Generalized Block-Based Spatial Modulation and Space Shift Keying

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***Abstract*—Spatial modulation (SM) uses the spatial dimensions (antenna indices) to transmit information along with the conventional modulation symbols. The SM scheme fixes the number of active antennas in a transmit vector. The block-based spatial modulation (BSM) varies the number of active antennas in each transmit vector, but keeps the total number of active antennas over a block fixed. This work generalizes the BSM scheme by better utilization of spatial dimension to achieve a higher data rate and lower bit error rate (BER). We also extend the proposed generalized block-based scheme to space shift keying to improve its data rate and BER performance.**

***Index Terms*—Block patterns, space shift keying (SSK), spatial modulation (SM).**

I. Introduction

THE schemes that transmit information bits over the indices of the spatial dimension have recently attracted significant research attention [1]–[4]. The generalized space shift keying (GSSK) scheme maps information bits over the antenna-patterns alone [1], while the generalized spatial modulation (GSM) scheme maps information bits by first using antenna-patterns, and then by transmitting M-ary symbols from the active antennas in the antenna patterns [3], [4].

Both GSSK and GSM schemes use fixed number of active antennas in a single transmit vector to encode information. The full potential of these schemes can be achieved if the number of active antennas can be varied [5]. The variable number of active antennas, however, leads to "detection ambiguity" at the receiver due to lack of information about the number of active antennas, which severely degrades the system performance [6].

We recently proposed a new block-based SM (BSM) scheme in [6] that varies the number of active antennas and transmits multiple M-ary symbols from them. This scheme encodes information bits over a block of transmit-vectors, where each transmit vector uses arbitrary number of antennas, but the total number of active antennas over a transmission block are fixed. This ensures that the total number of M-ary symbols transmitted over a block are fixed, which resolves the detection ambiguity as the symbols are now detected over a block. The BSM scheme in [6] maps the information bits to active antenna patterns over a block of vectors, unlike over a single vector in the GSM [3]. The BSM "block patterns" in [6], designed for active antenna patterns over a block, are at a larger Hamming distance than the GSM antenna patterns. The BSM scheme therefore has a lower BER than the GSM. The block patterns design in [6], however, imposed certain constraints on the design of active antenna patterns, which limited its constellation size, and consequently the achievable data rate and the reduction in BER.

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In this paper, we first discuss the constraints on the design of scheme and then propose a generalized design of block patterns by relaxing those constraints. The **main** contributions of this paper can be stated as follows:

- We propose a generalized design of block patterns by removing the constraints imposed in [6].
- We show that the *generalized* BSM scheme, proposed herein, has a higher a data rate and lower BER than the GSM and BSM schemes [3], [6].
- We also extend this generalized block-based scheme for SSK (GBSSK), and show that it achieves a lower BER than the GSSK scheme [1].

We now discuss the system model for the proposed block based schemes.

II. System Overview

We consider a MIMO system with N_t transmit and N_r receive antennas. We assume that the maximum number of active antennas in any transmit vector is $K < N_t$, and that all receive antennas are active. We consider a block of N_b transmit vectors

$$\mathbf{X} = [\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_{N_b}], \tag{1}$$

referred to as a "transmit block", to encode information bits. The transmit block $\mathbf{X}$ is formed such that the total number of active antennas over a block remains fixed, say N_{total}. The input-output relationship for the ith transmit vector '$\mathbf{x}_i$' is

$$\mathbf{y}_i = \frac{1}{\sqrt{d_i}}\mathbf{H}_i\mathbf{x}_i + \mathbf{n}_i \quad i = 1, 2, \ldots, N_b. \tag{2}$$

The transmit vector $\mathbf{x}_i$ is normalized by $\sqrt{d_i}$, where $d_i \leq K$ denotes the number of active antennas in the ith transmit vector, to ensure that each transmit vector has unit energy. The vector $\mathbf{y}_i \in \mathbb{C}^{N_r \times 1}$, the matrix $\mathbf{H}_i \in \mathbb{C}^{N_r \times N_t}$ and the vector $\mathbf{n}_i \in \mathbb{C}^{N_r \times 1}$ represent, in a block of N_b transmissions, the ith receive vector, channel matrix, and additive white Gaussian noise (AWGN) vector, respectively. The elements of $\mathbf{H}_i$ and $\mathbf{n}_i$ are distributed as $\mathcal{CN}(0,1)$ and $\mathcal{CN}(0,\sigma^2)$ respectively, where σ^2 is the noise variance. Depending on the values

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taken by transmit block $\mathbf{X}$ in (1), we classify the proposed generalized block-based scheme as following.

1) *Generalized block-based SM (GBSM):* The transmit block $\mathbf{X}$ has each element $\in \{0, \Omega\}$, where '0' denotes an inactive antenna, and Ω is a set of unit energy M-QAM complex constellation symbols. The active antennas are decided using the block patterns, design of which is discussed in Sec IV. Here we encode the information bits using both block patterns and constellation symbols.
2) *Generalized block-based SSK (GBSSK):* The transmit block $\mathbf{X}$ has each element $\in \{0, 1\}$ where '0' denotes an inactive antenna and '1' represents an active antenna, similar to GBSM, are decided using the block patterns. Here we encode the information bits using the block patterns alone.

Note that we propose the generalized block based scheme for SM as well as SSK. The extension of block based scheme to SSK was not proposed in [6].

Maximum Likelihood (ML) Detection: We use the optimum ML receiver, and assume perfect channel state information (CSI) at the receiver. Let $\mathcal{T}$ be the set of possible transmit blocks $\mathbf{X}$. The ML detection returns the transmit block which minimizes the sum of euclidean distances between the block of receive vectors $\mathbf{Y} = [\mathbf{y}_1, \mathbf{y}_2, \ldots, \mathbf{y}_{N_b}]$ and the possible block of transmit vectors, according to the following rule,

$$\hat{\mathbf{X}}_{ML} = \underset{\mathbf{X} \in \mathcal{T}}{\operatorname{argmin}} \sum_{i=1}^{N_b} \|\mathbf{y}_i - \frac{1}{\sqrt{d_i}} \mathbf{H}_i \mathbf{x}_i\|^2, \tag{3}$$

where $\|\cdot\|$ denotes the l_2 norm. The detection complexity for ML detection per block is $\mathcal{O}(|\mathcal{T}| \times N_{total} \times N_r)$. A direction of research is to design low-complexity sub-optimal receiver. This work focuses on designing novel transmit block patterns.

III. Recap of Block-based Spatial Modulation (BSM)

We now briefly summarize the design of block patterns in BSM [6] for the system model considered in (2). The block patterns are designed by imposing the following constraints:
$\mathbf{R1}$: The number of vector in a block is equal to the maximum number of active antennas in any transmit vector i.e., $N_b = K$.
$\mathbf{R2}$: No two vectors in a block can have same number of active antennas.
$\mathbf{R3}$: Corresponding to a particular "distribution" (distribution shows the number of active antennas in each vector), the first block pattern has only consecutive active antennas, while the other block patterns are formed by circularly shifting all the antenna positions of the first block pattern.

To explain the BSM design from [6], we show in Fig. 1 an example BSM transceiver with $N_t = 4$ transmit antennas. We fix the maximum number of active antennas per transmit vector $K \leq N_t$ as 3. Thus according to $\mathbf{R1}$ and $\mathbf{R2}$, $N_b = 3$ and the total number of active antennas over this block is fixed to $N_{total} = 6$. We also assume $M = 4$-QAM. We consider an example bit stream of 16 bits which is mapped, according to the BSM protocol [6], as follows.

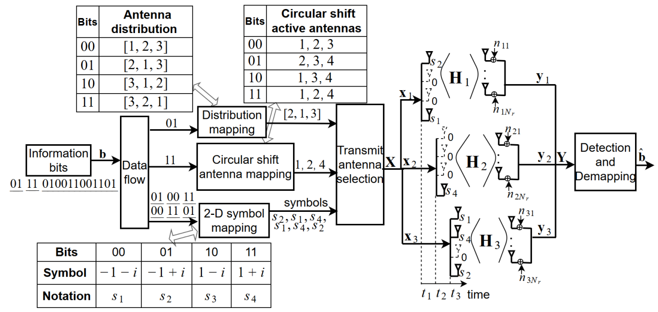


Fig. 1: Block diagram of BSM-MIMO transceiver with $N_t = 4$, $K = 3$, $N_{total} = 6$ and $M = 4$ $(QPSK)$.

1) Constraints $\mathbf{R1}$ and $\mathbf{R2}$ imply that we can form 3! permutations of a distribution $[1, 2, 3]$. The first $\lfloor \log_2 3! \rfloor = 2$ bits '01', as shown in Fig. 1, are mapped to the antenna distribution $[2, 1, 3]$.
2) Constraint $\mathbf{R3}$ implies that we can form 4 block patterns for each distribution by circularly shifting the position of active antennas in a block by $N_t = 4$. The four block patterns corresponding to the selected distribution $[2, 1, 3]$ are
$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix}, \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 0 & 1 \end{bmatrix} \text{and} \begin{bmatrix} 1 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}.$$
Thus, the next $\lfloor \log_2 4 \rfloor = 2$ bits '11', as shown in Fig. 1, select the fourth block pattern with the range of active antenna positions $[1, 2, 4]$.
3) The remaining 12 bits are mapped to the $N_{total} = 6$ 4-QAM symbols transmitted from the active antennas.

The mapping in first two steps combines to form a block pattern. The three vectors in the transmit block thus formed, are transmitted at time instances t_1, t_2 and t_3. The achievable data rate in bits per channel use (bpcu) for BSM is [6]

$$\text{BSM}: \ \frac{\lfloor \log_2 K! \rfloor + \lfloor \log_2 N_t \rfloor}{K} + \frac{(N_{total}) \times \log_2(M)}{K}. \tag{4}$$

IV. Generalized Design of Block patterns

The BSM scheme in [6], as discussed in Sec. I, imposes $\mathbf{R1}$, $\mathbf{R2}$ and $\mathbf{R3}$ constraints while designing the block patterns. We now remove these restrictions on block patterns and propose a generalized design as follows:
– Due to $\mathbf{R1}$ in BSM, block-length N_b was constrained equal to K. We now relax this constraint, and N_b can take any value.
– Let $\mathbf{d} = [d_1, d_2, \ldots, d_{N_b}]$ denotes the *distribution* of active antennas over a block, where d_i represents the number of active antennas in the ith transmit-vector, ranging from 1 to K. Due to the constraint $\mathbf{R2}$ in the BSM scheme, each d_i in a $\mathbf{d}$ takes a different value. We relax this constraint in the proposed design so that now multiple vectors in the block can have same number of active antennas. The total number of active antennas over a block remains constant $= N_{total}$. Each distribution should thus satisfy $\sum_{i=1}^{N_b} d_i = N_{total}$. Let N_d number of distributions satisfy this constraint.
– The constraint $\mathbf{R3}$ restricts the position of active antennas such that, corresponding to a particular distribution, one block pattern has consecutive active antennas, and the rest of block

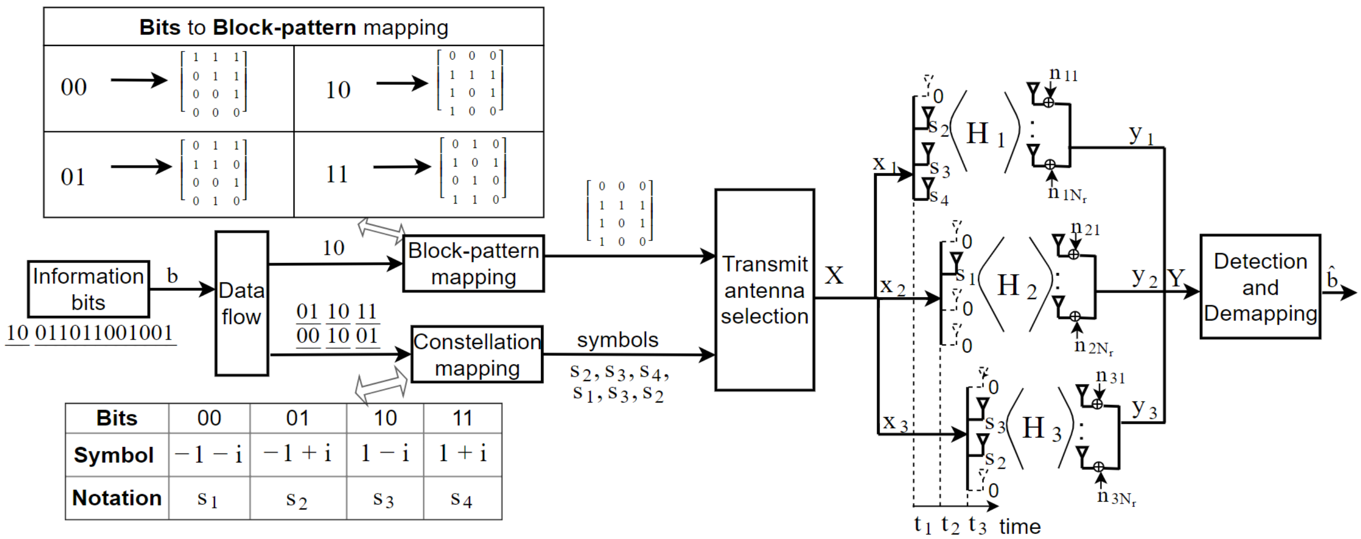


Fig. 2: Block diagram of GBSM-MIMO transceiver with $N_t = 4$, $N_b = 3$, $K = 3$, $N_{total} = 6$ and $M = 4$ $(QPSK)$.

patterns are formed by circularly shifting the positions of all active antennas of the first block pattern. We relax this constraint and take all the possible block patterns that can be formed by varying the position of active antennas. For any distribution $\mathbf{d}_j$, we can thus have $\prod_{i=1}^{N_b} \binom{N_t}{d_{ij}}$ number of different patterns by varying positions of active antennas in each vector. The total number of block patterns (N_{BP}) formed using the generalized design is therefore

$$N_{BP} = \sum_{j=1}^{N_d} \prod_{i=1}^{N_b} \binom{N_t}{d_{ij}}. \tag{5}$$

The number of bits mapped to block patterns is

$$\ell = \lfloor \log_2 (N_{BP}) \rfloor = \left\lfloor \log_2 \sum_{j=1}^{N_p} \prod_{i=1}^{N_b} \binom{N_t}{d_{ij}} \right\rfloor. \tag{6}$$

The achievable data rate in bits per channel use (bpcu) is thus

$$\boxed{\text{GBSSK} \ : \ \frac{\ell}{N_b}}, \ \boxed{\text{GBSM} \ : \ \frac{\ell}{N_b} + \frac{(N_{total}) \times \log_2 (M)}{N_b}}. \tag{7}$$

Note that apart from $\mathbf{R1}$, $\mathbf{R2}$ and $\mathbf{R3}$ restrictions, the BSM design in [6] maps the bits to block patterns by splitting them into two parts – $\lfloor \log_2 N_b! \rfloor$ for the distribution and $\lfloor \log_2 N_t \rfloor$ for the circular shift. This also limits the constellation size of the block patterns. The generalized design proposed herein, in contrast, maps the bits to a complete block pattern. This results in a better block pattern design which, as shown in Sec. V, lowers its BER than the BSM scheme.

Remark 1*:* To transmit at a data rate lower than the above achievable data rate, a valid set of transmit blocks needs to be selected from the total set $\mathcal{T}$. In this work, for the sake of simplicity and to have similar encoding complexity with the GSM and BSM schemes, we randomly select the required number of transmit blocks from $\mathcal{T}$, which has a computational complexity of $\mathcal{O}(1)$. We will explain the proposed design using an example transceiver. Before doing that, we summarize the notations used in Table I.

TABLE I: Notations used in the paper.

Notations	Description
N_t	Number of transmit antennas
N_r	Number of receive antennas
N_b	Number of vectors per block (Block-length)
K	Maximum number of active antennas in each vector
N_{total}	Total number of active antennas/symbols in the block
d_{ij}	Number of active antennas in ith vector of jth distribution
ℓ	Number of bits mapped to block patterns

A. Example of the proposed GBSM scheme:

We explain the proposed design of block patterns using an example of GBSM-MIMO transceiver shown in Fig. 2. We consider $N_t = 4$, $N_b = 3$, $K = 3$, $N_{total} = 6$ and $M = 4$-QAM. The possible distributions for this configuration which satisfy $N_{total} = 6$ are $[2, 2, 2]$ and $3! = 6$ permutations of $[1, 2, 3]$. The total number of encoded bits can be calculated from (6) and is given as $\ell = \left\lfloor \log_2 \left[1 \binom{4}{2}^3 + 6 \binom{4}{1}\binom{4}{2}\binom{4}{3} \right] \right\rfloor = 9$. The total number of possible block patterns are consequently 512. For the sake of explanation, we keep a low transmit data rate and randomly select only 4 block patterns to map 2 bits onto it. Assuming a stream of 14 bits, we observe from Fig. 2, that the first 2 bits are mapped to one of the following four block patterns:

$$\begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 1 & 0 \end{bmatrix}.$$

The first two bits '10' choose the third block pattern, and the subsequent $N_{total} \times M = 12$ bits are transmitted from the N_{total} active antennas over the block. Hence, the transmit block $\mathbf{X}$ formed for the system model of Fig. 2 is

$$\mathbf{X} = \begin{bmatrix} 0 & 0 & 0 \\ s_2 & s_1 & s_3 \\ s_3 & 0 & s_2 \\ s_4 & 0 & 0 \end{bmatrix}. \quad (8)$$

The receiver, by assuming perfect CSI, detects over a block of N_b vectors.

Remark 2*:* We can form a similar transmit block for the GBSSK scheme, the only difference being that the QAM symbols in (8) will be replaced by ones.

B. Example data rate comparison:

Consider a MIMO system with $N_t = 4$ and $M = 4$. For GSSK and GSM, the respective data rates in bpcu for a fixed number of active antennas, say N_{fix} are [1], [3]

$$\left\lfloor \log_2 \binom{N_t}{N_{fix}} \right\rfloor \text{ and } \left\lfloor \log_2 \binom{N_t}{N_{fix}} \right\rfloor + N_{fix} \log_2 M. \quad (9)$$

For GSSK and GSM schemes, the maximum number of active antenna patterns is $N_{fix} = \lfloor \frac{N_t}{2} \rfloor$ [7]. The data rates for GSSK and GSM schemes with $N_t = 4 \Rightarrow N_{fix} = 2$ are thus 2 bpcu and 6 bpcu, respectively. For the BSM, and the proposed GBSSK and GBSM schemes, the data rates vary with N_b, K and N_{total}. For the sake of fairness, while comparing with the proposed GSSK/GSM schemes, we make the average number of active antennas per transmit vector equal to $N_{fix} = 2$. This will also ensure that the average number of M-ary symbols transmitted per transmit vector for the GBSM, BSM and GSM schemes is same i.e., $N_{total}/N_b = N_{fix}$. To achieve this objective, we fix $N_b = K = 3$ and $N_{total} = 6$. Hence, for the given configuration, we get achievable data rate 5.33 bpcu for BSM (refer eq. (4)). For GBSSK and GBSM, we get a value of $\ell = 9$ (refer eq. (6)), and thus an achievable data rate of 3 bpcu and 7 bpcu respectively. As $\frac{\ell}{N_b} > \lfloor \log_2 \binom{N_t}{N_{fix}} \rfloor$, the proposed GBSSK/GBSM schemes yield higher data rate than the respective GSSK/GSM/BSM schemes, i.e., if R denotes the achievable data rate, then $R_{GBSSK} > R_{GSSK}$ and $R_{GBSM} > R_{GSM} > R_{BSM}$.

C. BER discussion:

For the proposed GBSSK and GBSM schemes, the pairwise error probability (PEP) of deciding on a block $\mathbf{X}_j$ given that $\mathbf{X}_i$ is transmitted conditioned on $[\mathbf{H}_1, \mathbf{H}_2, \ldots \mathbf{H}_{N_b}]$ is

$$\begin{aligned} &P(\mathbf{X}_i \to \mathbf{X}_j | \mathbf{H}_1, \mathbf{H}_2, \ldots, \mathbf{H}_{N_b}) \\ &= P(\|[\mathbf{y}_1 \; \mathbf{y}_2 \ldots \mathbf{y}_{N_b}] - [\mathbf{H}_1\mathbf{x}_{1i} \; \mathbf{H}_2\mathbf{x}_{2i} \ldots \mathbf{H}_{N_b}\mathbf{x}_{N_b i}]\|_F^2 > \\ &\qquad \|[\mathbf{y}_1 \; \mathbf{y}_2 \ldots \mathbf{y}_{N_b}] - [\mathbf{H}_1\mathbf{x}_{1j} \; \mathbf{H}_2\mathbf{x}_{2j} \ldots \mathbf{H}_{N_b}\mathbf{x}_{N_b j}]\|_F^2) \\ &= Q\left(\sqrt{\frac{\|[\mathbf{H}_1(\mathbf{x}_{1i} - \mathbf{x}_{1j}) \; \mathbf{H}_2(\mathbf{x}_{2i} - \mathbf{x}_{2j}) \ldots \mathbf{H}_{N_b}(\mathbf{x}_{N_b i} - \mathbf{x}_{N_b j})]\|_F^2}{2\sigma^2}}\right), \end{aligned} \quad (10)$$

where $\| \cdot \|_F$ denotes the Frobenius norm. This PEP can be upper bounded using the Chernoff bound $Q(x) \leq \frac{1}{2} e^{-x^2/2}$ as:

$$\begin{aligned} &P(\mathbf{X}_i \to \mathbf{X}_j | \mathbf{H}_1, \mathbf{H}_2, \ldots \mathbf{H}_{N_b}) \\ &\leq \frac{1}{2} \cdot \exp\left(-\frac{1}{2} \frac{\sum_{k=1}^{N_b} \|\mathbf{H}_k(\mathbf{x}_{ki} - \mathbf{x}_{kj})\|^2}{2\sigma^2}\right) \quad (11) \\ &= \frac{1}{2} \cdot \prod_{k=1}^{N_b} \exp\left(-\frac{1}{2} \frac{\|\mathbf{H}_k(\mathbf{x}_{ki} - \mathbf{x}_{kj})\|^2}{2\sigma^2}\right) \end{aligned}$$

We see from (11) that the PEP of the block-based schemes decreases as the distance between the corresponding vectors of the transmit blocks increases. The generalized design proposed in Sec. IV provides us with a larger constellation of transmit blocks than the single vector GSSK and GSM schemes [1], [3], and the BSM scheme [6]. this increases the probability of choosing transmit blocks with a larger Euclidean distance between them. We can also infer from (11) that increasing the block-length further reduces the PEP, an observation which we will numerically validate in the next section.

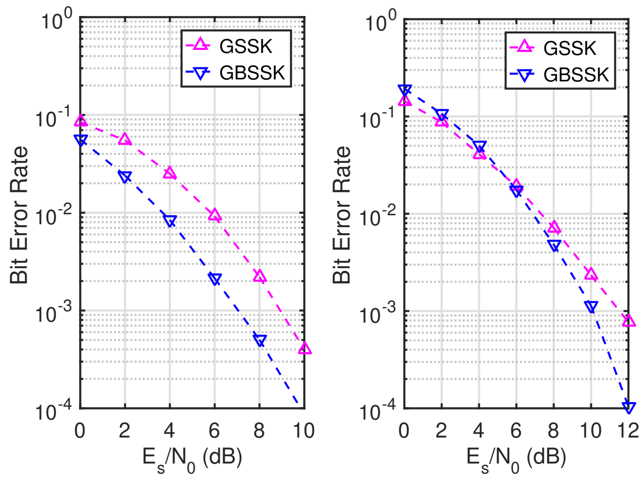
V. Simulation Results

We now numerically compare the performance of the proposed design with the other existing ones. We use ML detection at the receiver, as it gives the optimal performance for all the schemes during comparison.

Comparison of GBSSK and GSSK : For this study, we consider a 4×4 ($N_r \times N_t$) MIMO system. For GSSK, we take the number of active antennas $N_{fix} = 2$. For GBSSK, we consider $K = 3$, $N_b = 3$, and $N_{total} = 6$ which makes the average number of active antennas per transmit vector 2 for both schemes. The maximum achievable rate for the GSSK and GBSSK schemes, as derived earlier in (4) and (7), are 2 bpcu and 3 bpcu, respectively. We compare the BER of the GSSK and GBSSK schemes, as shown in Fig. 3a and Fig. 3b, for two different data rates of 1 bpcu and 2 bpcu, respectively. We ensure this data rate, as discussed in *Remark* 1, by randomly selecting the required number of block patterns and antenna-patterns for the GBSSK and GSSK schemes. respectively. We observe from these figures that the proposed GBSSK yields an SNR gain of at least 2 dB at a BER of 10^{-3}. Note, that we take $K = 3$ for the GBSSK and $N_{fix} = 2$ for the GSSK. This means that an extra RF chain is required for the GBSSK scheme. The number of RF chains that remain active per transmission on an average, however, remains same, i.e., two. It would seem here that the GBSSK scheme performs better due to 1 extra RF chain, but that is not the case as we will see in the next simulation result.

Effect of variation in block length: We now characterize the effect of block length on the BER of the proposed block-based schemes, while keeping the number of RF chains same. We demonstrate this for the proposed GBSSK scheme for an 8×8 MIMO system. We fix the number of active antennas like GSSK to 2, which yields a maximum data rate of 4 bpcu. To keep the detection complexity less, we fix the data rate to 2 bpcu by randomly selecting the required number of block patterns. We compare the BER for block length of 1, 2 and 3. We observe from Fig. 4 that the BER reduces with increase in block length, even though the number of RF chains remain same. Note that block-length 1 corresponds to GSSK, and 2 and 3 correspond to the proposed GBSSK scheme.

Effect of increasing N_t: We finally compare in Fig. 5a the BER of the proposed GBSM with that of the BSM [6], and the GSM scheme [3] for a 4×8 ($N_r \times N_t$) MIMO system. For the GSM scheme, we fix $K = 3$, $N_b = 3$, $N_{total} = 6$ for GBSM, and for the GSM $N_{fix} = 2$. For all the schemes, we consider BPSK constellation with $M = 2$. We note from (7)



(a) Data rate 1 bpcu.

(b) Data rate 2 bpcu.

Fig. 3: BER comparison of GBSSK and GSSK for 4×4 MIMO system

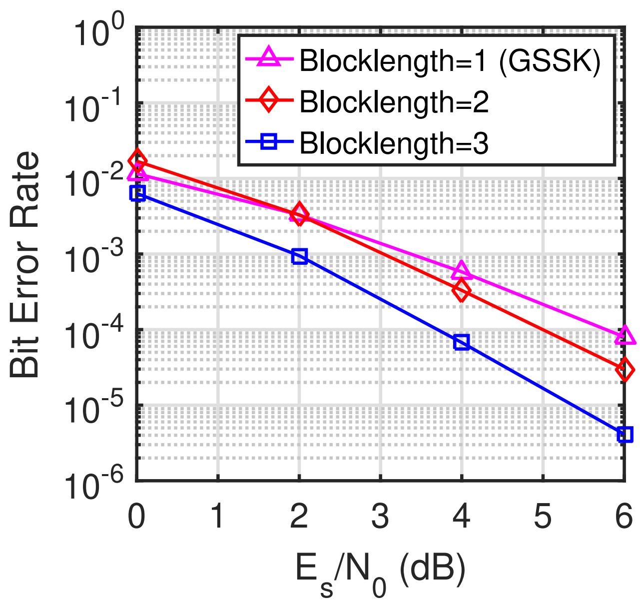
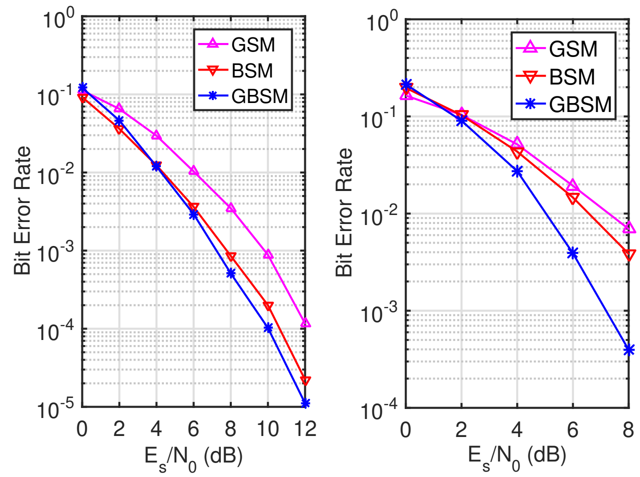


Fig. 4: BER comparison of block-based SSK for a 8×8 MIMO system with fixed number of active antennas, with a data rate of 2 bpcu.

and (4) that the achievable rate for the GBSM, GSM and BSM schemes is 5 bpcu, 4 bpcu and 3.33 bpcu, respectively. We fix equal data rate to 3 bpcu by performing a random selection as discussed in *Remark* 1. We observe from Fig. 5a that at a BER of 10^{-3}, GBSM has a gain of at least 0.5 dB over the BSM scheme and, at least 2.5 dB over the GSM scheme.

We now show Fig. 5b that increasing N_t further improves the BER gain for the GBSM scheme. For this study, we consider $N_t = 16$ and keep the number of active antennas same as in Fig. 5b. The data rate is fixed to 4 bpcu. We observe that the proposed GBSM achieves a BER of 10^{-2} at 2 dB lower SNR than the BSM scheme and at 2.5 dB lower SNR than the GSM scheme. Note that number of RF chains have remained constant. This shows that the proposed block-based schemes have a great potential for hybrid massive MIMO scenarios where the number of transmit antennas is large but the number of RF chains less [8].



(a) 4×8 MIMO system with data rate 3 bpcu

(b) 4×16 MIMO system with data rate 4 bpcu

Fig. 5: BER comparison of GBSM, BSM and GSM schemes.

VI. Conclusion and Future Work

We considered generalized block-based SSK (GBSSK) and SM (GBSM) schemes which encode information bits over a block of transmit vectors. These schemes vary the number of active antennas in a transmit vector such that the total active antennas in the block remains fixed. We proposed a generalized design of block patterns for these schemes, which has lower BER and higher data rate than the existing ones.

The cardinality of the proposed constellation for the GBSM scheme is large, and to derive a lower data rate, we randomly select the constellation points. A future direction of work could be to design optimal constellation set to improve its performance, and low complexity detectors to reduce the detection complexity.

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