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Power Optimization and Channel Maximization in MIMO OFDM Cognitive Radio Networks with ICI Elimination and PAPR Reduction

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ABSTRACT: In this paper, we consider a joint beam forming, Power optimization and channel maximization in a multi-user and multi-channel underlay multiple input multiple output (MIMO) cognitive radio network (CRN) and also we investigate the throughput trade-off in multi-antenna cognitive radio (CR) systems. Specifically, we optimize the power of a multi-input multi-output (MIMO) CR system for maximization of the opportunistic system throughput under transmit power, probability of false alarm and probability of missed detection constraints . In this project, efficient method for ICI cancellation based on factor graph and PAPR reduction using pre-coder by estimating carrier frequency offset (CFO) and channel parameters in MIMO-OFDM Cognitive Radio is proposed. By exchanging messages both in space domain and frequency domain, the water filling algorithm is used to perform channel maximization and ALL PASS FILTER reduce peak to average power ratio (PAPR) iteratively and progressively. Numerical results show that the LMMSE algorithm of the proposed method is very accurate in ICI cancellation which is also verified by matlab simulation.

KEYWORDS: cognitive radio network, power optimization, channel maximization, water filling algorithm, LMMSE algorithm, ICI cancellation, PAPR elimination

I. INTRODUCTION

Recent studies reveal that the existing static spectrum allocation is the key reason for highly inefficient spectrum utilization which in turn leads to a problem of spectrum scarcity [1],[3]. To overcome this issue, a novel concept called cognitive radio (CR) was introduced which allows unlicensed users or secondary users (SUs) to initiate transmissions with the licensed communications [4], [5]. Cognitive Radio is an adaptive, intelligent radio and network technology that can automatically detect available channels in a wireless spectrum and change transmission parameters enabling more communication to run concurrently & also improve radio operating behaviour. For an underlay CR network (CRN) coexisting with a multichannel primary user (PU) network, managing interference is a critical issue since spectrum reusing among multiple users may cause negative effects on received signals at both Pus and SUs.

By exploiting multiple antennas, a signal processing technology called beam forming [6] has been introduced to CR for directional signal transmission, so as to effectively mitigate the mutual interference and improve the signal-to-interference plus Noise ratio (SINR). In the literature [6], joint Beamforming and resources allocation have been widely studied for multiple-antenna CRNs. In this paper, we mainly address the ICI cancellation, power optimization, channel maximization and PAPR elimination in an underlay cognitive radio network with independent D2D communications among multiple PU and SU pairs. Specifically we use different type of algorithms to achieve the different parameters as discussed. Here mainly we use WATER FILLING algorithm [7], [8] LMMSE algorithm[10] to channel maximization, ICI cancellation and PAPR elimination with all pass filter.

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We consider a multi-channel multi input multi output underlay CR system with the capability of beam forming at each SU-TX to mitigate interference, allow more transmission opportunities, and exploit the benefits of spatial diversity. Two different algorithms are proposed to solve the problem which are mentioned. We develop a WATER FILLING ALGORITHM [9] to the capacity maximization which results in the channel maximization with the ICI cancellation [10], [11], [12]. By calculating the SVD we can give the power optimization in the model. Simulation results show that the proposed system model outperforms the previous models with the measures taken. The proposed algorithms can achieve close-to-optimal performance with low computation complexity so that they are more suitable for practical applications.

II. RELATED WORK

In [2] authors proposed a solution which consists of two stages. In the first stage, a feasible solution for power allocation and beam forming vectors is derived under a given channel allocation by converting the original problem into a convex form with an introduced optimal auxiliary variable and semi definite relaxation (SDR) approach. After that, in the second stage, two explicit searching algorithms, i.e., genetic algorithm (GA) and simulated annealing (SA)-based algorithm, are proposed to determine suboptimal channel allocations. Simulation results show that beam forming, power and channel allocation with SA (BPCA-SA) algorithm can achieve close to optimal sum rate while having a lower computational complexity compared with beam forming, power and channel allocation with GA (BPCA-GA) algorithm.

Here they discussed the model in multi input and single output (MISO). In the first sub-problem, the power and beamforming vectors are calculated based on a given channel allocation. After that, the second sub problem, which determines a suboptimal channel allocation, will be solved. For the second sub problem, two algorithms are proposed with different computational complexity. Here Genetic algorithm having a high accurate and sum rate where as the simulation annealing is having the less computational complexity. As the number of SU pairs increases, the BPCA-GA outperforms BPCA-SA. The computation time of BPCA-SA algorithm is always shorter than that of the BPCA-GA, which proves that the BPCA-SA has lower computational complexity than the BPCA-GA. In addition, such superiority becomes more obvious for larger values. By considering the Computational complexity, it can be concluded that BPCA-SA is more feasible for practical applications. ZFBF algorithm is used to compare the results with the proposed algorithms. The proposed model outperforms the ZFBF scenario irrespective to the channel allocation algorithms. It is because the degrees of freedom available on channel allocation in our proposed system model are much greater than those in the ZFBF model. Moreover, after $K > 3$, It is very difficult to find the beamforming vectors with ZFBF due to the increased channel access requirement of the SUs.Here the sum rate also increased with compared to the conventional ZFBF algorithm.

III. PROPOSED WORK

Here in the proposed system we mainly concentrate on the channel maximization by increasing the capacity of the channel with respect to different type of channels. Power optimization is one of the key factor in the cognitive radio (CR) should be maintained correctly and here we also concentrate on the ICI cancellation as well as PAPR elimination in order to achieve the high sum rate in the proposed model. Here in the previous model while concentrating on the ISI reduction this cost in the ICI increment. To eliminate the ICI [10] we use LMMSE ALGORITHM [11],[12] .PAPR elimination is one of the key factor which results in the reducing the poor power efficiency. The main advantages of the proposed system is

Makes efficient use of the spectrum by allowing overlap. By dividing the channel into narrowband flat fading sub-channels, OFDM is more resistant to frequency selective fading than single carrier systems .It Eliminate ISI and ICI through use of a cyclic prefix. Using adequate channel coding and interleaving one can recover symbols lost due to the frequency selectivity of the channel. Channel equalization becomes simpler than by using adaptive equalization techniques with single carrier systems. It is possible to use maximum likelihood decoding with reasonable complexity.OFDM is computationally efficient by using FFT techniques to implement the modulation and

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demodulation functions. It is less sensitive to sample timing offsets than single carrier systems. It provides good protection against co-channel interference and impulsive parasitic noise.

A.WATER FILLING ALGORITHM

Water filling algorithm [7] follows the simple strategy of pouring water into a vessel with its surface defined by the inverse channel gain (ICG). When ICG is small, more power is transmitted in the corresponding sub carrier and when ICG increases, the transmitted power in the corresponding sub carrier is significantly reduced. In other words more power is allocated to a better channel to maximize the throughput of the system. Water filling algorithm provides an optimal solution for the problem of maximizing the throughput of a time varying channel by adjusting the transmitted power based on channel gain. In present correspondence we develop proposed water filling algorithm for MIMO fading channel (Rayleigh Fading channel)[8]. Orthogonal Frequency Division Multiplexing (OFDM) becomes the chosen modulation technique for wireless communication. Multiple access points or small base stations send independent coded information to multiple mobile terminals through orthogonal Code division multiplexing channels. MIMO [16] is a promising high data rate interface technology. It is well known the capacity of MIMO can be significantly enhanced by employing a proper power budget allocation in wireless cellular network .The singular value decomposition and water filling algorithm have been employed to measure the performance of MIMO OFDM integrated system. When N_t transmit and Nr represented antennas are employed, outage capacity is increased. In MIMO OFDM [16] we transmit different stream of data through different antennas. We show that as we increase the power budget in the water filling algorithm the mean capacity of the system increased.

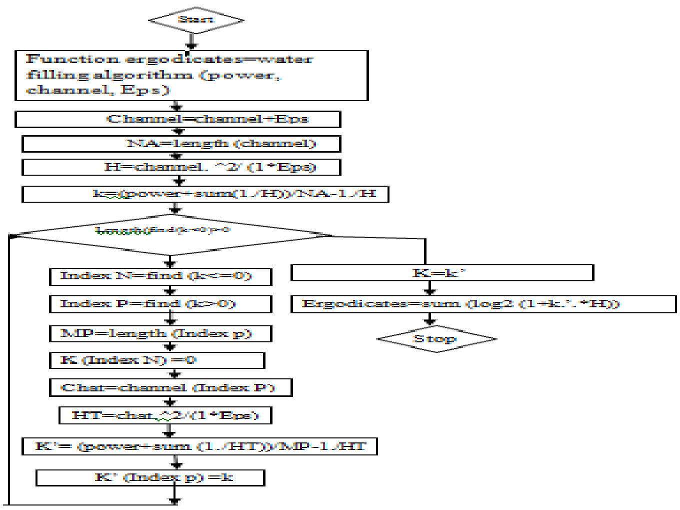

Fig 1: Flow chart of water filling algorithm

Water filling algorithm is mainly used to improve the capacity of the system which in turn increases the channel capacity with the increase in the snr. It is observed that an increase in number transmitter antennas with the water filling algorithm has improved the transmission capacity of the cognitive user when compared without water-filling algorithm. It is more increased with the use of MIMO [16].

B.LMMSE ALGORITHM

LMMSE algorithm [10] is used for ICI cancellation in the proposed model. In this we propose the effects of interference to channel estimation and present LMMSE algorithm for channel estimation by using the conjugate gradient method in time-varying multipath fading channels. The Doppler shift of fast-fading channels will generate inter-carrier interference (ICI) [11], hence, degrade the performance of orthogonal frequency-division multiplexing (OFDM) systems. Furthermore, when the length of channel impulse response (CIR) overstep the duration of cyclic

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prefix (CP), which will cause inter-symbol interference (ISI) and degrade system performance severely. Conventional channel estimation and equalization schemes, if applied to this case of insufficient CP, suffer significant performance degradation. By ISI and ICI analysis, an Interference elimination technique is proposed for channel estimation. After analyzing perturbation of least squares problems, we present total least-squares (TLS) scheme to eliminate the ICI [12], ISI and noise. We present a short theoretical overview of the TLS problem. In our estimation, residual ISI and ICI are not being handled as a noise. Since the introduction of interference, the operation of matrix becomes perplexed.

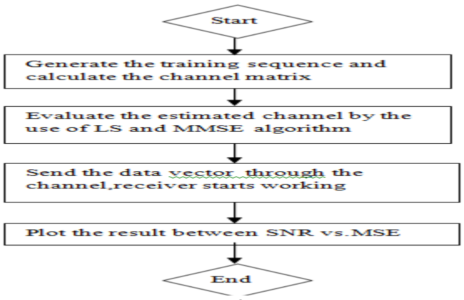

Fig 2: Flow chart of LMMSE algorithm

C.PAPR REDUCTION WITH ALL PASS FILTERS

The MIMO OFDM CR network system has become the superior wireless transmission technique in high speech wireless communication systems. It is more advantages than other communication system but the MIMO OFDM CR network occur high peak to Average Power ratio (PAPR) [13] due to fading channel in wireless communication. The multiple All Pass filter with clipping technique is proposed to reduce the PAPR on the receiver. The computational complexity is less compared to other techniques. We will discuss the clipping and filtering technique which is simple for the reduction in the PAPR. In MIMO OFDM CR network sub carriers are used to carry the data from the transmitter to the receiver. The guard bit interval in the system comes with the issues of PAPR and this will be minimized by providing proper synchronization between communication systems.

In general, the PAPR of MIMO OFDM CR network signals x(t) is defined as the ratio between the maximum instantaneous power and its average power

$$\mathrm{PAPR}[x(t)] = \frac{P_{PEAK}}{P_{AVERAGE}} = 10\log_{10}\frac{\max[|X(n)|^2]}{E[|x_n|^2]} \quad (1)$$

Where P_{PEAK} represents peak output power, $P_{AVERAGE}$ means average output power. E[·] denotes the expected value, x_n represents the transmitted OFDM CDMA signals which are obtained by taking IFFT operation on modulated input symbols X_k. x_n is expressed as:

$$x_n = \frac{1}{\sqrt{N}}\sum_{K=0}^{N-1} X_k {W_N}^{nk} \quad (2)$$

The instantaneous output of an MIMO OFDM CR network system often has large fluctuations compared to traditional single-carrier systems. This requires that system devices, such as power amplifiers, A/D converters and D/A converters, must have large linear dynamic ranges. PAPR reductions [14]-[15] techniques are therefore of great importance for MIMO OFDM CR network systems. Also due to the large fluctuations in power output the HPA (high power amplifier) should have large dynamic range. This results in poor power efficiency.

In a conventional SLM scheme, alternative frequency domain OFDM sequences are generated and then transformed into time domain sequences through the use of multiple IFFT modules. In the proposed scheme alternative OFDM sequences are directly generated in the time domain, thus eliminating the need for multiple IFFT modules. Generation of the alternative time domain OFDM sequences [16] are performed using multiple all-pass filters. An all-pass filter passes all frequency components of its input with constant gain, but with a desired phase shift [11]. The general form for the system function of an all-pass filter is given by

$$H(z) = \prod_{k=1}^{K}\frac{z^{-1} - c_k^*}{1 - c_k z^{-1}} \quad (3)$$

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Where and z^{-1} are the complex pole, its complex conjugate, and the number of the complex poles, respectively. Thus, the magnitude response and the phase response are given as

$$|H(e^{jw})|=1 \quad (4)$$

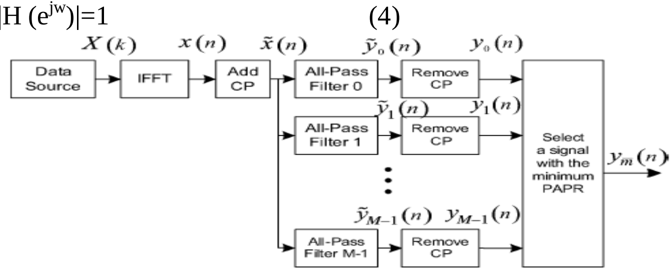

Fig 3: Block diagram of the proposed scheme using multiple all-pass filters.

With the phase response for of the all-pass filters, the time domain OFDM sequences for are represented as

$$\angle H(e^{jw}) = \sum_{k=1}^{K} \angle[-c_k^*] + \sum_{k=1}^{K} \angle\left[1 - \frac{1}{c_k^*}e^{-jw}\right] - \sum_{k=1}^{K} \angle\left[1 - c_k e^{-jw}\right]. \quad (5)$$

$$y_m(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} \left[X(k)e^{j\angle H_m(e^{j2\pi k/N})}\right] e^{j2\pi kn/N}. \quad (6)$$

Note that the frequency response in the proposed scheme replaces the phase sequence in the SLM scheme. Finally, the OFDM sequence with the minimum PAPR is selected for transmission [11]. The OFDM sequence in (6) corresponds to the circular convolution of the OFDM sequence with impulse response, which is defined as. original OFDM sequence. It is removed after passing through the all-pass filters. In order to determine the CP length, we considered effective length of infinite and decaying impulse response, which is defined in [12] as

$$N_e = \sqrt{\frac{1}{E}\sum_{n=0}^{\infty} n^2 h_m(n)^2} \quad (7)$$

Where is the total energy of the impulse response. Then, the circular convolution of with is represented as

$$y_m(n) = \sum_{k=0}^{N_e-1} h_m(k)x((n-k) \text{ modulo } N). \quad (8)$$

Because the all-pass filters perform the linear convolution with impulse response, Where in Fig. 3 is the OFDM sequence with CP, the output sequence of the linear convolution of with the impulse response of an all-pass filter is represented as

$$\tilde{y}_m(n) = \sum_{k=0}^{N_e-1} h_m(k)\tilde{x}(n-k). \quad (9)$$

From (8) and (9), the input sequence should be the same as for so that the linear Convolution would be equal to the circular convolution for .Therefore, the CP length should be larger.

As with the SLM scheme, the proposed scheme needs to send side information to receiver for its inverse operation. The receiver architecture is the same as that of the SLM scheme except that the selected all-pass filter ID is received as the side information instead of the phase sequence ID for the SLM scheme. In the receiver, inverse phase response sequence is used to cancel the phase shift by the all-pass filter, whereas inverse phase sequence is used for the SLM scheme.

C (i) All-Pass Filter Design

It was suggested in that any pair of candidate sequences should have a low cross-correlation so that the required PAPR reduction performance can be obtained. This cross-correlation between a pair of candidate sequences and for, is represented as

$$R_{pq}(n,n+d)=E[y_p(n)y_q^*(n+d)] \quad (10)$$

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Where then, by substituting (6) into (10), the cross-correlation is obtained as

$$R_{pq}(n, n+d) = \frac{1}{N}\sum_{k=0}^{N-1}\sum_{l=0}^{N-1} E\left[X(k)X^*(l)\right] \times e^{j\left(\angle H_p(e^{j2\pi k/N}) - \angle H_q(e^{j2\pi l/N})\right)} e^{-j2\pi ld/N}.$$

Note that in (11) the cross-correlation does not depend on the variable. The frequency domain symbol can be reasonably assumed to be a statistically independent and identically distributed (i.i.d.) random sequence with zero mean and unit variance [13]. From (11), can be rewritten as

$$R_{pq}(d) = \frac{1}{N}\sum_{k=0}^{N-1} e^{j\left(\angle H_p(e^{j2\pi k/N}) - \angle H_q(e^{j2\pi k/N})\right)} e^{-j2\pi kd/N}. \quad (12)$$

In order to consider all pairs of candidate sequences, a criterion, called the Variance of Correlation (VC) [13], is defined as

$$VC = \left(\sum_{0 \le p < q \le M \quad 1} Var\left[R_{pq}(d)\ ^2\right]_{d=-(N-1)}^{N-1}\right) / \binom{M}{2} \quad (13)$$

Where denotes the number of alternative pairs of and . Here, is the sample variance of defined as

$$Var\left[R_{pq}(d)|^2\right]_{d=-(N-1)}^{N-1} = \frac{1}{2N-1}\sum_{d= \quad (N \quad 1)}^{N-1}\left(|R_{pq}(d)|^2 - E\left[R_{pq}(d)|^2\right]_{d=-(N-1)}^{N-1}\right)^2 \quad (14)$$

where $E[\ R_{pq}(d)\ ^2]_{d=-(N-1)}^{N-1}$ is the sample mean of $R_{pq}(d)\ ^2$ and written as

$$E\left[R_{pq}(d)\ ^2\right]_{d=-(N-1)}^{N-1} = \frac{1}{2N-1}\sum_{d=-(N-1)}^{N-1} |R_{pq}(d)\ ^2. \quad (15)$$

The VC value in (13) is a representative value of cross-correlations between all pairs of candidate sequences. Therefore, we choose all-pass filters with low VC value in order to achieve a good PAPR reduction performance with the proposed scheme.

In order to get better approximation of the true PAPR, can be oversampled by a factor. The time domain OFDM sequence is then given by -point IFFT.

$$x'(n) = \frac{1}{\sqrt{LN}}\sum_{k=0}^{LN-1} X'(k)\, e^{\frac{j2\pi kn}{LN}} \quad (16)$$

where $X'(k) = X(k)$ for $0 \le k \le N/2 - 1$, $X'(k) = X(k - N(L-1))$ for $LN - N/2 \le k \le LN - 1$, and $X'(k) = 0$ for $N/2 \le k \le LN - N/2 - 1$. Hence, the cross-correlation $R_{pq}(d)$, $-LN + 1 \le d \le LN - 1$, in (12) is written as

$$R_{pq}(d) = \frac{1}{LN}\sum_{k=0}^{LN-1} W(k) \times e^{j\left(\angle H_p(e^{j2\pi k/LN}) - \angle H_q(e^{j2\pi k/LN})\right)} e^{-j2\pi kd/LN} \quad (17)$$

where $W(k)$ is the window function with $W(k) = 1$ for $0 \le k \le N/2 - 1$ and $LN - N/2 \le k \le LN - 1$, and $W(k) = 0$ for $N/2 \le k \le LN - N/2 - 1$. Finally, the VC value is given as

$$VC = \left(\sum_{0 \le p < q \le M-1} Var\left[R_{pq}(d)\ ^2\right]_{d=-(LN-1)}^{LN-1}\right) / \binom{M}{2}. \quad (18)$$

The Nyquist sampled OFDM signal is only considered in this paper.

IV.PSEUDO CODE

1. With the help of different types of noise distribution channel working of water filling algorithm is explained as below.
2. Take the inverse of the channel gains.
3. Water filling has non uniform step structure due to the inverse of the channel gain.
4. Initially take the sum of the total power Pt and the inverse of the channel gain. It gives the complete area in the water filling and inverse power gain

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$$Pt+\sum_{i=1}^{n}\frac{1}{Hi}$$

5. Decide the initial water level by the formula given below by taking the average power allocated

$$\frac{Pt+\sum_{i=1}^{n}\frac{1}{Hi}}{\sum Channel}$$

6. The power values of each sub channel are calculated by subtracting the inverse channel gain of each channel

$$\text{Powerallocated}=\frac{Pt+\sum_{i=1}^{n}\frac{1}{Hi}}{\sum Channel}-\frac{1}{Hi}$$

7. Plot the snr vs. capacity for different channels.
8. Create the PAPR function by using all the elements required like transmitter section, channel and receiver section.
9. All pass filter design is done in order to remove the PAPR and the CDF is calculated to plot the graph.
10. Plot the graph between the received power p_r and the PAPR in db.
11. MIMO transmitter and MIMO receiver are designed.
12. Calculating the MSE by using the LMMSE algorithm for the ICI cancellation.
13. Calculate the MSE of proposed CFO estimation and MSE of proposed SFO estimation in AWGN channel.
14. Plot the result between the SNR in db and the MSE calculated
15. End

V. SIMULATION AND RESULTS

The total simulation results are plotted by using the MATLAB software. The simulation results shows for the proposed work as below

Table 1 for capacity vs. snr (dB)

Iterations	SNR(dB)	Capacity
1	1	8.7520
2	2.0894	8.7520
3	2.9961	8.9329
4	4.0372	9.0415
5	4.9271	9.3607
6	6.029	9.4106

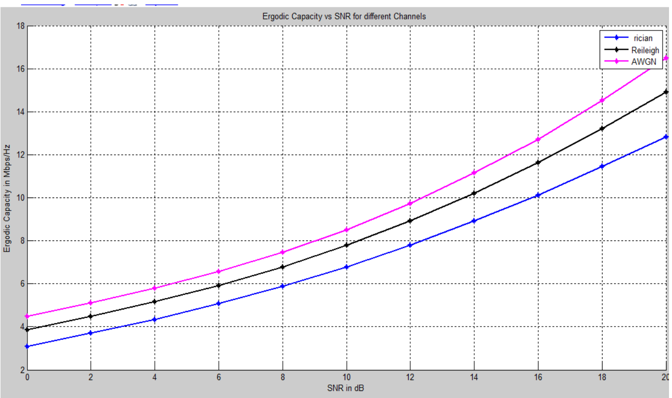

Fig 4: Ergodic capacity vs. SNR (dB) graph

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From the Table 1&fig 4 we can say that as SNR increases the ergodic capacity of the different noise distribution channels like AWGN, reileigh, rician channels increases. The increase in the capacity will result in the more channel utilization which leads to the channel maximization.

Table 2 for PAPR reduction comparision results

Iterations	PAPR	PAPR reduction using ALL pass filter
1	8.7520	2.9173
2	8.7520	2.9173
3	8.9329	2.9976
4	9.0415	3.0138
5	9.3607	3.1202
6	9.4106	3.1369

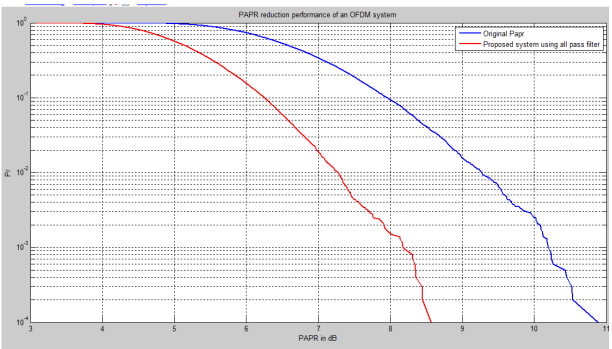

Fig 5: Graph drawn for PAPR reduction performance

From the Table 2& fig 5we can observe that how PAPR is reduced with the help of ALL PASS filter. The plot is drawn between the received power and the PAPR in db.PAPR is reduced to the large extent compared to previous models which is clearly evident in the graph.

Table 3 for MSE performance

SNR(dB)	MSE	MSE(ALL PASS FILTER)
1	0.115	0.00121
2.0894	0.108	0.00112
2.9961	0.96	0.00105
4.0372	0.84	0.0099
4.9271	0.79	0.0083
6.029	0.72	0.0075

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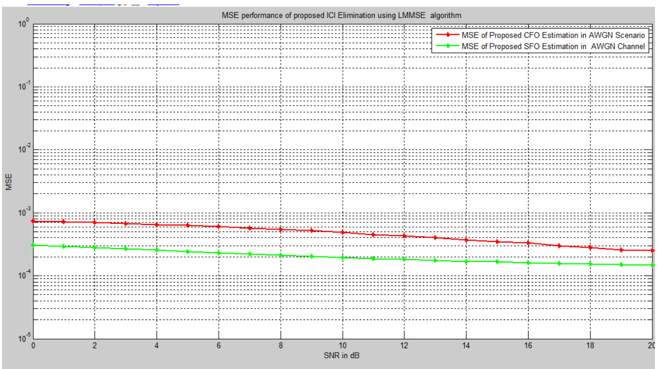

Fig 6: MSE performance of proposed ICI elimination using LMMSE algorithm

It is a plot drawn between the MSE and the SNR in db.The MSE is calculated by means of LMMSE algorithm. Here the MSE is calculated for the carrier frequency offset (CFO) and sample frequency offset (SFO) for the AWGN channel scenario. As the snr increases the MSE decreases to great extent which is shown in Table 3& fig 6.

VI. CONCLUSION

COGNITIVE RADIO (CR) is an emerging technology for the effective usage of the spectrum which reduces the white spaces effectively. In the proposed system it totally concentrates on the usage of the secondary users. So in order to increase the spectrum utility for the secondary users we propose the different techniques which can give access to the secondary users to use the spectrum without disturbing the benefits of the primary users in the network. This will increase the capacity with increasing the number of users in the network. Here in the paper we propose mainly two algorithms i.e., WATER FILLING ALGORITHM and LMMSE ALGORITHM to channel maximization and for the ICI cancellation which increases the network utilization while ALL PASS filter is used for PAPR reduction. The paper mainly concentrates on the power optimization and channel maximization by reducing the ICI and PAPR.Here the network is designed as MIMO. From the plotted graphs we can observe that the proposed algorithms can achieve better performance.

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