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MIMO Beamforming Network Having Polarization Diversity

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1. Introduction

The technology of mobile communication and wireless local network (WLAN) are expending at a fast rate which is to assure that the end users reach a maximum data transfer and a get a better of quality service. The MIMO system is introduced to improve the communication system without having an additional transmit power or larger bandwidth, this because the MIMO system can utilize the multipath propagation.
In [Agilent, 2008], there are three categories of MIMO system. The first system is spatial diversity which can be obtain by spaced the antenna in a dense of multipath scattering environment. The second category is spatial multiplexing where an independent data is transmitted over different antennas. Third category is beamforming network. Generally the MIMO system can be divided into two parts, which the first part is the digital signal processing (DSP) and representing as **Part A** in Fig. 1. The second part is radio frequency (RF) device and representing as **Part B** in Fig. 1. (Jensen & Wallace, 2004).

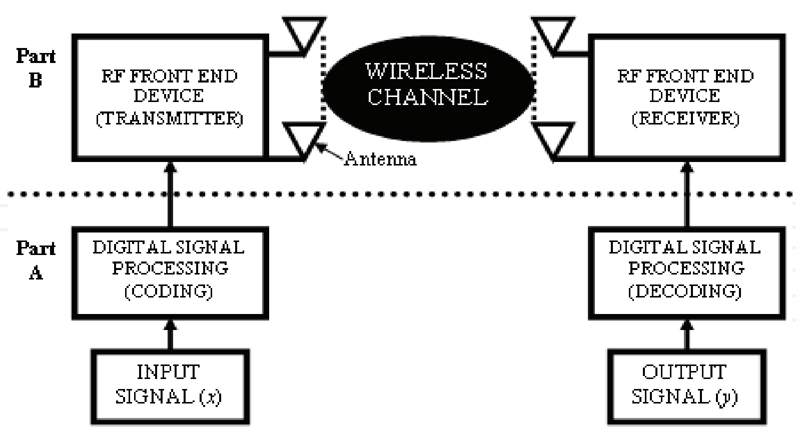


Fig. 1. Block diagram of MIMO systems

This paper is more focused to the RF section and antenna, the beamforming technique is used to act as MIMO system. The term beamforming related to the device in which energy radiated by an antenna that focused is focused along a specific direction in space (Mariadoss etc. al. 2005). So, there are several types of beamforming such as Blass matrix, Nolen matrix and Butler matrix (Desmond, 2001; Ahmad & Seman, 2005). The Butler matrix is used in this project because it simple circuit and easy to be fabricated (Mariadoss etc. al. 2005).

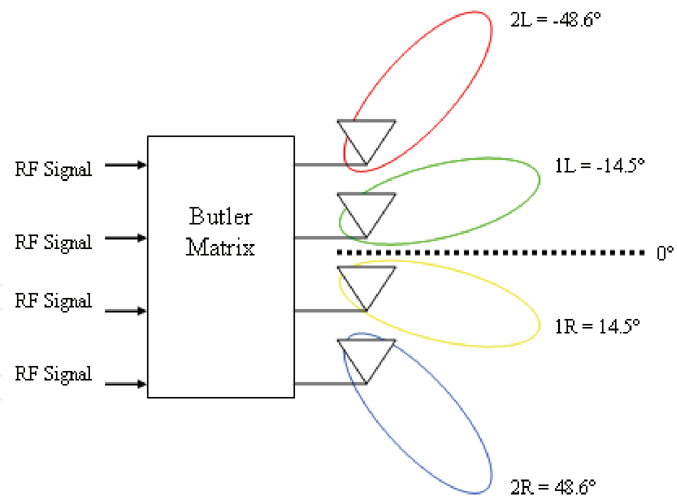


Fig. 2. An example of Butler matrix

Moreover, diversity technique was introduced in this measurement setup. The diversity is used to reduce the fading issues and multipath problems (Duman & Ghrayeb, 2007). By implementing diversity, the received power can be increased significantly, thus increasing the capacity of the system. Polarization diversity, angle diversity and pattern diversity are among the examples of diversity technique.

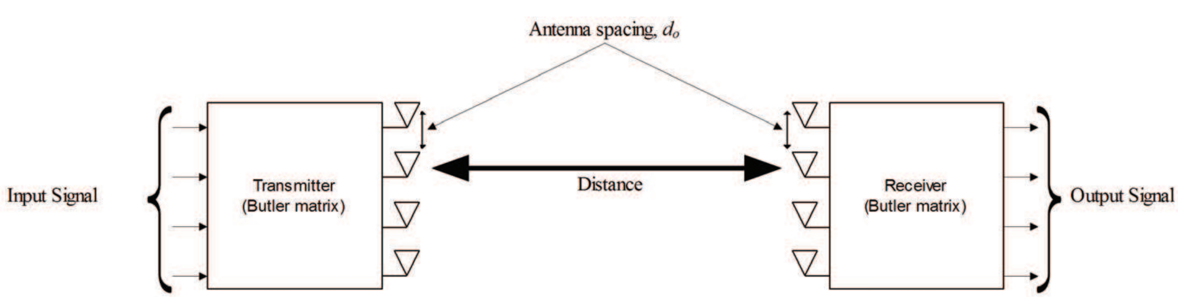
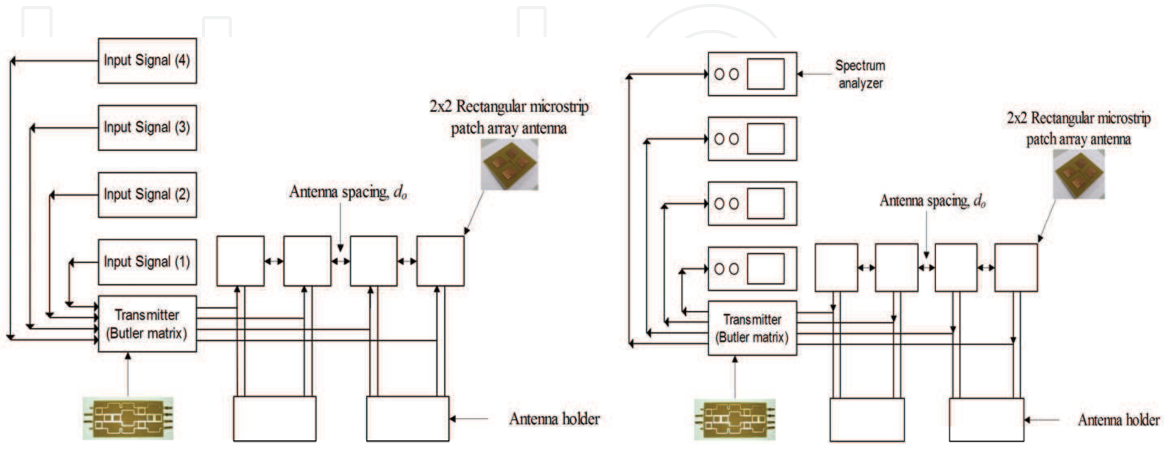


Fig. 3. The Concept of RF MIMO Front End Systems Measurement



(a) Transmitter Setup (b) Receiver Setup

Fig. 4. The Measurement Setup at (a) Transmitter (b) Receiver

2. MIMO channel matrix

Each of antennas in MIMO systems has its own vector. The transmit antenna vector is represented as $\boldsymbol{x}$ and the receive antenna is represented as $\boldsymbol{y}$ vector. The MIMO channel input-output relationship can be expressed as:

$$\boldsymbol{y} = H\,\boldsymbol{x} + \boldsymbol{\eta} \tag{1}$$

where the $\boldsymbol{\eta}$ is the noise and H is the MIMO channel matrix. The MIMO channel matrix size is depending on the number of transmit and receive antennas. The channel matrix size can be express as below:

$$H = \begin{bmatrix} \rho_{11} & \cdots & \rho_{14} \\ \rho_{21} & \cdots & \rho_{24} \\ \vdots & \ddots & \vdots \\ \rho_{41} & & \rho_{ij} \end{bmatrix}_{M\,x\,N} \tag{2}$$

where M was the number of transmit antenna and $\boldsymbol{N}$ was the number of receive antenna. The ρ_{ij} was represented as the correlation between transmit power and receive power where i^{th} was the input port and j^{th} was the output port signals. The ρ_{ij} components were direct depended on the physical characteristics of the propagation environment and also the structure of the antenna array (Kermoal et al., 2000).

Correlation coefficient was a statistic method to measure the correlation between two variables. The correlation coefficient can be calculated as:

$$\rho_{yx} = \frac{cov_{yx}}{\sigma_{yy}\sigma_{xx}} \tag{3}$$

The channel matrix, H will be analyzed for each type of antenna configuration which can be referred in Appendix. The eigenvalues can be calculated to estimate the receiving power for each eigen paths. The eigenvalues were calculated using eigen value decomposition (EVD) technique. The calculated eigenvalues were related with the MIMO average channel capacity by using the equation below (Hirayama etc. al. 2007):

$$C_{ave} = \left[\sum_{j=1}^{N} \log_2 (1 + \lambda_j SNR / N) \right] \tag{4}$$

where N was the number of transmit because there was no setting channel state information (CSI) at transmitter. λ_j was the eigenvalues from the matrix, H while the noise power of -76dBm was obtain from measurement.

3. Results and discussion

3.1 Antenna separation comparison

Fig. 5. shows the average channel capacity for configuration A and B. The distance for this measurement is set for 12 meters. Its shows that the average channel capacity for antenna separation 12 cm are higher for both configurations. The average channel capacity difference for antenna spacing between 12 cm and 6 cm for configuration A is 2.2848 bps/Hz and configuration B is 2.473bps/Hz. For the entire antenna configuration can be referred to Appendix.

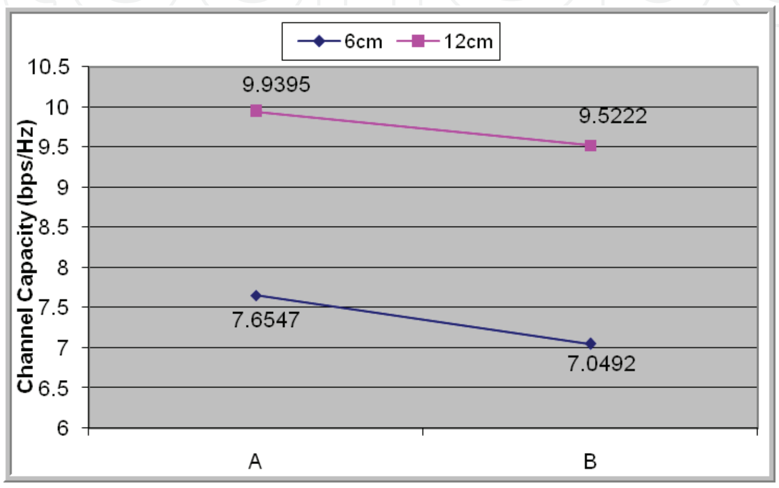
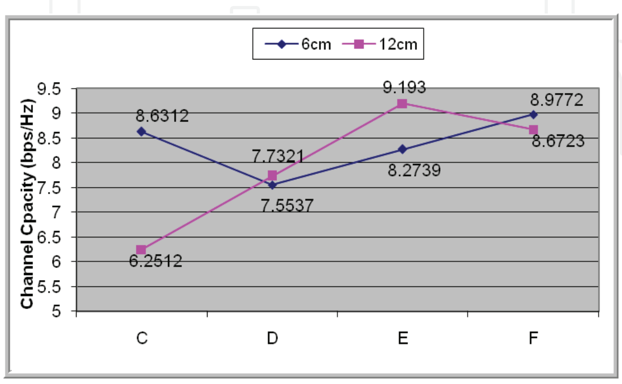
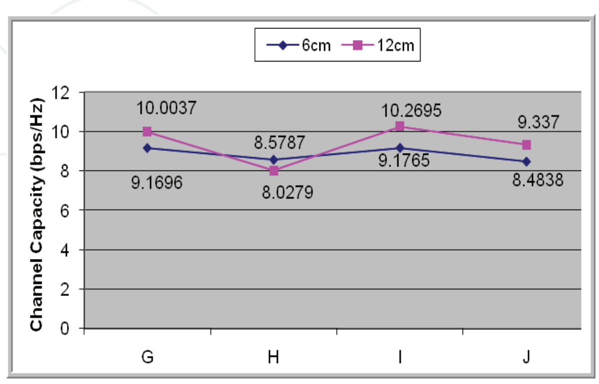


Fig. 5. Average Channel Capacity for Normal Configuration

In Fig. 6 (a)., the configuration E shows a higher average channel capacity is 9.193 bps/Hz with antenna separation is 12 cm and it is higher form others configuration. Fig. 6 (b). shows an average channel capacity for polarization diversity applied to the receiver side. Two configuration show high value which is indicated at configuration G and configuration I with antenna separation 12 cm.





(a) (b)

Fig. 6. (a) Average Channel Capacity for Polarization Diversity at Transmitter Fig. 6 (b). Average Channel Capacity for Polarization Diversity at Receiver

Fig. 7. shows the average channel capacity for both sides polarization diversity. The higher values are indicated at configuration K, L and M. For L an M the antenna separation is 12 cm, meanwhile the configuration K antenna separation is 6 cm.

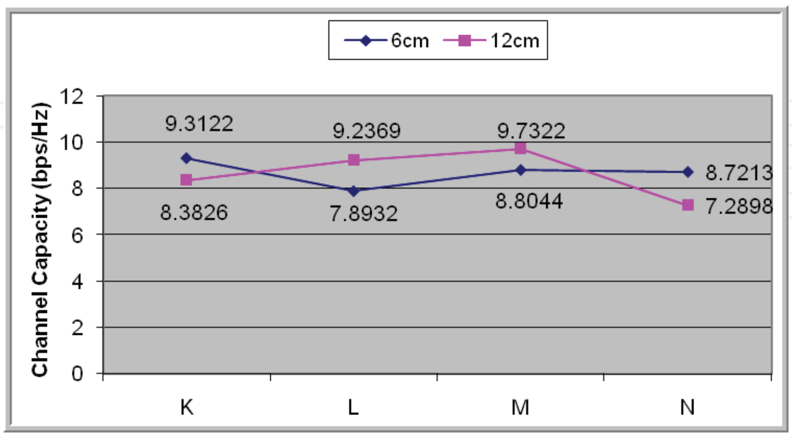


Fig. 7. Average Channel Capacity for Both Sides Polarization Diversity

4. Conclusion

As the conclusion, if the antenna spacing is double, the average channel capacity is increased. When polarization diversity is applied to the system, its show that average channel capacity is better than the normal configuration.

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In recent years, it was realized that the MIMO communication systems seems to be inevitable in accelerated evolution of high data rates applications due to their potential to dramatically increase the spectral efficiency and simultaneously sending individual information to the corresponding users in wireless systems. This book, intends to provide highlights of the current research topics in the field of MIMO system, to offer a snapshot of the recent advances and major issues faced today by the researchers in the MIMO related areas. The book is written by specialists working in universities and research centers all over the world to cover the fundamental principles and main advanced topics on high data rates wireless communications systems over MIMO channels. Moreover, the book has the advantage of providing a collection of applications that are completely independent and self-contained; thus, the interested reader can choose any chapter and skip to another without losing continuity.

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