ANALYSIS OF SPATIAL MODULATION

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Abstract - *Spatial modulation(SM) is a digital modulation concept of Multiple –input-multiple-output (MIMO) wireless systems, which has been introduced recently to increase the data rate of single antenna system. In this paper the performance of Spatial Modulation(SM) Multiple-Input- Multiple-Output wireless systems is studied.*

KeyWords: (Multiple-input-Multiple-output (MIMO), Spatial Modulation, 4G wireless communication, Bit error rate

1. INTRODUCTION

Mobile communication faces two main challenges due to the success of smart phones and the enormous amount of data generated by these smart phones. The data traffic almost doubles every year. The first challenge is that there is not enough radio spectrum to feed the demand. Therefore, it is necessary to increase the number of transmitted bits per hertz. The other challenge is that the large numbers of cellular base stations that exist today require a huge amount of energy. The systems need to be made more energy efficient. Multiple-input Multiple-output (MIMO) systems help overcome these challenges. MIMO systems use multiple transmitting and receiving antennas without increasing the bandwidth requirement. Reliability and diversity are achieved through using the spatial domain as a coding mechanism.

High spectral efficiency and high transmission rate are the challenging requirements of future wireless broadband communications. In a multipath wireless channel environment, the use of Multiple Input Multiple Output (MIMO) systems leads to the accomplishment of high data rate transmission without escalating the total transmission power or bandwidth

Keywords: precoding, spatial multiplexing, diversity coding, spatial constellation

2. SPATIAL MODULATION

2.1 MIMO SYSTEMS

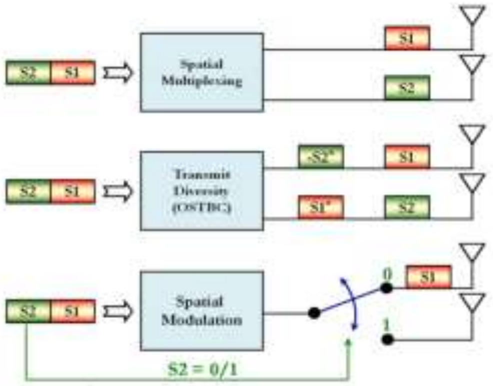
MULTIPLE-INPUT-MULTIPLE-OUTPUT is a method for multiplying the capacity of a radio link using multiple transmit and receive antennas to exploit multipath propagation. MIMO has become an essential element of wireless communication standards including IEEE 802.11n (Wi-Fi), IEEE 802.11ac (Wi-Fi), HSPA+ (3G), WiMAX (4G), and Long Term Evolution (LTE 4G). More recently, MIMO has been applied to power-line communication for 3- wire installations as part of ITU G.hn standard and Home Plug AV2 specification [3][4].

2.2 Functions of mimo systems

Precoding is multi-stream beamforming, in the narrowest definition. In more general terms, it is considered to be all spatial processing that occurs at the transmitter. In (single- stream) beamforming, 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 beamforming 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, beamforming 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 beamforming 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 requires MIMO antenna configuration. In spatial multiplexing, [5][6] 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.

Diversity coding 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 the transmitter.



3. WORKING OF SM-MIMO

3.1 The working of SM-MIMO

The SM– MIMO concept has been illustrated as follows. Nt and Nr represent the number of transmit antennas (TAs) and receive antennas (s), respectively. The cardinality of the signalconstellation diagram is denoted by M. Either PSK or QAM are considered. In general, Nt, Nr, and M are independent of each other. Optimum ML demodulation is considered at the receiver. It is assumed that Nt = 2nt and M= 2m, nt and m being two positive integers. In SM–MIMO, one symbol S1 is explicitly transmitted, and the other symbol S2 is transmitted implicitly by the receiver as it determines the index of the transmit antenna that is active. The information symbols are portioned into two modulated parts: i. one symbol undergoes general modulation such as PSK/QAM ii. An information-driven antenna-switching mechanism drives a transmitting antenna. For an antenna Nt and M, the SM bit rate is given by

RSM=log2(M)+log2(Nt) bpcu (1) [2] defined. Do not use abbreviations in the title or heads unless they are unavoidable.

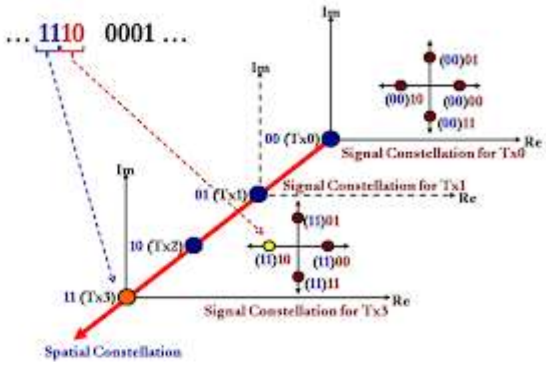


Figure 1: Spatial constellation diagram using 4 transmit antennas and QAM[1]

Here MIMO is defined for Nt = M=4 by considering two generic channel uses in Figure1. The figure introduces the concept of „„SM or spatial-constellation diagram"". The rate is given by

RSM=log2(M)+log2(Nt)

bpcu= log2(4)+log2(4)= 4 bpcu

The information bits is processed in blocks of four bits each by the encoder. As shown in figure 1, the first transmission block of bits to be undergoing encoding is „„1100."" The single active TA is determined by he first log2(Nt)=2 bits, i.e „„11,"" while the PSK/QAM symbol to be transmitted is determined by the second log2(M)=2bits, i.e „"00.""

It is to be observed that

i. Based on the input information bits, the TA activated may change for every channel use. Thus, switching of TA proves to be an effectual method of correlating the information bits to TA indices. This increases the rate of transmission. This has been referred to in many MIMO papers under the concept of „„spatial cycling using one transmitter at a time""

ii. The input information bits are mapped onto a 3-D constellation diagram, which adds a third dimension provided by the antenna indices to the known 2-D signal-constellation diagram of PSK/QAM modulation techniques. This is known as the „„spatial-constellation diagram"" as shown in figure 1. Mathematically, assuming a frequency-flat channel model, the SM– MIMO signal model is shown in Eq (2)

$$Y = Hx + n \quad (2)$$

Where y- the complex received vector

H- the complex channel matrix

n- the complex AWGN at the receiver

x- being the complex (scalar) PSK/QAM modulated symbols belonging to the signal-constellation diagram in a complex modulated vector[2]

3.2 Operational Principle of SM MIMO

The operational principles of SM MIMO rely on transmitting part of the information bits via an implicit information-driven antenna-switching mechanism. The bit-to-symbol mapping is illustrated in Figure 1. And the transmission process through the communication channel along with the decoding process of SM MIMO transmission is illustrated in Figure 2, respectively.

Here, using Eq 1,

log2(Nt)=2 and log2(M)=1.

This means that RSM=3 bpcu

If the input at the SM modulator is „„101"". The „„1"" PSK bit is transmitted from the TA element "TX 2" is activated. The independent transmitter – receiver channel impulse responses are illustrated in Figure 2.[2]

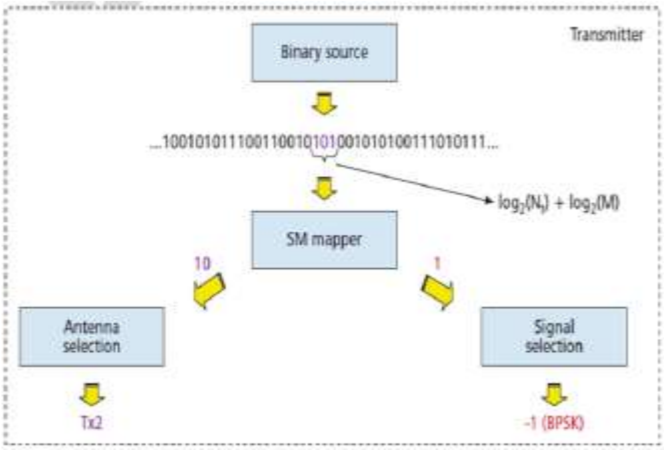
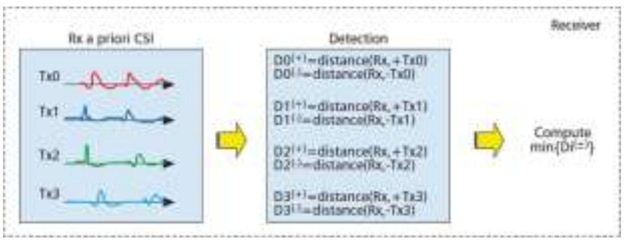


Figure 2: Bits to symbol mapping at the Transmitter. For the symbol 101, 10 is implicitly transmitted and 1 is explicitly transmitted.[1]

At the receiver, the demodulation unit exploits the unique fingerprint introduced by the wireless channel for retrieving the information bits. This is illustrated in Fig. 6, where a coherent demodulation scheme based on the minimum Euclidean distance is considered. The receiver is assumed to be aware of the Nt channel impulse responses, however the actual channel impulse response that is received in each channel use depends on the index of the active TA. The demodulator performs an exhaustive search among all the possible combinations of channel impulse responses and modulation symbols, and makes a decision in favour of the hypothesis associated with the lowest Euclidean distance. In a nutshell, due to the information-driven antenna-switching mechanism of SM– MIMO transmission, the Nt channel impulse responses become part of the search space of the hypothesis-testing problem solved by the receiver. Based on the estimated channel impulse response, the demodulator is capable of retrieving the information bits associated with it. In summary, the essence of SM–MIMO transmission is all about exploiting the TA-specific property of the wireless channel, i.e., the uniqueness of each transmit-to-receive wireless link, for data communication.



The spatial modulation for multiuser MIMO systems is given below

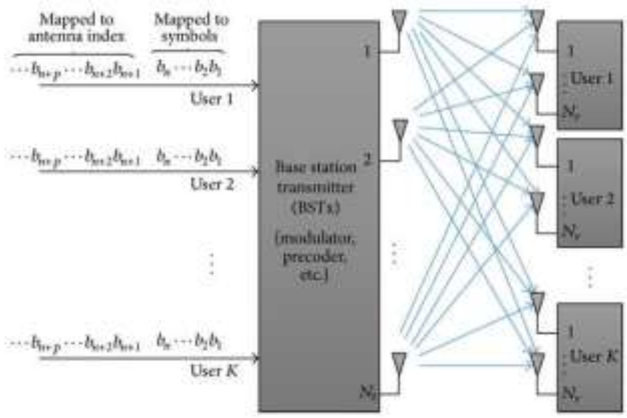


Figure3: Spatial Modulation for multiuser MIMO system

3.3 BER Analysis of Spatial Modulation

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors.

The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. Bit error ratio is a unit less performance measure, often expressed as a percentage.

The bit error probability pe is the expectation value of the bit error ratio. The bit error ratio can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors.

The BER analysis is done by using MATLAB and the simulation result is shown below [7]

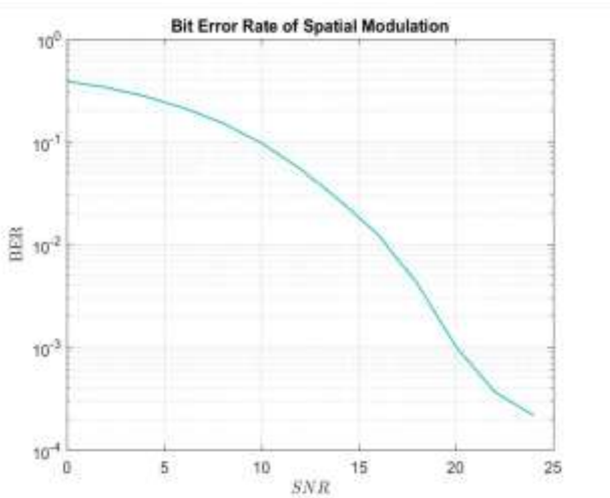


Figure 4: BER Analysis of spatial modulation

4. Result and conclusion

Spatial modulation (SM), an effective and robust multiple antenna transmission approach has been applied to multi carrier MIMO wireless communication system. Such modulation scheme can be used in 5G compatible massive/large MIMO wireless communication systems. The system performance under implementation of spatial modulation in independent and identically distributed Rayleigh flat fading channels has been assessed critically with various resource allocation and PAPR reduction schemes. [1]

In this paper study about the multiple input multiple output sysytems and spatial modulation system is made. Then study about the BER (Bit error rate) of spatial modulation is made and simulated it using MATLAB and the simulation was shown.

The need for power-efficient MIMO-aided cellular networks requires a paradigm shift in the wireless system design. This trend is irreversible and will have a profound impact on both the theory and practice of future heterogeneous cellular networks, which will no longer be purely optimized for approaching the attainable capacity, but will explicitly include the energy efficiency during the design and optimization of the entire protocol stack. In this paper, we have critically appraised SM, which constitutes a promising transmission concept in the context of MIMO communications, and have described both a business case and the technical foundations for making it a suitable air-interface candidate for powerefficient, yet low-complexity MIMO cellular networks.

5. Future Scope

The future scope of Spatial Modulation is an energy-efficient spatial modulation based molecular communication (SM-MC) scheme, in which a transmitted symbol is composed of two parts, i.e., a space derived symbol and a concentration derived symbol. The space symbol is transmitted by embedding the information into the index of a single activated transmitter nano machine.

The concentration symbol is drawn according to the conventional concentration shift keying (CSK) constellation. Befitting from a single active transmitter during each symbol transmission period, SM-MC can avoid the inter-link interference problem existing in the current multiple-input multiple-output (MIMO) MC schemes, which hence enables low-complexity symbol detection and performance improvement. Specifically, in our low-complexity scheme, the space symbol is first detected by energy comparison, and then the concentration symbol is detected by the equal gain combining assisted CSK demodulation.[8]

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