MIMO System for Next Generation Wireless Communication

Sharif
Lab Demonstrator, Dept. of EEE, University of Information Technology and Sciences (UITS), Baridhara, Dhaka-1212, Bangladesh

Mohammad Emdadul Haq
Lab Demonstrator, Dept. of EEE, University of Information Technology and Sciences (UITS), Baridhara, Dhaka-1212, Bangladesh

Md. Arif Rana
Lab Demonstrator, Dept. of ECE, University of Information Technology and Sciences (UITS), Baridhara, Dhaka-1212, Bangladesh

ABSTRACT

It is well known that Multiple Input-Multiple Output systems enhance the spectral efficiency significantly of wireless communication systems. However, their remarkable hardware and computational burden hinders the wide deployment of such architectures in modern systems. It is a big challenge to reduce hardware complexity, use power with flexible capacity, data rate and bit error rate for the MIMO technology. In this paper we give a theoretical overview of several important theoretical concepts which is related to MIMO. The main part of this thesis can be considered as a most efficient decision for highest capacity with the reasonable BER performance. Hence we came up with an idea to write this thesis paper where we investigated the techniques which we can utilize in order to increase capacity (Bit/s/Hz) and hence provide the less BER in MIMO system. For this system we use Hybrid selection/Maximal-ratio transmission technique over a faded correlated MIMO quasi-static channel. Here faded correlated channel has the ability to carry high capacity data and HS/MRT technique minimizes the BER of system. For this system we use MSK modulation technique which reduces the complexity at transmission side. In practically, For more complexity free in this technique excludes the up converter, amplifier and filtered stage which also alleviate the cost. In this paper at first we try to focus the main important related techniques used in MIMO with the advantages and drawbacks. Then we review the MIMO system from the several past paper works and then we compare the performance of this technique. From this comparison result and using best technique we suggest a future work which will give the best performance. Finally, we describe the technique which we used in our suggested work.

Keywords

Multiple Input-Multiple Output, BER Performance, Wireless Communication, Capacity Improvement of MIMO, SNR Improvement with BER.

1. INTRODUCTION

Traditional wireless communication systems use multiple antennas for transmission and reception. The system is developed from SISO, SIMO and MISO. SISO established with single transmitter and single receiver. In SIMO system, single antenna for transmitter and multiple antennas for receiver [1]. In MISO system multiple transmitter are use for transmit but single receiver is used. Recently, multiple antennas are used at the transmitter and receiver both side as a result the system's performance has improved. That's the system is called Multiple Input Multiple Output (MIMO) system. This is an antenna technology at which both transmitter and receiver equipment are used for wireless communication system [2]. The latest IEEE MIMO standard is 802.11n. MIMO has become popular because of the fading of the signal is low and reach signal's destination anyway in any environment like urban or rural at which the signals will bounce off trees and buildings but in different directions It also provide significant high data rate and link range without additional bandwidth or increased transmit power. It also provide significant high data rate and link range. It saves extra bandwidth and transmission power by spreading same power over the transmitters. In MIMO system, receiving ends use a special signal processing to sort out one that has originally transmitted. MIMO has some performance drawback. Additional cost for initial implement and high power consumption are main challenge in MIMO. Competitive challenges of consumer impact tolerable cost (area), while battery life time and thermal effect on power consumption of portable device of wireless communication. Lack of perfect implementation can make cross-talk, Inter channel Interference (ICI). So the modern MIMO will be most cost efficient to implement and ultra-low cost solution that which increase battery life for mobile device.

2. TECHNIQUE USING IN MIMO

i. Space–time coding
ii. Space–time code design criteria
iii. Theory of space time coding
iv. Optimal designs for Space-Time Linear Pre-coders and Decoders
v. Hierarchical Diversity-Embedding Space Time Block Coding

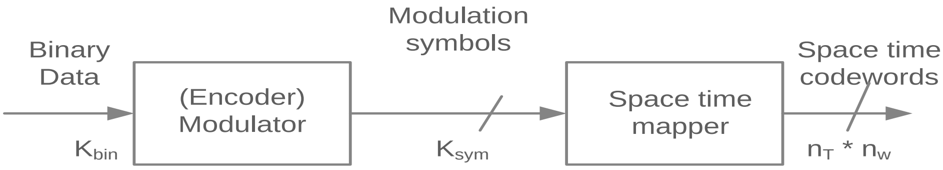

Figure 1: A typical Space time coder

3. MODULATION

Modulation is the process where a radio frequency of light wave's amplitude, frequency, or phase is changed in order to transmit intelligence. The characteristics of the carrier wave are instantaneously varied by another "modulating" waveform. Naturally carrier signals occur at frequencies which are directed by the properties of the data signal. Transmitting signal over frequency band need to understand the physical properties of media and data frequency and transmission frequency band must not be same [3]. The data spectrum needs to shift to frequency band for transmitting a signal through a medium without fascinated by the medium or aliasing. This is modulation process. The choice of modulation type varied with bandwidth of the channel, efficiency and signals to noise ratio and power requirements. To improve the S/N it's need to increase bandwidth. The error rate becomes specific by transmitting maximum amount of data with given bandwidth in a coding system.

i. PSK (Phase shift Keying Modulation.
ii. BPSK (Binary Phase Shift Keying) Modulation Technique of BPSK
iii. MIMO M-ary code-selected DS-BPSK communication system
iv. QPSK (Qudrature Phase shift Keying Modulation)
v. Modern MIMO with PSK
vi. MSK (Minimum shift keying)
vii. ACM (Adaptive Coded Modulation)

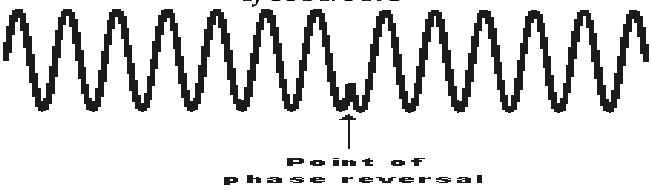

Figure 2: Binary phase shift keying, BPSK

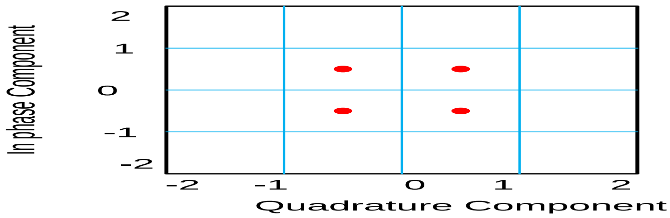

Figure 3: Constellation point for QPSK

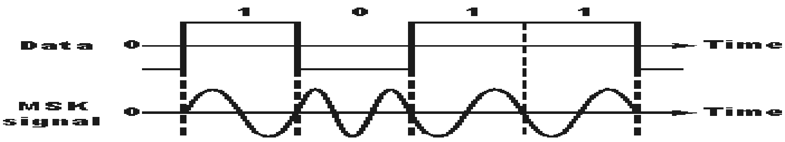

Figure 4: Signal using MSK modulation

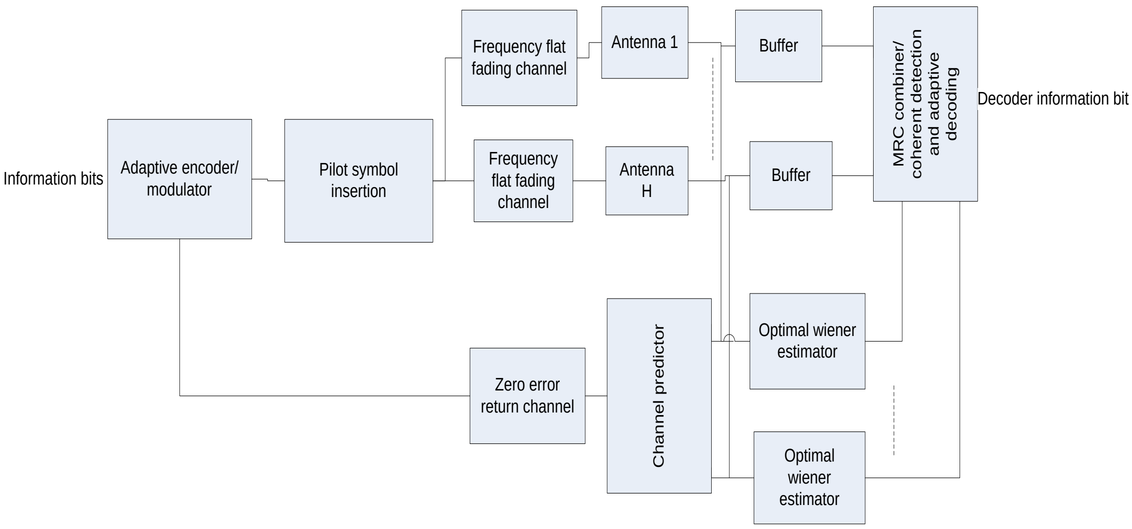

Figure 5: Adaptive Coded Modulation

4. MULTIPLEXING

i. TDM (Time Division Multiplexing)
ii. An architecture for TSI-Free Non-blocking Optical TDM Switches
iii. FDM (Frequency Division Multiplexing)
iv. Low-complexity and frequency-scalable analog real-time FDM receiver
v. OFDM (Orthogonal Frequency Division Multiplexing)

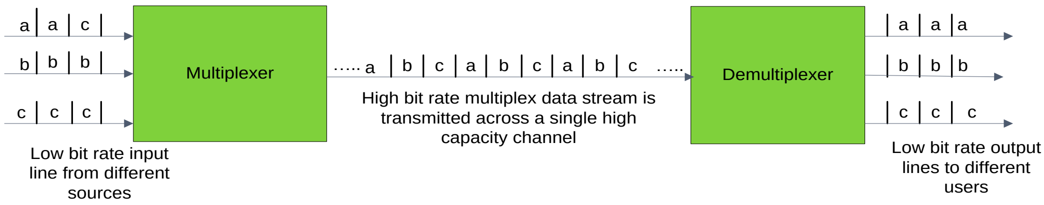

Figure 6: Time division multiplexing

Figure 7: Time division multiplexing (TDM)

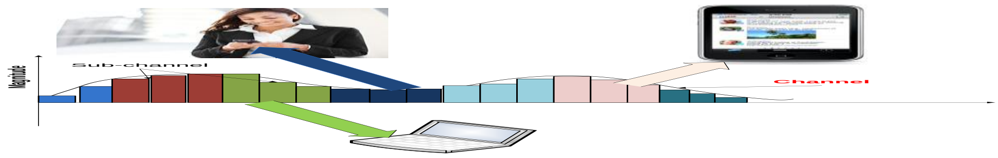

Figure 8: Frequency division multiplexing

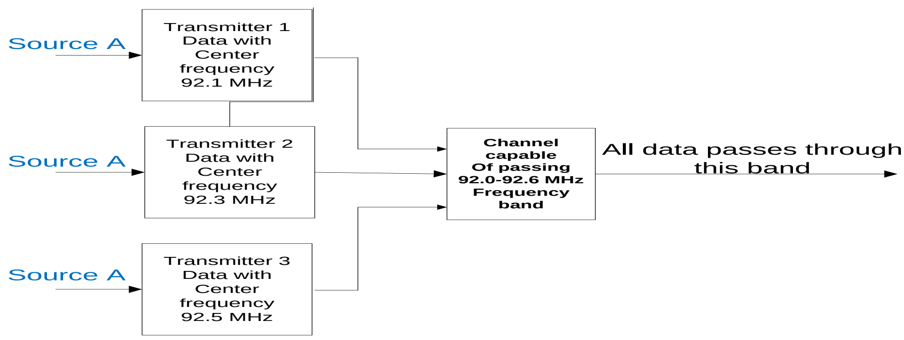

Figure 9: A system using frequency division multiplexing

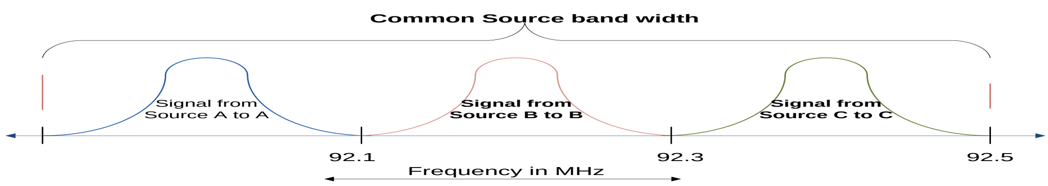

Figure 10: Spectral occupancy of signals in an FDM system

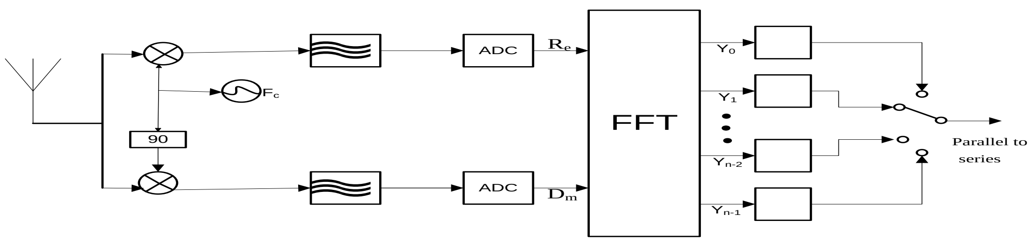

Figure 11: A transmitter architect with OFDM system

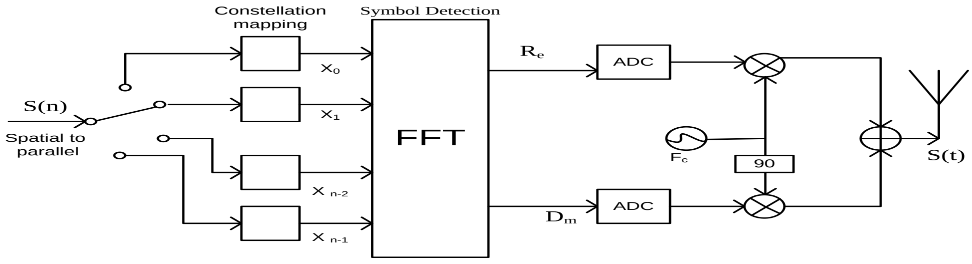

Figure 12: A receiver architect with OFDM system

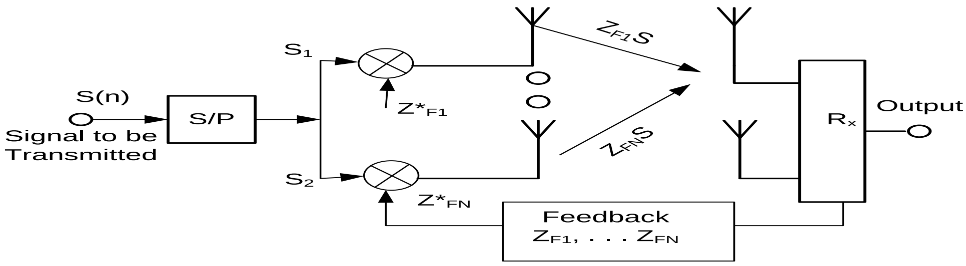

Figure 13: A block Diagram of a Spatial Multiplexing

5. DIVERSITY

In wireless communications, diversity is a method by which reliability can be improved using more than one communication channel. It improves the reliability of a data with reducing fading, co-channel interference and minimizing error bursts. [4]. Diversity techniques can be used as a multipath propagation and it is called diversity gain. In a channel with multiple transmit or receive antennas spaced sufficiently, diversity is such an important resource, a wireless system typically uses several types of diversity.

i. Time diversity
ii. Frequency diversity
iii. Space diversity
iv. Polarization diversity
v. Multiuser diversity

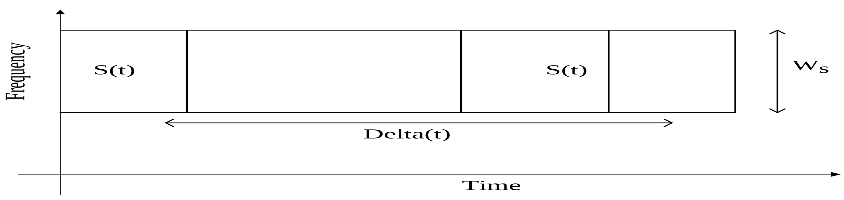

Figure 14: Time Diversity

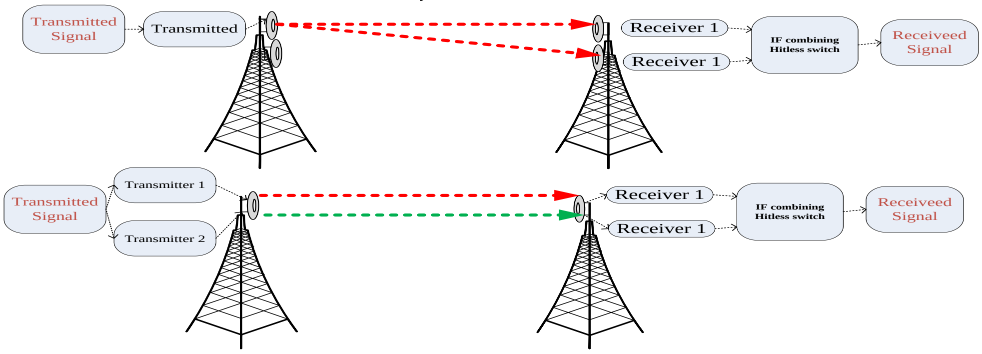

Figure 15: Frequency diversity in various antenna techniques

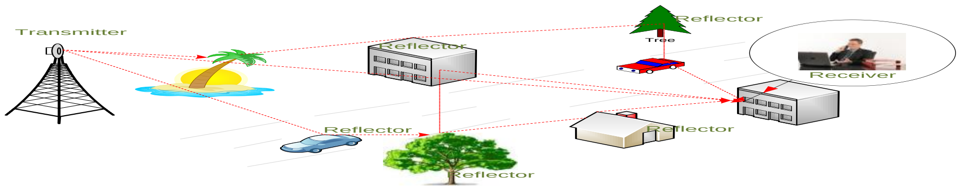

Figure 16: Signal faded or reflected in various object of multipath

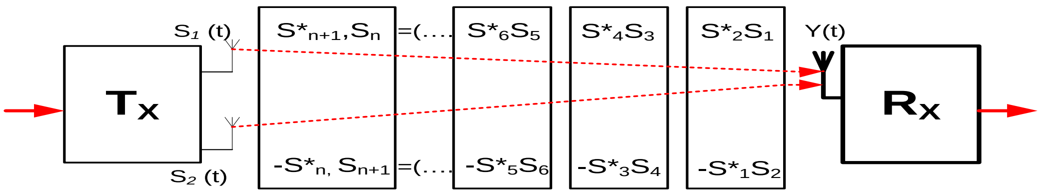

Figure 17: A simple block coding scheme used in the Alamouti scheme

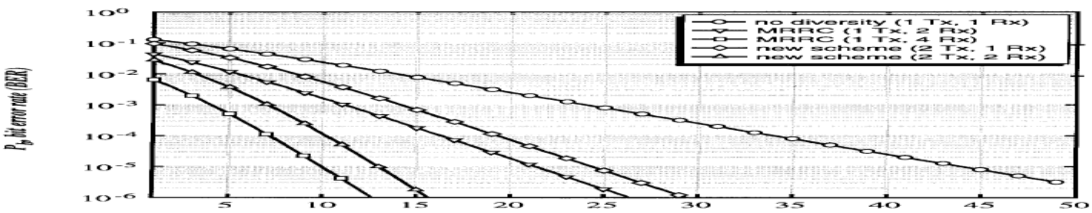

Figure 18: BER performance of Alamouti BPSK with MRRC STBC schemes under flat Rayleigh fading for various set of Antenna.

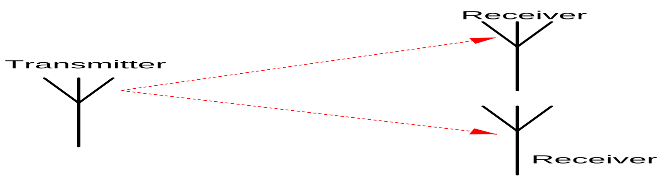

Figure 19: Receive diversity

6. MIMO CHANNEL

MIMO channel describes the connection between the transmitter (*Tx*) and receiver (*Rx*). In following, only 2 antennas at the *Tx* and 2 antennas at the *Rx* are considered, i.e. 2x2 MIMO system. Figure 20 illustrates a 2x2 MIMO system with the *H* channel matrix and the scattering medium around.

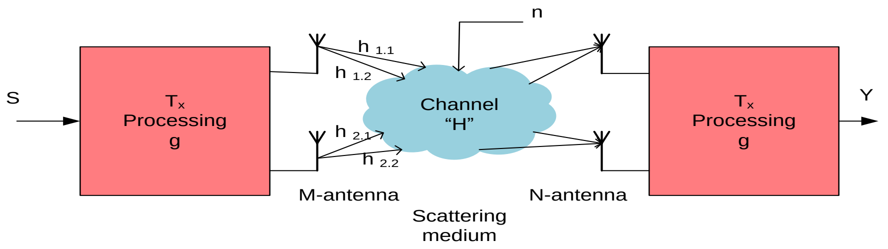

Figure 20: MIMO channel representation where M=N=2 represents Number of antenna at T_x and R_x, respectively.

For the above 2x2 MIMO channel, the input-output relationship can be expressed as $y(t) = H(t) * s(t) + n(t)$ (1)

Where *s(t)* is the transmitted signal, *y(t)* is the received signal, *n(t)* is additive white Gaussian noise (AWGN), *H(t)* is an *N* by *M* channel impulse response matrix and (*) denotes convolution. The channel matrix *H* fully describes the propagation channel between all transmits and receive antennas. The MIMO channel without noise and with representation of the channel matrix *H* can be expressed as: $H(\tau)=\sum_{l=1}^{L} H_l \delta(\tau - \tau_1)$

Where *L* is the number of taps (time bins) of the channel model, *H* (τ) is the *MxN* matrix of the channel impulse responses.

$$H(\tau) \in \mathbb{C}^{MxN} \Rightarrow H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$$

$H_l = [\alpha^1 MN]_{MxN}$ is a complex matrix which describes the linear transformation between two considered antenna arrays at delay τ_l and α^l_{MN} is the complex transmission coefficient from antenna *M* at the transmitter to antenna *N* at the receiver. The complex transmission coefficients are assumed to be zero mean complexes Gaussian.

Figure 21: The MIMO channel

7. STUDY ON MIMO SYSTEM

The study on MIMO is focused on the following two strategies:

i. Study on capacity improvement of MIMO
ii. Study to SNR improvement with BER

7.1 Study on Capacity improvement of MIMO

The capacity of MIMO system is highly depend on the selecting appropriate set of antennas array, Number of RF, different channel condition, beam forming ability. We show the results in various schemes of recent research on MIMO capacity. We try to find the best way to obtain the better capacity. The correlated channel has a larger capacity than the i.e. channel at the 2 dB SNR's below. So it is generally clear form that rich scattering environments are needed for optimal use of multiple antennas [5]. The capacity is 20 Bits/s/Hz at 20 dB SNR for using Uniform linear arrays of antennas at both end .So the capacity of the correlated channel can be approached by using beam forming inputs at low SNR's. It is shown that in the low SNR regime using the proposed limited feedback technique there is a gain over open loop BSMIMO systems of more than 2dB in the resulting SNR. In terms of from the above discussion we draw a comparison diagram and observe the capacity of MIMO system for using different scheme in MIMO.

Table 1: Comparison table of Capacity for using different schemes in MIMO

Different systems	Capacity (Bits/s/Hz) at 20 dB SNR
Uniform linear arrays of antennas at both end	20
Correlated Rician fading channel	22.5
Single RF at both end	11.8
Closed-loop BS-MIMO	11.5
Using HS-MRT	10.75
Optimum signaling scheme	12.3
Line link end to all available antennas and H-S in receiving side	22
Low complexity linear multiuser beam forming system	15

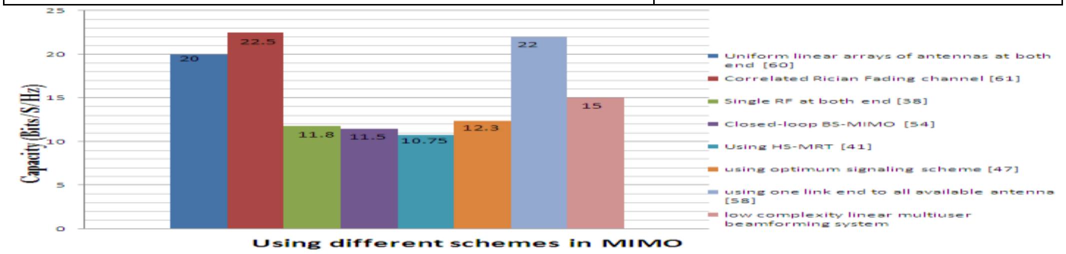

Figure 22: Comparison of Capacity for using different schemes in MIMO

7.2. Study on SNR improvement with BER

Study on SNR improvement with BER of a System means quantity of data bits that receiver receive over a channel distorted for the noise interference. The modern researches treys to reduce the BER with respect to SNR. Using HS/MRT approach at one link end and choosing 2 out of 8 receiving antenna, 10^{-5} BER occurred at 1db SNR. It is observed that selecting higher number of antenna is not efficient and performance is not differs much. Only additional 1.5 dB SNR gets for 8/8 antenna selection [6]. A new MU-MIMO with allowing more users in the same frequency and time slot propose good signal to leakage ratio. It offers 10^{-5} BER for 6.9 dB SNR. Another paper applies the concept of spatial diversity at transmitter and receiver. For this condition BER is 10^{-5} at 7 dB SNR. Alamouti coding method for systems over frequency selecting fading channels offers the BER 10-5 at 23.6 dB SNR. Switch diversity MIMO for the flat and quasi-static relay fading is also a new idea in MIMO systems. This technology provides the optimum BER at higher fading channels also in 11.8 dB SNR.

Table 2: Comparison table of BER for using various techniques in MIMO

Different system for gain 10^{-5} BER	SNR (dB)
Using HS-MRT	1
MU-MIMO allowing more user	6.9
Applying spatial diversity to MIMO system	7
In asynchronous cooperative communication system applying Alamouti coding method	23.6

We assume that 10^{-5} BER is the reasonable for the high faded environment. This table compares the Bit Error Rat (BER) of different MIMO system. It is known that SNR is inversely proportional to noise. So it is expected that same BER at lower SNR. Using HS/MRT approach at one link end and choosing 2 out of 8 receiving antenna offer the better BER at low 1 dB SNR. Then the MU-MIMO with allowing more users in the same frequency and time slot also offer good offer optimum BER at low value of SNR. Switch diversity MIMO and concept of diversity to MIMO system also give the optimal BER at high noised environment.

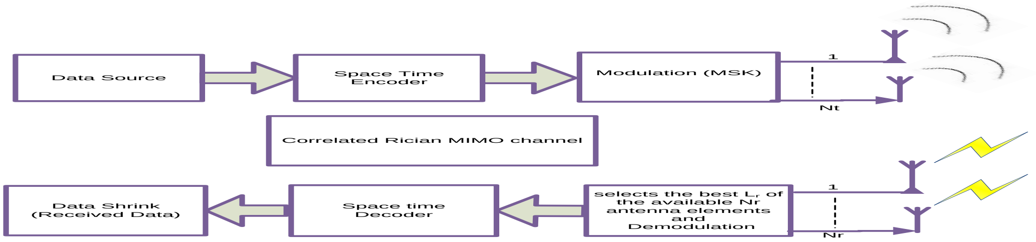

Figure 23: A new system with HS/MR transmission over the correlated rician MIMO flat fading wireless channel

8. TECHNIQUES USED TO ENHANCE THE PERFORMANCE

i. One line link end to all available antennas and hybrid selection in receiving side
ii. Correlated rician MIMO flat fades Wireless Channels where the receiver has knowledge of channel properties and transmitter has the behavior of channel statistics.

8.1. Hybrid selection/maximal-ratio transmission methods

In this system a bit stream is sent through a space time encoder whose outputs are forwarded to the N_t transmit antennas. In a real system, the signals are subsequently up-converted to pass band, amplified by a power amplifier, and filtered. For our model, we omit these stages, as well as their corresponding stages at the receiver, and treat the whole problem in equivalent baseband because of expensive and make the use of reduced-complexity systems desirable. The received signal, which is written as $Y = Hs + n = X + n$ is received by Nr antenna elements, where s is the transmit signal vector and n is the noise vector [7]. Then a control algorithm selects the best L_r of the available Nr antenna elements and down converts their signals for further processing (note that only L_r receiver chains are required). Space time encoder and decoder are assumed to be ideal so that the capacity can be achieved. We assume ideal knowledge of the channel at the receiver so that it is always possible to select the best antennas. However, we do not assume any knowledge of the channel at the transmitter. This implies that no water filling can be used and that the available transmitter power is equally distributed among the transmit antennas.

8.2. Correlated rician MIMO flat fading Wireless Channels

Some recent papers have investigated the capacity and corresponding optimal input distributions for correlated proper-complex Gaussian MIMO channel models. The outcome of these papers is the product-form correlation assumption, where the correlation between the fading of two distinct antenna pairs is the product of the corresponding transmit correlation and receive correlation. This correlation model is referred to as the Kronecker model in the literature. Unfortunately such a correlation structure is still quite restrictive, and can only be justified in scenarios where the scattering is locally rich at either the transmitter or the receiver.

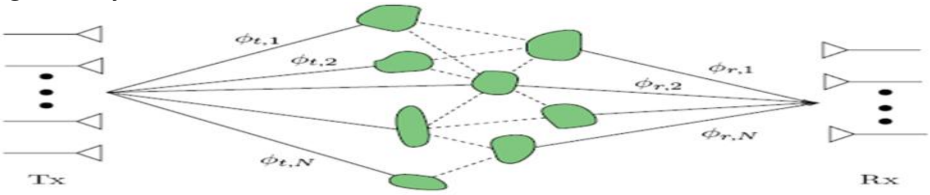

Figure 24: Physical model of a MIMO channel

The amplitude gain of Rician fading can be defined by Rician distribution [8]. Transmission is over a flat-fading Rician channel with t antennas at the transmitter and r antennas at the receiver. The vector of received symbols can be expressed as $y = Hx + n$

In Rician fading the elements of H are non-zero mean complex Gaussians. Hence we can express H in matrix $H = aH^{sp} + bH^{sc}$

Where H^{sp} is is a matrix of unit entries denoted as H1. And The Rician K-factor is defined as $10\log_{10}(a^2/b^2)\,dB$

The capacity of Rician fading channel is define as $C = \log_2(I + \frac{\rho}{t}\, HH^{*})$ where, t is the number of transmitter and ρ is the SNR at transmitter side. In correlated rician fading, channel of rician fading is correlated and the H^{sc} matrix can be modeled as $H^{sc} = R_r^{1/2} H_\omega R_t^{1/2}$

Here, R_r and R_t are the correlation matrix at the transmitter and at the receiver side, respectively. The correlation matrix is defined in. So, the channel matrix H can be written as

$$H = \sqrt{\frac{K}{K+1}} H_1 + \sqrt{\frac{1}{K+1}} H^{sc}$$

The capacity equation for the correlated rician fading channel is,

$$C = E_\lambda \left\{ \log_2 \left(I + \frac{SNR}{t} \lambda \right) \right\}$$

Where, λ is the positive eigenvalues of HH^H and E_λ is the expectation overλ.

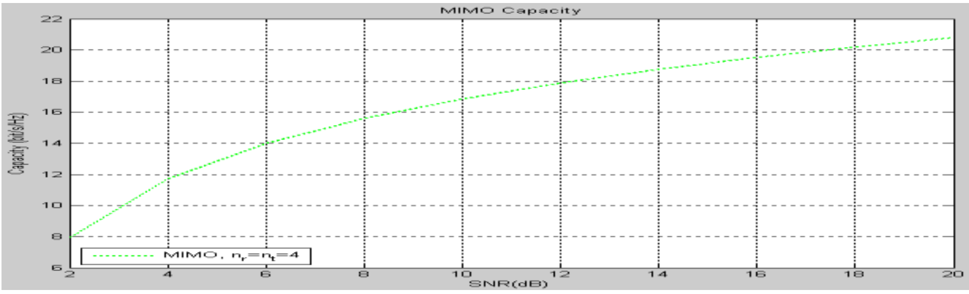

Figure 25: Output of capacity vs SNR for Correlated Ricien fading channel at n_r=n_t=4.

CONCLUSION

This paper has discussed most important portions of the MIMO wireless communication system and analytical review. This paper has mentioned different modulation technique (PSK, QPSK, BPSK, MSK, and ACM diversity technique (Time, Frequency, Space, Polarization and Multiuser diversity), channel capacity and technique to increase channel capacity.

- The important and concerning issue of MIMO wireless system and way of some limitation are shown in this paper.
- Hybrid selection technique can give us the new way to research to reduce the data loss in the high scatter and faded environment. Because day by day the environment will be more complex for data transmission.
- About to high data rate communication system correlate quasis-static channel agree to maintain current data rate but it is no still possible to implement practically.

REFERENCES

[1]. Bell Labs., Lucent Technol "*Smart antenna technologies for future wireless systems: trends and challenges*" Communications Magazine, IEEE, V: 42 , Issue: 9 , Sept. 2004

[2]. Cheolkyu Shin Hyounkuk Kim Kyeong Jin Kim Hyuncheol Park , Daejeon," *High-Throughput Low-Complexity Link Adaptation for MIMO BIC-OFDM Systems* " IEEE Transactions on, V.59, April 2011

[3]. H. Liao, H. Wang, and X.-G. Xia, "*Some designs and normalized diversity product upper bounds for lattice-based diagonal and full-rate space-time block codes*," IEEE Trans. Inform. Theory, vol. 55, no. 2, pp. 569-583, Feb. 2009.

[4]. Vlasis Barousis, Athanasios G. Kanatas, and George Efthymoglou " *A Complete MIMO System Built on a Single RF communication End*." PIERS ONLINE, VOL. 6, NO. 6, 2010

[5]. Bains, R.; Muller, R.R.; "*Using Parasitic Elements for Implementing the Rotating Antenna for MIMO Receivers*" Wireless Communications, IEEE Transactions on, Volume : 7, PP: 4522 – 4533, December 2008

[6]. Barousis, V.; Kanatas, A.G.; Kalis, A.; Papadias, C.; "*Closed-Loop Beamspace MIMO Systems with Low Hardware Complexity*" Vehicular Technology Conference, 2009. VTC Spring 2009. IEEE 69th, PP: 1 – 5, June 2009

[7]. Deepa , .baskaran, pratheek, aswath " *STUDY OF SPATIAL DIVERSITY SCHEMES IN MULTIPLE ANTENNA SYSTEMS*" Journal of Theoretical and Applied Information Technology 2005-2009

[8]. Youngpo Lee, Youngje Kim, Sun Yong Kim, Gyu-In Jee, Jin-Mo Yang, Seokho Yoon "*An Alamouti Coding Scheme for Relay-Based Cooperative Communication Systems*" The Third International Conference on Emerging Network Intelligence, 2011