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RESEARCH ARTICLE

PERFORMANCE OF MIMO - OFDM BASED COGNITIEVE RADIO SYSTEM FOR SELECTIVE ADAPTIVE ARRAYS AND SELECTIVE SPACE-TIME CODING SIGNAL PROCESSING

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ABSTRACT

The wireless channel is central within this context, thus estimating the channel is the key to make CR operational, taking in consideration that the transmission-reception technology is available. In this thesis, we design a MIMO system using OFDM modulation technology to transmit and receive two signals over the mobile wireless channel. First formulate the pilot design as a new optimization problem. We use MIMO concept to enhance system capacity and robustness of the wireless transmission. In Multi-Input Multi-Output (MIMO) based cognitive radio (CR) systems, with the increasing demand for data rate and reliability in Wireless communications and devices, several issues become very important like bandwidth efficiency, quality of service and radio coverage. In this paper, we evaluate the performance of selective adaptive arrays signal processing and selective space-time block coding signal processing and compare their performance under perfect CSI available at both the transmitter and receiver. By comparing their performance, we see that selective adaptive arrays signal processing outperforms selective space-time coding signal processing when perfect CSI is available at both the transmitter and receiver.

INTRODUCTION

The use of the radio spectrum is regulated by governmental rules. Almost all parts of the radio spectrum are licensed today. The FCC published a thesis in (F. C. C. 2002) where the spectrum use in the United States is presented in the aim of better spectrum utilization. On the other hand, studies have shown that major licensed bands are largely underutilized. This has initiated the idea of cognitive radio (CR), where secondary users are allowed to utilize the licensed bands without causing armful interference to the licensed or primary users (Mitola and Maguire 1999). The CR technology has the potential to significantly increase the efficiency of the spectrum utilization while maintaining the QoS requirement of the primary users. Multi-Input Multi-Output (MIMO) is the most widely used technology in current and future wireless communication systems. Since OFDM can naturally provide flexibility to fill in spectrum holes over a wide bandwidth, it has been considered as one of the best candidates for the physical layer of CR systems (Mahmoud *et al.,* 2009; Farhang-Boroujeny and Kempter 2008).The channel state information (CSI) is crucial for CR systems (Haykin 2005). In practice, the CSI can be estimated by usingpilot tones. The selections of pilot tones will significantly affect the channel estimation performance. For conventional OFD M systems where all subcarriers can be used for transmission, the issue of pilot design has been well studied (Negi and Cioffi 1998). However, these methods are not effective for OFDM-based CR systems, since the subcarriers used by the primary users cannot be employed by the secondary users. Hence the available subcarriers forthe secondary users may be non-contiguous which brings new challenges to pilot design.

The simplest pilot design for OFDM-based CR system is to predesign pilot tones for the conventional OFDM system and then deactivates those tones already used by the primaryusers according to the result of spectrum sensing. At thereceiver, the remaining activated pilot tones are used for channel estimation. Directly implementing channel estimation based on such pilot pattern leads to poor performance (Liu *et al.,* 2009). To obtains satisfactory channel estimation performance, a shift pilot scheme is proposed in (Liu *et al.,* 2009). After predesigning pilot tones and deactivating some of them according to the spectrum sensing result, this scheme selects some activated data subcarriers as the new pilot tones. Specifically, when a pilot toneis deactivated, its nearest activated data subcarrier is then use das the new pilot tone. The similar idea can be also found in (Rashad *et al.,* 2007; Budiarjo *et al.,* 2007). Although such a scheme outperforms the aforementioned done, it cannot provide satisfactory performance in all cases. This is mainly because the positions of pilot tones are not optimized. In this thesis, we propose a new practical pilot design method for MIMO-based CR systems. Unlike the above two schemes, the proposed one does not predesign the pilot tones. The pilot

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design is performed after spectrum sensing (i.e., after the set of activated subcarriers is obtained). To obtaina low-complexity method, we first formulate the pilot designin terms of a new optimization problem. Instead of minimizingthe mean-square error (MSE) of the least-squares (LS) channel estimator itself, we minimize an upper bound which is related to this MSE. The MSE and BER are used as measure in judging the performance of each pilot pattern. According to that performance of pilot pattern has been implemented in MIMO based CR system. Virtual pilot concept has been reviewed and implemented in all proposed pilot patterns. The advantages and disadvantages of virtual pilot concept has been discussed through our simulation results analysis. Performance of the system while a licensed user is occupying asub-band of the spectrum and the effect of the licensed user on the pilot pattern has been studied. Spectrum overlying according to licensed user activity has been simulated. The three proposed pilot patterns were implemented in the MIM Osystem and their performances were tested. The decision of the best performing pattern is made by observing the MSE and BER obtained from the simulation results in the case where no LU is active. The hexagonal pattern shows the lowest MSE and BER compared to the other two patterns. Hence the hexagonal pattern is chosen to be implemented in the CR system.

SYSTEM DESIGN MODEL

MIMO model with CR system

The MIMO-based CR system under consideration is shown in Fig.1. The pilots are designed according to the result of the spectrum sensing. After subcarrier assignment where the subcarriers occupied by the primary users are deactivated,pilot symbols are inserted and the data are modulated onthe remaining activated subcarriers. We employ the MIMO concept in our simulation platform because it has beenproven that MIMO can achieve a major breakthrough in providing reliable wireless communication links. This reliability is in the context of the channel estimation in our case. With the MIMO concept we improve the bitrate and BER of the overall system. MIMO is capable of this improvement, because of the property of multiple transmission multiple reception. This property is a form of spatial diversity. This diversity is the most effective technique to accomplish reliable communication over the wireless channel and combating with fading, because it provides the receiver with multiple copies of the transmitted signal. Those multiple copies are independently faded. If at least one copy of the transmitted signal is received correctly, we will have the transmitted signal back. This property improves the BER significantly (low BER) as shown in chapter 6. Beside this, MIMO increases the channel capacity also, which means more throughputs. There are different ways to exploit multiple antennas at both sides of the communication channel. To improve the transmission reliability, the transmit antennas should be used such that transmit diversity is achieved. The transmission rate is comparable to the one obtained in SISO. To improve the transmission rate, independent signals are transmitted from the different transmit antennas. i.e. there is no correlation between the transmitted signals from the different antennas. In this case the reliability is not much improved (Duman and Ghrayeb 2007).

$$y_r(t)=\sum_{k=0}^{K-1}\sum_{i=1}^{M}h_{i,r}^{(k)}(t)s_i(t-k)+n_r(t) \qquad (1)$$

Where si(t) is the transmitted signal from antenna i at time t, h(k) i,r(t) is the channel coefficient for the kth path from transmit antenna i to receive antenna r at time t. nr(t) is the Additive White Gaussian Noise. For mobile communications, the channel tap coefficients are random variables. In case the wireless channel varies very slowly, the tap coefficients remain constant for each frame of data. For Rayleigh fading channels, the channel tap coefficients are modeled as complex Gaussian random variables which have zero mean. The different channel taps are assumed to be independent. The average channel gains for different paths are determined from the power Delay profile of the wireless channel. In this work we assume that the channel tap powers decays exponentially. Hence we use the exponential power delay profile. If the MIMO-OFDM system has Nc subcarriers and the fading coefficients are spatially uncorrelated and that the fading coefficients remain constant during one OFDM symbol. Then the transmitted signal over M antennas can be represented by a matrix XOFDM with dimensions NcxM. A symbol transmitted at subcarrier n on transmit antenna is xi (n).

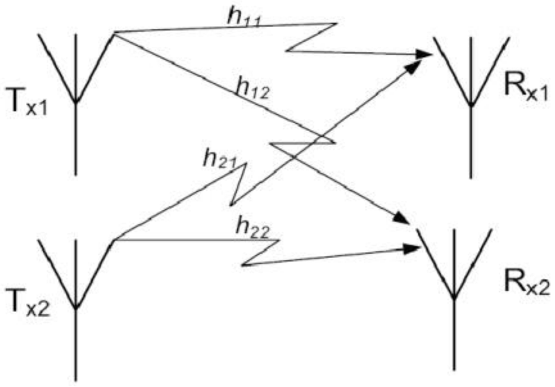
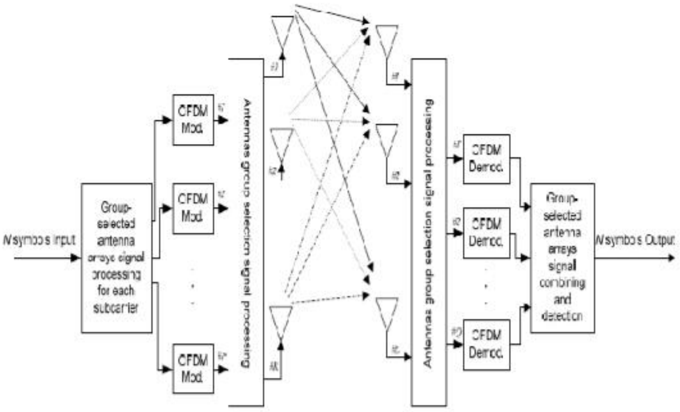


Figure 1. MIMO setup

MIMO/OFDM system Model group selection array signal processing

The communication system model is plotted in Fig. 2.Communication system side at transmitter is equipped with *M* transmitting antenna arrays and communication system side at receiver is equipped with *K* receiving antenna arrays. The *N* signal symbols in put d =(*d(0), d(1)*,*d(2)*,*d*(*N* -1)) is converted into parallel signal symbols. Group-selected arrays signal processing for each sub-carrier is performed with antenna arrays group selected from *NPM* antenna arrays according to arrays group selection criterion. The inverse fast Fourier transforms (IFFT) transforms the group-selected signal symbols into the time domainsamples. Communication system sides at receiver, out of antenna arrays are group-selected. Then, the group-selected signals are transformed back into the frequency domain with an FFT. Finally, the signal symbol data originating from the group-selected transmitting antenna arrays is combined to form the arrays of outputsignals *i* thdˆ = (*d*ˆ(0), *d*ˆ(1),*d(2)*….*d*ˆ(*N* -1)) .



Assume the wireless communication networks channel between and the antenna array at the transmitterand receiver, respectively, to be characterized by a multipath fading channel. Let the H(*i*) denote *M* x *K*discretetime MIMO/OFDM channel matrix on the *i* subcarrier, Then weighting coefficient vector and receiving antenna arrays weighting coefficient vector for the sub-carrier as and, respectively. Then, the received signal, , for sub-carrier can be written as

$$\mathbf{H}(i)=\begin{bmatrix} H_{1,1}(i) & H_{1,2}(i) & \cdots & H_{1,K}(i) \\ H_{2,1}(i) & H_{2,2}(i) & \cdots & H_{2,K}(i) \\ \vdots & \vdots & \ddots & \vdots \\ H_{M,1}(i) & H_{M,2}(i) & \cdots & H_{M,K}(i) \end{bmatrix}$$

$$\hat{d}(i)=\left(\mathrm{S}_r(i)\right)^H\left(\mathrm{H}_S(i)\right)^T\mathrm{S}_t(i)d(i)+\left(\mathrm{S}_r(i)\right)^H\mathrm{N}(i)$$

where the superscript *H* denotes the Hermitianoperation, the superscript *T* denotes the transpose operation, is a *Q*x1 column vector with the arrays modeled as complex AWGN model with variance $\sigma_n^2$is the *P*x *Q* group-selected sub-channel matrix out of $H_s(i)M$ x *K* channel matrix *H*(*i*) and can be rewritten asfollows

$$\mathrm{H}_s(i)=\begin{bmatrix} H^s_{1,1}(i) & H^s_{1,2}(i) & \cdots & H^s_{1,Q}(i) \\ H^s_{2,1}(i) & H^s_{2,2}(i) & \cdots & H^s_{2,Q}(i) \\ \vdots & \vdots & \ddots & \vdots \\ H^s_{P,1}(i) & H^s_{P,2}(i) & \cdots & H^s_{P,Q}(i) \end{bmatrix}$$

Then the maximal instantaneous receiving SNR for the *I* th sub-carrier signal processing can be written as

$$\left(SNR_s(i)\right)_{\max}=\frac{E\left(\left|d(i)\right|^2\right)\cdot\lambda_{\max}\left[\left(\mathrm{H}_s(i)\right)^*\left(\mathrm{H}_s(i)\right)^T\right]}{\sigma_n^2}$$

Where $\lambda_{max}[A]$are the largest eigen value of the matrix A. The objective of group selected antenna arrays at both the transmitter and receiver sides for grouping is to maximize the average SNR. Therefore, the optimal group selected sub-channel matrix H_s(i) on the ith sub-carrier should maximize the largest eigen value of channel matrix$(H_s(i))^*(H_s(i))^T$

SIMULATION RESULTS

In this section, we demonstrate the capacity lower bound of MIMO-OFDM systems using pilot symbol based MMSE channel estimation with the optimized PDR using Monte Carlo simulation over the channel realizations, for each of the three considered pilot symbol constructions.

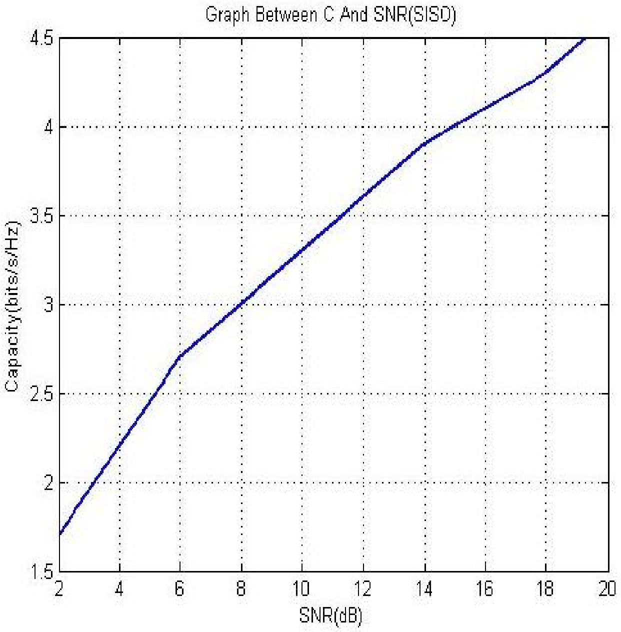


Fig. 2. Graph Between C And SNR

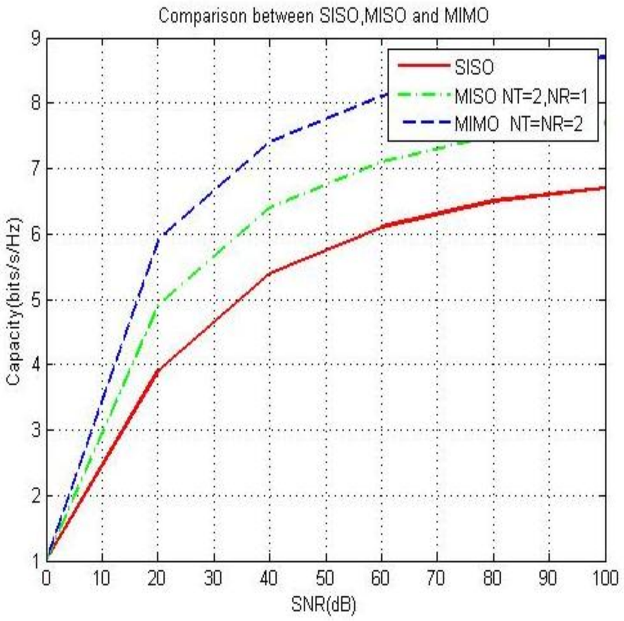


Fig 3. Capacity Enhancement in MIMO

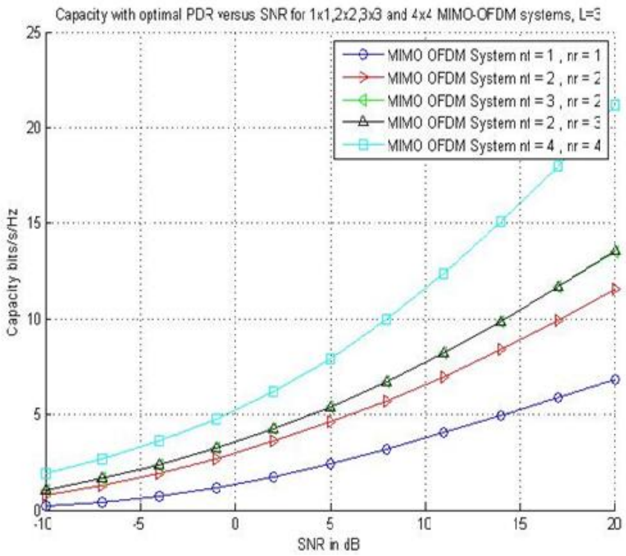


Fig.4. Capacity with optimal PDR versus SNR for 2£2 and 4£4 MIMO-OFDM systems

An overall observation is that the capacity is not especially sensitive to the PDR as long as it is in a certain region. For example, a quasi-optimal region in 2*X*2 MIMO-OFDM systems with independent or orthogonal pilot patterns. Fig. 4 shows the comparison of the capacity of 2*X*2, 2*X*4, and 4X4 MIMO-OFDM systems with three different pilot patterns versus the percentage of pilot power when SNR is 10dB. The optimal PDR of scattered pilot pattern is more sensitive to the number of transmit antennas than that of independent pilot and orthogonal pilot.

Conclusion

In this paper, a new practical pilot design method for MIMO-based CR systems has been proposed. We have also proposed an efficient sequential method to solve the corresponding optimization problem. The performance of this pattern converges at almost 20dB SNR for different filter lengths. Above this SNR value increasing the filter size has no influence any more on improving the performance. Adaptive antenna arrays can promise to achieve significant increases in a system's capacity and bandwidth efficiency as well as in QoS improvement in wireless communications, but they are characterized by a relatively higher implementation complexity.

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