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STUDY ON BER IMPROVEMENT IN MIMO SYSTEMS USING ADAPTIVE MODULATION

JENIFER.J.R[1], PREMNATH.S.P[2], ARUNACHALAPERUMAL.C[3]

PG Scholar, Dept of PG studies in Engineering, S.A Engineering College, Chennai, INDIA.[1]

PG Scholar, Dept of PG studies in Engineering, S.A Engineering College, Chennai, INDIA.[2]

Assistant professor, Dept of PG studies in Engineering, S.A Engineering College, Chennai, INDIA.[3]

ABSTRACT : ***Increasing demand in high transmission capacity has to be satisfied by a better use of existing frequency bands and channel conditions. One of the recent technical breakthroughs, which will be able to provide the necessary data rates, is the use of multiple antennas at both link ends. Spatial Modulation (SM) is used in wireless systems, which can offer good data rates and error performance with a moderately low system complexity. Adaptive modulation schemes for fading channels are usually required to fulfil certain long-term average BER targets. Performance of SSK modulation increases for increasing values of the target bit rate and of the number of antennas at the receiver. This modulation has the same robustness to channel estimation errors as conventional modulation schemes. Hence a new modulation called CoMP (Coordinated MultiPoint)–SSK modulation is proposed. CoMP-SSK modulation can provide very high bit rates at the cost of network cooperation. In this paper bit error rate performance of some popular modulation schemes have been studied and compared with their results.***

Keywords*:* Spatial modulation(SM), Space Shift Keying (SSK) modulation, Multiple-Input-Multiple-Output (MIMO), Coordinated MultiPoint (CoMP), (BER), adaptive modulation.

I. INTRODUCTION

Wireless communications undergoes a dramatically change in recent years. More and more people are using modern communication services, thus increasing the need for more capacity in transmissions. Since bandwidth is a limited resource, the strongly increased demand in high transmission capacity has to be satisfied by a better use of existing frequency bands and channel conditions. One of the recent technical breakthroughs, which will be able to provide the necessary data rates, is the use of multiple antennas at both link ends. These systems are referred to as multiple-input multiple-output (MIMO) wireless systems.

All radio communications systems, regardless of whether mobile radio networks like 3GPP UMTS or wireless radio networks like WLAN, must continually provide higher data rates. In addition to conventional methods, such as introducing higher modulation types or providing larger bandwidths, this is also being achieved by using multiple antenna systems (Multiple Input, Multiple Output – MIMO). A MIMO wireless system consists of N transmit antennas and M receive antennas. However, unlike phased array systems where a single information stream, say x(t), is transmitted on all transmitters and then received at the receiver antennas, MIMO systems transmit different information streams, say x(t), y(t), z(t), on each transmit antenna. These are independent information streams being sent simultaneously and in the same frequency band. At first glance, one might say that the transmitted signals interfere with one another. In reality, however, the signal arriving at each receiver antenna will be a linear combination of the N transmitted signals [1]. Thus, instead of sending only one signal at every time instant, i.e. time slot, N_t signals are transmitted at the same time instant using the same frequency band. As a result, the capacity of the overall system is linearly proportional to N_t, which is a considerable increase in the capacity and the spectral efficiency is improved as well.

MIMO systems can produce different gains such as array gain, diversity gain and multiplexing gain. Despite the fact that these gains compete each other, they may combined to increase the coverage area and to reduce the required transmit power. Assume that there are N_r receive antennas and only one transmit antenna, then the average SNR is approximately N_r , then it can be found that the coverage area is increased by a multiplicative factor $N_r\gamma$, where γ is the average SNR per branch. This can be used to increase the coverage area for a fixed transmitted power, or it can be used to reduce the transmitted power requirement for a given coverage area. Many techniques have been proposed to increase data rates in wireless systems without requiring additional power or bandwidth. Within this context, two of the most promising and powerful techniques are adaptive modulation and multiple-input multiple-output (MIMO) systems [2]. Moreover, adaptive modulation and MIMO can

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be combined to leverage both of their potentials. In addition MIMO beam forming can be easily combined with adaptive modulation since it can be reduced to an equivalent SISO (Single-input Single-Output) channels [3]. The remainder of analysed in Section IV. Finally, conclusions are provided in Section V.

II. SYSTEM MODEL

The system model for MIMO beam forming with MRC (Maximal Ratio Combiner) is shown in Fig. 1. The following channel model is assumed. We consider $N_T \geq 1$ this paper is organized as follows. Section II describes the system model. In Section III, the QAM, TOSD-SSK, CoMP-SSK adaptation policies are obtained, with their performance

transmit antennas and $N_R \geq 1$ receive antennas. Channel gain is modelled by the $N_R \times N_T$ complex matrix H, so that each entry H_{ij} denotes the channel gain between the jth transmit and the ith receive antenna. Transmit and receiver MIMO processing are as follows; the input data stream is mapped onto a single signal z (t) at the transmitter. The entries H_{ij} are assumed independent and identically distributed, zero mean and unity-variance. The received signal is expressed as

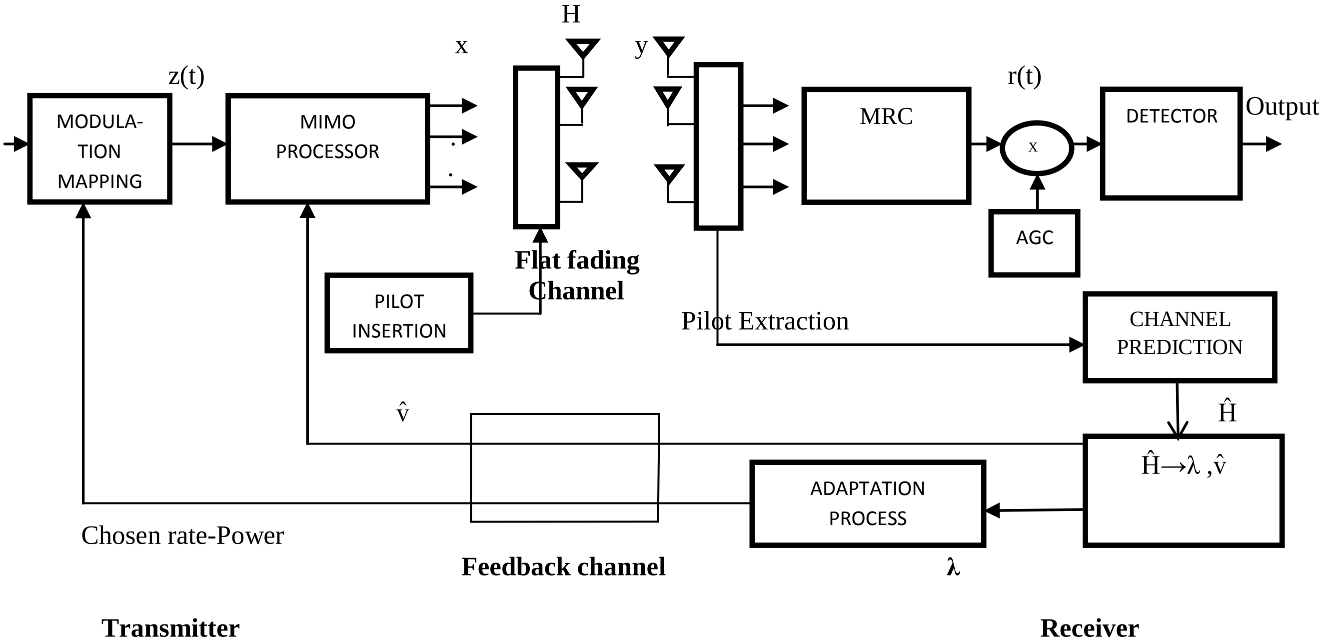

Fig 1. System model for MIMO Beam forming with MRC and imperfect CSI

$$y = Hx + n \qquad (1)$$

where y is an N_R- dimensional complex vector and x is the transmitted N_T- dimensional complex vector.

The N_T-dimensional $x = \hat{v}.z$ (t) is then sent across N_T antennas where $\hat{v}$ is the beam-steering vector with $\hat{v}^H\hat{v}=1$. To maximise the received SNR , $\hat{v}$ is chosen as the eigen vector corresponding to the largest eigenvalue λ of $\hat{H}^H\hat{H}$. At the receiver, MRC results in a single signal r (t) to be detected. Pilot symbols can be reused to perform very accurate noncausal channel estimation [2] for both the MRC and the automatic gain control (AGC). Thus, we assume perfect CSI for such signal processing at the receiver.

A. MIMO BEAMFORMING WITH MRC

Multiple-input multiple-output (MIMO) systems can provide increased reliability in wireless communication links by exploiting the spatial diversity due to the increased number of transmit-receive paths. A simple technique to obtain the highest possible diversity order is to employ transmit beam forming and receive combining, which simultaneously improves the array gain. This technique requires that the transmitter has channel state information in the form of a transmit beam forming vector. It is often impractical to have a reciprocal channel for the transmitter to estimate the channel, and thus a small number of bits are sent via a feedback path for the transmitter to recreate the beam forming vector. Such

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systems are known as limited feedback systems [4]. In these limited feedback systems, the transmitter and receiver share a codebook of possible beamforming vectors indexed by a number of bits. The receiver chooses a beam forming vector from the codebook on the basis of maximizing the effective signal-to-noise ratio (SNR) after combining, and sends the corresponding bits to the transmitter. At first maximum ratio transmission (MRT) is considered, where the beamforming vectors are constrained to have unit length, so that the energy expended in each packet transmission is unchanged. Secondly, we consider equal gain transmission (EGT), where the transmit power of each antenna is unaffected, and thus the amplifier requirements are not increased.

Unfortunately, the codebook size increases exponentially with the number of transmit antennas to maintain a given effective SNR or capacity loss with respect to the ideal unquantized system [4].The QAM codebooks are used for quantizing the ideal infinite-precision MRT vector, and since PSK symbols have equal envelope, the PSK codebooks are used for quantized EGT. Since QAM and PSK constellations have simple bit-to-symbol mapping algorithms no codebook storage is required at either the transmitter or receiver. To maximize the SNR, the receiver chooses the beamforming vector from the codebook according to

$$w = \arg\max_{v \in C} \frac{\|Hv\|^2}{\|v\|^2} \qquad (2)$$

and then sends the corresponding index bits to the transmitter. The beam forming scheme employing the ideal unquantized beam forming vector with $\|w\| = 1$ is known as maximum ratio transmission (MRT) [4].

B. TOSD-SSK MODULATION

TOSD-SSK modulation provides, even in the presence of channel estimation errors and with a single active antenna at the transmitter, a diversity order that is equal to 2Nr. This is achieved by using time-orthogonal shaping filters at the transmitter, which is an additional design constraint [5].

This modulation is to take advantage of multiple–antenna technology with a single Radio Frequency (RF) front end at the transmitter. The adoption of shaping filters that are not time–limited would require a number of RF chains that is equal to the number of signalling time-intervals T_m where the filter has a non-zero time response. Thus bandwidth-limited shaping filters would require multiple RF chains. TOSD–SSK modulation is more robust to channel estimation errors than the Alamouti scheme [6] and only few training pilots are needed to get reliable enough channel estimates for data detection.

TOSD–SSK modulations work as follows [7] i) the transmitter encodes blocks of $\log_2 (N_t)$ data bits into the index of a single transmit– antenna, which is switched on for data transmission while all the other antennas are kept silent and ii) the receiver solves an N_t hypothesis detection problem to estimate the transmit antenna that is not idle, which results in the estimation of the unique sequence of bits emitted by the encoder. This modulation is different from conventional Single– Input–Single–Output (SISO) schemes with Orthogonal Pulse Shape Modulation (OPSM), which are unable to achieve transmit–diversity as only a single wireless link is exploited for communication. Also, TOSD–SSK modulation is different from conventional transmit–diversity schemes, and requires no extra time–slots for transmit–diversity.

C. CoMP-SSK MODULATION

Coordinated multipoint (CoMP) or cooperative MIMO is one of the promising concepts to improve cell edge user data rate and spectral efficiency beyond what is possible with MIMO OFDM. COMP approaches need to exchange direct information between cells, with different requirements of necessary backhaul throughput and latency. This scheme requires the exchange of channel state information, control data, user data, and received signals, in a pre-processed or quantized format.

CoMP-SSK modulation can provide very high bit rates at the cost of network cooperation. The main idea is to share the antenna arrays of multiple transmitters, thus having a larger equivalent (virtual) antenna-array that can be used to encode a large number of information bits. $N_t=N_t^{BS}*N_t^{AR}$. It can transmit $\log_2(N_t)=\log_2(N_t^{BS})+\log_2(N_t^{AR})$ bits/time slot. With respect to conventional BS (Base Stations) cooperation methods, in CoMP–SSK modulation the backhaul has less stringent requirements as the coordinated BSs do not have to exchange data for cooperative beam forming, but the backhaul is used only for disseminating the information from the core network to the BSs. Furthermore, since the cooperative BSs do not perform distributed beam forming, no transmit–CSI is required, even though it might be beneficial.

CoMP can be implemented in two ways: centralized or distributed. In the centralized CoMP transmission concept, a central unit (CU) is the genius where all CSI and data are available. The CU pre-computes all waveforms and sends them over a star-like network to the coordinated base stations acting as remote radio heads (RRHs). For distributed CoMP transmission a limited set of BS transmit data jointly to multiple terminals in their cells. For each terminal, the serving BS coordinates the data flow coming from the advanced gateway (aGW) to the terminal. As a fundamental requirement of the distributed approach, BSs involved in a CoMP

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transmission exchange data and CSI over a meshed signaling network.

III. ANALYSIS

In TOSD-SSK if the percentage of energy that is required to be contained in the bandwidth (FPCB) is 99%, then the best shaping filter to use is the half–sine. But to reduce the interference produced in adjacent transmission bands, the requirement moves from 99% to 99.99999%, then the best shaping filters is orthogonal shaping filters. TOSD–SSK modulations have a SNR penalty, with respect to the P–CSI lower–bound, of approximately 3dB and 2dB when N_P=1 respectively [5]. It significantly outperforms SSK modulation, due to the transmit-diversity gain introduced by the orthogonal pulse shaping design. The Alamouti scheme is superior to TOSD–SSK modulation in the P–CSI scenario, but TOSD–SSK modulation provides better performance if N_P =1 and N_r > 1. This modulation is more robust than the Alamouti scheme to imperfect channel knowledge, and it provides better performance when the target spectral efficiency is greater than 2 bpcu. TOSD-SSK outperforms SSK modulation, due to the transmit-diversity gain introduced by the orthogonal pulse shaping design [5]. By increasing the number of antennas at the transmitter, spatial–multiplexing MIMO with QAM achieves, as expected, better performance than single antenna QAM. However, the price to pay for this performance improvement is, multi–stream decoding at the receiver [9].

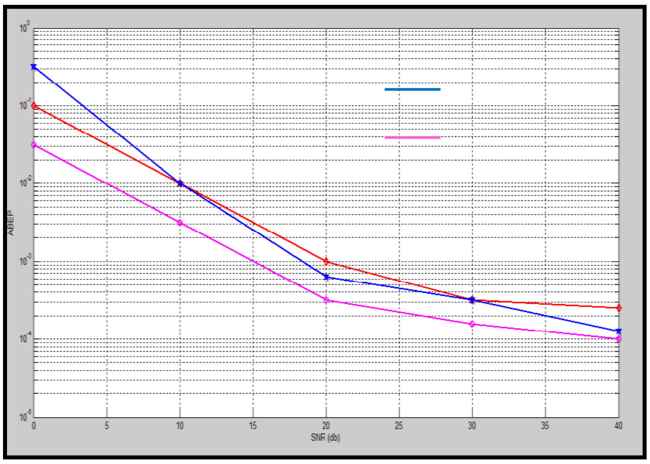

Fig 2.1 Comparison of different modulation schemes

Very interestingly, SSK modulation is never worse than spatial–multiplexing MIMO, even though SSK modulation needs just low–complexity single–user decoding. Fig. 2 depicts the comparison of the performance of QAM, SSK, TOSD-SSK and CoMP-SSK modulations for various target bit rates. QAM and PSK modulation outperform SSK modulation only if the bit rate if less than 2 bits/s/Hz, and SSK modulation always outperforms GSSK modulation [9]. Also, the higher the target bit rate is, the larger the gap is. If N_r = 3 there is a non–negligible performance gain, if the bit rate if greater than 2 bits/s/Hz, provided by SSK modulation with respect to QAM [9]. The price to be paid is, of course, the need to exploit the CoMP principle to achieve very high bit rates, e.g., when N_t = 64. If N_r = 1 i.e (if a single user scenario is considered and the receiver can be equipped with only one receive antenna), then QAM is always superior to SSK modulation, while SSK modulation is better than PSK and GSSK modulations. In all other cases, SSK modulation is superior to QAM. Finally ABEP for very high bit rates (CoMP–SSK have a large number of cooperative BSs) there is a significant performance gain of SSK modulation with respect to all the other modulation schemes.

IV. CONCLUSION

In this paper, the performance of various modulation schemes is being analysed. A comprehensive performance comparison of QAM, SSK, TOSD-SSK and CoMP-SSK modulations with respect to signal to noise ratio and average bit error probability is done. These results confirm that the new adaptive modulation technique called CoMP-SSK modulation can provide a good BER performance when compared to other conventional modulation schemes. In this proposed modulation scheme cooperative BSs do not perform distributed beamforming, hence no transmit-CSI is required even though it might be beneficial.

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