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# Quadrature Spatial Modulation in MIMO Cognitive Radio Systems with Imperfect Channel Estimation and Limited Feedback

Mr.R.Murugan, Keerthika.S

*SENIORAssistant Professor, Electronics and communication Engineering, IFET College of Engineering, Anna University, India.*

*Electronics and communication Engineering, IFET College of Engineering, Anna University, India.*

***Abstract:*** *This paper studies the recent novel multiple- input multiple-output (MIMO) transmission technique called, quadrature spatial modulation (QSM), in underlay cognitive radio (CR) systems. In particular, a multi-antenna secondary transmitter (ST) communicates with a multi-antenna secondary receiver (SR) in the presence of a primary receiver (PR). Considering only statistical knowledge of the ST-PR channel gain, the QSM-CR scheme is investigated using a mean value (MV)-based power allocation strategy referred to as MV-based scheme. Furthermore, assuming that the ST-PR channel gain is perfectly known, the QSM-CR scheme is investigated using a power allocation method based on instantaneous channel state information (CSI) referred to as CSI-based scheme. In each scheme, considering imperfect ST-SR channel estimation, we study the secondary system performance, where closed-form expressions for the average pairwise error probability (PEP) are derived over Rayleigh fading channels. A tight upper bounded average bit error ratei obtained using the derived PEP expression..Moreover, simple approximate expressions are obtained to get insights on the system diversity and channel estimation errors' effects. Numerical results, which match with simulations, illustrate the robustness of QSM in enhancing the overall system performance in the presence of estimation errors.*

***Keywords:*** *Interleaver Division Multiplexing (IDM) - Multiple Input Multiple Output (MIMO) – Spatial Modulation (SM) - Quadrature Spatial Modulation (QSM)*

## I. Introduction

Nowadays During the last decade, high spectral efficiency has been the first priority for any wireless communication system in order to increase its performance. Single antenna systems failed to provide high spectral efficiency while multiple antenna such as the MIMO systems provided it [1]. Spatial Modulation (SM) [2], Space Shift Keying (SSK) [3], and Space-Time Shift Keying (STSK) [4] are (MIMO) techniques that utilize the various transmit antennas in an inventive manner. Increasing complexity, energy consumption and cost are the major problems of traditional MIMO techniques. These drawbacks primarily result from the Inter Channel Interference (ICI) caused by the increasing number of transmitting antennas, Inter-Antenna Synchronization (IAS), and multiple Radio Frequency (RF) chains which in turn increase the complexity and cost of a MIMO system [1]. Spatial Modulation is an integration between digital modulation systems and multiple antenna system to accomplish spatial multiplexing gain by using multiple antennas at transmitter in a unique method [2]. SM used to overcome the problem of ICI and requires no synchronization between transmit antennas with low complexity and cost without reducing the system performance. Besides, it is shown that SM is more robust to channel variations, such as spatial channel correlation and channel estimation errors, as compared to other MIMO techniques. In SM, a block of any number of information bits is mapped into a constellation point in the signal domain and a constellation point in the spatial domain. Distinction between channels of transmit antenna is a major parameter influence on bit error rate of SM instead of channel realization. Only one transmit antenna of the set will be active at any time. The key of spatial modulation is that it takes the advantage of the spatial position of each transmit antenna as an extra source of information to enhance the spectral efficiency.

SM multiplexing picks up expansions logarithmically with the number of transmit antennas and not directly as in Bell Labs Layered Space–Time

(BLAST) strategies [5]. Regardless of the critique of SM, the information rate is increased in correspondence to base-two logarithm of the number of transmit antenna. In paper [6], the authors have proposed a new modulation called Trellis Coded Spatial Modulation (TCSM). The aims of this scheme is to reduce the effect of channel correlation on the performance of SM. It exploits convolutional encoding and Maximum–Likelihood Sequence Estimation (MLSE) decoding to increase the free distance between sequences of spatial–constellation points. Generalized SM (GSM) systems are reported in [5] using a group of transmit antennas which are considered as a spatial constellation point and are activated simultaneously to enhance the overall spectral efficiency. A main drawback of GSM is that the increasing number of antenna combinations adds detection complexity to the receiver and a slight performance degradation to this system as compared to its SM/SSK counterpart reported in [7]. An alternative SSK scheme called BiSpace Shift Keying (Bi-SSK) is reported in [8], where orthogonal symbols are transmitted simultaneously from one or two transmit antennas to enhance the spectral efficiency of the SSK system. Minor performance degradation is reported, as compared to the SSK system, but with twice the data rate.

Recently, QSM has been a new MIMO scheme which is based on the expansion of the spatial constellation domain to a new dimension by utilizing both in-phase and quadrature components from one or two antennas at the same time [9]. QSM gives the same error performance and spectral efficiency of SM with 3 dB less signal power while holding all its implicit in advantages [10]. The first dimension transmits the real part of a signal constellation symbol and the other one transmits the imaginary part of the constellation symbol. ICI is also maintained since the two-transmitted information are orthogonal and adjusted on the real part and the imaginary part of the carrier signal. However, an additional base-two logarithm of the number of transmit antennas bits can be transmitted in QSM, compared to a conventional SM system [10].

## II. System Model

In this section, a proposed system model for (QSM-IDM) is introduced. The proposed MIMO system consists of transmit antenna and receiver antenna. The transmitter of the proposed QSM-IDM scheme is shown in Fig.1. Letbe the group of data bits to be transmitted at one particular time instant with denoting the modulation order of arbitrary M-quadrature amplitude modulation (M-QAM) over L layer subsequence.

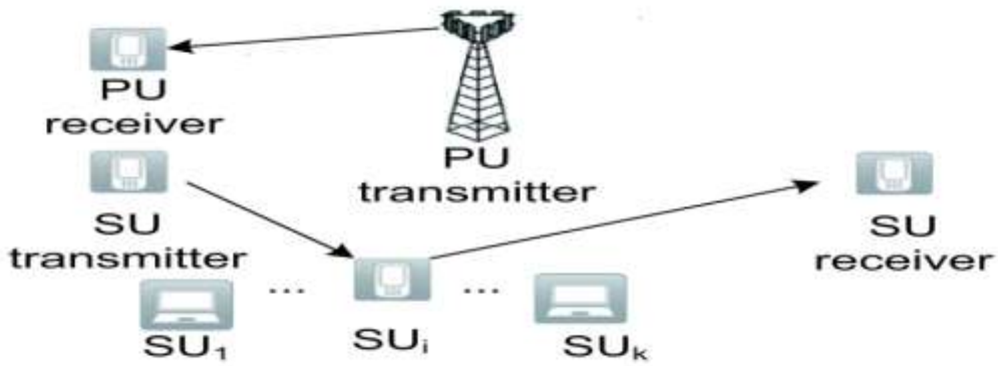


**Figure 1:** QSM-MIMO CR system with single PU

The source information is divided into three sets, two sets for spatial constellation and one for information as in the conventional QSM [10]. Two spatial constellations are modulated each by log bits. The antenna activated for transmission is assigned by bits of antenna sets as used in QSM after spreading it by spread sequence which is same for both real and imaginary antenna sets. In addition, the signal constellation symbol is modulated by log bits. To produce the QSM-IDM symbol, the data bits are further segmented into L subsequences, each of which structures one layer of the QSM-IDM signal. The bits in the information set is spread by same sequence to form the spread sequence . Then, the bits sequence are permutated by various chip random interleaver producing independently permuted spreaded bit sequences Furthermore, the sequences on each layer are changed into binary balanced sequence signals as 1→−1, with every two successive bits mapped onto the real and imaginary parts of one QPSK symbol, respectively. Moreover, the corresponding QPSK symbols " from every layer are directly superimposed together to yield the output signal as: A. Channel Model We consider a MIMO spectrum sharing system operating over a Rayleigh flat fading channel with ST of Nt transmit antennas and SR of Nr receive antennas in the presence of a single antenna PR. The MIMO channel for the secondary system is denoted as H with Nr×Nt dimension, and the ST-PR channel is denoted as f with Nr × 1 dimension. The system model is depicted in Fig. 1. We assume that incoming bit sequence of a length of b = log2(MN2 t ) enters the ST at each transmission interval. This sequence is processed and divided into three parts. The first two parts of log2(Nt) bits of b decides the index of the active transmit antennas, and the remaining third part of log2(M) bits is mapped onto one of the desired M-ary coherent/non-coherent modulation schemes. The QSM constellation symbol, x, is further expanded to its real, $x\Re$ and imaginary, $x\Im$, components, which are orthogonal and performing as the in-phase and the quadrature components of the carrier signal. $x\Re$is conveyed from a single transmit antenna among the available Nt antennas, where the index of the activated antenna is determined by the first log2(Nt) bits. Similarly, x𝔍 is conveyed by another or the same antenna depending on the second log2(Nt) bits. The vector, s = s𝔑+ js𝔍, is sent over an Nr ×Nt Rayleigh complex channel H. Its entry hr,t denotes the complex channel coefficient between the tth transmit antenna and rth receive antenna and hℓ𝔑is the ℓth 𝔑column of H, i.e., hℓ𝔑= [h1,ℓ𝔑··· ,hNr,ℓ𝔑]T. The channel elements are assumed to be independent identical distribution (i.i.d.) complex Gaussian r.v. with zero mean and variance σ2 h. The channel vector n = [n1,n2,··· ,nNr]T is a complex additive white Gaussian (AWGN) noise vector with zero mean and variance N0. The received signal vector at the input of the receiver side is given as

y =√Ps(hℓ𝔑x𝔑+ jhℓ𝔍x𝔍) + n,
ℓ𝔑ℓ𝔍= 1,2,··· ,Nt, (1)

where Ps denotes the secondary transmitted power. B. QSM Detection The following common estimatoris considered assuming the orthogonality between the channel estimate and the estimation error, which is expressed as

ehr,t = hr,t −e hr,t, (2)

where e hr,t is the estimate of the hr,t, and they are jointly ergodic and stationary Gaussian processes. ehr,t is the channel-estimation error, and modeled as ehr,t ∼ CN(0,σ2 e). Note that σ2 e is an indicator for the quality of the channel estimation and changes depending on the channel variations and estimation schemes. In this model, Orthogonal pilot channel estimation sequences are used, which reduce the estimation errors linearly with increasing the number of pilots. Considering this, the optimum ML detector for MIMO-QSM system at the SR is given by *[ˆ ℓ𝔑 ˆ ℓ𝔍 ˆ x𝔑 ˆ x𝔍]=arg min ℓ𝔑ℓ𝔍x𝔑x𝔍*

*y−√Ps(˜ hℓ𝔑x𝔑+j˜ hℓ𝔍x𝔍)* (3)
arg min *ℓ𝔑ℓ𝔍x𝔑x𝔍‖z‖2 −2𝔑{yHz}* (4)

where *z = √Ps(˜ hℓ𝔑x𝔑+ j˜ hℓ𝔍x𝔍*.The detected an-tenna indices ˆℓ 𝔑and ˆ ℓ𝔍 along with the detected data symbols ˆ *x𝔑* and ˆ *x𝔍* are used to retrieve the original information bits.

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## III. Complexity Analysis

In this section, a complete study for the complexity of the proposed QSM-IDM system is introduced. The complexity increase in the QSM-IDM transmitter is negligible compared to that in the original QSM transmitter. Therefore, our emphasis is on the complexity of the receiver end. Motivated by [21] , we compute the complexity of the proposed detector in terms of real multiplications. There are two stages in the proposed detector. In the initial stage, the complexity of the i-MRC detector is E=2 [2]. The following stage work in an iterative manner. The overall complexity of the proposed

receiver is given by: E=2+165 (27) From the above analysis we conclude that the complexity for the proposed detector increased linearly with the increasing number of sublayers and number of iterations. Consequently, decreasing the number of iterations as possible results in better performance for the proposed system compared to the conventional QSM.

## IV. Simulation and Discussions

The main objective in this section is to evaluate the performance of the proposed QSM-IDM system. The proposed system performance is evaluated through Monte Carlo simulations. It is compared to the conventional QSM and conventional SM combined with iterative detector under the constraint of similar spectral efficiency. Throughout the simulation, we assumed that the Gaussian MIMO channel with a unit variance and that it is uncorrelated flat Rayleigh fading channel in what follows. During data transmission, the full knowledge for channel and perfect frequency synchronization were assumed.

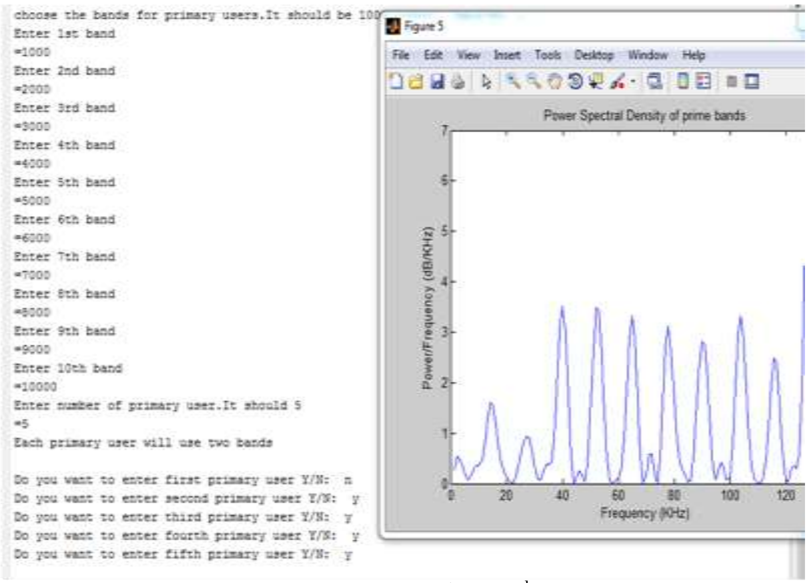


**Figure 2 :** Holes in 1st and 2nd band

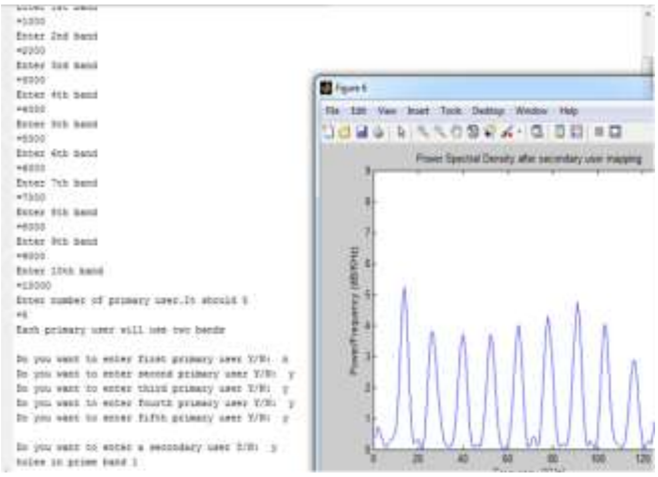


**Figure 3 :** After mapping

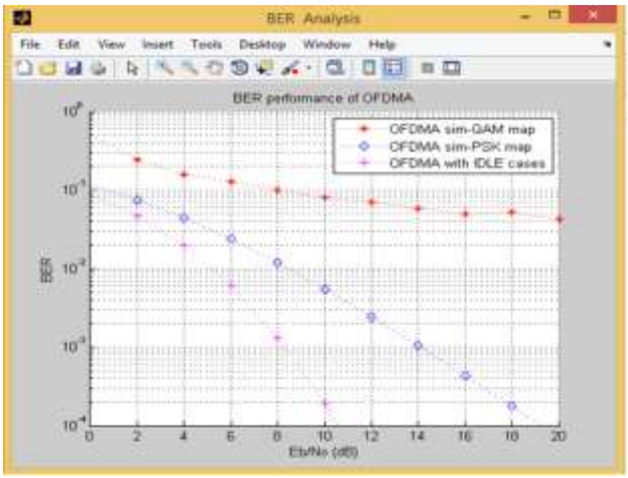


**Figure 4 :** BER analyzes with shorter distance

The performance of the QSM-MIMOCR systems with imperfect channel estimation at the receiver is computed via analytical results and validated through simulations for 4-quadrature amplitude modulation (QAM) scheme. Unless otherwise stated, we assume Nt = 2,Pm =10 dB, and σ2 h = 1,N0 = 1. The case of perfect CSI (σ2 e = 0) is included for comparison purposes.

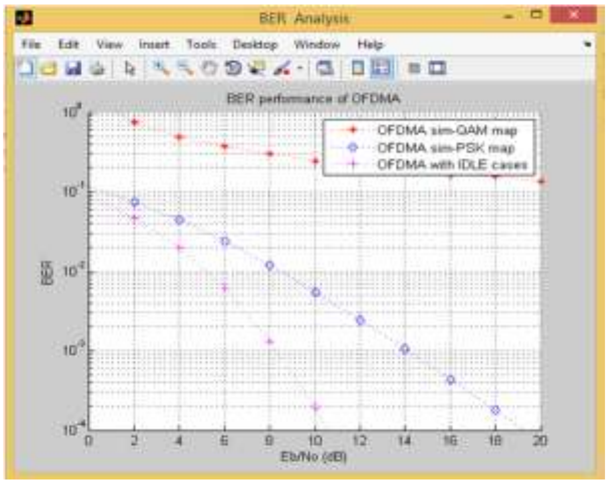


**Figure 5 :** BER analyzes over longer distance

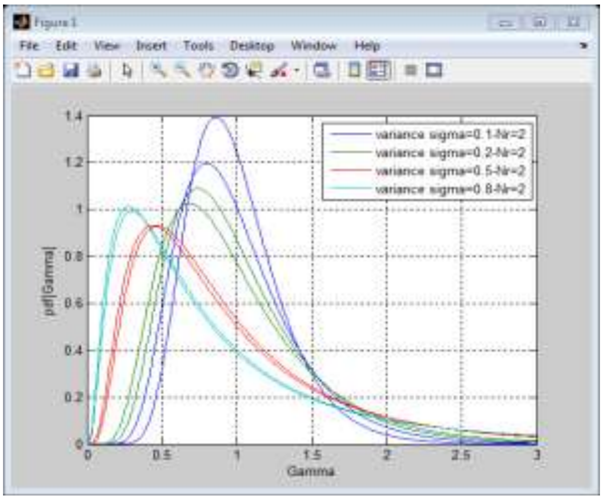


**Figure 6 :** Noise variation

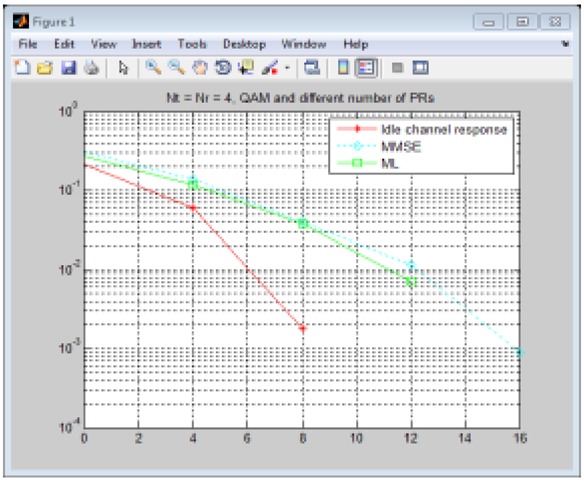


**Figure 7 :** length variation with detection

## V. Conclusion

In this paper, a QSM-IDM combined to the conventional QSM is to be applied to spread information bits which is used to modulate the information into the constellation points. The antenna set is also applied to spreader before using it to assign the antenna number for information transmission. An iterative detector with low complexity has been designed for the proposed QSM-IDM system. The simulation results for the proposed system in different antenna combinations with the proposed system QSM-IDM performs much better than the conventional QSM system. In addition, the performance of the proposed system can be improved by increasing number of iterations of iterative detector and increasing the length of the spreader used for information set of antennas sets. So, IDM combined with QSM to have collaborative performance improvement form user prospective as network prospective. Finally, the main drawback of our proposed system is increasing system complexity and processing time which is negligible compared to that in the original QSM system. Eventually, it is recommended to use QSM-IDM system for delay insensitive applications as data networks.

## References


[1]. M. Di Renzo, H. Haas, A. Ghrayeb, S. Sugiura, and L. Hanzo, "Spatial modulation for generalized MIMO: Challenges, opportunities, and implementation," Proc. of the IEEE, vol. 102, no. 1, pp. 56–103, Jan. 2016.

[2]. 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, Jul. 2011

[3]. R. Mesleh, H. Haas, S. Sinanovi´c, C. W. Ahn, and S. Yun, "Spatial modulation," IEEE Trans. on Veh. Tech., vol. 57, no. 4, pp. 2228 – 2241, Jul. 2010.

[4]. J. Jeganathan, A. Ghrayeb, and L. Szczecinski, "Spatial modulation: optimal detection and performance analysis," IEEE Commun. Lett., vol. 12, no. 8, pp. 545–547, Aug. 2010.

[5]. A. Stavridis, S. Sinanovic, M. Di Renzo and H. Haas, "Energy evaluation of spatial modulation at a multi-antenna base station," in IEEE 78th Vehicular Technology Conference (VTC Fall), 2013, Las Vegas, NV, 2015, pp. 1-5.

[6]. A. Stavridis, S. Sinanovic, M. D. Renzo, H. Haas, and PeteGrant,"Anenergysavingbasestationemployingspatialmodulation", IEEE CAMAD 2012, September 2014, Barcelona, Spain