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Out of Band Radiation Control in OFDM Based Cognitive Radio Systems

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Abstract: Out of band radiation is one of the research challenges in Orthogonal Frequency Division Multiplexing (OFDM) based Cognitive Radio Systems. Power control is also an important issue in Cognitive Platform. In this paper, performance of soft window and Joint Spectral Shaping and Power Control for out of band radiation control is investigated. The soft window function is smoothing window that has faster decay than the conventional window and it can be used for out off band radiation control. Simulation results show that Bit Error Rate (BER), Minimum Mean Square Error (MMSE) and Signal to Interference plus Noise Ratio (SINR) of the soft window scheme is better than joint spectral shaping and power control scheme.

Key words: Cognitive Radio · OFDM · Joint Spectral shaping and Power Control · Soft window

INTRODUCTION

Recent studies show that the most of the licensed spectrum is underutilized and there is enough space to significantly increase the spectrum utilization and efficiency. Cognitive Radio (CR) is an intelligent system that can adapt the spectrum changes dynamically. A CR system must be flexible in regard to spectrum shape. Orthogonal Frequency Division Multiplexing (OFDM) has many attractive advantages to interface with CR system. In OFDM based Cognitive Radio system Out of band radiation from secondary user will cause interference to the Primary user. Hence spectrum shaping is required to have an Interference free system. In [1], Joint spectral shaping and power control is discussed and transmitter adaptation mechanism is used in spectrum overlay Cognitive Radio System. In spectrum overlay approach discussed in [2], the secondary users will not operate at the Primary user's operating frequency bands and to achieve the specific Signal to Noise plus Interference Ratio (SINR) power control is enabled.

From the recent studies, combination of power control and spectrum shaping will allow the Cognitive Radio transmitters to meet the desired spectrum overlay approach and desired Quality of Service. An OFDM signal is windowed by rectangular window in time domain, causing spectrum spreading. It introduces interference to the adjacent channels. So time domain windowing is introduced in ODFM system to reduce the interference.

One simple way to minimize the out of band radiation is to use a low pass filter. But it requires higher order filter to meet the desired specifications. The recent literature studies show that Insertion of cancellation carriers, Subcarrier weighting, adaptive symbol transition, spectral precoding are the few techniques to mitigate the out of band radiation in OFDM system. In this paper soft window and joint spectral shaping and power control performance parameters are compared.

The rest of the paper is organized as follows. Section II explains the system model. Section III deals with the joint spectral shaping and power control scheme. Section IV depicts the soft window function. Simulation results and Conclusion are presented in Section V and VI respectively.

System Model: The OFDM based cognitive radio system discussed in [1] uses coded precoder matrix to get the coded data. The coded matrix is chosen to meet the

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desired spectral characteristics of the transmitted signal by cognitive radio and also to meet desired SINR values. The coded information data symbols of N-dimension is given as

$$x = \sum_{m=1}^{M} b_m s_m \sqrt{p_m} = SP^{1/2} b, \tag{1}$$

where S is precoder matrix, P is a diagonal matrix comprising of power values and b is a vector of information symbols.

The transmitted power of OFDM based Cognitive Radio can be limited as

$$Trace\,[P] \le P_{T,max} \tag{2}$$

where $P_{T,max}$ is defined to be maximum transmit power.
The CR OFDM received signal is expressed as,

$$y = \Lambda SP^{1/2}\, b + w, \tag{3}$$

where Λ is diagonal matrix comprising the N-point Fast Fourier transform (FFT) of the channel impulse response and w is the correlation matrix.

The SINR expression

$$y = \overbrace{\Lambda_m b_m s_m \sqrt{p_m}}^{desirdsymbol} + \underbrace{\sum_{\substack{k=1 \\ k \neq m}}^{M} \Lambda_k b_k s_k \sqrt{p_k} + w}_{i_m interference + noise} \tag{4}$$

The correlation matrix is given as,

$$R_m = E[i_m i_m^H = R_y - p_m \Lambda s_m s_m^H \Lambda^H \tag{5}$$

where R_y is the received signal correlation matrix

$$R_y = E[yy^H] = \Lambda SPS^H \Lambda^H + R_w \tag{6}$$

Joint Spectral Shaping and Power Control Scheme: In [1], the joint spectral shaping and power control is framed and the optimal solution for MMSE, specified SINR, precoder matrix with S and P (power matrix) are developed. A cost function is defined as sum of MMSE of the CR receiver and the minimum cost is achieved to meet target SINR values. This algorithm incrementally updates the joint adaptation of spectral shaping and power control matrices. The complexity analysis is done for the convergence of precoder updates.

Soft Window Method: In conventional OFDM, rectangular window is used. In [3], a smooth window is used to control the out of band radiation. Time domain windowing yields convolution in frequency domain. The Fourier Transform of window function will shape the OFDM spectrum to desired level. Hence selection of roll off factor β plays an important role in spectrum shaping. It is discussed in [3] that conventional OFDM requires symbol length of T0 whereas the soft window requires the symbol length of (1+β) T0. The soft window uses the vestigial symmetry and also provides fast roll off. By using vestigial symmetry, it is possible to control the out of band radiation.

The window function is given in [3]

$$w(t) = \begin{cases} \sum_{k=0}^{N} a_k, & |t| \le \frac{1-\beta}{2} \\ \sum_{k=0}^{N} a_k \cos\left(\frac{k\pi}{\beta}\left(|t| - \frac{1-\beta}{2}\right)\right), & \frac{1-\beta}{2} < |t| \le \frac{1+\beta}{2} \\ 0, & Otherwise \end{cases} \tag{7}$$

The above window function can be used for spectrum shaping. It is seen that for N=1 and $a_0 = a_1$ 1/2 this diminishes to the Raised Cosine with a roll-off of β. The vestigial symmetry can be expressed as,

$$w(t) + w(t-1) = 1, \forall y \in [0, 1] \tag{8}$$

Implies that $a_0 = 1/2$ and $a_{2k} = 0$, $k \ge 1$.
The multicarrier signal is expressed as

$$x(t) = \sum_{k=0}^{N-1} a_k e^{j2\pi\left(f_0 + \frac{k}{NT}\right)t} w(t) \tag{9}$$

where f_0 is the frequency of the first carrier.
The different window functions can be written as

$$< |w(t)|^2 >_t = \begin{cases} 1, & Rectangularwindow \\ \frac{4-\beta}{4(1+\beta)}, & RC\ window \\ \frac{128-23\beta}{123\,(1+\beta)}, & Soft\ window \end{cases} \tag{10}$$

Simulation Results: This section deals with the performance comparison of soft window and joint spectral shaping and power control schemes. Numerical results are compared in terms of Minimum Mean Square Error, Signal to Interference + Noise Ratio and BER [4-20].

Fig. 1 represents comparison of Minimum Mean Square Error (MMSE) of soft window and joint spectral shaping and power control schemes. For various values of SNR, the corresponding MMSE values are measured.

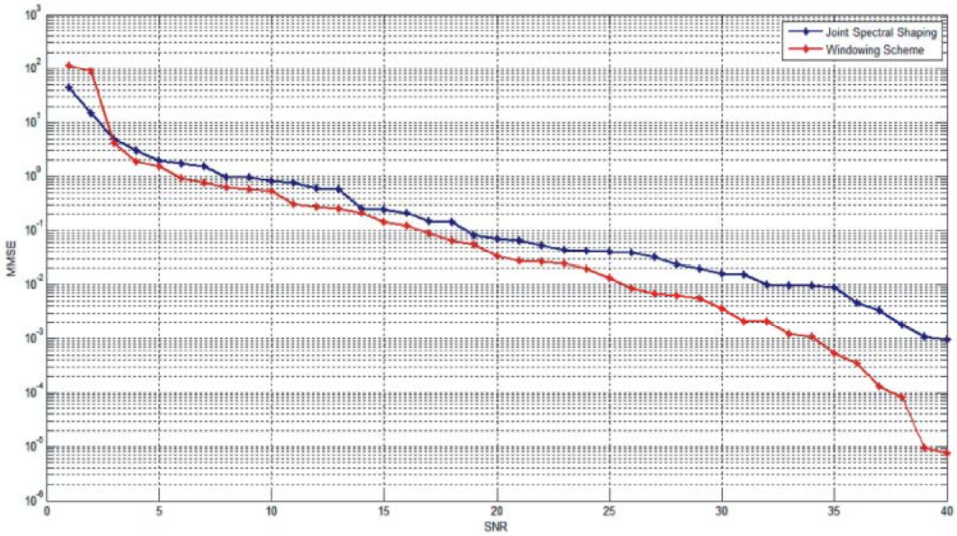

Fig. 1: Comparison of MMSE

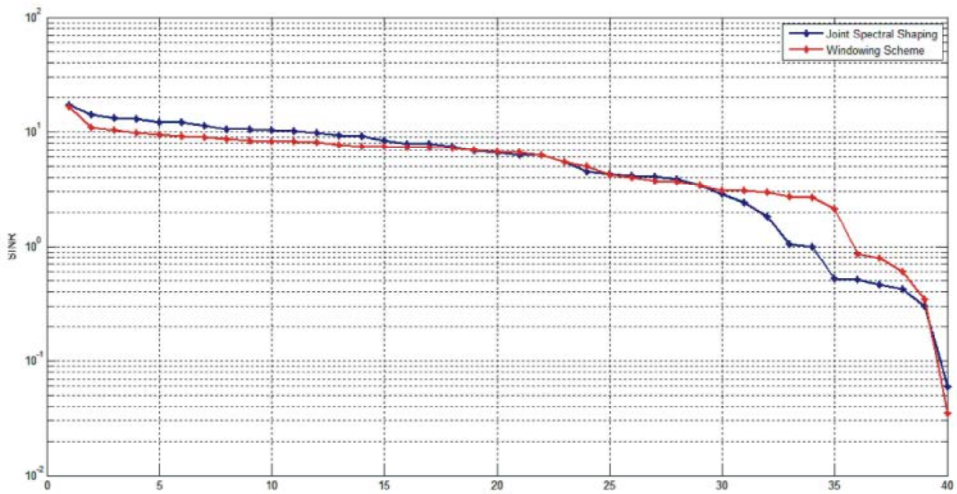

Fig. 2: SINR Comparison

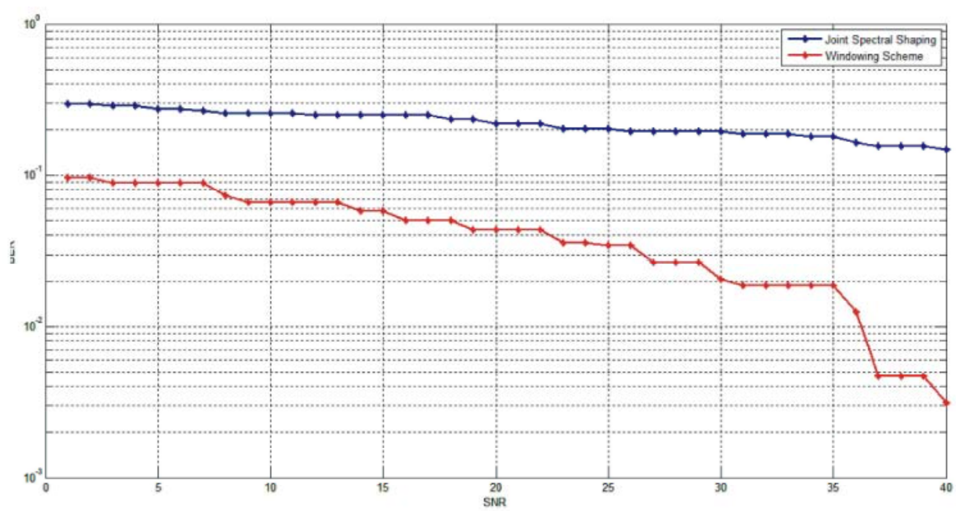

Fig. 3: BER comparison

It can be seen that MMSE performance of soft window is better than joint spectral shaping and power control scheme. The MMSE performance is improved by 68% from joint spectral shaping and power control method at SNR 5dB.

Fig. 2 shows comparison of Signal to Interference + Noise Ratio (SINR) of soft window and joint spectral shaping and power control schemes. For different values of SNR, the corresponding SINR values are measured. It can be inferred that SINR performance of soft window is better than the joint spectral shaping and power control scheme. The SINR performance is improved by 10.8% from the joint spectral shaping and power control scheme at SNR 5dB.

Fig. 3 shows that the comparison of Bit Error Rate (BER) of soft window and joint spectral shaping and power control schemes. BER values were analysed for various values of SNR. It is clear that BER performance of soft window is better than joint spectral shaping and power control scheme.

CONCLUSION

The performance comparison is done in this paper for OFDM based Cognitive Radio for soft window method and joint spectral shaping and power control method. Soft window method outperforms than the joint spectral shaping and power control in terms of BER, SINR & MMSE. Also soft window method meets the desired spectral characteristics.

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