Performance Analysis of MIMO-CDMA System

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Abstract - Nowadays, the demand on communication system is towards high capacity and faster data transmission with minimum error or losses. In Wireless Communication, Multiple Input Multiple Output (MIMO) is one of the techniques that can increase spectral efficiency and link reliability. Therefore, the performance of MIMO – CDMA with comparison to conventional Code Division Multiple Access (CDMA) system has been analyzed. The simulations models are simulated with different number of antenna which are two transmit – two receive (2Tx2Rx) and four transmit – four receive (4Tx4Rx). System specification is based on voice application. The simulation results shows that the proposed MIMO – CDMA (2Tx2Rx) is improved by 43% of BER and MIMO – CDMA (4Tx4Rx) improved by 63% of BER performance compared to conventional CDMA. Capacity performance of MIMO-CDMA (2Tx2Rx) improved by 50% and MIMO-CDMA (4Tx4Rx) improved by 75% compared to conventional CDMA.

Keywords: MIMO; MIMO – CDMA; BER performance

1. Introduction

Multiple Input Multiple Output (MIMO) transmission techniques are applicable for both second and third generation system [1]. MIMO refers to links with multiple antennas at the transmitter and the receiver side. This technique can be exploited to improve the performance of the wireless link. Performance of this system usually measured in average bit error rate (BER) and capacity.

Communication system is a fast evolving sector in this modern world. Day by day the subscribers are continuously increased. The demands for capacity are higher and will become congested in future. Hence, this system needs new technique or mechanism that able to accommodate and compensate this insufficiency. MIMO is one of the techniques that capable to provide promising approaches.

There are various types of diversity which are frequency diversity, time diversity and space/spatial diversity. Space diversity, also known as antenna diversity or spatial diversity, is one of the most popular forms of diversity used in wireless system. The concept of antenna space diversity is also applied in base station design. Redundancy is provided by employing an array of antennas, with a minimum separation of $\lambda/2$ between neighboring antennas. Different polarized antennas can be utilized. Figure 1 shows the separation of $\lambda/2$ between other antennas.

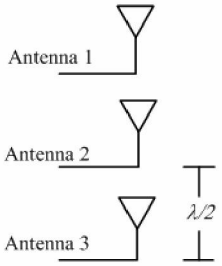

Figure 1: Separation of $\lambda/2$ between other antennas.

In space diversity technique, at each cell site, multiple base station receiving antennas are implemented in order to provide diversity reception. Space diversity reception methods can be classified into four categories which are selective diversity, feedback diversity, maximal ratio combining and equal gain diversity.

2. MIMO-CDMA Model

The usage of multiple antennas at transmitter and receiver can significantly improve the performance of a wireless communication system. Block diagram in Figure 2 shows the N transmits and M receives antenna for MIMO-CDMA architecture. At the transmitter, information or data source output are divided into N parallel bit streams. Each bit streams are independently modulated and spreaded before transmitting it through Additional White Gaussian Noise (AWGN) channel.

Eventually, the resulting N signal streams are transmitted simultaneously after the signal has scrambled. At the receiver, the signal is then be de-spreaded and demodulated. Therefore, the signal is presumed to be received at same time at the parallel to serial block. The original data stream is recovered and will be displayed at the output.

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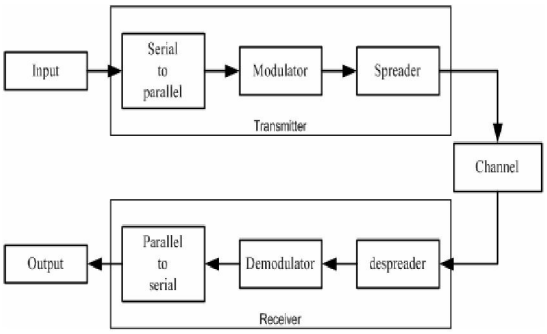

Figure 2: MIMO-CDMA Model.

In this simulation model, each model has been analyzed by using same modulation technique and carrier frequency, f_C. It is important to make sure it is synchronize for comparison purposes. Table 2.1 shows basic characteristic of CDMA simulation model.

Table 2.1: Basic Specification of CDMA

Frequency band	824-849 MHz and 1850-1910 MHz
Duplexing	FDD
Modulation	BPSK, QPSK
Carrier separation	1.25 MHz
Chip rate	1.228 Mchip/sec
Channel bandwidth	1.25 MHz

MIMO channel offer a significant capacity gain over a conventional Single Input Single Output (SISO) channel as there is an increased in spectral efficiency. It is provided by MIMO that based on the utilization of space diversity at both transmitter and receiver. The research will be focused on Shannon theoretic for MIMO channel capacity. The Shannon's capacity theorem is given in equations (1) and (2). To calculate the capacity for the simulation model of 1Tx1Rx or (SISO),

$$C = B \times \log (1 + SNR) \qquad (1)$$

where, C = Capacity
B = Bandwidth
SNR = Signal to Noise Ratio

but to calculate the simulation model that used an antenna array, M the equation is,

$$C = B \times M \times \log (1 + SNR) \qquad (2)$$

where, M = Number of Antenna Array

Shannon's channel capacity formula is applicable to the AWGN channel. Equation (2.1) is used to calculate the capacity for conventional system. Where C is the channel capacity (bit per second), B is the transmission bandwidth (Hz) and Signal to Noise Ratio is used to define the capacity value. For a system that using an antenna array, the equation (2.2) is used to calculate the capacity of channel.

3. Results and Discussions

3.1 Bit Error Rate Performance

Monte Carlo simulation had been used to analyze the Bit Error Rate (BER) performance. The results from these analysis shows that the BER performance increases when space diversity concept is applied at both transmitter and receiver compared to the conventional system.

Figure 3 shows the BER performance comparison between conventional CDMA with MIMO – CDMA system. The same method is used for all models. The result shows that MIMO technique served better performance than conventional CDMA. Besides, the result shows MIMO – CDMA (4Tx4Rx) have better performance than MIMO – CDMA (2Tx2Rx).

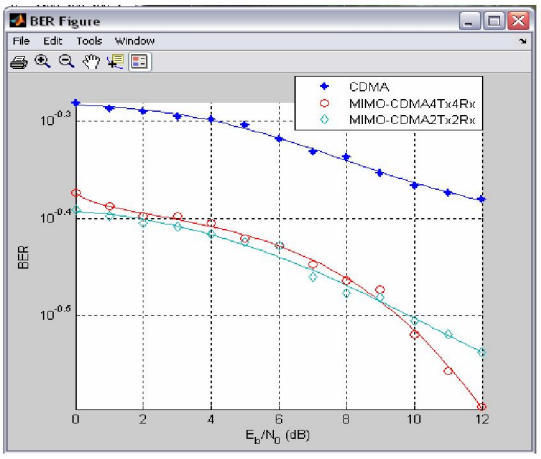

Figure 3: BER performance.

Although there has an overlapping between MIMO – CDMA (2Tx2Rx) with MIMO-CDMA (4Tx4Rx), and yet the result showing that MIMO – CDMA (4Tx 4Rx) is predominant than MIMO – CDMA (2Tx2Rx). This figure shows that at the value for E_b/N_o equal to 7dB MIMO – CDMA (4Tx4Rx) has smaller BER compared to MIMO – CDMA (2Tx2Rx). Therefore, MIMO – CDMA has better performance than conventional CDMA. In MIMO technique, the increasing number of antenna used, it will also increase the BER performance.

Overall, the MIMO – CDMA (4Tx4Rx) gives the best BER performances. This model has improved 63% of BER performance compared to conventional CDMA. MIMO – CDMA (2Tx2Rx) also has improved by 43% of BER performance. However, MIMO-CDMA (4Tx4Rx) has better performances than MIMO-CDMA (2Tx2Rx).

Previously, the capacity is measured based on equations (2.1) and (2.2). Table 3.1 shows the result of capacity value for simulation model.

Table 3.1: Capacity Value for Simulation Model.

	1Tx 1Rx	2Tx 2Rx	4Tx 4Rx
SNR	Capacity (kbps)	Capacity (kbps)	Capacity (kbps)
1	41.71	83.42	166.84
1.259	49.04	98.07	196.15
1.585	57.15	114.29	228.59
1.995	66.01	132.02	264.03
2.512	75.59	151.18	302.36
3.162	85.81	171.62	343.24
3.981	96.62	193.24	386.47

Figure 4 shows the capacity performance for conventional CDMA and MIMO – CDMA. From this figure, the capacity performance of each model is obtained from the graph's slope which is measured in percentage value. The percentage value for conventional CDMA (1Tx1Rx), MIMO – CDMA (2Tx2Rx) and MIMO-CDMA (4Tx4Rx) are 11%, 22% and 44% as the number of antenna used is been increased.

The capacity calculation results show MIMO – CDMA gives the best performance compares to conventional CDMA. MIMO – CDMA (4Tx4Rx) improved by 75% of capacity performance and MIMO – CDMA (2Tx2Rx) improved by 50% of capacity performance. Both these MIMO techniques offer better performances than the conventional CDMA (1Tx1Rx).

4. Conclusion

Based on simulation result, it is known that by using MIMO technique at the transmitter and receiver of a communication system, it helps in order to achieve a very high spectral efficiency. Thus, the implementation of system by using space diversity concept in the wireless system will guarantee a high data speed rate and link reliability. The advantage of using antenna array shows that the capacity has increased while using MIMO technique. This is true as referred to Shannon's capacity equations. It can be concluded that the Multiple Input Multiple Output

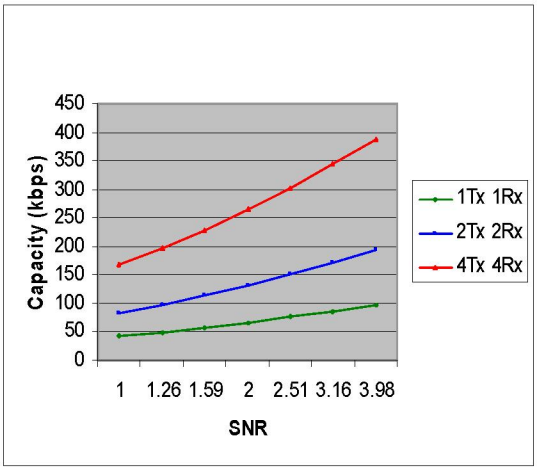

Figure 4: SNR versus Capacity.

system has contribute a better result in terms of BER performance and capacity by increasing the number of antenna. For further research, the same method and approach may be used in other system such as MIMO – OFDM in order to observe and perceive the improvement of BER performance and capacity in comparing to MIMO – CDMA.

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