Linear Transmit-Receive Strategies For Multi-User MIMO Wireless Communication

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Abstract - *MIMO is an acronmy for Multiple Input Multiple Output. This technology uses multiple antennas at the transmitter and at receiver in order to overcome the detrimental effects of signal multipath and fading when trying to achieve high data throughput in limited-bandwidth channels. MIMO system uses multiple signals to improve the quality and the reliability of transmitted data and also increase the capacity of the system. By introducing additional spatial channels which is exploited by using a coding technique known as Space Time Block Coding, the capacity of MIMO system is also enhanced. The channel capacity is evaluated as a function of SNR. Starting from AWGN channels, we bring out how fading, which is typically an undesirable phenomenon, can be gainfully exploited to attain large capacities under MIMO configuration.*

Key Words: **MIMO, DIVERSITY, FADING, CAPACITY, BANDWIDTH, SDMA.**

1. INTRODUCTION

The ever growing demand for reliable high data rates, enlarged coverage, and spectral efficiency in the existing third generation (3G) and fourth generation (4G) of mobile communication systems and future systems, has inspired intensive research efforts in the field of multi-user multiple-input multiple-output (MIMO) communications. In order to combat interference and exploit large multiplexing gains of the multi-antenna systems, a particular interest in spatial division multiple access (SDMA) techniques has emerged. Linear precoding techniques, as one of the SDMA strategies, have obtained more attention due to the fact that an increasing number of users and antennas involved into the existing and future mobile communication systems requires a simplification of the pre coding design. Therefore, this thesis contributes to the design of linear transmit and receive strategies for multi-user MIMO broadcast channels in a single cell and clustered multiple cells. We further quantify lower and upper bounds of the rate and power offset between them as a function of the system parameters such as the number of users and antennas. These analytical results are useful from the system design perspective. with the exception of our new method support a MIMO system with multiple users and multiple transmit antennas. In contrast, our new method solves this problem and can support a MIMO system with an arbitrary number of users and transmit antennas. Moreover, the application of our new method is not only for CBF, but also for blind source separation (BSS), since the same mathematical model has been used in BSS application. Our objective is to efficiently reduce the inter-cluster and intra-cluster interference and enhance the performance of the cluster edge users in terms of users' throughput. Finally, we present three strategies for channel state information (CSI) acquisition regarding various channel conditions and channel estimation strategies such as the time-varying correlated channel model, the finite rate feedback channel. The CSI knowledge is required at the base station in order to implement SDMA techniques. The quality of the obtained CSI heavily affects the system performance. The performance enhancement achieved by our new strategies has been demonstrated by numerical simulation results in terms of the system sum rate and the bit error rate.

1.1 CONCEPT OF MIMO

The most important technical breakthroughs in future wireless communication is the concept of using multiple transmit and receive antennas. The result of preliminary prototyping and research of MIMO systems have shown improvement in spectral efficiency in wireless communications. MIMO is thus a cardinal technology element for improving the throughput of wireless broadband information systems. In straight forward terms, MIMO uses multiple antennas at the transmitter and receiver to improve the performance of communication system, thus, a kind of smart antenna technology. [1] Without the need of additional bandwidth and transmit power, MIMO provide significant improvement in data throughput and link range, made possible by higher link reliability or diversity (reduced fading). MIMO emerged out as an essential component of latest wireless communication standards such as IEEE 802.11n (Wifi), IEEE 802.16e (WiMAX), 3GPP Long Term Evolution (LTE), 3GPP HSPA+, and 4G systems. Radio communication deploying MIMO systems introduces extra spatial channels which enable increased spectral efficiency for a given total transmit power by using space-time coding. Detection of MIMO techniques are based on VBLAST (Vertical Bells Lab Layered Space Time) architecture that also provide improvement in spectral efficiency.

2 FUNDAMENTALS OF MIMO

In order to transmit more information simultaneously Multiple-Input Multiple-Output (MIMO) technology makes use of multiple transmitters and receivers. MIMO technology is the wireless technology. The advantage of radio wave phenomenon called multipath is taken by MIMO technology where the transmitted data get refracted from the walls, ceilings and other object, arriving at the receiving antenna several times over different angles at different times.

MIMO technology make use of multipath behaviour by using multiple, "smart" transmitters and receivers with an added "spatial" dimension in order to increase range and performance. MIMO enable multiple antennas to send and receive multiple spatial streams at the same time. MIMO makes antennas work smarter by allowing them to combine information streams reaching from different paths and at different times to effectively improve receiver signal-capturing power. Smart antennas use spatial diversity technology, which puts surplus antennas to good use. If there are more antennas than multiple signal streams, the additional antennas can add receiver diversity and increase range coding opportunities.

2.1 Mimo-Basics

As a result of the utilization of multiple antennas, MIMO wireless technology is ready to significantly increase the capacity of the given channel. By increasing the amount of transmit and receive antenna it is possible to linearly increase the output of the channel with each pair of antennas added to the system. This makes MIMO wireless technology one amongst the foremost necessary wireless techniques used in recent years. As spectral bandwidth is changing into an ever a lot of valuable commodity for radio communication system, techniques are required to use the out there bandwidth a lot of effectively. MIMO wireless technology is one amongst those techniques.

2.2. MIMO

MIMO uses multiple antennas at the transmitter and the receiver that enable a number of signal paths to carry the information along the channel which choose the different path for each antenna to make the use of multiple signal paths to be used.

In MIMO wireless systems space-time signal processing, time is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas, i.e. the use of multiple antennas located at different points

From many years in order to improve wireless communication, MIMO wireless system can be viewed as a logical extension to the smart antennas. The signal can take many paths between transmitter and receiver. Also, the paths used will change if the antennas are moved even by a small distance. A large number of paths are available that occur as result of objects that appear to the side or even in the direct path between transmitter and receiver. Earlier these multiple paths were introduced only to serve interference. The advantage of MIMO is that these additional paths now can be used. MIMO provide additional robustness to the radio link either by increasing the data capacity or by improving the signal to noise ratio.

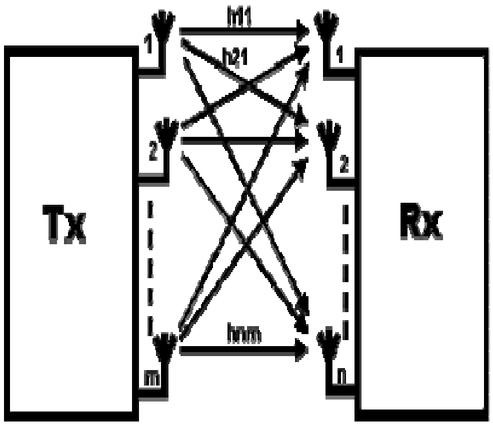

Fig 1 Multiple Input Multiple Output

2.3 Mimo Catogeries

MIMO can be sub-divided into three main categories

- Precoding,
- Spatial Multiplexing (SM),
- Diversity Coding.

1 Precoding

Precoding is multi-stream beamforming, within the narrowest definition. in additional general terms, it's considered to be all spatial process that happens at the transmitter. In (single-stream) beamforming, the same signal is emitted from every of the transmit antennas with appropriate phase and gain coefficient such the signal power is maximized at the receiver input.

3 Spatial Multiplexing

Spatial multiplexing needs MIMO antenna configuration. In spatial multiplexing,[2][3] a high-rate signal is split into multiple lower rate streams and every stream is transmitted from a unique transmit antenna within the same frequency channel. If these signals make the receiver antenna array with sufficiently totally different spatial signatures and also the receiver has correct CSI, it will separate these streams into (almost) parallel channels.

3 Diversity Coding

Diversity coding techniques are used where there's no channel information at the transmitter. In diversity ways, one stream (unlike multiple streams in spatial multiplexing) is transmitted, however, the signal is coded using techniques referred to as space-time coding. The signal is emitted from every of the transmit antennas with full or close to orthogonal coding.

2.3 Benefits Of Mimo Technology

- Multiple antenna configurations can be used to overcome the detrimental effects of multi- path and fading when trying to achieve high data throughput in limited-bandwidth channels
- Superior Data Rates, Range and Reliability

2.4 Mimo Channel Capacity

At the tip of the 1990s, pioneering works in Bell Labs showed for the first time that the utilization of multiple antennas at the either side of the transmission link may result in tremendous channel capacities, only if the propagation medium is rich scattering [4,5]. This increase in capacity is obtained without any need for further bandwidth or transmission power. Multipath propagation, earlierly considered an impediment to reliable communication, was shown to be exploitable for increasing the information output. In this section, we briefly describe by exploiting the spatial dimension how it will cause a rise in the system spectral efficiency. Only single-user applications are considered.

3 MIMO CHANNEL MODEL

Many different Multiple-input multiple-output channel models are introduced within the previous years. MIMO channel models may be divided into two, one physical and other analytical models. Physical channel models listen to the environmental characteristic and also the propagation of electromagnetic wave between the transmitter and also the receiver, additionally, they take care of the number of antennas at each end. On the opposite hand, analytical models don't give the site-specific descriptions so they are not going to take not take into consideration the wave propagation characteristics. The model impulse response is mathematically generated and associated with the statistical properties of the propagation environment. However, because of its simplicity, an analytical channel model is extremely helpful for manufacturing MIMO channel matrix for various reasonably communication systems

In literature, physical models will be distinguished into deterministic models [6] and geometry-based stochastic channel models [7]. deterministic models (such as ray-tracing and recording impulse response models) begin by making a synthetic environment. The channel response will be consequently calculated for simulation functions. however during this case, the calculation time is significantly high. Geometry-based stochastic channel models (GSCM) consider that the channel response is carried out by respecting the characteristic of wave propagation, each site-specific Tx-Rx environments, and scattering mechanism. All parameters are statistically defined to closely match the measured channel observation. The channel response will be rapidly computed for a single-bounce, double-bounce or multi-bounce scattering mechanism.
Analytical channel models will be further illustrated into correlation-based models, statistical cluster models, and propagation-based models. Correlation-based models contain the TX and Rx correlations overall channel matrixes. for instance, the i.i.d. model is proposed within the case of rich scattering environment with no spatial correlation result [4], [8].

4 FADING

The term fading, or, small-scale fading, means rapid fluctuations of the amplitudes, phases, or multipath delays of a radio signal over a short period or short travel distance. This might be so severe that large scale radio propagation loss effects might be ignored.

In wireless communication fading is variation of attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency. Fading is often modeled as a random process. A fading channel is a communication channel that experiences fading.

4.1 Multipath Fading Effects

In principle, the following are the main multipath effects:

1. Rapid changes in signal strength over a small travel distance or time interval.

2. Random frequency modulation due to varying Doppler shifts on different multipath signals.

3. Time dispersion or echoes caused by multipath propagation delays.

4.2 Factors Influencing Fading

The following physical factors influence small-scale fading in the radio propagation channel:

(1) Multipath propagation – Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. The effects of multipath include constructive and destructive interference, and phase shifting of the signal.

(2) Speed of the mobile – The relative motion between the base station and the mobile results in random frequency modulation due to different doppler shifts on each of the multipath components.

(3) Speed of surrounding objects – If objects in the radio channel are in motion, they induce a time varying Doppler shift on multipath components. If the surrounding objects move at a greater rate than the mobile, then this effect dominates fading.

(4) Transmission Bandwidth of the signal – If the transmitted radio signal bandwidth is greater than the "bandwidth" of the multipath channel (quanti- fied by coherence bandwidth), the received signal will be distorted.

5 DIVERSITY

In wireless communication the scheme of diversity refers to a technique for improving the reliability of message signal by using two or more different characteristic communication channels. Diversity plays a vital role in order to overcome fading and co channel interference and also avoiding error bursts. Transmitter sends multiple version of same signal that are received and combined in receiver.
Alternatively, a redundant forward error correction code may be added and different parts of the message may be transmitted over different channels.
In other words, a diversity scheme is a method that is used to develop information from several signals transmitted over independent fading path. This means that the diversity method requires that a number of transmission independent fading statistics. The mean signal strengths of the paths should be approximately the same. The basic requirement of the independent fading is that the received signals are uncorrelated. Therefore, the success of diversity schemes depends on the degree to which the signals on the different diversity branches are uncorrelated.
There are two types of diversity
1 Receive Diversity: Multiple antennas are use at the receiver to obtain diversity and employ switching and combining or selection intending to improve the quality of received signal. Since it is easier and cost effective to use multiple antennas at the base station than the terminal which is a positive manner of receive diversity. This technique may utilize channel state information (CSI) at receiver and it's fully fit for uplink which is remote to base. But the main problems of receive diversity are cost, size and necessary power at the remote units. This technique is larger in size and expensive in cost because of multiple antennas, radio frequency chains or selections and its switching circuits.

2 Transmit Diversity: Unlike receive diversity, transmit diversity needs multiple transmitting antennas. Moreover, unlike receive diversity, transmit diversity does not utilize CSI in its single information signal. Effective signal processing technique should be used to extract the noisy and distorted received signal in transmit diversity.

6 ANALYTICAL RESULTS

In MIMO channel, different factors or parameters exist such as fading, noise, phase shift. As a result the signal loses its strength before arriving at receiver. In order to recollect all the signal strength multiple antennas are used. In our case we are dealing with receive diversity i.e, single transmit antenna and multiple receive antenna.

First case: one transmitter and one receiver Simulation result:

As shown in figure 2 with one transmitter and one receiver, Eb/No and symbol rate is mentioned.

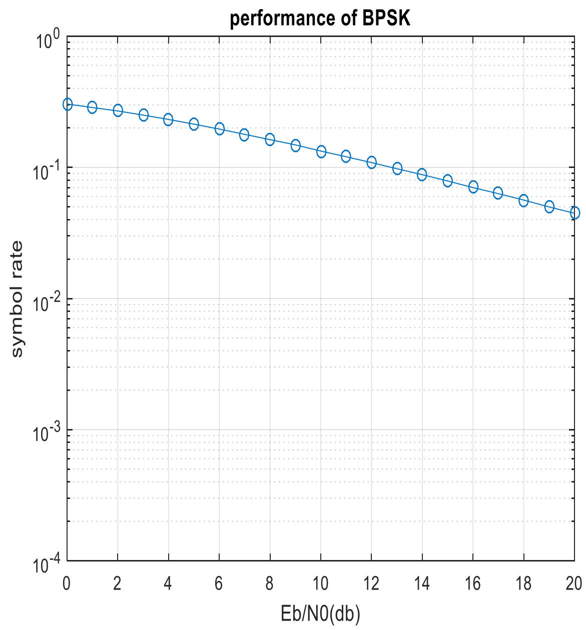

Fig 2: 1 Tx and 1Rx.

Second case: one transmitter and two receiver
Simulation result:

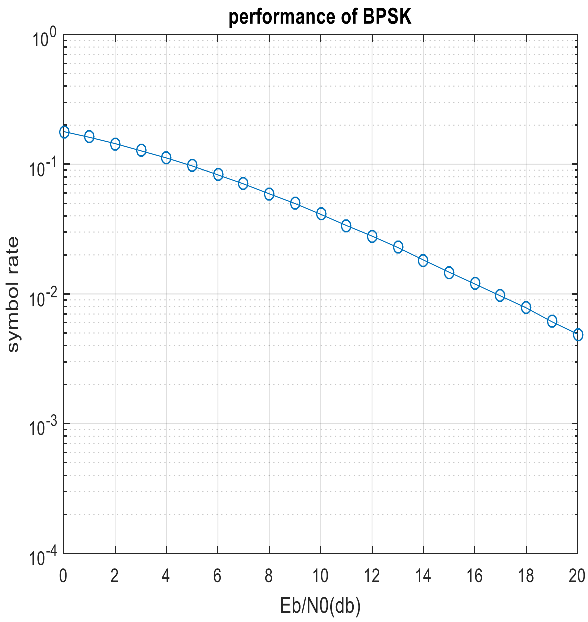

Fig 3: 1 Tx and 2 Rx

As shown in figure 3 with 1 transmitter and 2 receiver, Eb/N0 is improved with respect to first case.

Third case: one transmitter and three receiver
Simulation result:

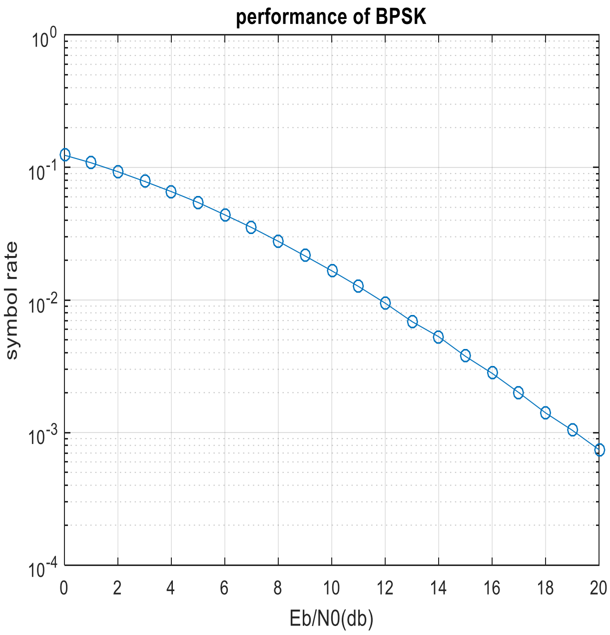

Fig 4: 1 Tx and 3 Rx

As shown in figure 4 with one transmitter and three receiver, Eb/No is improved compared to second case.

Fourth case: one transmitter and four receiver
Simulation result:

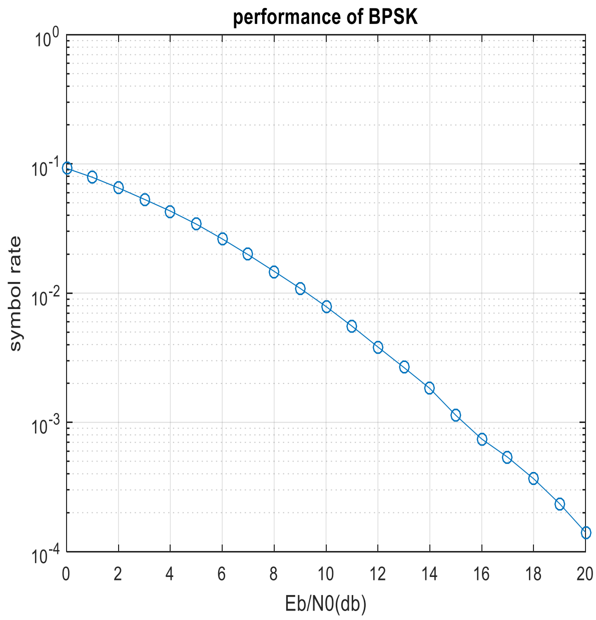

Fig 5: 1 Tx and 4 Rx

As shown in fig 5 with one transmitter and four receiver, Eb/No is improved much more as compared to all above three cases.

7 CONCLUSION

As the number of receiver increases the symbol rate is improved. There is a relationship between Eb/No and probability of error, as Eb/No increases probability of error decreases, and symbol rate is increased. We find that the result is better with more number of receivers than the transmitter. As a result of the use multiple antennas, MIMO wireless technology is able to considerably increase the capacity of a given channel while still obeying Shannon's law. By increasing the number of receive and transmit antennas it is possible to linearly increase the throughput of the channel with every pair of antennas added to the system. This makes MIMO wireless technology one of the most important wireless techniques to be employed in recent years. As spectral bandwidth is becoming an ever more valuable commodity for radio communications systems, techniques are needed to use the available bandwidth more effectively. MIMO wireless technology is one of these techniques.

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