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Implementation of LPPH by MFJ O

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ABSTRACT

Space shift keying (SSK) modulation is an emerging transmission technique for multiple-input multiple-output (MIMO) wireless channels that exploits spatial domain to convey information. In this paper, we present a layered space shift keying (LSSK) modulation scheme to fully exploit spatial domain to transmit information bits, where a layered architecture is developed to achieve spatial multiplexing transmission in SSK system. With the layered structure, LSSK can achieve much higher spectrum efficiency than the conventional SSK modulation system. The proposed LSSK scheme introduces layer mapping and bit-mapping operations at the transmitter to achieve layered SSK modulation directly with low computation overhead. More precisely, leveraging the phase shift keying (PSK) modulation symbols previously known at the transceiver to identify different layers, multiple antennas are activated simultaneously to emit layered signals. The theoretical bit error probability of LSSK with optimal maximum likelihood (ML) detection is also derived in this paper. Results demonstrate that the proposed LSSK scheme substantially improves the spectrum efficiency of SSK system and outperforms other existing MIMO schemes.

Index Terms— MIMO, SSK modulation, LSSK modulation , ML detection.

INTRODUCTION

The increasing requirements of high data rate and high spectrum efficiency have led to extensive research on multiple input multiple-output (MIMO) techniques . The conventional Vertical Bell labs layered space-time (VBLAST) MIMO technique is designed for achieving high multiplexing gain by transmitting layered signals simultaneously . In recent years, space shift keying (SSK) modulation is regarded as an emerging MIMO transmission technique that exploits spatial domain to convey information . Unlike traditional APM based MIMO technique, SSK conveys source information by indices of active antennas rather than transmitting APM symbols. The spectrum efficiency of SSK is log2*M* bps/Hz, where *M* is the number of transmit antennas and that is called *M*-ary SSK modulation .

Since SSK activates only one antenna each time, it provides benefits such as no inter-channel interference, no inter-antenna synchronization and reduction of radio frequency (RF) chains compared with conventional MIMO systems. The work in and shows that this kind of transmission can significantly reduce total power compared with other multi-RF chain MIMO architectures.

However, the main disadvantage of SSK transmission is its low spectrum efficiency. Intensive research work has been conducted to exploit spatial domain in more efficient ways to improve the spectrum efficiency of SSK system. However, existing schemes are far from optimal design. Potential gain provided by spatial multiplexing in SSK systems could be further exploited. Although some existing proposed solutions are able to provide higher spectrum efficiency than SSK, their computational complexity is high for high spectrum efficiency scenarios. In this paper, we aim at providing an efficient solution to fully exploit the spatial domain to convey information with a low computational overhead at both transmitter and receiver.

In order to further exploit the spatial domain to transmit more information bits, SSK is generalized to a fixed number of multiple active antennas in GSSK . The authors of provide a method to activate *n* antennas from *Nt* total transmit candidate antennas to achieve log2(*Nt* *n*) bps/Hz spectrum efficiency. Hamming code-aided space shift keying (HSSK) in is designed to activate a varying number of antennas each time with Hamming distance principle and thus achieves higher spectrum efficiency than GSSK. The energy-efficient HSSK transmission in achieves minimum average symbol power consumption by incorporating Hamming code and Huffman code techniques in the alphabet and bit-mapping designs. The above GSSK transmission schemes adopt a varying number of multiple activated antennas to map information. All the selected active antennas emit the same symbols and no source bits are conveyed by these transmit symbols.

Generalized spatial modulation (GSM) also allows several antennas to be activated simultaneously to achieve high spectrum efficiency. However, GSM uses the indices of multiple transmit antennas to map a portion of the data bits and an APM symbol to map the rest of the data bits [13], [14]. All the selected active antennas transmit the same APM symbols. In [15], a multiple active spatial modulation (MASM) is presented to allow multiple transmit antennas in SM system to transmit different APM symbols at the same time.

Conventional VBLAST architecture utilizes layered structure to fully exploit the constellation domain to convey information.

The drawback of VBLAST is that more antennas are required at receiver than that at transmitter, which is typically not valid in downlink cellular system. In consequence, precoding technique for downlink MIMO system, which requires channel state information (CSI) at the transmitter, is developed to solve the problem. However, GSSK is appropriate for unbalanced antenna configuration, especially in massive MIMO systems, where the base station has massive antennas but the user equipment has very few antennas.

The resource of spatial domain is sufficiently rich at the base station in future massive MIMO systems [16]. It is worthwhile mentioning that GSSK seems to be an attractive technique for high-rate and low-complexity MIMO implementations that exploit massive MIMO paradigm. However, spatial domain is not fully exploited by existing GSSK schemes since the achievable spectrum efficiency and performance for GSSK are not satisfactory, which motivates our work in this paper In order to fully exploit the spatial domain to transmit information, we propose a layered SSK (LSSK) modulation scheme to further improve the spectrum efficiency of SSK systems. LSSK employs a layered architecture to achieve spatial multiplexing transmission in SSK systems. Therefore, LSSK modulation improves spectrum efficiency of SSK system by increasing the number of layers, where every additional layer provides additional log2*M* bps/Hz spectrum efficiency by adding just one transmit antenna. We present the general principle for designing the efficient LSSK for arbitrary number of layers with various SSK modulation order. The transmit sparse signal for LSSK is obtained after LSSK modulation directly without incurring intensive computational overhead.

Convention PSK modulation symbols that are predetermined at the transceiver are adopted to identify different layers. With the architecture, greater Euclidean distance is achieved between different transmit signals than that in conventional GSSK scheme. The special architecture guarantees good performance and provides the possibility to apply layered detection to reduce detection complexity. For evaluating the performance of the proposed LSSK, we derive a closed form bound for the bit error probability of LSSK system with optimal maximum likelihood (ML) detection. We also deduce the error probability with a loose upper bound to clearly show the diversity effect of LSSK systems. Numerical results of the comparison with existing schemes such as GSSK, HSSK and VBLAST demonstrate the efficiency of LSSK.

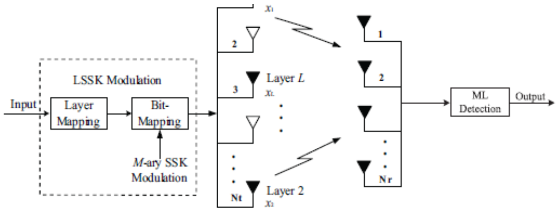
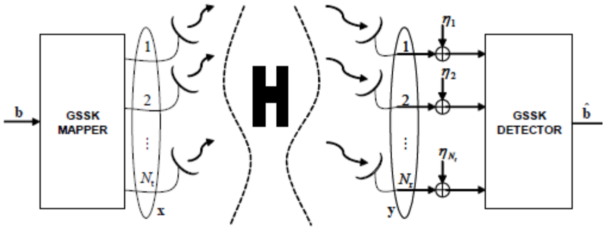


Fig. 1: LSSK system model

GSSK MODULATION

The general system model consists of a MIMO wireless link with Nt transmit and Nr receive antennas, and is shown in Fig. 1. A random sequence of independent bits b = £b1 b2 · · · bk ¤ enters a GSSK mapper, where groups of m bits are mapped £ to a constellation vector x =x1 x2· · · xNt ¤T , with a power constraint of unity (i.e. Ex£xHx¤= 1). In GSSK, only nt antennas remain activeduring transmission, and hence, only nt of the xj ’s in x arenonzero. The signal is transmitted over an Nr × Nt wireless channel H, and experiences an Nr − dim additive white Gaussian (AWGN) noise η = £η1 η2 · · · ηNr¤T. Thereceived signal is given by y =√ρHx + η, where ρ is the average signal to noise ratio (SNR) at each receive antenna, and H and η have independent and identically distributed (iid) entries according to CN (0, 1).



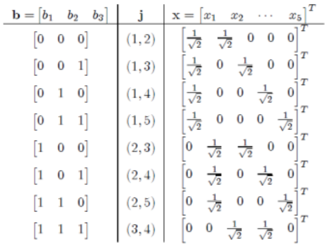
GSSK system model.

At the receiver side, the GSSK detector estimates the antenna indices that are used during transmission, and de maps the symbol to its component bits ˆb.

Transmission

The underlying concept in GSSK is using only antenna indices to relay information. In general, combinations of antenna indices can be used. Therefore, for GSSK using nt antennas, there are M0 = ¡Nt nt ¢ possible constellation points.

TABLE I
EXAMPLE OF THE GSSK MAPPER RULE.



$\mathbf{b} = [b_1 \quad b_2 \quad b_3]$	j	$\mathbf{x} = [x_1 \quad x_2 \quad \cdots \quad x_5]^T$
$[0 \quad 0 \quad 0]$	$(1,2)$	$[\frac{1}{\sqrt{2}} \quad \frac{1}{\sqrt{2}} \quad 0 \quad 0 \quad 0]^T$
$[0 \quad 0 \quad 1]$	$(1,3)$	$[\frac{1}{\sqrt{2}} \quad 0 \quad \frac{1}{\sqrt{2}} \quad 0 \quad 0]^T$
$[0 \quad 1 \quad 0]$	$(1,4)$	$[\frac{1}{\sqrt{2}} \quad 0 \quad 0 \quad \frac{1}{\sqrt{2}} \quad 0]^T$
$[0 \quad 1 \quad 1]$	$(1,5)$	$[\frac{1}{\sqrt{2}} \quad 0 \quad 0 \quad 0 \quad \frac{1}{\sqrt{2}}]^T$
$[1 \quad 0 \quad 0]$	$(2,3)$	$[0 \quad \frac{1}{\sqrt{2}} \quad \frac{1}{\sqrt{2}} \quad 0 \quad 0]^T$
$[1 \quad 0 \quad 1]$	$(2,4)$	$[0 \quad \frac{1}{\sqrt{2}} \quad 0 \quad \frac{1}{\sqrt{2}} \quad 0]^T$
$[1 \quad 1 \quad 0]$	$(2,5)$	$[0 \quad \frac{1}{\sqrt{2}} \quad 0 \quad 0 \quad \frac{1}{\sqrt{2}}]^T$
$[1 \quad 1 \quad 1]$	$(3,4)$	$[0 \quad 0 \quad \frac{1}{\sqrt{2}} \quad \frac{1}{\sqrt{2}} \quad 0]^T$

For example, with nt = 2 and Nt = 7, there are M0 = 21 possible combinations. Since we require a constellation size M in multiples of 2, we only use 16 of the possible 21 combinations. The set of antenna combinations, X, may be chosen at random, but we will see in Section IV that more optimal selection rules exist.

Once X is formulated, the GSSK's mapper rule is straightforward. Groups of m = log2 (M) bits are collected and mapped to a vector xj, where j ∈ X specifies the antenna combination for the given m bit pattern. The symbols in xj do not contain information, but can be designed to optimize transmission.1

The vector xj specifies the activated antennas, during which all other antennas remain idle, and has the following form:

$$\mathbf{x}_\mathbf{j} \triangleq \underbrace{\begin{bmatrix} \frac{1}{\sqrt{n_t}} & 0 & \cdots & 0 & \frac{1}{\sqrt{n_t}} & \cdots & \frac{1}{\sqrt{n_t}} & 0 \end{bmatrix}}_{n_t \text{ of } N_t \text{ non-zero values}}^T .$$

An example of 8-ary GSSK modulation is given in Table I, where we use Nt = 5, nt = 2, and X is chosen randomly. The output of the channel is therefore given by

$$\mathbf{y} = \sqrt{\rho'}\mathbf{h}_{\mathbf{j},\text{eff}} + \boldsymbol{\eta},$$

where ρ0 = ρ nt , and hj,eff = hj(1)+hj(2)+· · ·+hj(nt) (j (·) = j ∈ {1, 2, . . . , Nt} specifies the column index of H). We refer to hj,eff as an effective column, which represents the sum of nt distinct columns in H.

LSSK system model

We consider an LSSK system with *Nt* transmit and *Nr* receive antennas respectively, as depicted in Fig. 1. The information bits are sent to LSSK modulation block to generate the layered transmit signal. A sparse transmit signal comprising *L* layers' signals **s** is emitted from the transmitter after LSSK modulation as

$$\mathbf{s} = \begin{bmatrix} 0 & \cdots & \underset{a_i th}{\overset{x_i}{\uparrow}} & \cdots & \underset{a_L th}{\overset{x_L}{\uparrow}} & \cdots & \underset{a_1 th}{\overset{x_1}{\uparrow}} & \cdots & 0 \end{bmatrix}^T, \quad (1)$$

where **s** is the *Nt* ×1 dimensional sparse transmit signal with *L* non-zero elements *xi, i* ∈*L* = *{*1, 2, ...,*L}*. The signals *xi*, *i* ∈ *L* = *{*1, 2, ...,*L}* are the predetermined PSK symbols to identify the *i*-th layer. For example, the BPSK signals of *x*1 = +1, *x*2 = −1 are introduced to LSSK with *L* = 2 and the 4-PSK signals of *x*1 = +1, *x*2 = +*j*, *x*3 = −1, *x*4 = −*j* are introduced to LSSK with *L* = 4. *ai* ∈*N* = *{*1, 2, ...,*Nt}* denotes the activated transmit antenna index/position for the *i*-th layer.

Each active antenna emits one layer's signal, conveying the same number of log2*M* bits, where *M* is the SSK modulation order. Thus, the achievable spectrum efficiency for LSSK system is *L*log2*M* bps/Hz. We have

$$N_t = M + L - 1. \qquad (2)$$

The received signal at the receiver is given by

$$\mathbf{y} = \sqrt{\frac{\rho}{L}}\mathbf{H}\mathbf{s} + \mathbf{n}, \qquad (3)$$

where ρ is the total transmit power and **n** is the additive white Gaussian noise (AWGN) with independent and identically distributed (i.i.d.) entries obeys a complex Gaussian distribution *CN* ∼ (0, 1). The MIMO channel is assumed to be flat Rayleigh fading and the channel matrix **H** is defined by

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1N_t} \\ h_{21} & h_{22} & \cdots & h_{2N_t} \\ \vdots & & \ddots & \vdots \\ h_{N_r1} & h_{N_r2} & \cdots & h_{N_rN_t} \end{bmatrix},$$

where *hi,j* indicates the channel impulse response coupling the *j*-th transmit antenna to the *i*-th receive antenna with IEEE ICC 2015 - Wireless Communications Symposium 2149 independent and identically complex Gaussian distribution *CN* ∼ (0, 1).

In most fundamental sense, communication involve that transmission of information from one point to another point through a succession of process as listed a head :

1. The generation of a thought pattern or image in the mind of an originator.
2. The description of that image , with a certain measure of precision , by a set of oral visual symbols.
3. The encoding of these symbols in a dorm of that is suitable for transmission of the encoded symbols to the desired destination.
4. The decoding and reproduction of the original symbols.
5. The re creation of the original thought pattern or image, with a definable degradation in quality, in the mind of a recipient.

Hence, as discussed above, the purpose of a communication system is to transmit an information the transmitter bearing signal, from a source, located at one point, to a user or destination, located at another point some distance away. The figure shows the block diagram of a general communication system in which the different functional elements are represented by blocks. The essential components of a communication system are information source, input transducer, transmitter, communication channel, receiver and destination.

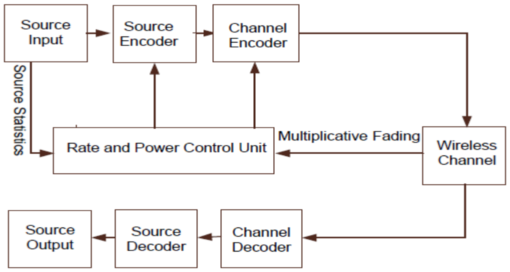


Fig 1.1 Block diagram of the system

- ## Receiver:

The main function of the receiver is to re produce the message signal in electrical form from distorted received signal. This re production of the original signal is accomplished by a process known as the demodulation or detection. Demodulation is the reverse process of modulation carried out in transmitter.

- ## Destination:

Destination is the final stage which is used to convert an electrical message signal into its original form. For example in radio broadcasting, the destination is a loud speaker which works as a transducer i.e, it converts the electrical signal in the form of original sound signals.

- ## Concept of bandwidth:

Bandwidth may be defined as the portion of the electromagnetic spectrum occupied by a signal. We may also defined the band width as the frequency range over which an information signal is transmitted. Band width is the difference between the upper and lower frequency limits of the signal. We already know different types of pass band signal such as voice signal, music signal, tv signal etc. Each of the signals will have its own frequency range. This frequency range of a signal is known as its band width. As an example, the range of music signal is 20 HZ – 15KHZ. Therefore, as shown in figure, the band width is (f2-f1).

Thus, we write BW=(f2-f1)

=15000-20

=14980 HZ

Functions of MIMO

MIMO can be sub-divided into three main categories, precoding, spatial multiplexing or SM, and diversity coding.

Preceding

it is multi-stream beam forming, in the narrowest definition. In more general terms, it is considered to be all spatial processing that occurs at the transmitter. In (single-stream) beam forming, the same signal is emitted from each of the transmit antennas with appropriate phase and gain weighting such that the signal power is maximized at the receiver input. The benefits of beam forming are to increase the received signal gain, by making signals emitted from different antennas add up constructively, and to reduce the multipath fading effect. In line-of-sight propagation, beam forming results in a well defined directional pattern. However, conventional beams are not a good analogy in cellular networks, which are mainly characterized by multipath propagation. When the receiver has multiple antennas, the transmit beam forming cannot simultaneously maximize the signal level at all of the receive antennas, and precoding with multiple streams is often beneficial. Note that precoding requires knowledge of channel state information (CSI) at the transmitter and the receiver.

Spatial multiplexing :

it requires MIMO antenna configuration. In spatial multiplexing, a high rate signal is split into multiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. If these signals arrive at the receiver antenna array with sufficiently different spatial signatures and the receiver has accurate CSI, it can separate these streams into (almost) parallel channels. Spatial multiplexing is a very powerful technique for increasing channel capacity at higher signal-to-noise ratios (SNR). The maximum number of spatial streams is limited by the lesser of the number of antennas at the transmitter or receiver. Spatial multiplexing can be used without CSI at the transmitter, but can be combined with precoding if CSI is available. Spatial multiplexing can also be used for simultaneous transmission to multiple receivers, known as space-division multiple access or multi-user MIMO, in which case CSI is required at the transmitter.[9] The scheduling of receivers with different spatial signatures allows good separability.

Diversity Coding

The techniques are used when there is no channel knowledge at the transmitter. In diversity methods, a single stream (unlike multiple streams in spatial multiplexing) is transmitted, but the signal is coded using techniques called space-time coding. The signal is emitted from each of the transmit antennas with full or near orthogonal coding. Diversity coding exploits the independent fading in the multiple antenna links to enhance signal diversity. Because there is no channel knowledge, there is no beamforming or array gain from diversity coding. Diversity coding can be combined with spatial multiplexing when some channel knowledge is available at.

Forms of MIMO

Example of an antenna for LTE with 2 ports antenna diversity

Multi-antenna types

Multi-antenna MIMO (or Single user MIMO) technology has been developed and implemented in some standards, e.g., 802.11n products.

- SISO/SIMO/MISO are special cases of MIMO
    - ○ Multiple-input and single-output (MISO) is a special case when the receiver has a single antenna.
    - ○ Single-input and multiple-output (SIMO) is a special case when the transmitter has a single antenna.
    - ○ single-input single-output (SISO) is a conventional radio system where neither the transmitter nor receiver have multiple antenna.
- Principal single-user MIMO techniques
    - ○ Bell Laboratories Layered Space-Time (BLAST), Gerard. J. Foschini (1996)
    - ○ Per Antenna Rate Control (PARC), Varanasi, Guess (1998), Chung, Huang, Lozano (2001)
    - ○ Selective Per Antenna Rate Control (SPARC), Ericsson (2004)
- Some limitations

○ The physical antenna spacing is selected to be large; multiple wavelengths at the base station. The antenna separation at the receiver is heavily space constrained in hand sets, though advanced antenna design and algorithm techniques are under discussion. *Refer to: multi-user MIMO*

Multi-user types

Recently, results of research on multi-user MIMO technology have been emerging. While full multi-user MIMO (or network MIMO) can have a higher potential, practically, the research on (partial) multi-user MIMO (or multi-user and multi-antenna MIMO) technology is more active.

- Multi-user MIMO (MU-MIMO)
  - In recent 3GPP and WiMAX standards, MU-MIMO is being treated as one of the candidate technologies adoptable in the specification by a number of companies, including Samsung, Intel, Qualcomm, Ericsson, TI, Huawei, Philips, Alcatel-Lucent, and Freescale. For these and other firms active in the mobile hardware market, MU-MIMO is more feasible for low complexity cell phones with a small number of reception antennas, whereas single-user SU-MIMO's higher per-user throughput is better suited to more complex user devices with more antennas.
  - PU^{2}RC allows the network to allocate each antenna to a different user instead of allocating only a single user as in single-user MIMO scheduling. The network can transmit user data through a codebook-based spatial beam or a virtual antenna. Efficient user scheduling, such as pairing spatially distinguishable users with codebook based spatial beams, is additionally discussed for the simplification of wireless networks in terms of additional wireless resource requirements and complex protocol modification. Recently, PU^{2}RC is included in the system description documentation (SDD) of IEEE 802.16m (WiMAX evolution to meet the ITU-R's IMT-Advance requirements).
  - Enhanced multiuser MIMO: 1) Employs advanced decoding techniques, 2) Employs advanced precoding techniques
  - SDMA represents either space-division multiple access or super-division multiple access where *super*emphasises that orthogonal division such as frequency and time division is not used but non-orthogonal approaches such as superposition coding are used.

- Cooperative MIMO (CO-MIMO)

- Uses distributed antennas which belong to other users.
- Macrodiversity MIMO
  - A form of space diversity scheme which uses multiple transmit or receive base stations for communicating coherently with single or

multiple users which are possibly distributed in the coverage area, in the same time and frequency resource.

- The transmitters are far apart in contrast to traditional microdiversity MIMO schemes such as single-user MIMO. In multi-user macrodiversity MIMO scenario, users may also be far apart. Therefore, every constituent link in the virtual MIMO link has distinct average link SNR. This difference is mainly due to the different long-term channel impairments such as path loss and shadow fading which are experienced by different links.
- Macrodiversity MIMO schemes pose unprecedented theoretical and practical challenges. Among many theoretical challenges, perhaps the most fundamental challenge is to understand how the different average link SNRs affect the overall system capacity and individual user performance in fading environments.

- MIMO Routing
  - Routing a cluster by a cluster in each hop, where the number of nodes in each cluster is larger or equal to one. MIMO routing is different from conventional (SISO) routing since conventional routing protocols route node by node in each hop.

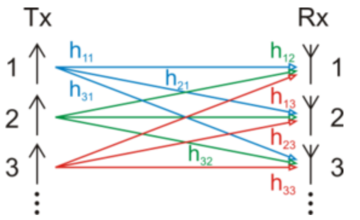
Applications of MIMO

Spatial multiplexing techniques make the receivers very complex, and therefore they are typically combined with Orthogonal frequency-division multiplexing (OFDM) or with Orthogonal Frequency Division Multiple Access (OFDMA) modulation, where the problems created by a multi-path channel are handled efficiently. The IEEE 802.16e standard incorporates MIMO-OFDMA. The IEEE 802.11n standard, released in October 2009, recommends MIMO-OFDM.

MIMO is also planned to be used in Mobile radio telephone standards such as recent 3GPP and 3GPP2. In 3GPP, High-Speed Packet Access plus (HSPA+) and Long Term Evolution (LTE) standards take MIMO into account. Moreover, to fully support cellular environments, MIMO research consortia including IST-MASCOT propose to develop advanced MIMO techniques, e.g., multi-user MIMO (MU-MIMO).

MIMO technology can be used in non-wireless communications systems. One example is the home networking standard ITU-TG.9963, which defines a powerline communications system that uses MIMO techniques to transmit multiple signals over multiple AC wires (phase, neutral and ground).

Mathematical description



SIMULATION RESULTS

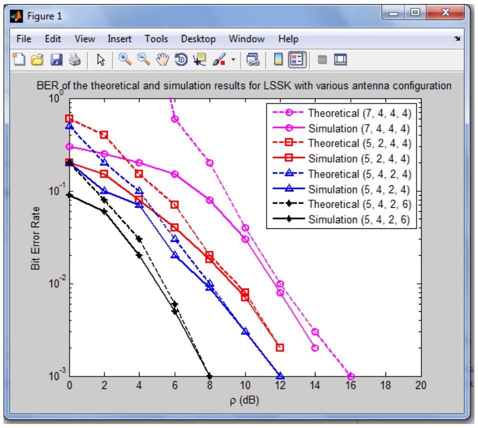
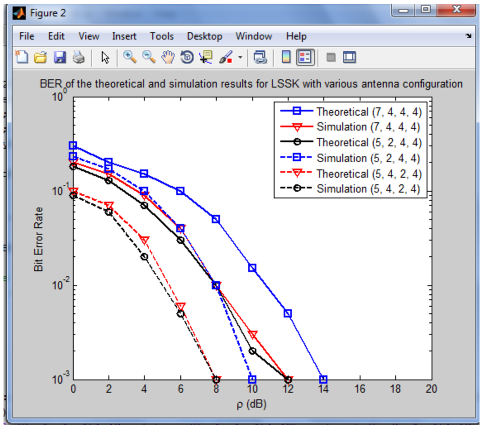
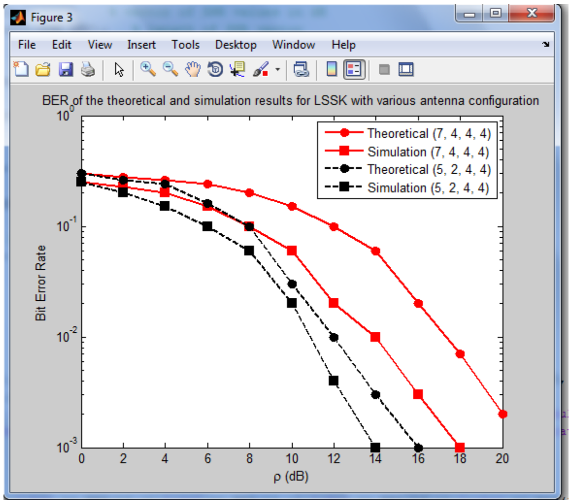


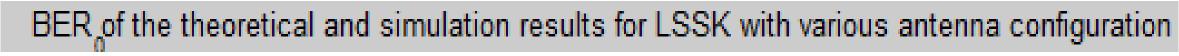
Fig (a)



Fig(b)



Fig(c)


BER$_0$ of the theoretical and simulation results for LSSK with various antenna configuration

CONCLUSION

In this paper, we have presented a layered space shift keying modulation scheme over MIMO channels to fully exploit the spatial domain to convey information. LSSK employs a layered architecture to achieve spatial multiplexing transmission in SSK systems and substantially improves the spectrum efficiency of SSK system. Conventional PSK symbols are adopted for identifying different layers and improving performance.

The transmit sparse signal of LSSK is generated directly by the proposed LSSK modulation scheme with low computational overhead. We have also derived a theoretical closed form upper bound for bit error probability of LSSK. Comparisons with some existing schemes such as GSSK, HSSK and VBLAST demonstrate the efficiency of LSSK.

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