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An Efficient Performance of Mimo - Ofdm Based Cognitieve Radio System for Arrays 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 communicationsand devices, several issues become very important like bandwidth efficiency, quality of service and radio coverage. In this new scheme, adaptive arrays are group-selected in the spatial domain. Simulation shows that the proposed system can get significant performance improvements over the conventional array based OFDM systems over frequency-selective multipath fading channels with cognitive radio (CR) system.*
Keywords: *Cognitive radios, MIMO, OFDM, and Joint transmit and receive group selected arrays.*

I. Introduction

The use of the radio spectrum is regulated by governmental rules. Almost allparts of the radio spectrum are licensed today. The FCC published a thesis in [1] where the spectrum use in the United States is presented in the aim of betterspectrum utilization.On the other hand, studies have shownthat major licensed bands are largely underutilized. This hasinitiated the idea of cognitive radio (CR), where secondaryusers are allowed to utilize the licensed bands without causing armful interference to the licensed or primary users [2].The CR technology has the potential to significantly increasethe efficiency of the spectrum utilization while maintaining the QoS requirement of the primary users. Multi-Input Multi-Output (MIMO) is the most widelyused technology in current and future wireless communicationsystems. Since OFDM can naturally provide flexibility to fill inspectrum holes over a wide bandwidth, it has been considered as one of the best candidates for the physical layer of CR systems [3], [4].The channel state information (CSI) is crucial for CR systems [5].

In practice, the CSI can be estimated by using pilot tones. The selection of pilot tones will significantly affect the channel estimation performance. For conventional OFDM systems where all subcarriers can be used for transmission, the issue of pilot design has been well studied [6]. 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 for the 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 the receiver, the remaining activated pilot tones are used forchannel estimation. Directly implementing channel estimationbased on such pilot pattern leads to poor performance [7].To obtains satisfactory channel estimation performance, a shift pilot scheme is proposed in [7]. After predesigning pilot tonesand deactivating some of them according to the spectrumsensing result, this scheme selects some activated data subcarriersas the new pilot tones. Specifically, when a pilot toneis deactivated, its nearest activated data subcarrier is then usedas the new pilot tone. The similar idea can be also found in [8], [9]. 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 notoptimized.

In this thesis, we propose a new practical pilot design method for MIMO-based CR systems. Unlike the above twoschemes, the proposed one does not predesign the pilot tones.The pilot 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) channelestimator itself, we minimize an upper bound which is relatedto this MSE. The MSE and BER are used as measure in judging the performance of each pilotpattern. According to that performance of pilot pattern has beenimplemented in MIMO based CR system. Virtual pilot concept has beenreviewed and implemented in all proposed pilot patterns. The advantages anddisadvantages of virtual pilot concept has been discussed through our simulationresults 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 patternhas been studied. Spectrum overlying according to licensed user activity has beensimulated. The three proposed pilot patterns were implemented in the MIMOsystem and their performances were tested. The decision of the best performingpattern is made by observing the MSE and BER obtained from the simulation resultsin the case where no LU is active. The hexagonal pattern shows the lowestMSE and BER compared to the other two patterns. Hence the hexagonal pattern is chosen to be implemented in the CR system.

II. System Design Model

A. MIMO model with CR system

The MIMO-based CR system under consideration is shownin Fig.1. The pilots are designed according to the result ofthe spectrum sensing. After subcarrier assignment where thesubcarriers 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 wirelesscommunication links. This reliability is in the context of the channel estimationin our case. With the MIMO concept we improve the bitrate and BER of theoverall system. MIMO is capable of this improvement, because of the property ofmultiple transmission multiple reception. This property is a form of spatial diversity.This diversity is the most effective technique to accomplish reliable communicationover the wireless channel and combating with fading, because it providesthe receiver with multiple copies of the transmitted signal. Those multiple copiesare independently faded. If at least one copy of the transmitted signal is receivedcorrectly, we will have the transmitted signal back. This property improves theBER significantly (low BER) as shown in chapter 6. Beside this, MIMO increases thechannel capacity also, which means more throughputs. There are different ways toexploit multiple antennas at both sides of the communication channel. To improvethe transmission reliability, the transmit antennas should be used such that transmitdiversity is achieved. The transmission rate is comparable to the one obtainedin SISO. To improve the transmission rate, independent signals are transmittedfrom the different transmit antennas. i.e. there is no correlation between the transmittedsignals from the different antennas. In this case the reliability is not muchimproved [10].

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

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).

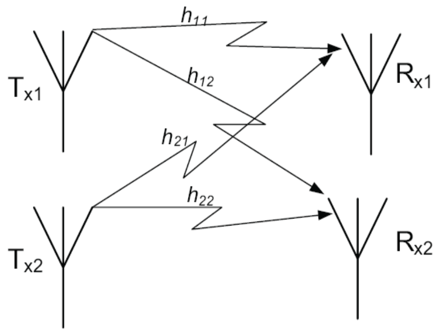
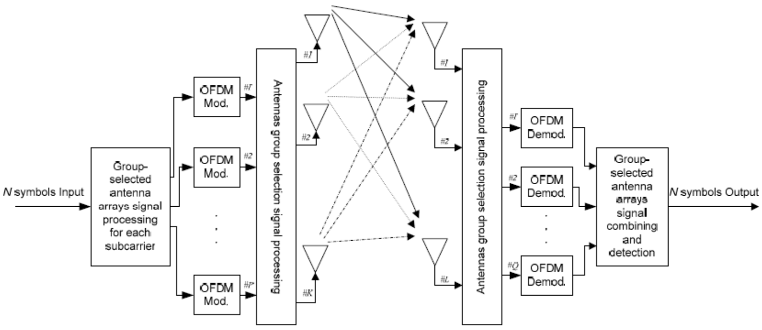


Figure 1: MIMO setup

B. 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 systemside at receiver is equipped with *K* receiving antennaarrays. The *N* signal symbols input**d** =[*d(0), d(1),d(2),d*(*N* -1)] is converted into parallelsignal symbols. Group-selected arrays signal processing foreach sub-carrier is performed with antenna arrays groupselectedfrom*NPM* antenna arrays according to arrays groupselectioncriterion. The inverse fast Fourier transforms (IFFT)transforms the group-selected signal symbols into the timedomainsamples. Communication system sides at receiver, out of antenna arrays are group-selected. Then, thegroup-selected signals are transformed back into thefrequency domain with an FFT. Finally, the signal symboldata originating from the group-selected transmittingantenna arrays is combined to form the arrays of outputsignals *i* th**d**ˆ = [*d*ˆ(0), *d*ˆ(1),*d(2)*....*d*ˆ(*N* -1)] .



Assume the wireless communication networks channelbetween 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*discretetimeMIMO/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

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

$$\hat{d}(i) = (\mathbf{S}_r(i))^H \, (\mathbf{H}_S(i))^T \, \mathbf{S}_t(i) d(i) + (\mathbf{S}_r(i))^H \, \mathbf{N}(i)$$

where the superscript *H* denotes the Hermitian operation, 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 $\mathbf{H}_s(i)$ *M* x *K* channel matrix *H*(*i*) and can be rewritten as follows

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

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

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

Where λ_{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$(H_s\,(i))^*(H_s\,(i))^T$

III. Simulation Results

In this section, we give some performance simulation results to evaluate the performance of our proposed group selected arrays signal processing based new systems. The performance simulation is reached for

MIMO/OFDM communication systems by computer simulation over typical-urban (TU) frequency-selective Rayleigh fading channels. The RMS delay spread of the 6-ray TU channels we use is 1.0μs , respectively. We consider MIMO/OFDM communication stems employing QPSK for 128 subcarriers with diff rent antenna arrays configurations at oth transmitter and receiver sides. We use one OFDM symbol of 148 μs comprised of one OFDM data symbol duration of 128μs and the cyclic prefix duration of 20 μs .

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Imperfect feedback channel is another case of imperfect channel information. To deeply investigate how the feedback channel imperfectability affects the performance of the proposed system, we plot in Fig. 4 the BER performance of the proposed group-selecting approach and conventional antenna arrays without group-selecting with 2 group-selected transmitting antenna arrays from 3 transmitting and 2 receiving antenna arrays configuration versus the quality of feedback channel. The SNR was set at 6dB in this figure. As a comparison, the BER performance of the conventional adaptive antenna array based OFDM system with the same adaptive antenna arrays configuration at both the transmitter and receiver is also plotted. A close observation of the results indicates that the proposed approach outperforms the conventional adaptive antenna array based OFDM system.

IV. 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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