing at transmitter.

Table 2: Result for MIMO Channel capacity by changing l at receiver with fixed antenna spacing at transmitter.

	Antenna Spacing at Receiver, ln				
Antenna Spacing at transmitter lm=λ	λ/4	λ/2	λ	2λ	3λ
Channel capacity (b/s/Hz)	6.92	6.134	7.7265	7.4282	7.8934

The result from Table 2 is a comparison of measurement result for MIMO Channel capacity by changing l at receiver with fixed antenna spacing at transmitter. From the table, the largest MIMO channel capacity is 7.8934 b/s/Hz at 3□ antenna spacing configuration. Due to the previous literature on spatial diversity, the capacity increase by expansion of spacing between the antennas.

From the Fig. 2, the result shows the channel capacity of Weichselberger model is closer to the measured data compare to Kronecker model.

The observation result of MIMO channel of that graph also shown capacity is increase by increasing the number of antennas. However, the capacity from measured data does not increase linearly by increasing antennas spacing.

Table 3 shows the result for antenna spacing at transmitter is changing with fixed l at receiver. Compared to typical configuration, the MIMO channel capacity is lower when applying spatial diversity at the transmitter which is the inter element antenna spacing is shifted from l=□/4 until 3□. From the observation, the highest MIMO channel capacity is 7.7265b/s/Hz while the lowest value of the system is 6.3301b/s/Hz when applying □/2 inter element antenna spacing. The differentiation between highest and lowest value is 18.07%.

Table 3: Result for antenna spacing at transmitter is changing with fixed l at receiver

	Antenna Spacing at Transmitter(I_m)		
Antenna Spacing at receiver ln=λ	λ/4	λ/2	λ
Channel capacity (b/s/Hz)	7.3274	6.3301	7.7265

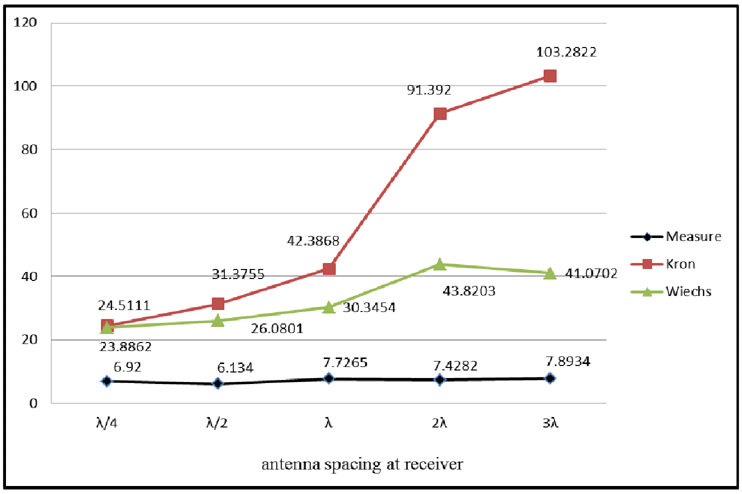

Fig. 2: Comparison between Measurement result and Simulation result for Spatial Diversity at Receiver.

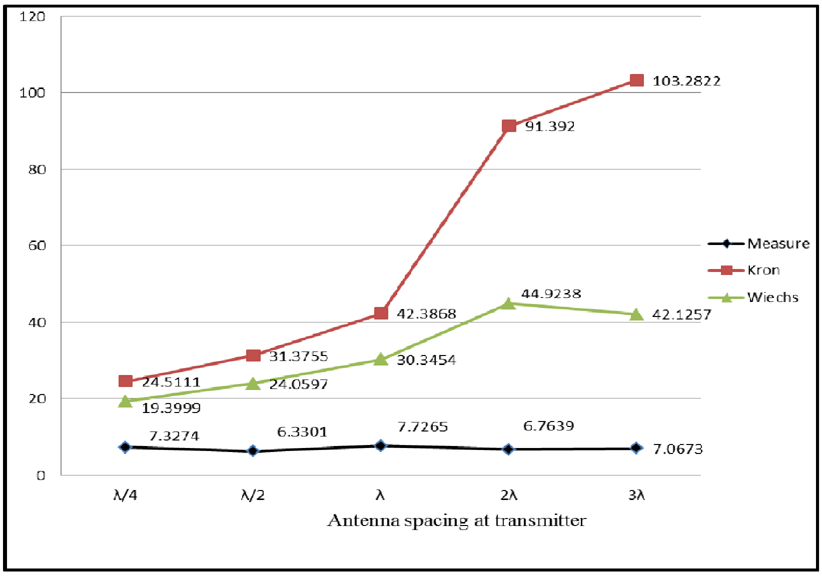

Fig. 3: MIMO Channel Capacities with Spatial Diversity at Transmitter.

Fig. 3 show the comparison between simulation and measurement result of MIMO channel capacity with spatial diversity at transmitter. The result has shown similar to the system with spatial diversity at transmitter where the simulation result is much differs from the measurement result. The MIMO channel capacity increase by increasing the spacing between the antennas for all models.

1.6 Eigenvalue Analysis and MIMO Channel correlation Coefficient:

Figure 4 shows the result of Eigenvalue analysis for measurement result of spatial diversity at transmitter.

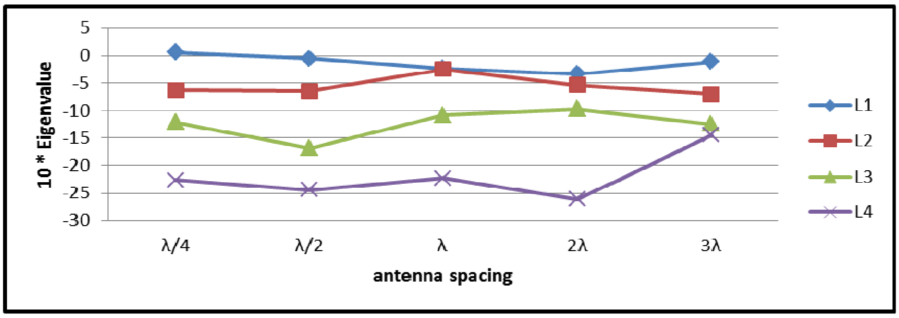

Fig. 4: Eigenvalue for Measure Data with Spatial Diversity at Transmitter.

From the graph, the highest eigenvalue of the system is L1 especially when the antennas are placed with □/2 inter element spacing but the L2 and L3 is lower than the system with □ antenna spacing.

Correlation coefficient is used in order to calculate MIMO channel capacity. Table 4 summarize the correlation coefficient of MIMO system with spatial diversity at the receiver. The table 5 had shown the average of correlation coefficient from the previous table. The average correlation is decrease by increasing the spacing (Lrx). Due to the result of average correlation, the capacity of the system is better when the correlation coefficient is higher.

Table 4: Correlation Coefficient at lm=0.5.

Receiver (l_n=λ/4)				Receiver (l_n=λ)			
-0.08116	-0.25826	0.07135	0.278584	0.184097	-0.22019	-0.05203	-0.06486
-0.36418	0.073011	0.320501	-0.02726	0.14998	0.53665	-0.30272	0.12837
0.013381	-0.1958	0.069882	-0.51134	-0.20811	-0.23324	0.401047	-0.2107
0.168741	0.105638	0.428591	0.447742	0.331321	0.037825	-0.36922	0.280644
-0.08116	-0.25826	0.07135	0.278584	0.184097	-0.22019	-0.05203	-0.06486
-0.36418	0.073011	0.320501	-0.02726	0.14998	0.53665	-0.30272	0.12837

Table 4: Result Average Correlation Coefficient.

	l_n=λ/4	l_n=λ
Average Correlation	0.033713	0.024304

Fig. 5 show the eigen value of the MIMO system when applying the spatial diversity at receiver. The channel capacity increase when the eigenvalue of the system close within each other such as at ln=3□. Other than the L1, the eigenvalue of L4 also give a significant contribution in enhancing the capacity at ln=3□ because the value is highest at that configuration compared to others.

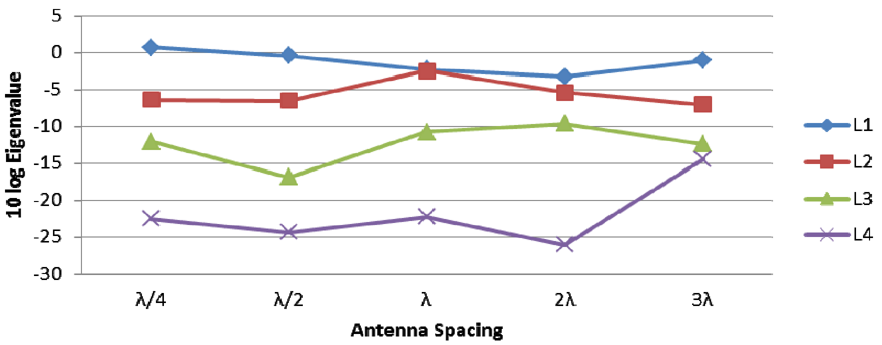

Fig. 5: Eigenvalue for MIMO System with Spatial diversity at Receiver.

Conclusions:

The paper presented a brief analysis of the MIMO channel capacity by using spatial diversity technique at 2.4 GHz operating frequency. The analysis on the experiment data shows the MIMO channel capacity increase by increasing antenna spacing. The capacity of Weichelberger model is more suitable to the measured channel capacity compared to Kronecker model when physical effect were considered.

REFERENCES

Almers, P., E. Bonek, A. Burr, N. Czink, M. Debbah, V. Degli-Esposti, H. Hofstetter, P. Kosti, D. Laurenson, G. MAtz, A.F. Molisch, C. Oestges, and H. Özcelik, 2007. “Survey of Channel and Radio Propagation Models For Wireless MIMO Systems”, Research Article, EURASIP Journal on Wireless Communications and Networkinh, Volume 2007.

Anreddy, V.R., M.A. Ingram, 2006. Capacity of Measured Ricean and Rayleigh Indoor MIMO Channels at 2.4 GHz with Polarization and Spatial Diversity. IEEE Wireless Communication and Networking Conference, 2006 (Anreddy, V. R & Ingram, M. A.), pp: 946 -951.

Botonjiæ, A., “MIMO channelmodels”, Diploma Thesis,Examensarbete utfört i Elektronikdesign vid Linköpings Tekniska Högskola,Campus Norrköping.

Duman, Tolga M., Ghrayeb, Ali, 2007. Coding For MIMO Communication Systems, England: John Wiley & Sons Ltd.

Foschini, G.F. and M.J. Gans, 1998. “On limits of wireless communication in a fading environment when using multiple antennas,” Wireless Pers. Commun, 6(3): 311-335.

Australian Journal of Basic and Applied Sciences, 8(21) Special 2014, Pages: 118-123

Hüseyin Özcelik, 2004. “Indoor MIMO Channel Models”, PhD Thesis, submitted to Institute für Nachrichtentechnik and Hochfrequenztechnik of the Technische Universität Wien, December.

James, R. Schott, 1997. “Matrix Analysis for Statistics”, page 24, New York: John Wiley & Sons.

Jensen, M.A. and J.W. Wallace, 2004. “A review of antennas and propagation for MIMO wireless communications (invited paper),” IEE Trans. Antennas Propagat, 52: 2810-2824.

Kermoal, J.P., 2000a. Experimental Investigation of Multipath Richness for Multi-Element Transmit and Receive Antenna Arrays. IEEE Vehicular Technology Conference Proceedings (Kermoal, J.P.: Mogensen, P.E.: Jensen, S.H.: Andersen, J.B.: Frederiksen, F.: Sorensen, T.B. & Pedersen, K.I.), pp. 2004 – 2008, vol. 3.

Leilei Liu, Wei Hong, 2007. “Characterization of line-of-sight MIMO channel for fixed wireless Communications”.

Molina-Garcia-Pardo, J.M., 2007. Polarized Indoor MIMO Measurements at 2,45 GHz. IEEE Antennas and Propagation Society International Symposium (Molina-Garcia-Pardo, J.M.: Castillo Olmo, I.: Egea-Garcia, F. & Juan-Llacer, L.), pp: 5335–5338.

Pérez Fontán, F., P. Mariño Espiñeira, 2008. Modeling The Wireless Propagation Channel, John Wiley & Sons.

Poon, A.S.Y., 2004. ”A Spatial Channel Model For Multiple – Antenna Systems”,

Richard Jaramillo, E., Oscar Fernandez and P. Rafael Torres, 2006. “ Empirical Analysis of 2x2 MIMO channel in Outdoor-Indoor Scenarios for BFWA Applications”, IEEE Antennas and Propagation Magazine, 48(6).

Theodore, S. Rappaport, 2007. ‘Wireless communications (principle and Practice)’, Second Edition, Prentice Hall of India, 2007

Yu, K. and B. Ottersten, 2002. “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