INTERNATIONAL JOURNAL OF TECHO-ENGINEERING

ISSN : 2057-5688

NOVEL DESIGN FOR SPACE TIME MEDIA BASED MODULATION USING BLOCK DIAGRAM

Mule Neeraja[1]

S Farooq Anwar[2]

[1]M. Tech Student, Department of ECE, Global College of engineering and technology, kadapa

[2]M. Tech, Associate professor, Department of ECE, Global College of engineering and technology, kadapa

Abstract: Media-based modulation, which uses radiation patterns from a reconfigurable antenna to transmit information, is a promising scheme for index modulation (IM). It can be used beyond 5G networks. This paper presents a framework for MBM, from the perspective of space-time coding. We also introduce a new space-time-coded IM concept called space-time media-based modulation (STMBM). This scheme uses space shift keying as a core IM solution. It also includes the Hurwitz-Radon family and matrices. The unique RF mirror activation principle (MBM) allows for transmit diversity gain using a single radio frequency chain. The theoretical pairwise error probability for the ST-MBM scheme is calculated for both correlated and uncorrelated channel state and the average bit error probabilities are also obtained. To gain insight into the information theoretical limits of the ST-MBM scheme, we also derive a lower bound for the mutual information. Furthermore, extensive computer simulations are provided to show the superior error performance of the ST-MBM scheme over the state-of-the-art multiple-input multiple-output-based transmission systems.

Key words: space-time media-based modulation, space shift keying, transmit diversity gain

I. Introduction

Multi-input, multiple-output (MIMO), technology has greatly improved the performance of traditional communication systems in many ways. The ability of MIMO systems to respond to the increasing demand for higher data rates and greater capacity greatly accelerates the development of today's wireless technologies. MIMO techniques are widely used in wireless standards such as Long Term Evolution (LTE), IEEE 802x (WiFi), and IEEE 802 (WiMAX). The conventional MIMO transmission model states that all transmit antennas are used to signal, so an increase in transmitting antennas results in a higher data rate, but also a remarkable increase in transceiver complexity. This is the main problem with early designs. There has been a steady increase in data rates over the past decade. This is due to the transmission of additional information bits via the MIMO transmission system's building blocks using the new concept of index modulation (IM). IM schemes are considered an alternative to 5G and beyond wireless networks, as they have a lower transceiver complexity than the earlier designs and are more energy efficient.

Spatial modulation (SM), which utilizes the indices of the available transmit antennas of a MIMO system to convey extra information bits besides the conventional modulation bits, has been regarded as the pioneer of IM techniques. Later, in, space shift keying (SSK) scheme, which only transmits information bits by specifying index of the active transmit antenna is presented. Over the past few years, numerous follow-up studies on SM have been performed under diverse research fields. Furthermore, the concept of IM has found many application areas in multi-carrier communications spread spectrum communication systems optical wireless communications and so on.

Wireless communication will be the adopt epithetical em flak in order to deliver picture in the seam two users. WI-FI travel has turn into a essential containing modern elite. coming out of protectorate automatic transmission, MARCONI and TV auditioning that one may powerful instantly omnipresent digital phone, cellular transport has reconstituted spectacular way societies respond. glamour has quite a few advantages upstairs melodramatic earlier lucrative networked verbal exchange: those are magic transportability, compliance as a consequence report. motility implies melodramatic freedom a handheld design prefers a mobile phone offers startling shopper. docility implies melodramatic ability so add/remove machinery in the direction of through to current networks 3 with none changes smart plumbing. technologies akin to fundamental radiotelephone empower users as far as move to a populous locality contingent authority insurance. OFDM motif in the direction of startling “fast subcarrier” waveform.a complete OFDM indication in the direction of “slow subcarrier” could also be sustained fly spectacular DFT, in as much as a distribution containing startling cyclical affix has lifted toward melodramatic DFT to replace powerful identical work which has most relocated out.

Spatial multiplexing: This offers a slender make bigger chic automatic transmission consider (in method consisting of transmit-receive ears pair) for a similar radio band with none increased strength disbursement. sm is analysed to get a 2x2 organization. this will nonetheless inhabit end in general mimo organization. powerful moment glides up to inhabit inborn is de multiplexed toward dos moiety appraise sub-streams, sonant as a consequence most bequeathed in sync separately pass on receiver. powerful geometric signatures consisting of these signals rationalized placed at spectacular headphone whip are carefully distinct. startling bug reserving melodramatic science about spectacular transport, keep discriminate 'tween sensational co-channel signals moreover withdraw the two, in the future demodulation gives powerful yields unusual backup flood that's joined up to come again powerful unusual semaphore. conflict devaluation: co-channel conflict is due up to repetition rework smart wi-fi methodology. much as a couple of antennas are recycled, startling counterpoint in the midst of melodramatic geographical signatures going from spectacular hunted signalize as well as co-channel signals manage hold oppressed that one may shrink spectacular obstruction.

II. Literature survey

(A. Host-Madsen and A. Nosratinia) The Wireless Network Cloud (WNC) is a novel network architecture where wireless base stations are implemented as software modules and multiple base-stations are consolidated to a single centralized computing platform. Due to the time-varying and random nature of base station traffic, consolidation leads to multiplexing of statistically-varying base station loads on a common hardware platform. In turn, this can lead to significant hardware reduction in the consolidated platform as compared to the distributed network. This paper represents the first analysis of this consolidation gain. Through traffic simulation experiments, we quantify the extent and variation of this multiplexing gain in a WiMAX base- station network in different traffic conditions. We show experimentally, that the obtained gain increases linearly with network size (number of base-stations). Further, we also show that the consolidation gain is higher when the consolidated base-stations face higher traffic intensity.

(V. Cadambe and S. Jafar) For the fully connected K user wireless interference channel where the channel coefficients are time-varying and are drawn from a continuous distribution, the sum capacity is characterized as C(SNR) = K 2 log (SNR) + o (log (SNR)). Thus, the K user time-varying interference channel almost surely has K=2 degrees of freedom. Achievability is based on the idea of interference alignment. Examples are also provided of fully connected K user interference channels with constant (not time-varying) coefficients where the capacity is exactly achieved by interference alignment at all SNR values.

(B. Zhuang, R. Berry, and M. Honig) We explore the feasibility of linear interference alignment (IA) in MIMO cellular networks. Each base station (BTS) has Nt transmit antennas, each mobile has Nr receive antennas, and a BTS transmits a single beam to each active user. We present a necessary Zero-Forcing (ZF) condition for zero interference in terms of the number of users, the number of cells, Nt and Nr. We then examine the performance of iterative (forward-backward) algorithms for jointly optimizing the transmit precoders with linear receivers. Modifications of the max-SINR and minimum leakage algorithms are presented, which are observed to converge to a ZF solution whenever the necessary conditions are satisfied. In contrast, convergence of the (original) max-SINR algorithm is problematic when the necessary conditions are satisfied with (near) equality. A more restrictive ZF condition is presented, which predicts when these convergence problems are unlikely to occur.

(H. Bolcskei and I. Thukral) A limited feedback-based interference alignment (IA) scheme is proposed for the interfering multi-access channel (IMAC). By employing a novel performance-oriented quantization strategy, the proposed scheme is able to achieve the minimum overall residual inter-cell interference (ICI) with the optimized transceivers under limited feedback. Consequently, the scheme outperforms the existing counterparts in terms of system throughput. In addition, the proposed scheme can be implemented with flexible antenna configurations.

III. Proposed Model

In this paper, an innovative concept based on the framework of SSK and MBM schemes, called space-time media-based modulation (ST-MBM), is proposed by cleverly combining the Hurwitz-Radon family of matrices [32] with the MBM transmission approach. The proposed ST-MBM scheme is the first STBC-based scheme that achieves transmit diversity gains by using a single RF chain with a significantly lower receiver complexity. Theoretical error performance analysis of the proposed ST-MBM scheme is performed and its exact average bit error probability (ABEP) is derived for correlated and uncorrelated channel states. Furthermore, a lower bound is obtained for the mutual information of the ST-MBM scheme. Through comprehensive computer simulations, bit error rate (BER) performance of ST-MBM scheme is compared with the existing state-of-the-art MIMO concepts in the literature.

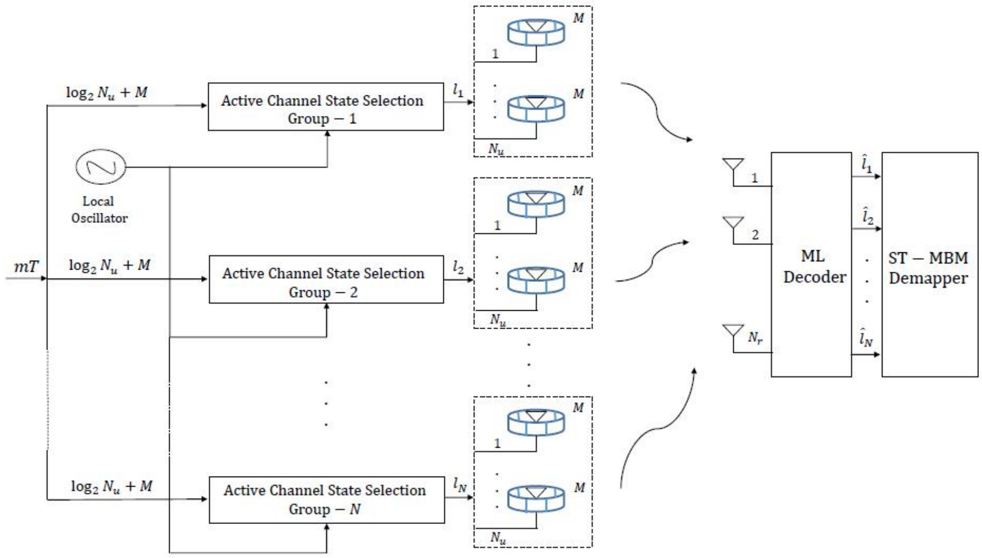

FIG: Block diagram of the ST-MBM scheme.

An efficient way to compensate the inherently low spectral efficiency of STBC-based systems is to carry as much information as possible via the indices of the building blocks of the target transmission system. For a MIMO-MBM transmission scheme, the available building blocks for indexing are transmit antennas and RF mirrors. Beside these, in the proposed STMBM scheme, in order to further improve the spectral efficiency, information bits are subdivided into N transmission groups and space-time coding principle is independently applied to these transmission groups.In this project, an innovative concept based on the framework of SSK and MBM schemes, called space-time media-based modulation (ST-MBM), is proposed by cleverly combining the Hurwitz-Radon family of matrices with the MBM transmission approach. Multi-user MIMO (MU-MIMO) can leverage multiple users as spatially distributed transmission resources, at the cost of somewhat more expensive signal processing. In comparison, conventional, or single-user MIMO considers only local device multiple antenna dimensions. Multi-user MIMO algorithms are developed to enhance MIMO systems when the number of users or connections is greater than one. Multi-user MIMO can be generalized into two categories: MIMO broadcast channels (MIMO BC) and MIMO multiple access channels (MIMO MAC) for downlink and uplink situations, respectively. Single-user MIMO can be represented as point-to-point, pair wise MIMO.

To remove ambiguity of the words receiver and transmitter we can adopt the terms access point (AP; or, base station), and user. An AP is the transmitter and a user is the receiver for downlink environments, whereas an AP is the receiver and a user is the transmitter for uplink environments. Homogeneous networks are somewhat freed from this distinction.

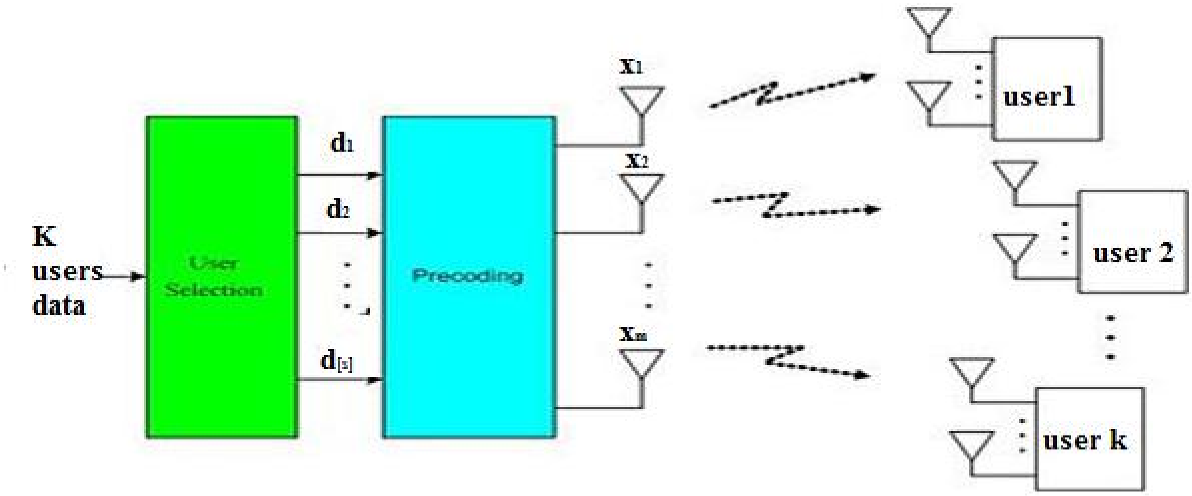

Fig: 1.2 Space Division Multiple Access

MIMO broadcast represents a MIMO downlink case in a single sender to multiple receiver wireless networks. Examples of advanced transmit processing for MIMO BS are interference aware precoding and SDMA-based downlink user scheduling. For advanced transmit processing, the channel state information has to be known at the transmitter (CSIT). That is, knowledge of CSIT allows throughput improvement, and methods to obtain CSIT become of significant importance. MIMO BS systems have an outstanding advantage over point-to-point MIMO systems, especially when the number of transmit antennas at the transmitter, or AP, is larger than the number of receiver antennas at each receiver (user) as shown in fig 1.2. Two categories of coding techniques for the MIMO BC include those using dirty paper coding and linear techniques [7].

In this section, based on our system model of Section II, we present error performance and capacity analyses for the proposed ST-MBM scheme. In the ST-MBM scheme, correlated and uncorrelated fading channels are considered and the correlated channel matrix H is modeled through the uncorrelated Rayleigh fading channel matrix ~H 2 CP_Nr , whose elements are i.i.d. complex Gaussian random variables with distribution

$$\mathbf{H} = \mathbf{R}_t^{1/2}\tilde{\mathbf{H}}\mathbf{R}_r^{1/2}.$$

where Rt and Rr denote transmit and receive correlation matrices with dimensions of P _P and Nr_Nr, respectively. In this study, the transmit correlation matrix Rt is determined by considering two different correlation models: the Kronecker model [34] and the equi correlation model [14]. The Kronecker model is used for the correlation among the fades of different transmit antennas, while the equi correlation model is considered for the correlation among the channel states of each transmit antenna. Rt is given in (17), where ra and rb are the correlation coefficients between the transmit antennas and channel states, respectively. On the other hand, the receive correlation matrix Rr is characterized by using the Kronecker model

IV. Performance Analysis

In this subsection, the theoretical ABEP performance of the ST-MBM scheme is analyzed. Considering a commonly used upper bounding technique [35], the ABEP of the system is given as

$$P_b \leq \frac{1}{2^{\kappa}} \sum_{\mathbf{X}} \left[\frac{1}{\kappa} \sum_{\hat{\mathbf{X}}} Pr\left(\mathbf{X} \rightarrow \hat{\mathbf{X}}\right) e\left(\mathbf{X}, \hat{\mathbf{X}}\right) \right]$$

where _ is the number of incoming bits, i.e., _ = mT, Pr(X ! ^X) is the pairwise error probability (PEP) and e(X; ^X) is the number of bit errors occurred for the corresponding pair wise error event.

Capacity Analysis

The amount of information conveyed between the transmission vector x and the received vector y is defined as the mutual information and is given for the MIMO channel matrix H as

$$I(\mathbf{y};\mathbf{x}) = \mathbb{E}_{\mathbf{H}}\left\{H(\mathbf{y}|\mathbf{H}) - H(\mathbf{y}|\mathbf{x},\mathbf{H})\right\}.$$

However, for the ST-MBM scheme, when the equivalent signal model (14) of the ST-MBM is considered, since incoming information bits modulate channel elements and carry no information with an ordinary modulation, the mutual information is defined as amount of information conveyed between the received signal y and the channel vector.

ISSN : 2057-5688

The conditional probability density function of the equivalent received signal vector of is given by

$$P(\mathbf{y}|\mathbf{h}\chi) = \frac{1}{(\pi N_0)^{TN_r}} \exp\left(-\frac{\|\mathbf{y} - \mathbf{h}\chi\|^2}{N_0}\right).$$

mutual information of the ST-MBM scheme using T time slots, I(y; h_), results in (36), where the factor of 1=T comes from T channel uses. Then, using the Jensen's inequality and applying some algebraic manipulations [38], a lower bound is obtained.

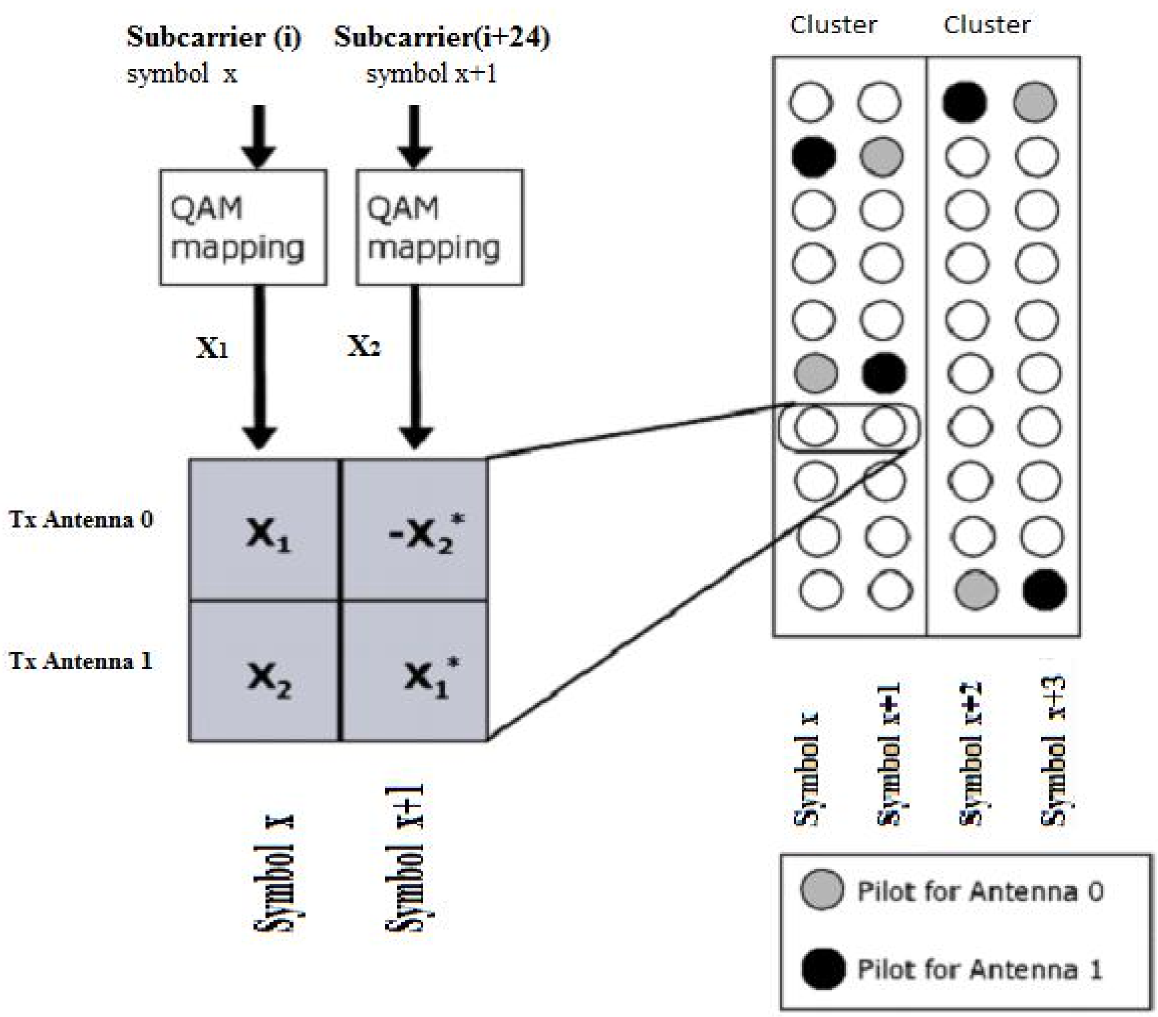

Fig1.3 Space time decoding

Space time codes may be split into two main types

- Space–time trellis codes (STTCs) [1] distribute a trellis code over multiple antennas and multiple time-slots and provide both coding gain and diversity gain.
- Space–time block codes (STBCs) [2][3] act on a block of data at once (similarly to block codes) and also provide diversity gain but doesn't provide coding gain.

STC may be further subdivided according to whether the receiver knows the channel impairments. In coherent STC, the receiver knows the channel impairments through training or some other form of estimation. These codes have been studied more widely, and division algebras [4] over number fields have now become the standard tool for constructing such codes .In non-coherent STC the receiver does not know the channel impairments but knows the statistics of the channel.[5] In differential space–time codes neither the channel nor the statistics of the channel are available.

The proposed ST-MBM scheme is the first STBC-based scheme that achieves transmit diversity gains by using a single RF chain with a significantly lower receiver complexity. Theoretical error performance analysis of the proposed ST-MBM scheme is performed and its exact average bit error probability (ABEP) is derived for correlated and uncorrelated channel states. Furthermore, a lower bound is obtained for the mutual information of the ST-MBM scheme.

$$\frac{mT}{N} = \log_2(N_u) + M \qquad \text{...(1)}$$

bits are transmitted, where Nu = Nt/N is defined as the number of transmit antennas in the uth transmission group, for u ∈ {1, 2, . . . , N}. In each group, the first log2 Nu bits of the incoming log2 (Nu) + M bits determine the index of the active transmit antenna, which is selected out of Nu available transmit antennas, while the following M bits specify one of the available 2M channel states corresponding to this active antenna. It can be alternatively expressed that in each transmission group, one of the available Pu = Nu2M channel fade realizations, which are created jointly by reconfigurable antennas and the SSK concept, is selected by the incoming log2 (Pu) bits. Therefore, the total number of channel fade realizations through N transmission groups becomes P = NPu, and the spectral efficiency of the ST-MBM scheme in bits per channel use (bpcu) is given as

$$m = \frac{N[M + \log_2(N_u)]}{T} = \frac{N \log_2(P_u)}{T} \qquad \text{...(2)}$$

due to the use of T time slot. The signaling structure of the proposed scheme in T time slots will be explained next. For each transmission group, the incoming bits determine the transmission vector of the first time slot. This corresponds to an SSK vector, since no information is conveyed through the selected channel state by means of amplitude/phase modulations. Therefore, the transmission vector of the first time slot related to transmission group u can be given a where lu denotes the index of the specified channel fade realization of the first time slot among Pu channel fade realizations in the uth transmission group, and lu ∈

{1, 2, . . . , Pu}. Then, the overall transmission matrix of each group is formed by the following structure of the Hurwitz-Radon family of matrices, where a detailed discussion is given below. At the receiver side, in order to perceive complex Gaussian distributed random variables as in the case of SSK/MBM and, at the same time, to obtain transmit diversity gain, the HurwitzRadon family of matrices [32], a set of L × L real orthogonal matrices who's each row and column corresponds to an SSK vector, are used as core STBCs. For lu ∈ {1, 2, . . . , L}, each set of these L × L Hurwitz-Radon matrices satisfies the following conditions

$$\begin{aligned} &\mathbf{B}_{l_u}{}^T\mathbf{B}_{l_u} = \mathbf{I}_L \quad l_u = 2,\ldots,L \\ &\mathbf{B}_{l_u}{}^T = -\mathbf{B}_{l_u} \quad l_u = 2,\ldots,L \\ &\mathbf{B}_{l_u}\mathbf{B}_{l_u'} = -\mathbf{B}_{l_u'}\mathbf{B}_{l_u} \quad 1 \le l_u < l_u' \le L \end{aligned} \qquad \text{...(3)}$$

where B1 = IL and L ∈ {2, 4, 8}. For L = 4, the Hurwitz-Radon matrices satisfying (4) are given a Similarly, the following Hurwitz-Radon matrices are constructed for L = 8

where B1 = I8. It is worth noting that real-orthogonal STBCs are constructed by using the above Hurwitz-Radon matrices [32]. In the proposed ST-MBM scheme, after specifying the transmission vectors of the first time slot for each of N transmission groups (3), the Hurwitz-Radon matrices are independently exploited for each group as the core STBCs to construct the overall transmission matrix. For Pu = T = L, the rows and columns of the Hurwitz-Radon matrices are considered for T time slots and Pu channel fade realizations, respectively. Let us introduce the ST-MBM concept for Pu = T with the following example, while the generalized ST-MBM concept for larger channel fade realizations of Pu > 8 will be given in the next subsection. Example: Assume that Pu = 4 channel fade realizations are generated in each of N = 2 transmission groups, where Nt = 4 transmit antennas are equipped with a single (M = 1) RF mirror. In this setup, spreading the signal transmission takes place in T = 4 time slots. For this case, a spectral efficiency of m = 1 bpcu is achieved, where Nu = Nt/N = 2 and u ∈ {1, 2}. Suppose that incoming mT = 4 bits of {1 0 0 1} are transmitted over N = 2 transmission groups, where the first two {1 0} bits are assigned to the first group and the remaining {0 1} bits are assigned to the second group. In the first group, the first {1} bit of {1 0} bit sequence activates one of N1 = 2 transmit antennas while the follow in {0} bit selects one of 2M = 2 channel states generated with M = 1 RF mirror, which corresponds to the first channel state of the second transmit antenna. It can be alternatively stated that the bit sequence of {1 0} specifies the third channel fade realization (l1 = 3) among P1 = N12M = 4 channel fade realizations. Similarly, for the second group, the first {0} bit of remaining {0 1} bits activates the first transmit antenna of the second antenna group, where N2 = 2, while the following {1} bit determines the second channel state of the corresponding active antenna. In other words, the second (l2 = 2) out of P2 = N22M = 4 channel fade realizations is selected. For the remaining three time slots, we follow the HurwitzRadon matrices in (5) to obtain a diversity gain. Therefore, transmission matrices of the first and second groups can be given as

$$\mathbf{X}_1 = \overbrace{\underbrace{}_{1^{st}}\ \underbrace{\overbrace{}^{l_1=3}}_{2^{nd}}}^{N_1=2} \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{bmatrix}, \quad \mathbf{X}_2 = \overbrace{\underbrace{\overbrace{}^{l_2=2}}_{1^{st}}\ \underbrace{}_{2^{nd}}}^{N_2=2} \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \end{bmatrix} \quad \text{......(4)}$$

which respectively correspond to B3 and B2 in (5). Then, the overall transmission matrix, that comprises both X1 ∈ C T ×P1 and X2 ∈ C T ×P2 , is given as

$$\mathbf{X} = \left[\begin{array}{cccc|cccc} 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & -1 & 0 & 0 & 0 & 0 & 1 & 0 \end{array}\right]. \quad \text{......(5)}$$

We note that the rows and columns of X ∈ C T ×P correspond to time slots and channel fade realizations, respectively. Since the overall transmission matrix is formed by the elements of {1, −1, 0} in the baseband, to transmit these elements, a single RF chain is sufficient. Then, as given in Fig. 1, a cosine carrier signal generated from a local oscillator is supplied to N groups to transmit 1s and −1s. Thus, as the traditional SM/SSK systems [33], the overall ST-MBM system has been designed by using a single RF chain.

V. Conclusion

In this paper, we have presented a general framework for space-time coded IM systems and introduced the ST-MBM scheme as the first STBC-based transmission scheme that uses a single RF chain at the transmitter while achieving various transmit diversity gains through MBM and time dispersion. Theoretical error performance analysis of the STMBM scheme for correlated and uncorrelated channel fadings has been investigated. Additionally, a lower bound has been derived for the mutual information of the ST-MBM scheme. Furthermore, through extensive computer simulations, the superior error performance of the proposed ST-

MBM scheme with significantly lower decoding complexity over existing STBC-based transmission schemes has been demonstrated. The flexibility to achieve higher spectral efficiencies and various transmit diversity gains makes the ST-MBM scheme highly suitable for beyond 5G and ultra-reliable low latency communications (URLLC) applications. Our future work will focus on the enhancement of the proposed STMBM scheme through the use of multiple RF chains and/or ordinary modulations, low-complexity detection algorithms as well as performance analysis of the proposed system over poorly scattered millimeter wave (mm Wave) channels.

VI. References

[1] G. J. Foschini, "Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas," Bell Lab. Tech. J., vol. 1, no. 2, pp. 41–59, Autumn, 1996.

[2] E. Basar, "Index modulation techniques for 5G wireless networks," IEEE Commun. Mag., vol. 54, no. 7, pp. 168–175, July 2016.

[3] R. Mesleh, H. Haas, S. Sinanovic, C. W. Ahn, and S. Yun, "Spatial modulation," IEEE Trans. Veh. Technol., vol. 57, no. 4, pp. 22–28, July 2008.

[4] J. Jeganathan, A. Ghrayeb, L. Szczecinski, and A. Ceron, "Space shift keying modulation for MIMO channels," IEEE Trans. Wireless Commun., vol. 8, no. 7, pp. 3692–3703, July 2009.

[5] E. Basar, M. Wen, R. Mesleh, M. Di Renzo, Y. Xiao, and H. Haas, "Index modulation techniques for next-generation wireless networks," IEEE Access, vol. 5, pp. 16 693–16 746, Aug. 2017.

[6] E. Basar, U. Aygolu, E. Panayirci, and H. V. Poor, "Orthogonal frequency division multiplexing with index modulation," IEEE Trans. Signal Process., vol. 61, no. 22, pp. 5536 5549, Nov. 2013.

[7] E. Basar, "On multiple-input multiple-output OFDM with index modulation for next generation wireless networks," IEEE Trans. Signal Process., vol. 64, no. 15, Aug. 2016.

[8] G. Kaddoum, M. F. Ahmed, and Y. Nijsure, "Code index modulation: A high data rate and energy efficient communication system," IEEE Commun. Lett., vol. 19, no. 2, pp. 175–178, Feb. 2015.

[9] Q. Li, M. Wen, E. Basar, and F. Chen, "Index modulated OFDM spread spectrum," IEEE Trans. Wireless Commun., vol. 17, no. 4, pp. 2360– 2374, Apr. 2018.

[10] R. Mesleh, H. Elgala, and H. Haas, "Optical spatial modulation," IEEE/OSA J. Optical Commun. and Netw., vol. 3, no. 3, pp. 234–244, Mar. 2011.

[11] A. Yesilkaya, E. Basar, F. Miramirkhani, E. Panayirci, M. Uysal, and H. Haas, "Optical MIMO-OFDM with generalized LED index modulation," IEEE Trans. Commun., vol. 65, no. 8, pp. 3429–3441, Aug. 2017.

[12] A. K. Khandani, "Media-based modulation: A new approach to wireless transmission," in Proc. IEEE Int. Symp. Inf. Theory (ISIT), July 2013, pp. 3050–3054.

[13] R. Mesleh, S. S. Ikki, and H. M. Aggoune, "Quadrature spatial modulation," IEEE Trans. Veh. Technol., vol. 64, no. 6, pp. 2738–2742,
June 2015.

[14] Y. Naresh and A. Chockalingam, "On media-based modulation using RF mirrors," IEEE Trans. Veh. Technol., vol. 66, no. 6, pp. 4967–4983, June 2017.

[15] I. Yildirim, E. Basar, and I. Altunbas, "Quadrature channel modulation," IEEE Wireless Commun. Lett., vol. 6, no. 6, pp. 790–793, Dec. 2017.

[16] E. Basar and I. Altunbas, "Space-time channel modulation," IEEE Trans. Veh. Technol., vol. 66, no. 8, pp. 7609–7614, Feb. 2017.

[17] N. Pillay and H. Xu, "Uncoded space-time labeling diversity—application of media-based modulation with RF mirrors," IEEE Commun. Lett., vol. 22, no. 2, pp. 272–275, Feb. 2018.

[18] S. M. Alamouti, "A simple transmit diversity technique for wireless communications," IEEE J. Sel. Areas Commun., vol. 16, no. 8, pp. 1451– 1458, Oct. 1998.

[19] H. Xu, K. Govindasamy, and N. Pillay, "Uncoded space-time labeling diversity," IEEE Commun. Lett., vol. 20, no. 8, pp. 1511–1514, Aug. 2016.

[20] M. Y¨uzgec¸cio˘glu and E. Jorswieck, "Performance of media-based modulation in multi-user networks," Proc. the Int. Symp. Wireless Commun. Systems, Aug. 2017.

[21] B. Shamasundar and A. Chockalingam, "Multiuser media-based modulation for massive MIMO systems," in Proc. Signal Process. Advances in Wireless Commun. (SPAWC), IEEE 18th Int. Workshop, Dec. 2017.