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SPACE SHIFT KEYING FOR STRAIGHT AND SHORT COMMUNICATION USING MMWAVE FREQUENCIES

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Abstract - We use space shift keying (SSK) techniques, which is the simplest form of spatial modulation (SM), to present and analyze the idea of spatial modulation in line-of-sight (LOS) conditions. We show that SSK can operate effectively in LOS conditions provided that the antennas are properly placed at TX and RX such that a high-rank LOS MIMO channel is constructed. The operating conditions for LOS-SSK with parallel uniform linear arrays are established and two schemes, namely orthogonal SSK and bi-orthogonal SSK, are introduced. The bit error probabilities for both methods are derived and given in closed form. It is shown that LOS-SSK (more generally LOS-SM) is a promising technique and might especially be attractive in millimeter-wave communications which due to its high frequency and small wavelength inherently prefers LOS transmission and also enables packing of a large number of antennas in terminals.

1. INTRODUCTION

MIMO:

The wireless system designers are faced numerous challenges to fulfill the demand of the wireless communication for higher data rates, better quality service, fewer dropped calls , higher network capacity including limited availability of radio frequency spectrum and transmission problems caused by various factors like fading and multipath distortion. These needs require new techniques that improve spectral efficiency and operational reliability. Multi-Input-Multi-Output (MIMO) technology promises a cost effective way to provide these capabilities. MIMO uses multiple antennas at both the transmitter and receiver to improve the communication performance. It is one of the several forms of smart antenna technology. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading). Because of these properties, MIMO is a current theme of international wireless research. The increasing demand for capacity in wireless systems has motivated considerable research aimed at achieving higher throughput on a given bandwidth. One important recent discovery shows that in a multipath environment, the use of space-time coding with multiple antennas on both ends of the link can increase the capacity of the wireless channel., thereby increasing the amount of information the system carries and the data is received by multiple antennas and recombined properly by other algorithms to recover the data at the receiver. MIMO is an underlying technique for carrying data. It operates at the physical layer, below the protocols used to carry the data, so its channels can work with virtually any wireless transmission protocol. For example, MIMO can be used with the popular IEEE 802.11 (Wi-Fi) technology. For these reasons, MIMO eventually will become the standard for carrying almost all wireless traffic. MIMO the only economical way to increase bandwidth, range and will become a core technology in wireless systems. Assessing the performance of these algorithms requires detailed understanding of multiple-input multiple-output (MIMO) channels as well as models that capture their complex spatial behavior. There are four types of Communication models or multiple antenna systems – SISO, SIMO, MISO and MIMO.

SISO:

The existing technology is Single Input Single Output (SISO). This has one antenna at both the transmitter and the receiver employs no diversity technique. Both the transmitter and the receiver have one RF chain (that's coder and modulator). SISO is relatively simple and cheap to implement and it has been used age long since the birth of radio technology. It is used in radio and TV broadcast and our personal wireless technologies (e.g. Wi-Fi and Bluetooth).

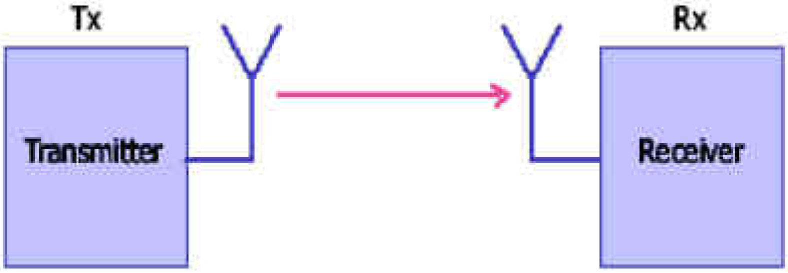


Fig.1.1- Single Input Single Output (SISO)

SIMO:

One antenna at the transmitter, two antennas at the receiver employs a receive diversity technique. To improve performance, a multiple antenna technique has been developed. A system which uses a single antenna at the transmitter and multiple antennas at the receiver is named as Single Input Multiple Output (SIMO). The receiver can either choose the best antenna to receive a stronger signal or combine signals from all antennas in such a way that maximizes SNR (Signal to Noise Ratio). The first technique is known as switched diversity or selection diversity. The latter is known as maximal ratio combining (MRC).

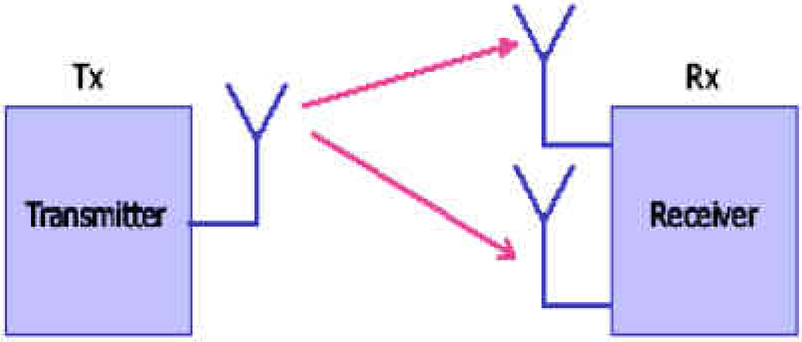


Fig.1.2- Single Input Multi Output (SIMO)

MISO:

Two antennas at the transmitter, one antenna at the receiver employs a transmit diversity technique. A system which uses multiple antennas at the transmitter and a single antenna at the receiver is named Multiple Input Single Output (MISO). A technique known as Alamouti STC (Space Time Coding) is employed at the transmitter with two antennas. STC allows the transmitter to transmit signals (information) both in time and space, meaning the information is transmitted by two antennas at two different times consecutively. Multiple antennas (each with an RF chain) of either SIMO or MISO are usually placed at a base station (BS). This way, the cost of providing either a receive diversity (in SIMO) or transmit diversity (in MISO) can be shared by all subscriber stations (SSs) served by the BS.

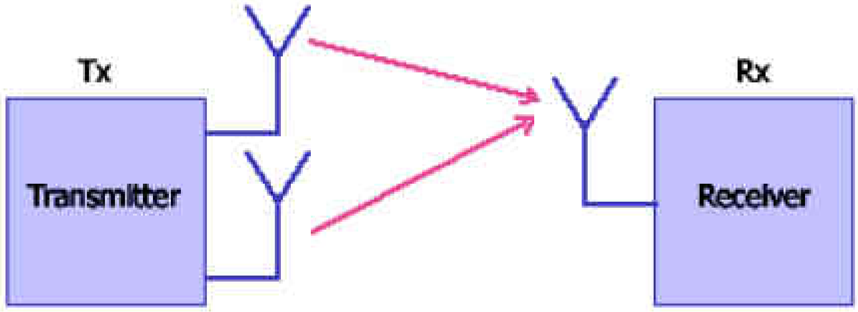


Fig.1.3- Multi Input Single Output (MISO)

MIMO:

To multiply throughput of a radio link, multiple antennas (and multiple RF chains accordingly) are put at both the transmitter and the receiver. This system is referred to as Multiple Input Multiple Output (MIMO). A MIMO system with similar count of antennas at both the transmitter and the receiver in a point-to-point (PTP) link is able to multiply the system throughput linearly with every additional antenna. For example, a 2x2 MIMO will double the throughput. Two antennas at both the transmitter and the receiver side uses transmit and receive diversity.

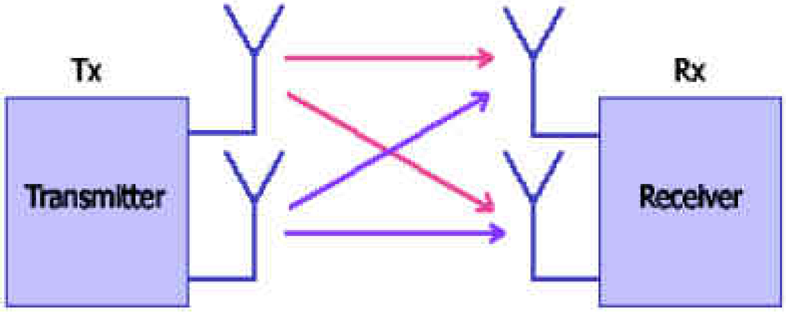


Fig.1.4- Multi Input Multi Output (MIMO) - size2x2

BENEFITS OF MIMO TECHNOLOGY

The benefits of MIMO technology that help achieve such significant performance gains are array gain, spatial diversity gain, spatial multiplexing gain and interference reduction. These gains are described in brief below.

- Array gain
- Spatial diversity gain
- Spatial multiplexing gain
- Interference reduction and avoidance

2. PROJECT DESCRIPTION

2.1 MODULES:

MODULES NAME

- SYSTEM MODEL
    - LINE-OF-SIGHT
    - spherical wave modeling
    - MIMO
    - space shift keying (SSK),

SYSTEM MODEL

We consider an $Nt \times Nr$ LOS-MIMO system, as shown in with uniform linear arrays at TX and RX which are parallel to each other, where Nt and Nr are the number of TX and RX antennas, respectively. The inter-antenna separation of the TX array and RX array are $s1$ and $s2$, respectively, and the array distance from the TX to the RX is D. The transmission coefficient from the i-th TX antenna to the j-th RX antenna is denoted by $hji = |hji|\exp(-\mathrm{j}kdji)$ where upright j is the imaginary unit, $k = 2\pi/\lambda$ is the wave number, dji denotes the propagation path length, and $|hji|$ is the transmission "gain" of the channel which, for LOS conditions, can be calculated from the Friis transmission equation. The small change of $|hji|$ for different i and j is ignored. We can thus collapse $|hji|$ into the transmit power and have a simplified channel model as

$$\mathbf{H} = \begin{bmatrix} \exp(-\mathrm{j}kd_{11}) & \cdots & \exp(-\mathrm{j}kd_{1N_t}) \\ \vdots & \ddots & \vdots \\ \exp(-\mathrm{j}kd_{N_r1}) & \cdots & \exp(-\mathrm{j}kd_{N_rN_t}) \end{bmatrix}.$$

where Ei is the energy allocated to the i-th symbol, and $\mathbf{x}i$ denotes the i-th TX symbol for which—due to the usage of SSK—only the i-th TX antenna is activated and the other TX. antennas are left silent. Furthermore, it is assumed that the antenna couplings are negligibly small. The actually received symbol would be noise-corrupted as given by $\mathbf{y} = \mathbf{y}i + \mathbf{n}$, where $\mathbf{n}$ is an Nr-element vector of i.i.d (independent and identically distributed) circularly symmetric complex additive white Gaussian noise variables with variance $2\sigma2$ and power spectral density $N0$, i.e., $\mathbf{n} \sim CN(\mathbf{0}, 2\sigma2\mathbf{I}Nr)$, where $\mathbf{I}Nr$ is an $Nr \times Nr$ identity matrix and $2\sigma2 = N0$. We are expecting to establish a high-rank MIMO channel, in which the antenna separations in general should be larger than half wave length, i.e., $s1, s2 > \lambda/2$.

Establishment of a high capacity LOS-MIMO channel relies on proper placement of the antennas.

Optimal Detection:

Since in SSK the information is solely conveyed in the index of the transmitting antenna, the optimal detector, given that the symbols are equally probable, would be the maximum-likelihood (ML) detector given by

$$\hat{i} = \underbrace{argmax}_{i}\, p_y(y|x_i,\mathrm{H}) = \underbrace{argmax}_{i}\, \|\mathrm{y}-y_i\|$$

Operating Conditions:

We first consider a simple case with only two TX antennas, i.e., a 2×*Nr* LOS-MIMO, and seek to maximize the Euclidean distance of the two received symbols. The optimization problem is formulated as: In addition, **H** is constrained by the distance *D*, antenna separations *s*1 and *s*2, and even the array structure itself. Based on the understanding of how to maximize the Euclidean distance between symbols for SSK with dual TX antennas, we now consider the general case with *Nt* ≥ 2. We wish to maximize the Euclidean distances between all possible pairs of received symbols, and, even more importantly the smallest Euclidean distance.

$$\boldsymbol{s_1 s_2 \approx nD\lambda/\mathrm{Nr}}$$

Spherical wave modeling:

We consider pure line-of-sight multiple-input multiple-output (MIMO) channels employing uniform linear antenna arrays. We investigate the influence of exact spherical wave propagation modeling versus approximate plane wave propagation modeling on the properties of the MIMO channel matrix. When the transmission distance increases, the properties of the singular values of the MIMO channel matrix given by the spherical wave model approach the properties given by the simpler plane wave model. We investigate this transition between the two channel models, which results in a new tool giving us analytical expressions describing when spherical wave modeling is necessary and when plane wave modeling gives sufficient modeling accuracy. The parameters of interest are the transmission distance, the frequency, the array orientation, and the array size. The tool introduced is general, in the sense that it supports different performance measures when deciding on the transition between the two models. As an example, we investigate underestimation of the mutual information in this paper. The results show that the spherical wave model should be applied e.g. in some practical WLAN scenarios where plane wave modeling is commonly applied today.

Bit Error Probability for OSSK:

In the current context, all possible *i* → *i*_ detection errors are equally likely, so the symbol-to-constellation mapping can be chosen arbitrarily. The bit error probability can be found to be

$$P_b = \frac{\sum_{k=1}^{\mathrm{N}} \mathrm{k}\binom{n}{k}}{\mathrm{N(M-1)}}\left[1-(1-\mathrm{Q}(\sqrt{\mathrm{NrN\gamma 0}}))^{M-1}\right]$$

where Pi denotes the probability of i being successfully detected, M Δ= Nt , N =log2Nt and γ0Δ=$Em/N0/N$ being the $Eb/N0$ per RX branch.

Bit Error Probability for BiSSK:

$$P_b = \frac{\sum_{k=1}^{N-1} \mathrm{k}\binom{n}{k}}{\mathrm{N(M-2)}}\left[1-\left(1-\mathrm{Q}\left(\sqrt{\mathrm{NrN\gamma 0}}\right)\right)^{M-2}\right]$$

To compare 2Nr ×Nr BiSSK and Nr ×Nr OSSK with Nr × Nr M-QAM1: in a larger size MIMO system, BiSSK and OSSK have significant gain (in $Eb/N0$) over M-QAM. In a smaller size MIMO system, on one hand, BiSSK and OSSK have lower gain than M-QAM. On the other hand, we should note that BiSSK and OSSK use one PA and are constant envelope. However, M-QAM uses Nt PAs and is in general non-constant envelope implying a lower PA efficiency. To compare with spatial multiplexing (SMX)MIMO, we also considered SMX-QPSK 2 × 16, which has the same rate of 4 bits/symbol as 16-QAM 16 × 16, OSSK 16 × 16 and BI-SSK 16 × 8. We see that OSSK and BI-SSK significantly outperform SMX-MIMO in this comparison. While having its simplicity and performance, the price to pay with SSK is much larger TX array size, 16 vs. 2 in this comparison. The enormous gain and simplicity being exhibited by LOSSSK makes spatial modulation an attractive MIMO solution in LOS conditions To compare 2Nr ×Nr BI-SSK and Nr ×Nr OSSK with Nr × Nr M-QAM1: in a larger size MIMO system, BI-SSK and OSSK have significant gain (in $Eb/N0$) over M-QAM. In a smaller size MIMO system, on one hand, BI-SSK and OSSK have lower gain than M-QAM. On the other hand, we should note that BI-SSK and OSSK use one PA and are constant envelope. However, M-QAM uses Nt PAs and is in general non-constant envelope implying a lower PA efficiency. To compare with spatial multiplexing (SMX)MIMO, we also considered SMX-QPSK 2 × 16, which has the same rate of 4 bits/symbol as 16-QAM 16 × 16, OSSK 16 × 16 and BI-SSK 16 × 8. We see that OSSK and BI-SSK significantly outperform SMX-MIMO in this comparison. While having its simplicity and performance, the price to pay with SSK is much larger TX array size, 16 vs. 2 in this comparison. The enormous gain and simplicity being exhibited by LOS SSK makes spatial modulation an attractive MIMO solution in LOS conditions.

3. EXISTING SYSTEM

We study the performance of Space Shift Keying (SSK) modulation for a generic Multiple–Input– Multiple–Output (MIMO) wireless system over correlated Rician fading channels. In particular, our contribution is twofold. First, we propose a very general framework for computing the Average Bit Error Probability (ABEP) of SSK–MIMO systems over a generic Rician fading channel with arbitrary correlation and channel parameters. The framework relies upon the Moschopoulos method. We show that it is exact for MIMO systems with two transmit –antenna and arbitrary receive–antenna, while an asymptotically–tight upper–bound is proposed to handle the system setup with an arbitrary number of transmit–antenna. ii) Second, moving from the consideration that conventional SSK– MIMO schemes can offer only receive–diversity gains, we propose a novel SSK–MIMO scheme that can exploit the transmit– antenna to increase the diversity order. The new method has its basic foundation on the transmission of signals with good time–correlation properties, and is called Time–Orthogonal– Signal–Design (TOSD–) assisted SSK modulation (TOSD–SSK).

It is shown that the proposed method can increase twofold the diversity order for arbitrary transmit– and receive–antenna. In particular, for MIMO systems with two transmit–antenna and *Nr* receive–antenna full–diversity equal to 2*Nr* can be achieved. Analytical frameworks and theoretical findings are substantiated via Monte Carlo simulations for various system setups

3.1 DISADVANTAGES OF EXISTING SYSTEM

- Average Bit Error Probability
- Transmit power is high

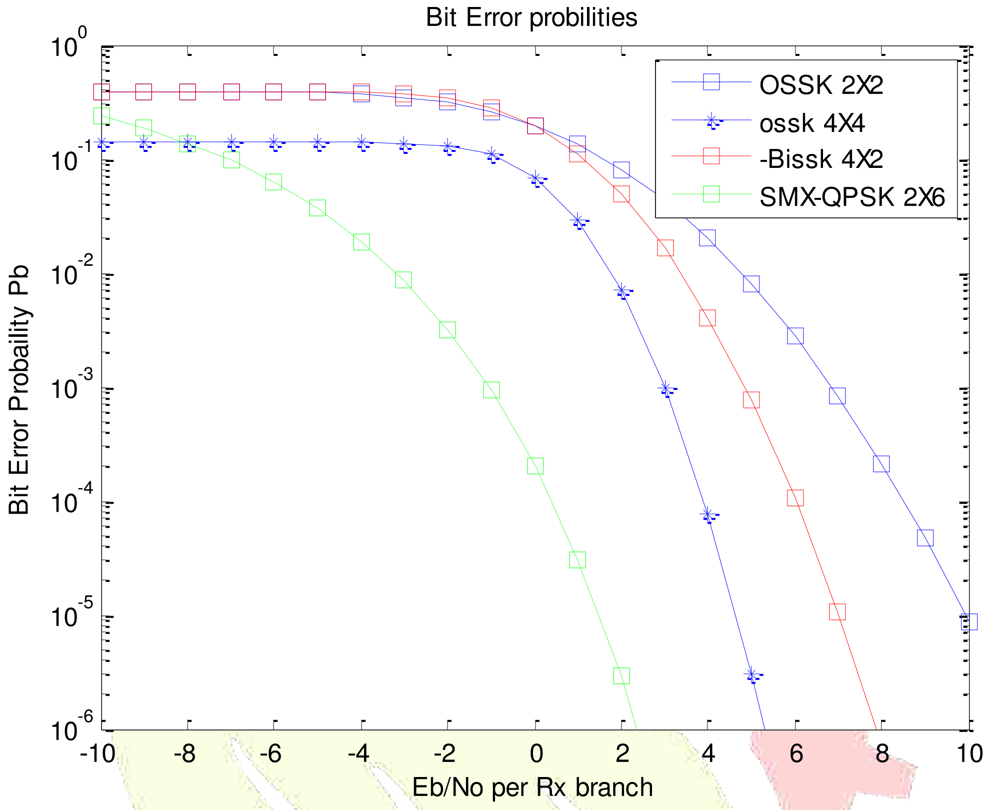
4. PROPOSED SYSTEM

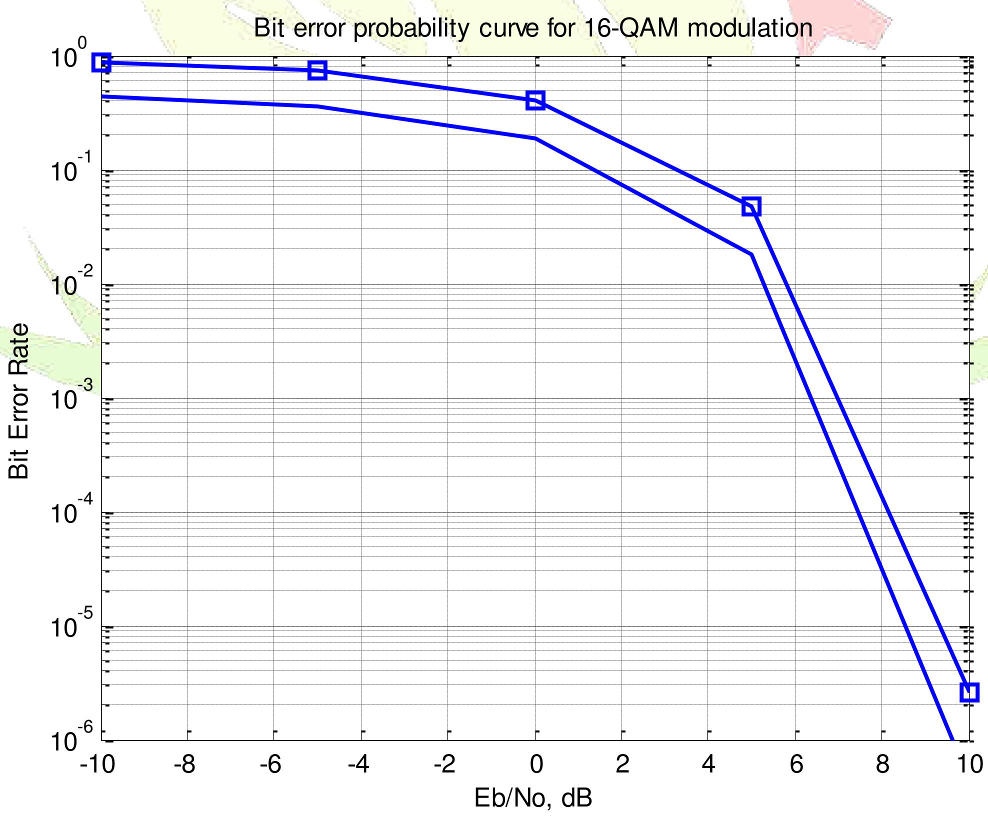
Spatial Modulation (SM) has been recently proposed as a new and promising candidate transmission technique for low–complexity implementations of Multiple–Input–Multiple– Output (MIMO) wireless systems that require a medium/high transmission rate. In particular, it has been shown that SM is an excellent solution to solve the three main issues amongst the adoption of MIMO systems for low–complexity and power–efficient applications, *i.e.*, i) inter–channel interference, ii) inter–antenna synchronization, and iii) multiple radio frequency chains at the transmitter Numerical results in have shown that SM can offer better performance and a reduced computational complexity than other popular MIMO schemes for fading channels. Furthermore, in a low–complexity implementation of SM, which is called Space Shift Keying (SSK) modulation, has been suggested and studied. SSK modulation offers a good solution to trade–off receiver complexity for data rate.

1.4 ADVANTAGES OF PROPOSED SYSTEM

- SSK reduces the system complexity
- High Bit Error performance(BER) can be achieved
- power–efficient applications

5. SIMULATION RESULTS





6. CONCLUSION:

We have shown that SSK can operate efficiently in LOS conditions. Two operating conditions, namely OSSK and Bi-SSK, are established. A system setup with dual TX arrays and single RX array is proposed to achieve Bi-SSK. The BEP for both schemes are derived and given in closed form. Ongoing research is concerned with the sensitivity of LOS-SSK to practical issues such as array misalignment, displacement, and multi-path propagation.

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