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Abstract: The rapid growth of wireless communications has made the problem of spectrum utilization ever more critical. The increasing diversity (voice, short message, Web & multimedia) and demand of high quality-of-service (QoS) applications have resulted in overcrowding of the allocated (officially sanctioned) spectrum bands, leading to significantly reduced levels of user satisfaction. The concepts of GLRT algorithm and substantial improvement over the U-GLRT algorithm are explained. This paper presents a model which uses efficient CP method for CR in Wireless Systems. Primary signal has been detected in the OFDM transmission with both the CPCC and MP–based C-GLRT algorithms greatly outperform energy detection in multi path environment has been implemented using software design. The signal model in our analysis is to efficiently exploit the correlation among the transmitted signals due to the presence of CP. Proposed method of cognitive radio takes two steps of implementation .first named as MP based is to detect the noise and de-noise the signal and the second is cp based in which the signals are identified based on the cyclic prefix.

Keywords: *Cyclic Prefix, Cognitive Radio, GLRT, C-GLRT, QoS, OFDM, spectrum sensing.*

1. INTRODUCTION

Most first generations systems were introduced in the mid 1980's, and can be characterized by the use of analog transmission techniques and the use of simple multiple access techniques such as Frequency Division Multiple Access (FDMA). First generation telecommunications systems such as Advanced Mobile Phone Service (AMPS) only provided voice communications. They also suffered from a low user capacity, and security problems due to the simple radio interface used. Second generation systems were introduced in the early 1990's, and all use digital technology. This provided an increase in the user capacity of around three times. This was achieved by compressing the voice waveforms before transmission.

The recent rapid growth of wireless communications has made the problem of spectrum utilization ever more critical. On one hand, the increasing diversity and demand of high quality-of-service (QoS) applications have resulted in overcrowding of the allocated (officially sanctioned) spectrum bands, leading to significantly reduced levels of user satisfaction. The problem is particularly serious in communication-intensive situations such as after a ballgame or in a massive emergency (e.g., the 9/11 attacks). On the other hand, major licensed bands, such as those allocated for television broadcasting, amateur radio, and paging, have been found to be grossly underutilized, resulting in spectrum wastage.

The concepts of GLRT algorithm provides a substantial improvement over the U-GLRT algorithm when only the observation $\mathbf{x}^{\cdot}$ is used. the reason for employing the signal model in our analysis is to efficiently exploit the correlation among the transmitted signals due to the presence of CP Furthermore, we detect the signal using the CPCC-based algorithm is only equivalent to the constrained GLRT (C-GLRT) algorithm when there is no multipath, it shall also be explicitly shown that its primary signal and the secondary signal .

Initial proposals for OFDM were made in the 60s and the 70s. It has taken more than a quarter of a century for this technology to move from the research domain to the industry.The concept of OFDM is quite simple but the practicality of implementing it has many complexities. So, it is a fully software project.

OFDM depends on Orthogonality principle. Orthogonality means, it allows the sub carriers, which are orthogonal to each other, meaning that cross talk between co-channels is eliminated and inter-carrier guard bands are not required. This greatly simplifies the design of both the transmitter and receiver, unlike conventional FDM; a separate filter for each sub channel is not required.

The estimated parameters are then used in the LRT as if they are the correct values. This results in the so-called *generalized* LRT (GLRT) [5]. GLRT has been widely employed in many hypothesis testing problems, e.g., [2][4] [5] including spectrum sensing applications [1][7].In this paper, it is first shown that the GLRT algorithm can exploit both multipath and cyclic correlations to yield a novel blind spectrum-sensing algorithm. It is then verified that the cyclic-prefix correlation coefficient (CPCC)-based detection algorithm is a special case of the constrained GLRT algorithm in the absence of multipath fading channel. It is further shown that, when multipath fading is present, which is the case for OFDM applications, performance of the detection based on the CPCC degrades. Furthermore, by exploiting the known structure of the OFDM channel matrix in a constrained GLRT algorithm, a detection algorithm that is solely based on the multipath correlation coefficients (MPCCs) is obtained. By combining the CPCC- and MPCC-based algorithms, an even more reliable spectrum-sensing method can be realized.

2. THE ARCHITECTURE-CPCC

The OFDM signal model considered in our work is the same as that in [1] [9], which assume that the primary OFDM system employs *L* subcarriers and the CR and primary users can be perfectly synchronized.

Let

$$\{S_{n,k}\}_{k=0}^{L-1}, \text{ with } E\{|S_{n,k}|^2\} = \sigma_S^2,$$

be the complex symbols to be transmitted in the *n*th OFDM block. Then, the baseband OFDM modulated signal can be expressed as

$$s_n(m) = \frac{1}{\sqrt{L}} \sum_{k=0}^{L-1} S_{n,k} e^{\frac{j2\pi mk}{L}}, \quad m = 0, \ldots, L-1$$

For a large number of subcarriers *L* [i.e., the size of discrete Fourier transform (DFT)/inverse DFT (IDFT)], $s_n(m)$ can be approximately modeled as a zero-mean circularly symmetric complex Gaussian random variable of variance σ_S^2.

Represent the length-(L + Lp) vector of the nth transmitted OFDM block as

$$\mathbf{s}_n = \left[s_n(L-1) \ldots s_n(0) \underbrace{s_n(L-1) \ldots s_n(L-L_p)}_{\text{Cyclic Prefix}} \right]^T$$

where L_p denotes the number of samples in the guard interval, i.e., the length of the CP. The corresponding received signal and noise vectors are denoted by

$$\mathbf{x}_n = [x_n(L-1)\ x_n(L-2) \ldots x_n(0) x_n(-1) \ldots x_n(-L_p)]$$

$$\mathbf{v}_n = [v_n(L-1)\ v_n(L-2) \ldots v_n(0) v_n(-1) \ldots v_n(-L_p)]^T$$

The primary user signal is received through a wireless multipath fading channel whose discrete-time baseband model is represented by channel filter taps h_i, $i = 1, \ldots, L_c$, where L_c denotes the number of multipath components. It is also assumed that the fading process remains static during the interval of spectrum sensing.

This implies that the channel filter taps can be treated as unknown constants during the period of spectrum sensing.

Two binary hypotheses $H0$ and $H1$ are defined in spectrum sensing, in which $H0$ denotes the idle state of the primary user and $H1$ represents the active state of the primary user.

To classify the observations into $H0$ or $H1$, a test statistics T is formulated, and a general test decision is given as follows:

Decide $H0$, if $T \leq e$

Decide $H1$, if $T > e$

where _ is some threshold value. Two probabilities of interest are given as follows: 1) the probability of detection *Pd*, which is the probability that the primary user is correctly detected in its active mode, and 2) the probability of false alarm *Pf* , which represents the probability of a false detection of the primary user when it is in the idle state. Mathematically

$$Pf = \Pr\{T > |H0\}$$

$$Pd = \Pr\{T > |H1\}$$

A CP correlation coefficient (CPCC)-based spectrum sensing algorithm was, in fact, proposed in [1] with the focus on AWGN channels. Next, it is shown that this CPCC-based sensing algorithm is exactly the constrained version of the GLRT algorithm based on observation $\mathbf{x}^{\cdot}$ and in the absence of multipath environment. It will be shown in Section VII that the constrained GLRT algorithm provides a substantial improvement over the U-GLRT algorithm when only the observation $\mathbf{x}^{\cdot}$ is used.

Furthermore, since the CPCC-based algorithm is only equivalent to the constrained GLRT (C-GLRT) algorithm when there is no multipath, it shall also be explicitly shown that its performance is degraded in a multipath environment.

3. MULTIPATH CORRELATION FOR GLRT

As shown in the previous section, the CPCC-based detection algorithm suffers a performance degradation in a multipath channel. On the one hand, this is expected, because the CPCC-based algorithm only uses observation in the head and tail of an OFDM block to exploit the correlation structure, which results from the use of the CP. On the other hand, multipath also introduces strong correlation to the received OFDM samples, which could also be exploited in the constrained GLRT algorithm. This is precisely the motivation and objective of this section. The developed algorithm shall use the portion of the received OFDM symbol that does not include the ISI part.

In this way, the known structure of the observation can be taken into account to improve the estimation of the signal covariance matrix. Furthermore, a simplified test statistics is derived as a function of the received signal correlation coefficients.

A.MPCC-Based Test:

Spectrum-sensing framework elaborated so far in this section makes use of the correlation property of the primary signal to identify it from the background noise. It is of interest to establish an approximated but simpler test that can still capture the multipath correlation of the primary signal. Some recent works [2] have also intuitively developed test statistics as functions of the received signal in the time domain by exploiting the multipath correlation property. By making appropriate approximation in the low-SNR region, the test can also be simplified as a function of the sample correlation coefficients.

In particular, the simplified test is

$$\widetilde{\mathcal{T}}(\ddot{\mathbf{x}}) = \sum_{m=1}^{L_p-1} |\widehat{\varrho}_m|^2$$

where Q_m represents the sample correlation coefficient corresponding to a delay of m samples, which is given as

$$\widehat{\varrho}_m = \frac{\sum_{n=1}^{N}\sum_{i=0}^{L-1} x_n(i)x_n^*\left((i-m) \bmod L\right)}{\sum_{n=1}^{N}\sum_{i=0}^{L-1} |x_n(i)|^2}.$$

The performance of the preceding simplified test is very close to that of the constrained GLRT

4. CPCC & MPCC-BASED DETECTION ALGORITHMS

The full multipath and cyclic correlations can be jointly considered in one covariance matrix. However, the success of the constrained GLRT algorithms introduced in Sections IV and V with a finite sample size and at low-SNR value lies in the structural constraints of their covariance matrices. A simple but effective approach to combine multipath and cyclic correlations is to decide $H1$ whenever one of the two constrained GLRT algorithms detects the presence of the primary user. The combined test always yields the best performance between the two detection algorithms in each channel realization. It should be noted that the threshold values have to be selected in such a way that the overall probability of false alarm meets the required constraint.

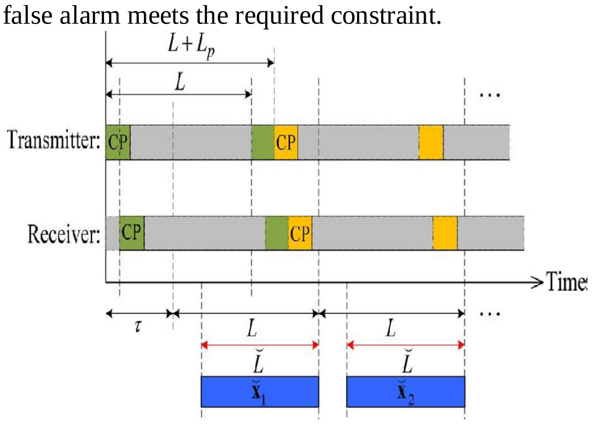

Fig.1 Timing relation between transmitter and receiver in the unsynchronized

The spectrum-sensing algorithms presented in Sections IV and V require symbol timing synchronization between the secondary and primary users. In the absence of symbol timing synchronization, the cyclic correlation is taken into account by considering samples located within the lags of $\pm L$ [11]. The consequence of this approach is a decrease in the correlation coefficient to $\breve{\rho} = (Lp/L + Lp)\ \rho$, which causes a drop in the performance of the detection algorithm.

At the secondary user's receiver, the received signal samples are divided into blocks of L samples each. This means that the corresponding samples in adjacent blocks are correlated due to the CP [11]. Compared with the received signal model in the synchronized case [see, e.g., (5)], the receiver in the unsynchronized case does not know exactly when an OFDM block will start. As such, the timing index in this section is with reference to the time the secondary user's receiver starts to collect the receive signal samples. In general, the timing origin at the secondary user's receiver can be lead or lag over the timing origin at the transmitter by τ samples, as shown in Fig. 1. For N transmitted OFDM blocks, the number of sample blocks processed by the receiver is $N = N(L + Lp - \tau)/L$.

To develop an efficient GLRT-based detection algorithm for unsynchronized OFDM signals, consider only the last portion of $L = L - Lp + 1$ samples in each block of L samples (seeFig. 1)

5. COMBINATION OF CPCC AND MPCC BASED DETECTION ALGORITHMS

By combining CPCC and MPCC based algorithms, an even more reliable spectrum –sensing method can be realized. GLRT algorithm can exploit both multipath and cyclic correlations to yield a novel blind spectrum-sensing algorithm. Proposed method is a VLSI implementation of cognitive radio .where the primary signal in digital nature is analyzed using multipath and cyclic prefix detection.

6. SIMULATION RESULTS

The simulation parameters are chosen similarly to those in [11]. In particular, the primary user's OFDM system has $L = 32$ subcarriers and transmits i.i.d. 8-QPSK symbols with normalized unit power. The detection period is taken to be equal to $N = 100$ OFDM blocks, and the results are averaged over 1000 random realizations of a Rayleigh multipath fading channel. Note that, for an OFDM system having a bandwidth of 5 MHz, 32 subcarriers, and a CP length of 8 (similar to [11]), the sensing time is roughly ((32 + 8)/5 × 106) × 100 = 8 × 10−4 s or 0.8 ms. The performance of different spectrum-sensing algorithms is evaluated and compared via the probability of detection Pd for a constant false alarm rate of $Pf = 0.05$.

First, Fig. 2 compares the detection performance of the energy detector (ED) and three spectrum-sensing algorithms developed and analyzed in this paper under perfect synchronization assumption, i.e., CPCC-based algorithm, multipath correlation-based constrained GLRT (MP-based C-GLRT algorithm) and the simpler MPCC-based algorithm (Section V-B). For this particular figure, $Lp = Lc = 8$ is used. As pointed out before, the ED algorithm requires a precise knowledge of the noise variance, and a small noise uncertainty, e.g., 0.5 and 1.0 dB, causes huge performance degradation, as can be seen from the figure. In contrast, the three other algorithms are completely blind, and their performances are impressive. Note that the simplified MPCC based algorithm performs closely to the MP-based C-GLRT algorithm, and both of them clearly outperform the CPCC based algorithm. This superior performance is expected since, with a large number of channel taps (Lc = 8), it would be more beneficial to exploit multipath correlation than CP correlation.

7. CONCLUSION

In this paper, Spectrum sensing method for OFDM based cognitive radio systems has been developed based on the GLRT frame work. Primary signal has been detected in the OFDM transmission with MP–based C-GLRT algorithms greatly outperform energy detection in multi path environment. Primary signal has been detected in the OFDM transmission 3 transmitters and receivers'. VLSI implementation has been done using verilog language for primary signal detection using cyclic prefix as reference.

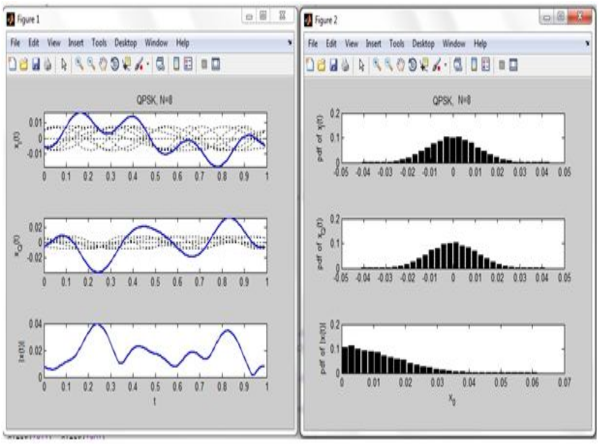

Fig.2 MATLAB Simulation Results of Signal Modulation and Demodulation

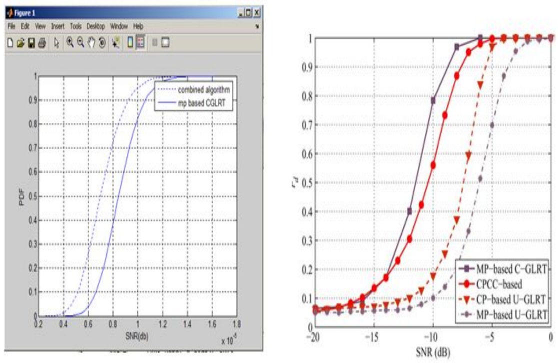

Fig.3 Performance comparison of C-GLRT and U-GLRT spectrum-sensing (Lp=Lc=8)

QPSK has been implemented for transmitting the orthogonal waves in mat lab 7.9. For the existing and the proposed architectures 3 no of transmitters are used .the primary signals detected are plotted in the simulation waveforms. The SNR for the proposed is computed by number of bits in error with the transmitter input. Further, Cognitive radio can be more simplified using better modulation techniques in the transmission. orthogonal signals takes a complex Fourier transforms which can be implemented by Hilbert transforms for better signal detection .error correcting codes should be implemented for attaining more accuracy.

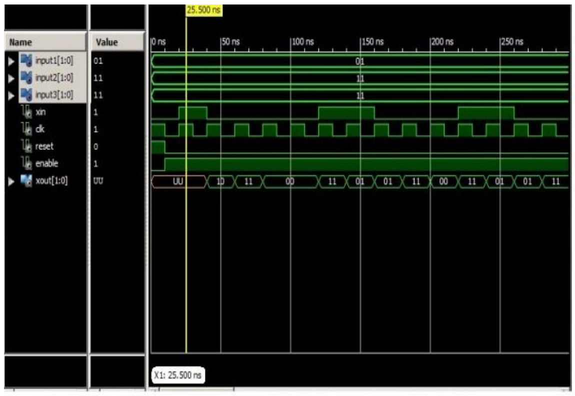

Fig.4: Proposed IFFT transformed output.

Fig.5: De-noised and detected simulation waveform

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