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Ber Performance Comparison Of Space-Shift Keying In Cooperative Multihop Mimo System

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Abstract: *Space-shift keying (SSK) is considered for multihop multiple-input-multiple-output (MIMO) networks. In SSK, only one among ns = 2^m available transmit antennas, Here 'm' input bits are mapped through antenna index values. The number of bits can be SSK modulated depends on number of transmitter antenna used in MIMO. We consider two different systems of multihop cooperation, where each node has multiple antennas and employs SSK. In system I, a multihop diversity relaying scheme and system II, a multihop multibranch relaying scheme is considered. In both systems, we adopt decode-and-forward (DF) relaying, where each relay forwards the signal only and received signals will be easily reconstructed based on its Euclidean distance values. We analyze the performance of space-shift keying and end-to-end bit error rate (BER) and diversity order of both the systems with SSK. MIMO cooperative multihop relay networks with the maximum available diversity. To prove the efficiency of relay based SSK MIMO over MIMO with phase-shift keying (PSK) modulation, Analyze its performance with various level diversity. Our analytical BER expression is exact, and our numerical results show that the BERs evaluated through the analytical expression. We show the comparison of the BERs of SSK and conventional phase-shift keying (PSK) and also show the instances where SSK outperforms PSK. We also present the diversity analyses for SSK in systems I and II, which predict the achievable diversity orders as a function of system parameters.*

I. INTRODUCTION

Wireless communication is one of the most vibrant areas in the communication field today. The past decade has seen a surge of research activities in the area. This is due to a confluence of several factors. First, there has been an explosive increase in demand for tether less connectivity, driven so far mainly by cellular telephony but expected to be soon eclipsed by wireless data applications.

This is an antenna technology which uses multiple channels in radios to provide the functions of both the transmitter and receiver of data signals sent over the network. It provides high spectral efficiency and link reliability facilitating significant increase in the data throughput and radio link usage without additional bandwidth and transmission power. This high efficiency is due to the availability of an independent path in a rich scattering environment for each transmitter and receiver antennas in the radio.

The MIMO channels can be used with OFDMA for transmission and reception of modulated signal over network to single or multiple users. This is currently used in WLAN – Wi-Fi 802.11n, Mesh Networks (e.g., WMAN– WiMAX 802.16e, RFID, and Digital Home).

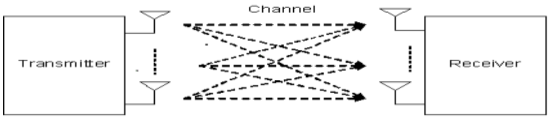

Fig.1 MIMO transceiver

In point-to-point multiple-input multiple-output (MIMO) systems, a transmitter equipped with multiple antennas communicates with a receiver that has multiple antennas. Most classic precoding results assume narrowband, slowly fading channels, meaning that the channel for a certain period of time can be described by a single channel matrix which does not change faster. In practice, such channels can be achieved, for example, through OFDM. The precoding strategy that maximizes the throughput, called channel capacity, depends on the channel state information available in the system.

This is the variant antenna technology that enhances the communication capabilities of the individual radio terminal used by radios in the network by introducing multiple independent radio terminals. This allows transmission and reception to and from multiple users using the same band.

The two-way MIMO relay channel extends the traditional two-way half-duplex relay channel to multiple antennas at each of the terminals. The channel is studied in several works, and the most studied relaying schemes for this channel are Decode-andForward (DF) and Precode-and-Forward (PF) schemes. The system model consists of two terminals, equipped with M antennas, and the objective is to exchanging messages. There is no direct link between the terminals, and communication is solely done through a relay with M antennas.

The channel matrices from terminal i, with i ∈ {1, 2} , to the relay are denoted Hi and reciprocal channels are assumed in the BC phase, i.e. HTi from the relay to terminal i. The time is divided into n channel uses, and the division constant τ divides these channel uses into a MA- and a BC-phase of nMA = bτnc and nBC = n − nMA channel uses, respectively. In the MAphase, terminal i transmits the signal xi ∈ CM×nMA , which satisfies the power constraint1

$$nMAxHi\ xi \leq Pi.$$

The relay then receives

$$y_R=H_1x_1+H_2x_2+z$$

Decode-and-forward (DF) DF decodes the codewords from each terminal in the end of the MA-phase. In the BC-phase, the relay reencodes the information into a codeword xR ∈ CM×nBC , such that, upon reception at the terminals, each terminal can reconstruct the message from the opposite terminal using its contribution to the reencoded signal as side information. In the MA-phase, to decode the codewords from the terminals, the MA-phase forms a MA channel, and hence the codewords can be decoded at rates satisfying

$$R_i\leq{}^{\prime\prime}I\log_2[I_M+H_iQ_iH_i^H]$$

where Qi denotes the covariance matrices of xi . In the BC-phase, the channel is known as a broadcast channel with side information at the receiver and the channel, where the following rate constraints are found Precode-and-Forward (PF) The precode-and-forward scheme extends the AF scheme to MIMO.

Upon reception in the end of the MA-phase, the relay left multiplies a relay precode matrix, GR ∈ CM×M onto the received signal yR to obtain xR. This implies that nMA = nBC and hence τ =1/2

The terminals then receive

$$y_i=H_i^TG_R(H_1x_1+H_2x_2+z)+w_i$$

Each of the terminals may cancel their own contribution, and in that way the scheme essentially creates a point-to-point MIMO channels in each direction between the two terminals.

The achievable rate of the communication flow from i to i is hence given by where ½ in front originates from the fact the communication is performed in two phases of ½ n channel uses. A performance metric can then be optimized over the covariance matrices Qi and the relay precode matrix GR. And hence difficult to solve. Various relaxation are performed in literature in order to obtain a solution. alternate optimization between the covariance matrices and the relay precode matrix is used, i.e. optimization alternates between optimizing with respect to Qi with GR fixed and with respect GR with Qi fixed.

The obvious advantage of PF is that the relay mapping is a per-channel use mapping, and hence significantly less complex than DF. Moreover, the behavior of PF at high SNR is also better, since the scheme achieves 1/2M DoF.

In this section, the results for the Four-way MIMO relay channel, one of the three sub networks identified are summarized. Where a DF relaying scheme is developed. The system consists of two terminals with two-way communication, two relays and one base station.

The aim of the base station is to serve the two terminals, through the relays, assuming that there are no direct links. In the MA-phase of nMA channel uses, the base station and the terminals transmit simultaneously such that the relay is can decode the codeword's from the base station and the terminals. In order to avoid interference at the relay, the base station uses zero-forcing. Let xB ∈ C2M×nMA denote the signal transmitted by the base station during the MA-phase, and let ui ∈ CM×nMA be the signal carrying the message to terminal i. To avoid relay i to receive a superposition of the signals uB1 and uB2 , the base station uses a precode matrices GBi such that

$$xB = GB1u1 + GB2u2.$$

Where Qi and QBi are the covariance matrices of xi and uBi , respectively. In the BC-phase of nBC channel uses, after decoding each of the code words from the MA-phase, the messages are re encoded into code words xRi ∈ CM×nBC which are broadcast to the terminals.

II. SYSTEM MODEL

MULTIHOP DIVERSITY RELAYING

In this section, it will be attempted to illustrate how SM works. We have all the possible cases of 4 bits transmission. When one antenna is employed then a 16-Quadrature Amplitude Modulation (16-QAM) constellation signal will be used so as to map bits into symbols. In the case now that 2 antennas are deployed each antenna will be designated to transmit a lower constellation signal namely an 8-QAM. The map of bits to constellation symbols in the simulations follows the Gray coding.

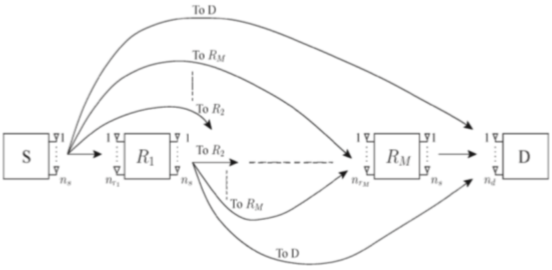

Fig.2 System I: Multihop diversity relaying scheme

When the number of antennas increases, the constellation order decreases. Thus, there is a trade-off between the number of antennas and the constellation signal used. Apparently, any number of antennas can be used with any constellation signal.

MULTIHOP MULTIBRANCH RELAYING

The multihop multibranch relaying system (referred to as system II)considered in this section is shown in Fig. 3.4 .In this system, the source node S communicates with the destination node D through a direct link as well as multiple multihop links. The system consists of L + 1 diversity branches, denoted by B0,B1,...,B l, connecting S and D. Branch B0 denotes the direct S-to-D link. Branch Bl, l = 1,...,L has Kl hops between S and D with one relay in each hop. The kth hop relay in branch Bl is denoted as Rk,l. Unlike in system I considered in the previous section, in system II, the signal transmitted from the source can be heard only by the relay nodes in the first hop of all branches, i.e., R1,l : l = 1,...,L. Moreover, the relays that are not in the first hop from S can receive the signal only from their corresponding previous hop relays, i.e., in the branch Bl, Rk,l : k = 2,...,K l receives signal from Rk−1,l only. Only the last hop relays in each branch, i.e., RKl,l : l = 1,...,L, forward signal to D. The source and relays are each equipped with ns transmit antennas. The relay Rk,l and the destination D are equipped nrk,l and nd receive antennas, respectively.

Relaying aided cooperative SM architecture, where SM is invoked at the SN and the information bit stream is divided into two different sets: the bits transmitted through the antenna indices (AI) and the APM constellations. For simplicity, we refer to these two sets of bits as AI-bits and APM bits. In contrast to the conventional AF-based SSK and DF-based STSK schemes our proposed DF-aided SM scheme assigns the relayed bits flexibly, in order to exploit the spatial dimension of the SD and relay destination (RD) links.

When Coded Cooperation is used cooperation and channel coding are combined. The rationale is that each user‘s bits are split and send to the destination through two different fading channels. Each partner receives incremental redundancy from its intended user, under the assumption that this is done properly. In case not, users do not cooperate with each other. The basic advantage is that all this is achieved through code design, thus no feedback is essential among the users and their partners.

By taking advantage of the properties of Cyclic Redundancy Codes (CRC), each user enciphers K source bits using a concatenation of CRC codes Cooperation is accomplished by initially sending the first frame of N1 bits and the proposed users detect and decode what has been sent. Under the assumption that bits are correctly detected and decoded, partners using the properties of CRC codes are attempting to calculate the remaining N2 bits of the source block. If bits are not properly decoded then no cooperation can be completed and users revert back to the non-cooperative mode.

Eventually a total of N bits are transmitted and the level of cooperation can be named as N2 N . With Coded Cooperation incorrect data are thwarted from being send leading to significant performance enhancement. Moreover, during the second frame users are surely independent from each other, requiring no knowledge of whether their own data was successfully decoded by their partner

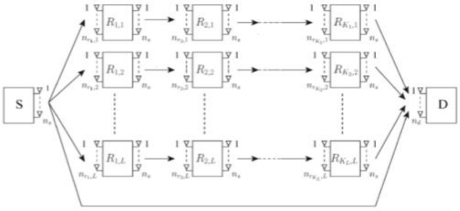

Fig.3 System II: Multihop multibranch relaying scheme

HM-BASED RELAY MODEL

During the cooperative phase of the RN relies on CRC-activated DF transmissions 1. More specifically, if any detection errors are identified by the CRC, the RN refrains from relaying the signals to the DN and the SN retransmits the corresponding frame during the broadcast phase.

By contrast, if the RN flawlessly detects the received signals **Y**SR(i) of (1), it re-modulates the detected bits using diverse relaying schemes. For example, the perfectly detected and hence retransmitted bits of the RN may be conveyed to the DN by using an ˜L - APM scheme, which may be different from the APM scheme adopted at the SN for SM. As a further benefit, because only a single antenna is utilized at the RN, the employment of multiple RF chains and tight IRS can be avoided. In this treatise, we consider HM-based DeF and its simplification forms: the partial and hybrid relaying schemes.

HYBRID DF RELAYING

In order to achieve a high spatial diversity gain, a hybrid DF (H-DF) relaying scheme may be conceived, which forwards the AI-bits plus either all or a fraction of the APM-bits from the RN. This H-DF relaying scheme creates subsets containing all the AI-bits and the log (L_) number of APM-bits from the SN. This selection is based on the fact that the AI-bits are slightly more vulnerable than the APM-bits in terms of the BER of SM-based systems.

The hybrid DF-based relay detects and forwards one of the three subsets: the AI-bits and the two lower-BER QAM bits; the AI-bits and the two higher-BER QAM bits; the AI-bits and all the four QAM-bits.

III. PERFORMANCE ANALYSIS

To understand the properties of the STC, we will give an overview on the performance analysis first developed by Tarokh and Vucetic . For the performance analysis of STCs it is important to evaluate the pair wise error probability (PEP). The pair wise error probability P**(S,ˆS)** is the probability that the decoder selects a codeword ˆs= [ˆs1, ˆs2, · · · , ˆsN], when the transmitted codeword was in fact S = [s1, s2, · · · , sN] ≠ ˆS. Assuming that the matrix H = [h1, h2, . . . , hN] is known, than the conditional pair wise error probability is given as:

$$\mathbf{P(S,\hat{S})} \quad = \quad Q\sqrt{\frac{Es}{2H}\, d^{\wedge}2H(S,S^{\wedge})}$$

Where d2H(S,ˆS) is given by

$$\mathbf{d2H(S,\hat{S}) = \|H(\hat{S} - S)\|^{\wedge}2.F}$$

Where Es is the energy per symbol at each transmit antenna, N0 is noise power spectral density and Q(x) is the complementary error function defined by:

$$Q(x) = 1/\sqrt{2\pi}\int_{x}^{\infty} e^{\wedge}{-t2/2}\ \mathrm{dt}.$$

By applying the bound

$$\mathbf{Q(x) \leq 1/2\ e^{\wedge}{-x2/2},\ x > 0}$$

The PEP 8 in 6 becomes

$$\mathbf{P(S,\hat{S}\ |H) \leq 1/2\exp(-\ d2H(S,\hat{S})Es/4N0)}.$$

MAXIMUM LIKELIHOOD (ML) DETECTOR

The resultant DF-SM is capable of striking a flexible tradeoff in terms of the achievable BER, complexity and unequal error protection .Moreover, by exploiting the benefits of our low-complexity relaying protocols and inter-element interference (IEI) model, the destination node (DN) is capable of jointly detecting the signal received from the SD and RD links using the proposed low-complexity maximum-likelihood (ML) detector. In this DeF-SM, the DN should jointly detected both the SD signals of (2) and the RD signals of (9) for achieving a beneficial cooperative diversity gain.

In many cases an optimal single-stream ML detector was proposed for conventional SM systems. Here, we extend it to the cooperative DeFSM receiver by exploiting our low-complexity relaying protocol and the IEI system model at the SN. With the added benefit of relaying, typically a good BER performance is expected.

The ML Detector is the optimum detector once the probability of error is minimized. The noise terms at the receiving antennas are statistically independent, identically distributed, zero mean Gaussian and therefore, joint conditional probability density function P y s (/) is Gaussian. Hence, the detector opts for the symbol vector that minimizes the Euclidean distance metric.

$$\mu(s) = \sum_{m=1}^{N_r} | y_m - \sum_{n=1}^{N_t} h_{nm} s_n |^2$$

IV. NUMERICAL RESULTS

BER PERFORMANCE OF SSK MODULATION

Here, we present the analytical and simulated BER plots that demonstrate the BER performance of SSK in multihop system and validate the analysis presented in the previous sections. For the purpose of comparison, we have also shown the BER versus SNR plot for SSK in the fixed DF relaying scheme, where all the relays forward the decoded signal irrespective of whether they decode the signal correctly or not. It can be seen that i) the BER plots obtained through analysis and simulation match exactly, and ii) the relaying scheme adopted in this paper outperforms the fixed DF relaying scheme in the BER plots obtained through analysis and simulation match exactly, thus validating the analysis. This figure further depicts that with increasing number of relays in the multihop network, the required SNR to achieve a given endto- end BER gets reduced.

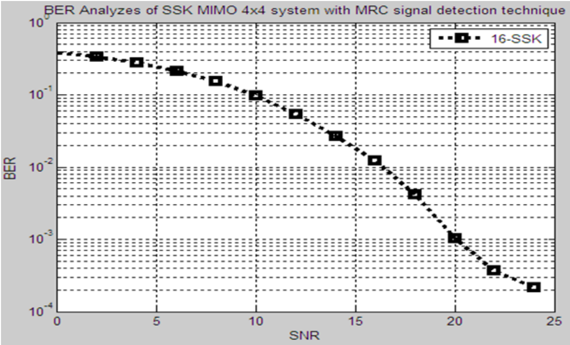

Fig.4 BER performance of SSK modulation

Here input bits are mapped through antenna index values using SSK modulation. Compare to QPSK with MIMO based diversity SSK modulated symbols will attain better QOS without having any diversity.

PERFORMANCE OF SSK MODULATION WITH MULTI-BRANCH

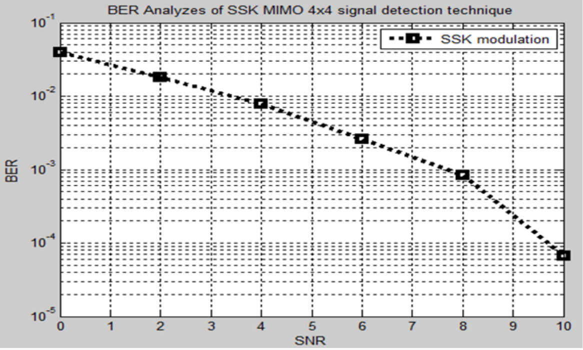

Fig.5 BER performance of SSK modulation with multi-branch

From the figure we conclude that multi branch MIMO based SSK modulation will give better QoS. Without diversity attainable QoS will be in the range of 20-25 SNR rate. But with diversity QoS is attained at SNR=8.

BER PERFORMANCE OF MIMO OVER 64- QAM MODULATION

Here with maximum constellation order without maximum MIMO diversity there is no QOS even with maximum signal energy(SNR). MIMO with 4x4 will give considerable BER reduction.

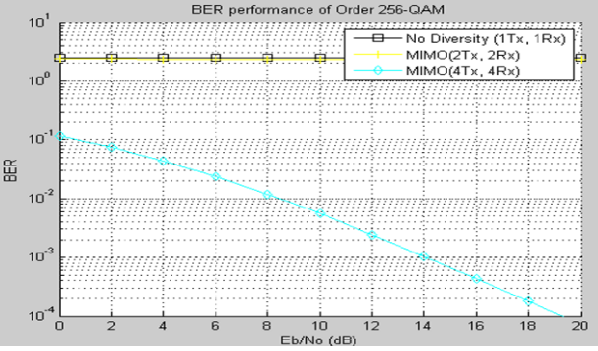

Fig.6 BER performance of MIMO over 4-QPSK modulations

BER PERFORMANCE OF MIMO OVER PSK MODULATIONS

From the figure we conclude that MIMO with 2 x 2 and 4x4 will give almost same BER performance over QPSK modulations. But there is considerable BER performance enhancement for MIMO over without diversity.

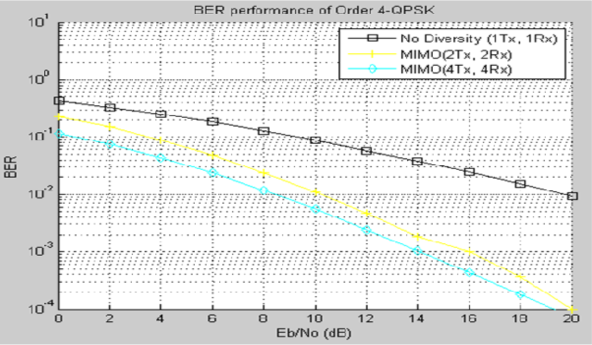

Fig.7 BER performance of MIMO over 4-QPSK modulations

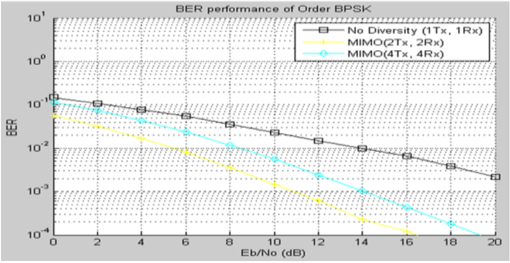

Fig.8 BER performance of MIMO over BPSK modulations

With least mapping rate like BPSK there is no significant BER performance change even with increase diversity with maximum antenna’s.

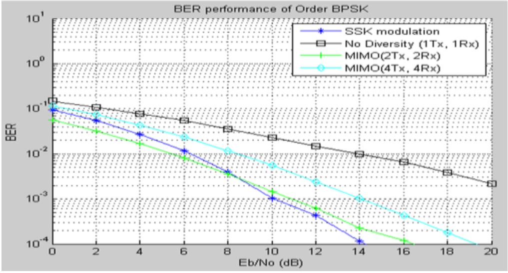

Fig.9 BER performance of MIMO over BPSK modulations on diversity

There is considerable BER performance enhancement for SSK-MIMO with dynamic SNR range.

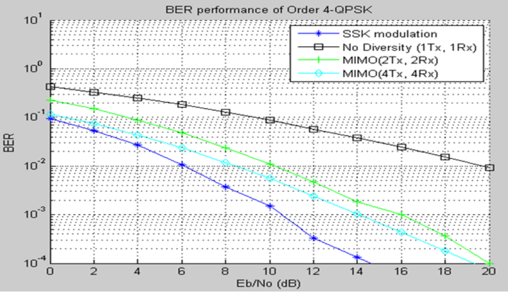

Fig.10 BER performance of MIMO over 4-QPSK modulations on diversity

Here SSK based modulation type will give better BER rate as compared to QPSK modulation with maximum diversity. The performance of MIMO cooperative system with time varying constellation points for better trade off between QoS vs. bit rate.

V. CONCLUSION

In this paper, we analyze performance of a cooperative system with multiple parallel relays using “Detect-and-Forward” (DF) strategy where each relay demodulates the overheard signal and forwards the detected words into destination. The proposed method is based on SSK modulation(SM) at the source node (SN) and the information bit stream is divided into different antenna index sets: the antenna index-bits (AI-bits) as well as the amplitude (QAM-modulation) and phase modulation (PSK-modulation)-bits. First, we derive analytical expressions of the elementary two-hop DF relay channel with different source-relay channel state information assumptions. Then, we apply the obtained expressions to calculate the theoretically achievable rates and compare them with the theoretical values of a simulated transmission. The approximations for the end-to-end coded bit error rate (BER) of a general cooperative scheme with multiple parallel relays. Simulation results demonstrate the accuracy of our derivations for different cooperation configurations and conditions.

Future work, This scheme can be extended to determine the most appropriate number of antennas to be used & to determine the most appropriate number of relay required to re-modulate the symbols by carefully considering their potential benefits and then assigning a specific modulation scheme for relaying the message. As a further benefit, the employment of more diversity to prove the efficiency of this system in high mobility channel with moderate Doppler shift.

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