A Low Complexity Active Interference Cancellation Method for OFDM based Cognitive Radios

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Abstract—We propose a low complexity active interference cancellation method applicable for OFDM based cognitive radios. The motivation for the new method comes from existing techniques proposed in the literature. We compare the performance of the new method with existing technique by using simulation results to highlight the interference suppression performance, power efficiency, and complexity.

Cognitive Radio, OFDM, Low complexity Iterative AIC

I. INTRODUCTION

Cognitive radios (CRs) are considered to be promising for various wireless applications in the light of the severe spectrum shortages [1]. Specifically, military systems are likely to be the early adopters of CRs due to various reasons. Orthogonal frequency division (OFDM) is considered as a suitable technology for use in CR due to the presence of certain inherent components like FFT and IFFT in the radio blocks. However, there are important challenges in getting CR systems to work in the presence of other legacy users (LUs) transmission. These include fast detection of the LUs transmission, bandwidth, etc., even at low SNR values. In this paper we focus on an OFDM CR working in the presence of a LU transmission. We shall address the interference caused by the OFDM CR to the LU transmission assuming that we can detect the latter and its bandwidth. In section II, we discuss an important method presented in the literature for reducing interference in the LU's band by a CR. We present a low complexity method for achieving the same objective in section III. In section IV, we present detailed simulation results followed by conclusions.

II. ACTIVE INTERFERENCE CANCELLATION

In an OFDM based CR, interference should be minimized in the LU band for co-existence purposes. To achieve this, active interference cancellation (AIC) has been proposed in [2] for a UWB based multiband OFDM system. Consider N subcarriers (tones) in the OFDM system as shown below in fig.1. Data is sent on the subcarriers adjacent to the LU band so that the interference from the CR is minimized in the LU band. In [3], details of the MMSE solution have been discussed along with simulation results. The number of adjoining subcarriers used denoted by AIC_n and the bandwidth of the LU in terms of the

subcarriers denoted by LU_n are varied in the study. Since the MMSE solution involves an inverse calculation, the complexity of the solution can be prohibitive as we increase AIC_n and LU_n . A low complexity solution which depends only on AIC_n has been proposed in [4].

Figure 1. Subcarrier Usage in a OFDM based CR

We present the main points in the mathematical model considered in [3] for further discussions. Let $F_{d_1 \times d_2} = \{F_{n,m}\}$ be the d_1 point FFT matrix with elements $F_{n,m} = \exp\left(\frac{-j 2 \pi n m}{d_1}\right)$. The time domain samples of the OFDM symbol can be expressed as,

$$x = \frac{1}{N} F_{N \times N}^H X \quad (1)$$

Where $X = [X_1, X_2, \dots, X_n]^T$ is the data symbols fed as an input to the IFFT in the OFDM transmitter and $()^H$ is the Hermitian operation. Since we would like to measure the interference caused by the CR in the LU band at the higher resolution, we oversample the spectrum of the transmitted signals as,

$$S = F_{vN \times N} x = Q X \quad (2)$$

Where $Q = \frac{1}{N} F_{vN \times N} F_{N \times N}^H$, and v is the spectrum oversampling factor. Let the LU band span from a subcarrier

index i to $i + LU_n - 1$, where i indicates the starting position of the LU band which can be flexible. We assume that the CR will not transmit any data on these subcarrier positions. The data to be transmitted on the AIC_n tones is given by the MMSE solution in [3] as,

$$X_I = -(Q_I^H Q_I)^{-1} Q_I^H Q_B X_B \quad (3)$$

where Q_B is the subset of Q containing only the rows corresponding to the LU band, Q_I is the subset of Q_B containing only the columns corresponding to subcarriers where the CR data is transmitted, X_B is the CR data vector with zeros in the cancellation and LU band subcarriers positions and $(\cdot)^H$ represents the Hermitian transpose of a matrix.

Simulation results in [3] indicate the effectiveness of this solution. However, we present further results which can be used for improving performance. To measure the effectiveness of the AIC method, we consider the average interference over the LU band. We have studied the interference suppression performance for different values of LU_n and AIC_n . Results shown in Fig.2 indicate that for a given LU_n , increasing AIC_n above a certain value leads to increasing interference. The extra power consumed due to the use of AIC tones increases with LU_n and AIC_n as shown in Fig.3. The reason for the increased interference above a certain value of AIC tones is that the matrix product, $Q^H Q$, becomes ill conditioned, for a given value of licensed user band LU_n . The inversion of such an ill conditioned matrix makes the MMSE solution diverge from the optimum. We have to use pseudo inverse (pinv in MATLAB) of the $Q^H Q$. The results obtained by using such a pseudo inverse are shown in Fig. 4 and 5. The performance numbers from the plots are better, but in finding the pseudo inverse, the convergence of the singular values and its singular vectors is the main concern. The convergence is very slow for a large size ill conditioned matrix [5].

III. LOW COMPLEXITY METHOD

We propose an iterative method to the above problem which will lead to lesser complexity while achieving good interference performance. The low complexity iterative AIC (LIAIC) is based on splitting AIC_n into smaller values called as AIC_{itr} and finding MMSE solutions for the smaller problems. For example, given a AIC_n value, we split it into several AIC_{itr} values and find an MMSE solution for AIC_{itr} tones at each step. We stop when we have a solution for the AIC_n tones. The choice of AIC_{itr} for a given AIC_n can be made based on complexity and performance aspects. The steps in LIAIC are as follows:

- i. Initialize Q and Q_B matrix for given system specifications namely number of subcarriers N , LU_n , AIC_n and v .
- ii. Determine the number of iterations to be performed for LIAIC tones calculation. Use the AIC_n and AIC_{itr} values to obtain the number of iterations. Note that the AIC_{itr} value need not be the same in all iterations.
- iii. Identify the submatrix Q_I from Q_B by considering only the columns corresponding to the AIC tones farthest

from the centre of LU band, with $AIC_{itr}/2$ number of tones on either side of the LU band.

- iv. Compute the LIAIC tone values by using the eqn 3.
- v. Update the above computed tone values at their corresponding position in X_B vector.
- vi. Repeat steps from iii to vi by suitably selecting the Q_I submatrix corresponding to the AIC tone positions converging towards the LU band, in steps of AIC_{itr} number of tones, till all the values of AIC tones are computed

Figure 2. Interference cancellation performance of AIC technique

Figure 3. Performance in terms of power transmitted by AIC technique

We need not use the same value of AIC_{itr} in all iterations. However, the sum of the AIC_{itr} should equal AIC_n .

By splitting AIC_n into smaller values of AIC_{itr} in multiple iterations, the size of the $Q^H Q$ is reduced in all iterations and thereby the complexity in singular vector convergence is reduced.

Figure 4. Interference cancellation performance of AIC technique with pseudo inverse

Figure 5. Performance in terms of power transmitted by AIC technique with pseudo inverse

IV. SIMULATION RESULTS

We compare the performance of the AIC method in [3] with that of the LIAIC method. Simulations were done with similar parameters as in [3], i.e., $N = 256$, LU_n values of 3, 7, 17, and 27, and BPSK symbols in the data tones. For comparison, the comparative plots of the LIAIC and the AIC methods are shown in figures 6 and 7 respectively. Only the case with $LU_n = 17$ and $AIC_n = 12$ is considered in these figures. The set of combinations considered for LIAIC is $\{(4, 4, 4), (6, 6), (8, 4), \text{ and } (10, 2)\}$. The x axis integer values in all these 3 plots refer to the index of the combination in the above set. For example, the 4th combination in the set refers to $(10, 2)$ combination of AIC_{itr} . These plots clearly highlight the advantage of LIAIC and the tradeoff between complexity, power efficiency and the interference suppression performance.

From figures 6 and 7, in the LIAIC method, the average interference level value and the relative power transmission

value are -108.27 dB and 26.11dB respectively. These values obtained by using the AIC_{itr} combination as (8, 4), with the index 3 in the above discussed AIC_{itr} combination set. The same interference level value in the AIC method is possible with $AIC_n = 16$, as shown in Fig.4, leading to increased complexity. However this complexity gain in the LIAIC comes with increased relative power transmission. Thus, there is a tradeoff between the power transmitted and the complexity. This means the LIAIC method can result in better complexity compared to the AIC method.

Figure 6. Interference Cancellation: Comparison between LIAIC and AIC

Figure 7. Transmitted Power: Comparison between LIAIC and AIC

V. CONCLUSION

We have proposed the LIAIC method for superior performance in OFDM based CRs. Under certain conditions, the LIAIC method can outperform the AIC method in complexity aspects. Extensive simulation results have been presented to highlight the tradeoffs that can be used judiciously in the LIAIC based CRs.

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