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Channel Maximization and PAPR Reduction in MIMO OFDM Cognitive Radio Networks

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ABSTRACT

In wireless sensor networks (WSNs) with tremendous sensorsthe spectrum scarcity for sensor networks is increasing terrifically. This shortage is improved by cognitive radio (CR) technology empowering multi-hop adaptable networking with spectrum re utilization. Here a system model for CR network is framed with multi-input multi-output (MIMO) and Orthogonal frequency division multiplexing (OFDM) modulation technique. The spectrum utilization is improved by maximizing channel gain with implementation of LMMSE equalizer which reduces the inter carrier interference. In multi carrier modulation the undesired effect due to high PAPR is reduced with all pass filter by applying linear phase variations.

INTRODUCTION

Cognitive Radio System (CRs) is a radio system employing technology that allows the system to obtain knowledge of its operational and physical situation; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained. The main objective of cognitive radio is to provide adaptability to wireless transmission through dynamic spectrum access so that the performance of wireless transmission can be elevated, as well as improving the employment of the frequency spectrum. Performance evaluations confirm that we successfully demonstrate communication efficiency from in-network computations and facilitate a new paradigm for spectrum efficient cognitive radio networks, which can be valid in general multi-hop wireless networks and spectrum-sharing WSNs. This document overviews implementation of Cognitive radio systems in MIMO-OFDM.

Orthogonal frequency-division multiplexing that is OFDM is a method of encoding digital data on multiple carrier frequencies. A special case of multicarrier transmission known as orthogonal frequency division multiplexing (OFDM) is one of the most widely used technologies in current wireless communications systems. OFDM is a multicarrier modulation technique that can overcome many problems that arise with high bit rate communications. The data bearing symbol stream is split into several lower rate streams and these streams are transmitted on different carriers. Since this splitting increase the symbol duration by the number of orthogonally overlapping carriers, multipath resonances affect only a minor portion of the adjacent symbols. Remaining inter-symbol interference (ISI) is removed by extending the OFDM symbol with a cyclic prefix (CP). Using this method, OFDM reduces the dispersion effect of multipath channels encountered with high data rates and reduces the need for complex equalizers. OFDM has the potential of fulfilling the aforementioned requirements of CR inherently or with minor modifications. Because of its good features, OFDM has been effectively used in numerous wireless technologies. We believe that OFDM will play an important role in realizing CR concept as well by providing a verified, accessible, and adaptive technology for air interface.

Multiple-Input Multiple-Output is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time. A natural radio-wave phenomenon called multipath in MIMO technology, transmitted dataspring back off walls, top limit, and other objects, attains the receiving antenna multiple times via different angles and at slightly different times. MIMO-OFDM system can provide high data throughput at low SNR as compared to MISO-OFDM system. This is again reconfirmed that increasing number of receiver antennas from 1 to 2 leads to improve the signal quality by reducing the fading effect. Therefore, with MIMO-OFDM system reliable communication is possible at low values of standard SNR.

The rest of paper is organized as follows. The background of for our study is in Section II and system model is presented in Section III. MIMO OFDM Cognitive Wireless Sensor network is implemented in Section IV. Performance evaluations are in Section V and this paper is concluded in Section VI.

System Model: The overall system architecture of proposed work is in fig. 1. It consists of OFDM modulation, OFDM demodulation, linear-minimum-mean-square-error (LMMSE) channel estimation for multicarrier systems, and comparison in AWGN and Rayleigh environment. The proposed technique is applicable to both point-to-point communication and multi-access communication where different users may experience different channel conditions.

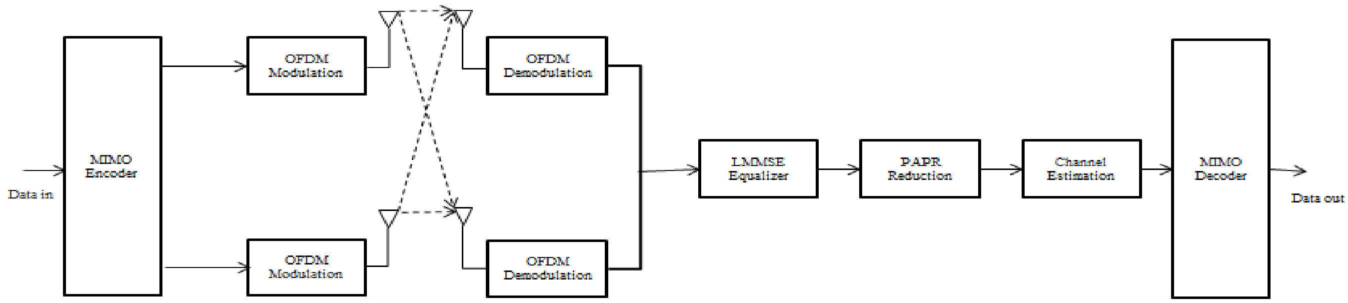

Fig.1.System Architecture

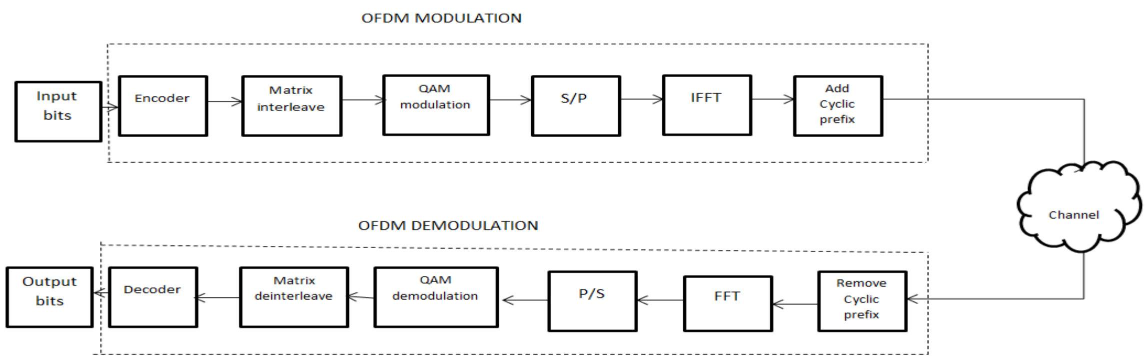

Fig.2.OFDM SISO Block Diagram

Input Data: The input Data to the OFDM is given in terms of high bit stream with 9.6KHz baud rate. The high bit streams are converted to low bit stream by applying data segmentation technique.

Serial to Parallel Conversion: The input serial data stream is formatted into the word size required for transmission, e.g. 2 bits/word for QAM, and shifted into a parallel setup. The data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

Matrix Interleaver: A block interleaver accepts a set of symbols and rearranges them, without omitting any of the symbols in the set. The number of symbols in to each set is fixed for a given interleaver. The interleaver'sprocess on a set of symbols is independent of its operation on all other sets of symbols. Matrix interleaver Fills a matrix with data elements row by row and then sends the matrix contents to the output column by column. For example, if the interleaver uses a 2-by-3 matrix to do its internal computations, then for an input of [1 2 3 4 5 6], the block produces an output of [1 4 2 5 3 6].

Modulation of Data: The data to be transmitted on each carrier is then differential encoded with previous symbols, then mapped into a Phase Shift Keying (PSK) format. Since differential encoding needs an initial phase reference an extra symbol is added at the start for this purpose. The data for each symbol is then mapped to a phase angle based on the modulation method. For example, for QAM the phase angles used are 0°, 90°, 180°, and 270°. The use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to fading.

Inverse Fourier Transform: After the required spectrum is operated, IFFT is used to find the resultant time waveform. The guard period is then added at the beginning of each symbol .OFDM uses the available spectrum efficiently by spacing the channels much closer together. This is attained by making all the carriers orthogonal to one another, avoiding

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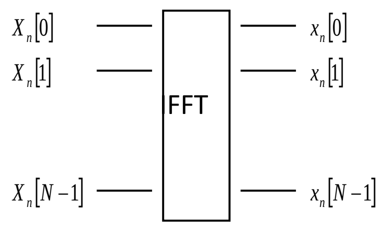
interference between the closely spaced carriers. To generate OFDM successfully the relationship between all carriers must be carefully to maintain the orthogonality of the carriers. For that, after choosing the spectrum required, we have to convert it back to its time domain signal using an Inverse Fourier Transform.

So, we can write:

$$x_n[l] = \frac{1}{N}\sum_{k=0}^{N-1} X_n[k]\exp\left(j2\pi l\frac{k}{N}\right)$$



For l = 0, 1, …, N-1 -------- (1)

Guard Period: One way to avoid the inter symbol interference is to set as small gap equal to the duration of delay spread between the symbols. So, each symbol does not affect the next one. We will all later this interval plays an important role in the implementation. The guard period used was made up of two sections. Half of the guard period time is a zero amplitude transmission. The other half of the guard period is a cyclic extension of the symbol to be transmitted. This was to allow for symbol timing to be easily recovered by envelope detection. After the guard has been added, the symbols are then converted back to a serial time waveform. This is then the base band signal for the OFDM transmission.

OFDM with a Cyclic Prefix: Two difficulties arise when the signal is transmitted over a dispersive channel. One difficulty is that channel dispersion destroys the orthogonality between subcarriers and causes intercarrier interference (ICI). In addition, a system may transmit multiple OFDM symbols in a series so that a dispersive channel causes intersymbol interference (ISI) between successive OFDM symbols. The insertion of a silent guard period between successive OFDM symbols would avoid ISI in a dispersive environment but it does not avoid the loss of the subcarrier orthogonality. This cyclic prefix both preserves the orthogonality of the subcarriers and prevents ISI between successive OFDM symbols. Therefore, equalization at the receiver is very simple.

Channel Noise (AWGN): OFDM systems often experience not only channel dispersion as addressed above, but also additive white Gaussian noise (AWGN), Doppler spreading and synchronization errors. Synchronization errors such as carrier frequency offsets, carrier phase noise, sample clock offsets and symbol timing offsets are discussed. The inclusion of Gaussian noise in the signal model yields a received OFDM signal.

$$\mathrm{r(t) = s(t) * h(t) + n_t(t)}\text{--------(2)}$$

In a fading channel, the channel variations affect the performance of the OFDM system. For a fixed sampling period, the OFDM symbol length increases with the number of subcarriers and so do its sensitivity to channel variations.

MIMO OFDM Cognitive Wireless Network: The antenna selection process for cognitive MIMO system needs to account for the CR specific constraints. The transmit antenna selection method in cognitive MIMO system is to reduce total system cost while considering its own power and interference constraints of the primary users. This helps to device the transmit antenna selection algorithms for cognitive MIMO to provide optimal performance over a wide range of SNR.

Consider a cognitive MIMO system with N_T transmits antennas and N_R receives antennas. There is M number of primary users each connected to a single antenna. These N_T antennas are connected N_TRF chains at the transmitter, (Nx N).Assuming that receive and transmitter has the channel state information (CSI), we denote the channel state between cognitive MIMO system by the matrix $\mathrm{H} \in \mathrm{C}^{N_R \times N_T}$and the channel between cognitive transmit antennas and M primary users by the complex matrix $\mathrm{G} \in \mathrm{C}^{M \times N_r}$ transmit antennas from the N_T transmit antennas for the transmission, so that interference to the primary user is under some threshold. The capacity of MIMO system under the assumption of white Gaussian noise No is given as

$$C_{MIMO} = \log_2 \det \left[I + \frac{P}{2\sigma^2} \frac{1}{N_T} Q \right]$$

Where

$$Q = HH^H \text{ if } N_R < N_T \text{--------(4)}$$

Where P is the total transmitter power, identity matrix. We assume that the transmitter allocates power uniformly among the selected transmit antennas and channel input to these antennas are un-correlated. We formulate the transmit. The antenna selection in cognitive MIMO system as combinational optimization problem. The main object of antenna selection and cognitive MIMO system is to maximize the capacity of secondary systems under interference constraints to primary users.

Using multiple antennas at both transmitter and receiver is to increase the data rate by creating multiple spatial channels . A sequence of input symbols is encoded by a space-time encoding function into MT × 1 discrete-time complex baseband sequence x[n](n is a discrete time index). The x[n] sequence is subsequently transformed by pulse shaping filter into MT × 1 continuous-time complex baseband sequence x(t) and then the baseband signal is modulated with a transmission carrier .

IMPLEMENTATION

Implementation of MIMO OFDM Cognitive Wireless Sensor Network

Step 1: Transmitter

1. High Bit Stream Signal Generation (High Bit Stream=10^4) .
2. Apply MIMO Antenna (2 x 2 Transmitter Antennas)
3. Apply QAM modulation
4. Apply Cyclic Prefix to cancel the Inter Symbol Interference

Step 2: Channelization

1. Assuming the presence of AWGN and Rayleigh Fading noise in the channel of propagation

Step 3: Receiver

1. Serial to Parallel Conversion
2. Remove the Cyclic Prefix
3. Apply FFT to remove the subcarrier from the modulated signal
4. Apply the QAM Demodulation
5. LMMSE Equalizer
6. CR Network Channel Estimation

LMMSE Equalizer: The proposed Linear MMSE algorithm is used to reduce or eliminate the cyclic delay and Inter symbol Interference. Two of the most equalization algorithms are minimum mean square error (MMSE) equalizer and Linear MMSE equalizer. The LMMSE equalizer is used to improve the channel gain in terms of Signal to noise ratio. An Optimal LMMSE per channel equalizer is developed for an OFDM/OQAM (Orthogonal QAM) system with a time varying channel (AWGN, Reileigh) under the assumption of perfect channel knowledge at the receiver. The equalizer is evaluated for an example with a doubly dispersive channel (MIMO) with high spectrum (High SNR) and a low cyclic delay profile (CCD), and where the transmitter and receiver filters.

The performance is measured in terms of ergodic capacity, assuming perfect channel estimation and ideal channel coding which will be an upper bound for the throughput of the system.

The LMMSE Equalizer algorithm is used at the receiver of the OFDM system to improve the bit error rate. Consider the MIMO channel model given in Equation.1.Where the N data sub streams are mixed by the channel matrix. The LMMSE equalizer can be applied to decouple the N sub streams. The LMMSE equalization matrices are

$$(H^*H + \frac{1}{SNR} I)^{-1} H^* \text{.--------(5)}$$

The above equation can be extended to the received Signal

$$\frac{\mathrm{SNR}}{\left[(\mathrm{H}^{*}\mathrm{H}+\frac{1}{\mathrm{SNR}}\mathrm{I})^{-1}\right]\mathrm{nn}}-1, 1 \leq \mathrm{n} \leq \mathrm{N_r} \text{--------(6)}$$

In a 2×2 MIMO channel, consider that we have a transmission sequence, for example {x1, x2,x3, x4}, In general transmission, we send first time slot with x1 , second with x2 and so on . However, as we now have 2 transmit antennas, we may group the symbols into groups of two. In the first time slot, send x1 and x2 from the first and second antenna. In second time slot, from the first and second antenna send x3 and x4 respectively; in the third time slot send x5 and x6 and so on. We are grouping symbols and sending them in single time slot, we need 'n'time slots to complete the transmission hence the data rate is doubled. This forms the simple explanation of a probable MIMO transmission scheme with 2 transmit antennas and 2 receive antennas. Equalizer minimizes the error between actual output and desired output by continuous Blind is a digital signal processing technique in which the transmitted signal is inferred from the received signal.

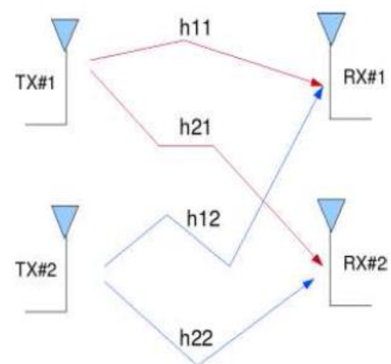


Fig. 3.The Proposed System - Transmit and Receive (2×2) MIMO Channel

Implementation of LMMSE Equalizer

1. Initiate the antennas at the receiver end
2. Apply the N bit FFT
3. Apply the Heuristic approach to find the equalizer parameters (Signal Phase angle, Magnitude)
4. Apply IFFT
5. Apply the twiddling factor
6. Apply the normalization technique to suppress the power delay
7. Calculate the magnitude of the received bits
8. Calculate the Mean Value
9. Calculate the maxima
10. Apply the decibel conversion

PAPR REDUCTION

PAPR Reduction: For MIMO OFDM CR WSNs less complex peak-to-average power ratio (PAPR) reduction scheme is proposed. The proposed scheme produces OFDM sequences by rotating the symbol phase using multiple all-pass filters; whereas the phase rotation of conventional selected mapping (SLM) scheme is performed with multiple complex multiplication modules in conjunction with IFFT modules. This doesn't need many IFFT modules.

PAPR Reduction Using All Pass Filter: Applying linear phase variations in the frequency domain correspond to cyclic shifting the time domain partial transmit sequences and can prevent "peak collisions". Applying constant phase variations (conventional PTS) change the phase but not the relative peak power positions of the partial transmit time sequences. An interesting feature of linear phase variation is: part of the data subcarriers will never be varied, whereas constant phase variation may change the phase of all subcarriers in the subblock. Pilot tones can thus be included in the subblocks for linear phase variation but not for constant phase variation. If the receiver fails to correctly recover the phase variation of a subblock, all data will be in error for constant phase variation but part of the data subcarriers can still be correctly recovered with linear phase variation.

Linear Phase Variation: The complex baseband time sequence of an OFDM symbol in a symbol duration can be expressed as the sum of N orthogonal subcarriers as follows:

$$x_k = \sum_{n=1}^{N} X_n e^{j2\pi(n-1)\Delta f Tk/L}, k = 0,1,..,LN-1 \quad \text{-------(7)}$$

N is the number of orthogonal subcarriers, L is the oversampling ratio, NT is the symbol duration, $\Delta f = 1/NT$ is the subcarrier frequency spacing, x_k is the kth time sample, and X_n is the frequency domain symbol for the nth subcarrier. The peak to average power ratio (PAPR) of a symbol is defined as follows.

$$PAPR = \max_k |x_k| / E[x_k], k = 0,1,..,LN-1$$

The N subcarriers can be partitioned into M disjoint subblocks of consecutive subcarriers with sizes $s_1,..,s_M$. $N = \sum_{m=1}^{M} s_m$. The time sequence { x_k } can be written as the sum of M partial transmit time sequences { x_k^m } as follows. $x_k = \sum_{m=1}^{M} x_k^m$, where

$$x_k^m = \sum_{n=1}^{N} X_n^m e^{j2\pi(n-1)\Delta f Tk/L}, k = 0,1,..,LN-1 \quad \text{-------(8)}$$

and $X_n^m = X_n \quad when\ n \in S_m, \quad X_n^m = 0 \ \ otherwise$ The subcarrier index in each subblock is as follows:

$$S_1 = \{1,..,s_1\}, S_2 = \{s_1+1, s_1+2,..,s_1+s_2\},...., \quad S_M = \{(\sum_{m=1}^{M-1} s_m)+1, (\sum_{m=1}^{M-1} s_m)+2,...,(\sum_{m=1}^{M} s_m)\}.$$

Each sub block contains consecutive subcarriers. The size of the sub blocks need not be equal.

PERFORMANCE EVALUATION

In this sectionthe results of the system are displayed in the form of BER and SNR curves. Tests are performed on MIMO ODFM cognitive system with 2x2transmitting and receiving antenna. Input data given is 9.6 kHzbud rate and modulation used is QAM. Size of pilot data is 52. The channel experience by each receive antenna, the noise has the Gaussian probability density function with Random Noise distribution for AWGN Channel, Rayleigh Channel. Capacity is estimated by comparing Ergodic rates with SNRup to 5x5 primary users. Finally PAPR is reduced by showing inches in SNR.

Channel Estimation for AWGN OFDM SISO:

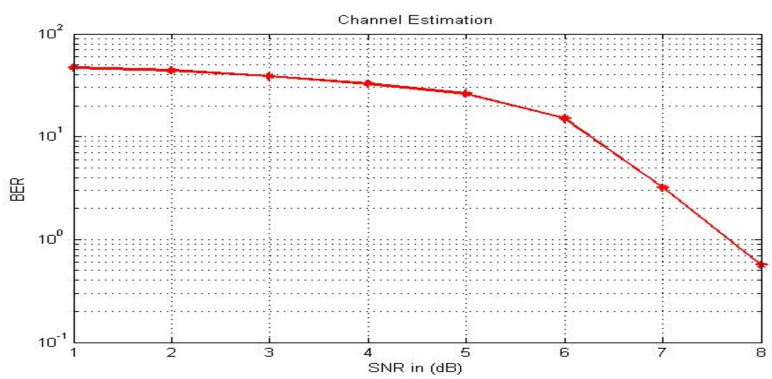


Fig.4.Channel Estimation for AWGN OFDM SISO

The channel capacity of the cognitive radio network is analyzed by using the OFDM SISO Scheme. The plot shown in figure 4 shows the Bit Error Rate (BER) and Signal to noise ratio (SNR) analysis of the signal in presence of AWGN. Obtained BER is around 10^1- 10^2 and SNR is 8dB

Channel Estimation for Rayleigh Fading and AWGN in OFDM MIMO: The channel capacity of the cognitive radio network is analyzed by using the OFDM MIMO Scheme. The plot shown in figure 5 shows the Bit Error Rate and Signal to noise ratio analysis of the signal in presence of AWGN and Rayleigh Fading environment.

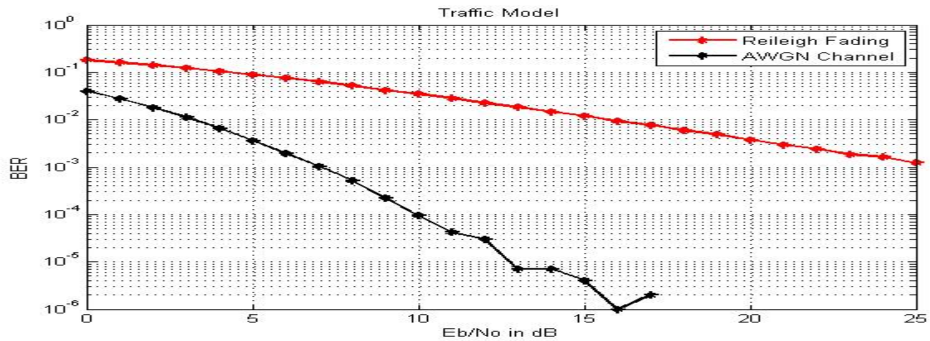


Fig. 5. Channel Estimation for Rayleigh Fading and AWGN in OFDM MIMO

By comparing figure 4 with figure 5, the BER is reduced to 10^{-1}-10^{-2} from 10^{1}- $10^{2}$and SNR is increased to 15 dB from 8dB. Also hear assumed the presence of Rayleigh Fading environment obtained BER is 10^{0}-10^{-1} and SNR is 25dB. The BER and SNR is much improved, and hence the channel utilization is improved compared with SISO CRN

Channel Estimation with LMMSE Equalizer for Rayleigh Fading and AWGN: The channel capacity of the cognitive radio network is analyzed by using the OFDM MIMO with LMMSE equalizer at the receiver end. The plot shown in figure 6 shows the Bit Error Rate and Signal to noise ratio analysis of the signal in presence of AWGN and Rayleigh Fading environment. By comparing figure 6 with figure 5, the BER is reduced comparatively and SNR is increased to around 35dB from 15dB in both the channel consideration.

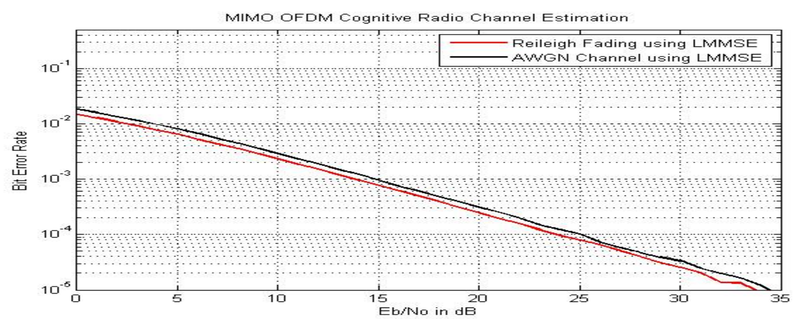


Fig. 6.Channel Estimation with LMMSE Equalizer for Rayleigh Fading and AWGN

The BER and SNR is improved, hence the channel utilization is improved by using LMMSE equalizer at the receiver end compared to the earlier MIMO CRNs.

Ergodic Rate verses SNR for Different Sizes: The figure shows the comparison of Ergodic rate verses SNR for different sizes. In this it has shown up to 5x5 primary users (PU). It shows the rate increases as no of user increases, and high SNR is achieved.

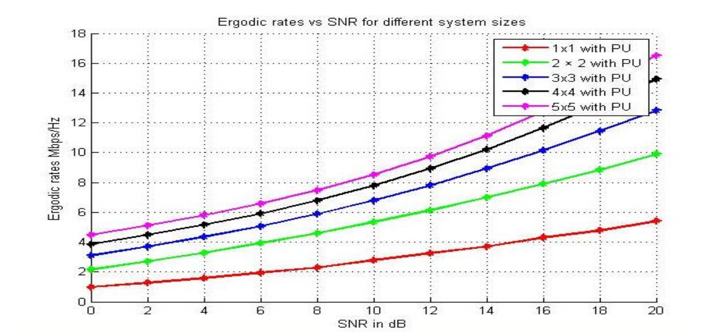


Fig.7.Ergodic Rate vs SNR for Different Sizes

Comparing fig 6 with fig 5 the SNR for 5x5 PU is 20 dB, but the total SNR with LMMSE equalizer is 35 db. The remaining difference 15dB can be allocated for secondary users (SU).

PAPR Reduction

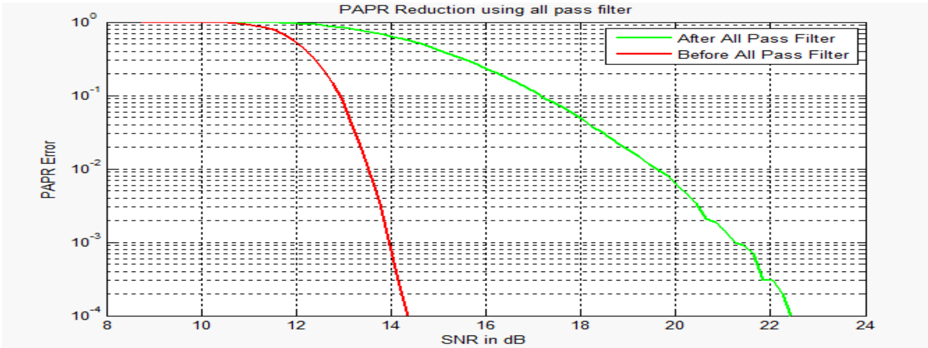


Fig. 8. PAPR reduction using all Pass filter

The PAPR reduction is using PTS technique is shown in fig 8. Here the all Pass filter is used to reduce the error. From the plot PAPR error is in 10^0, SNR is 14 dB before applying filter and SNR increased to 22dB.

CONCLUSION

In this paper the fundamental challenge for spectrum shortage for wireless sensor networks is alleviated by exploring system model of MIMO OFDM cognitive radio networks. By applying LMMSE we have increased channel gain with the reduction of BER and increase of SNR. Furthermore peak average power ratio is also reduced by using all pass filter with linear phase variation. Performance evaluation is analyzed by channel estimation through simulation and our results present a paradigm for spectrum efficiency in WSNs.

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