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Research Article

New Detection Scheme in Cognitive Radio by using 16-quadrature Amplitude Modulation for Bartlett Periodogram

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Abstract: The aim of this study is to use the Discrete Cosine Transform (DCT) instead of the previous methods which used the discrete Fourier transform (DFT) to detect the signal of a primary user by the Bartlett periodogram method. In this study the Digital Video Broadcast-Terrestrial (DVB-T) signals are used as an application example to analyze and assess the proposed spectrum sensing algorithm in the frequency domain using the AWGN channel. The study concludes that an accurate performance analysis of energy detection, reducing the noise variance without decreasing the signal resolution compared with the Bartlett periodogram based on DFT. By using 16-QAM modulation it can be seen the average variance of the noise in the DCT in all the scenario is 0.3478, while in FFT is 5841.37. This is mainly due to DCT being a real transform possessing an energy compaction property and the leakage effect is not there for DCT as compared to DFT. The Monte Carlo trials are used to confirm the accuracy of the proposed analysis. To obtain good accuracy with low noise variance to implemented the system in low complexity, it is required to use some trade-off between Probability of Detection (PD) and the Probability of False Alarm (PFA).

Keywords: AWGN, Bartlett's method, cognitive radio, DCT, DFT, spectrum sensing

INTRODUCTION

The rapid development of new communication systems especially the wireless communications and the foreseen spectrum occupancy problems have motivated the evolution of the concept of Cognitive Radios (CRs) and then search for the best ways to detect. Therefore, the best solution for the problem of letting secondary users utilize the spectrum licensed to the primary users when they are not active or idle is by using the technique CR device (Zeng and Liang, 2009). Where Cognitive Radio Network (CRN) consists of cognitive radios known as secondary users and legacy users known as primary users. Secondary users have to detect the existence of empty spectrum spaces (Spectrum Holes) to occupy without interfering with primary users. So, the most important thing for reliable detection of primary users and avoiding harmful interference is the spectrum awareness through robust spectrum sensing (Gismalla and Alsusa, 2012). The performance of the FD based energy detector is dependent on the variance of the spectrum estimate which is unique to the type of estimator used. The popular nonparametric spectrum estimators are the Periodogram, Bartlett's method, Welch method and the Multitaper estimate. These estimators differ in terms of computational complexity and estimate variance, a PSD estimates might be good with one but performs poorly on others. For cognitive radios, both simple and complex sensing methods are required as fast sensing and fine sensing are recommended (Olabiyi and Annamalai, 2012a; Salman *et al*., 2017).

Bartlett's modification (Babtlett, 1948) to the classical periodogram with periodogram partitioning shows an amelioration in the noise variance reduction but with some loss of resolution.

In Gismalla and Alsusa (2012), It shows a new approach in analyzing the performance of the FD energy detector when the decision statistic is taken from Bartlett's estimator which is known to offer reduced variance estimates with respect to the raw periodogram. The presented results aim to give an insight into the

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performance of this detector by evaluating its sensitivity to various parameters like the overall vector length and number of segments as well as the impact of the threshold on the probabilities of miss and false in three types of communication channels. Moreover, this way provides a lower probability of missed detection but its probability of false alarm is only better at relatively higher threshold values.

In Olabiyi and Annamalai (2012a), in general the performance of classical periodogram (based on the NP criterion) over fading channels by the use of rapidly convergent canonical series representation of the Marcum Q function. The analysis was also extended to the Bartlett's and Welch's periodogram to show the effect of partitioning and overlap on the sensing performance. To get the best average detection performance will use the zero padding. The Welch's overlapping periodogram averages was also shown to out-perform the Bartlett's non-overlapping periodogram. While in Olabiyi and Annamalai (2012b) it investigates the performance of spectrum sensing in the frequency domain when the classical and modified periodogram are analyzed based on the Neyman-Pearson (NP) criterion in conjunction with the analytical framework developed in the performance of spectrum sensing in the frequency domain was investigated, wherein the classical and modified periodogram are analysed based on the Neyman-Pearson (NP) criterion, in conjunction with the analytical framework developed in Olabiyi and Annamalai (2012a) in terms of false alarm and detection probabilities. This operation reduced the resolution with reduced the variance.

In Yousry *et al*. (2011), an IPB method based on the past periodogram methods was considered. They tested two methods: Bartlett's Method with varying segment lengths and Welch's method with varying overlap ratios and window shapes. The resulting IPB technique provides promising potential for use in other PSD estimation methods that could upgrade the detection of cognitive radio primary user even at very low SNR environments.

In Beheshti and Ravan (2008), it use finite length observed data to valuation the PSD by one of the existing periodogram estimators and also to estimate the Mean Square Error (MSE) in PSD estimation. This method provides the optimum window length for the Blackman-Tukey approach. But for any averaging PSDE approach, such as the Welch or Bartlett methods, the new method is guaranteed to perform better, as these averaging PSDE methods become special cases in the new approach when a window with maximum length is used.

In Stoica and Moses (2005) and Welch (1967), To split the existing data sequentially into segments, Bartlett's Method have the ability to reduce the periodogram's large fluctuations and high noise variance and average the periodograms obtained from the segmentation. Reduction of the Bartlett method's variance and spectral resolution is proportional to the number of segments. In an attempt to improve the statistical properties of the Bartlett's Method, the Welch's method (Stoica and Moses, 2005; Welch, 1967) decreases the estimated spectrum's variance at the expense of decreasing resolution-sometimes it is also known as the Welch-Bartlett Method.

Here it has been focused on the new work that analyzing the performance of the FD energy detector when the decision statistic is taken from DCT Bartlett's estimator which is known to offer reduced variance estimates without reduced the signal resolution with respect to the DFT Bartlett's estimator.

MATERIALS AND METHODS

Generating DVB-T signals: In transmition side used the OFDM system to generate of DVB-T signals. In this study concentrates on DVB-T signals that make use of a simple OFDM system model for the transmitter side. This acts as an application example for the examination of the proposed spectrum sensing algorithm in the frequency domain as depicted in Fig. 1. The experiment was done in Wireless and Photonics Network Research Centre, Malaysia.

According to the IEEE 802.22 standard, DVB-T signals consist of multiple parameters with several values for guard interval, bandwidth, FFT samples, modes and sampling time. The block diagram's operation is elucidated in the following:

The OFDM system model includes parallel/serial, modulation/demodulation and time/frequency conversions. Assuming that the information data are in bits format, channel coding methods are employed to code these bits. Digital modulation methods such as Quadrature Amplitude Modulation (16-QAM) can be employed to map the encoded bits into a signal constellation diagram. For smoothing data, the zero padding operation is adopted. IFFT processes the modulated data, which were converted from serial to parallel, to form an OFDM symbol. It establishes orthogonality among different subcarriers and aids in translating signals from frequency to time domain. Then, IFFT is employed to execute the OFDM modulation. The OFDM symbol is the output of the IFFT operator. To get rid of inter-block and inter-symbol interferences (ISIs), the Cyclic Prefix (CP) is introduced. CP can be defined as the process of inserting the last few samples of each frame in front of it. Since the complex baseband transmission is not meant for long-range communication, the baseband signal is converted to passband signal (Malkireddy, 2012).

OFDM systems can be adapted to different transmission environments and available resources. The

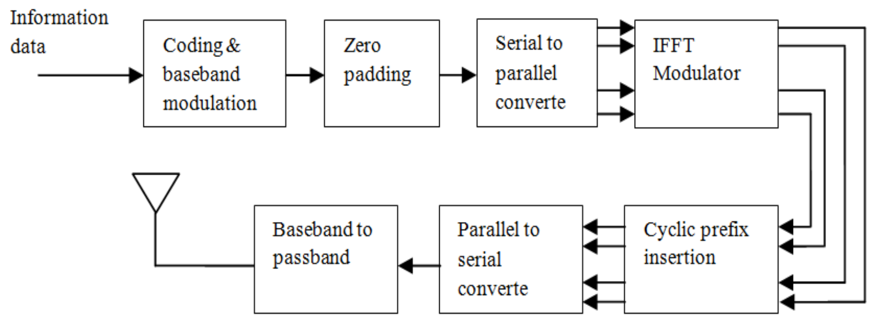

Fig. 1: Block diagram for the DVB-T signals adopt OFDM system model from transmitter side

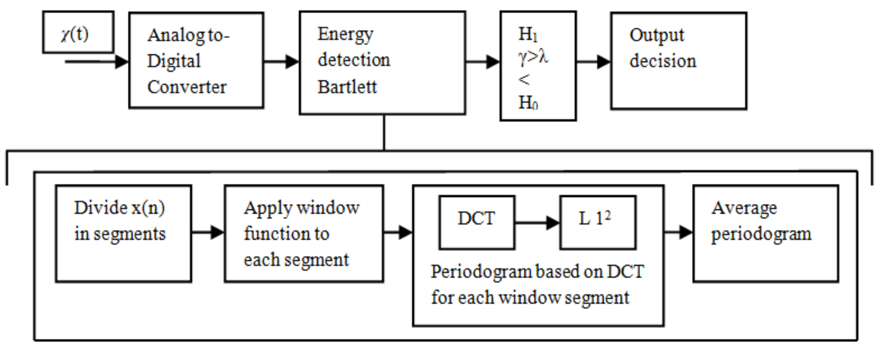

Fig. 2: Block diagram for energy detector Bartlett method based on DCT

primary user (DVB-T signals) based OFDM, where the transmission parameters of the OFDM can be changed based on the spectrum awareness which includes modulation, modes, FFT size, bandwidth, windows, active subcarriers and transmit power used for transmission. Moreover, the OFDM include high spectral efficiency, scalability, robustness against narrowband interference and easy implementation using Fast Fourier Transform (FFT). Therefore, the OFDM signals which using in the spectrum sensing with its adaptability and flexibility make it the best choice for the transmission technology for CR systems (Farhang-Boroujeny and Kempter, 2008).

Obtaining the received signal at Secondary User (SU): To determine whether the frequency band is idle or no, is detected of the primary signals, to determine whether it is idle or not. The AWGN channel analyses the received signal to test the binary hypothesis. Detection device is the function of detecting signals sent from a Primary User (PU) to the SU. The signal received at secondary receiver described as (Martínez and Andrade, 2013):

$$y(n) = s(n) + w(n) \tag{1}$$

where, s(n) represents the PU signal to be detected, which is considered to be an identical and independent random process (i.i.d) with zero mean and variance σ_s^2; w(n) represents the additive white Gaussian noise (AWGN) with zero mean and variance σ_w^2; and n represents the sample index.

Note: s(n) = 0 should there be no transmission by the PU. Furthermore, y(n) is expressed in terms of SS as the following binary hypothesis (Coase, 2013):

$$y(n) = \begin{cases} s(n) + w(n) H_0 \\ w(n) H_1 \end{cases} n = 1,2,3 \ldots N \tag{2}$$

where, N is the signal length.

H_0 and $H_1$are the idle and busy cases, respectively, for the PU signal (Mäkinen, 2015; Yousry *et al.*, 2011), i.e., i.e., H_0 specifies that the received signal is only noise and H_1 specifies that the received signal comprises PU signal with the noise.

Constructing the new modified bartlett periodogram based on DCT for received signal: The new proposed method's block diagram is presented in Fig. 2.

In the new proposed method, the DCT transform is used instead of the DFT transform as previously used on the Bartlett's periodogram. In this method, the sequence of the data is distributed as various segments without overlap (Bartlett's periodogram procedure). By taking the DCT of the square of the received signal samples, it can be converted into power spectral density, followed by taking the average over N samples (where N is the number of data samples). Also to develop the power spectrum density, the result is divided by the segments' length where the segmentation helps in determining the averages of the periodograms.

The DCT is a transform with basis sequences that are cosines. The cosines are both periodic and have even symmetry converses to the DFT that is only periodic. The DCT is defined by the transform pair (Alan *et al*., 1989).

$$A[k] = \frac{(-1)^k a[0]}{\sqrt{M}} + \sqrt{\frac{2}{M}} \sum_{n=1}^{M} a[n] \cos\left(\frac{\pi k(2n+1)}{2M}\right), 0 \leq k \leq M-1 \tag{3}$$

$$a[n] = \frac{A[0]}{\sqrt{M}} + \sqrt{\frac{2}{M}} \sum_{k=1}^{M} a[n] \cos\left(\frac{\pi k(2n+1)}{2M}\right), 0 \leq n \leq M-1 \tag{4}$$

where,

a[n] = The original M-point sequence

A[k] = The DCT M-point of a[n]

In most cases, the DCT-II has coefficients that give importance to low indices than the DFT where the importance is defined by the Paseval's theorem (Alan *et al*., 1989).

$$\sum_{n=0}^{M-1} |a[n]|^2 = \frac{1}{2M} |A[0]|^2 + \frac{1}{M} \sum_{k=1}^{M-1} |A[k]|^2 \tag{5}$$

This study contributes the possibility to apply the same procedure for the DFT to the DCT and to get better results compared to the previous method. This facilitates the creation of a power spectrum for each window segment of the DCT convert in a chain of signal sequences characterized by their cosine transforms. Therefore, employing the discrete Fourier transform through the normal periodogram (Bartlett), the binary hypothesis when sensing by ED in frequency domain (Ma *et al*., 2009) will be:

$$PSD(k) = \left|\frac{(-1)^k y[0]}{\sqrt{N}}\right|^2 + \sqrt{\frac{2}{N}} \left|\sum_{n=1}^{N-1} y[n] \cos\left(\frac{\pi k(2n+1)}{2N}\right)\right|^2 \tag{6}$$

where, λ represents the predefined threshold.

Equation (6) will give out the value of the PSD that can be compared with the predefined threshold value to decide the presence of the transmitted signal from the primary user's side. The test statistic is used as the PU signal, which is a complex valued for 16-QAM modulation over the AWGN channel. The predefined threshold λ is affected by the noise. However, the λ is chosen to determine the false alarm rate so that the variance of the noise is necessary to compute it (Yucek and Arslan, 2009). The probability of detection Pd and the probability of false alarm Pfa are mentioned in Martínez and Andrade (2013):

$$P_{fa} = P[Y > \lambda | H_0] = Q\left((\lambda - \sigma_w^2)/\sqrt{2/N}\sigma_w^2\right) \tag{7}$$

$$P_d = P[Y > \lambda | H_1] = Q\left((\lambda - \sigma_w^2 - \sigma_s^2)/ 2/N\sigma s2+\sigma w2 \right. \tag{8}$$

From (7), it can be deduced:

$$\lambda = \sigma_w^2 \left(1 + \sqrt{2/N} Q^{-1}(P_{fa})\right) \tag{9}$$

where,

λ = The threshold value

σ_w^2 = The noise variance for the noise

N = The length of the signal without the length of the samples that omitted because it is close to zero

Q(x) = The tail probability of the standard normal distribution given as:

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{\frac{-t^2}{2}} dt \tag{10}$$

Therefore, it can be established that the DCT is more focused on low indices in its sequence given that the remaining DCT coefficients are set to zero without affecting the signal energy (Oppenheim, 1999). Where the computing of the DCT coefficient is crucial as it allows overlooking the samples with near zero values in a particular rate.

Determining the noise variance for the recommended method based on DCT and Bartlett method employing FFT: The periodogram was not a consistent estimate of the power spectral density function. A technique introduced by Bartlett, however, allows the use of the periodogram and, produces a consistent spectral estimation by averaging periodograms. In the other word, Bartlett's approach reduces the variance of the estimates by averaging together several independent periodograms. If, for example X1, X2, X3,…, XL are uncorrelated random variables having an expected value E[x] and a varianceσ^2, then the arithmetic mean:

$$(X_1 + X_2 + X_3 + \cdots + X_L)/L$$

Has the expected value E[x] and a variance of σ^2/L. This fact suggests that a spectral estimator can have its variance reduced by a factor of L over the periodogram. The procedure requires the observed process, an N point data sequence, to be split up into L non overlapping M point sections and then averaging the periodograms of each individual section. Therefore, in this procedure it can be calculated the average variance of DCT and FFT by sum all the values for each case divided by the number of the values as follows:

$$av_{VAR_{DCT}} = sum(VAR_{DCT})/L$$
$$av_{VAR_{FFT}} = sum(VAR_{FFT})/L$$

The periodogram gives a spectrum estimate with good resolution, but with high variance. Bartlett's and Welch's based on FFT methods reduced the spectrum estimates variance by dividing data into blocks and average estimates over blocks. Therefore, improved variance come at the expense of reduced resolution. In the proposed method based on DCT it can be reduced the variance without on the expense of reduced resolution as it shown in the results.

RESULTS AND DISCUSSION

The DVB-T signals employ OFDM transmission. In this case, the Quadrature Amplitude Modulation (16-QAM) constellations are employed to modulate all data carriers in one OFDM frame. Two important parameters define the modulated signals: length of cyclic prefix and type of mode. The mode parameters determine the number of subcarriers to be used in the OFDM modulation, which can also take values of 2 k or 8 k modes, i.e., 2,048 or 8,192, respectively (Igbinosa *et al*., 2014). It considered the AWGN channel in all simulations that employed Quadrature Amplitude Modulation (16-QAM). When using the Quadrature Amplitude Modulation (16-QAM), the results for the implementation of the algorithm are evaluated in four scenarios.

Scenario 1: In this scenario, the 2 K mode in 16-QAM modulation is employed with varied cyclic prefix values at 1/4, 1/8, 1/16 and 1/32 and SNR fixed value kept at -20. Figure 3 shows the Receiver Operational Characteristic (ROC) curves for this scenario. It also presents the relationship between the probability of detection (Pd) and the probability of false alarm (Pfa) for the number of Monte Carlo Simulations (NS) = 1,000. When the Pfa is 0.1, the probability of detection values based on the DCT would be 0.905, 0.909, 0.91 and 0.913 for the cyclic prefix 1/8, 1/16, 1/4 and 1/32, respectively. The values based on the FFT are 0.09, 0.11, 0.12 and 0.13 for the cyclic prefix 1/4, 1/16, 1/32 and 1/8, respectively. Thus, it can be concluded that with a suitable value of coefficient number 0.9999, the performance can be improved by enhancing the detection probability Pd for the proposed method. This is because for the proposed method, the average variance of the DCT is decreased to 0.3400 compared with the previous method's average variance of the FFT at 2515.8 as presented in Table 1. The trade-off method between Pd and Pfa coefficient numbers is selected to get better detection performance for Pd with high value and Pfa with low value. Thus, it can be inferred that the performance of the method can be improved even under conditions where SNR has the lowest value (at -20)

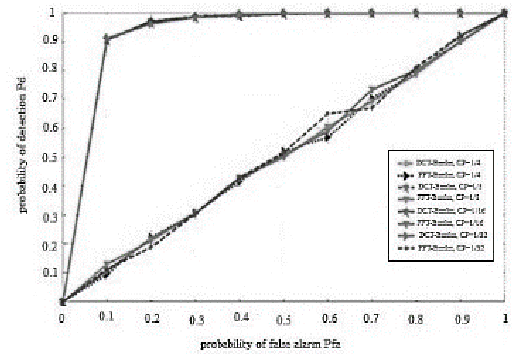

Fig. 3: ROC in AWGN channel, 16-QAM modulation for Pd and Pfa with number of segments = 2, CP is (1/4, 1/8, 1/16, 1/32), SNR=-20dB, Coefficient number = 0.9999, 2k mode

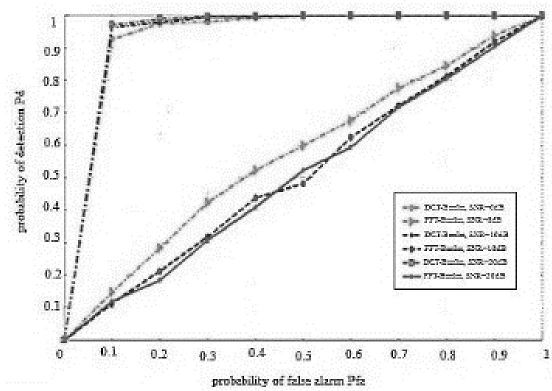

Fig. 4: ROC in AWGN channel, 16-QAM modulation for Pd and Pfa with number of segments = 2, SNR (0, -10, -20) dB, CP = 1/32, Coefficient Number = 0.9998, 2k mode

only if suitable value for coefficients number is selected.

Scenario 2: In this scenario, the 2k mode in 16-QAM is employed with different values of the SNR at (0, -10, -20) and fixed cyclic prefix value at 1/32. Figure 4 depicts the receiver operational characteristic (ROC) curves for this scenario.

The figure presents the relationship between the probability of detection (Pd) and the probability of false alarm (Pfa) for NS = 1,000. When Pfa is 0.1, the probability of detection values employing the DCT is found to be 0.93, 0.96 and 0.97 for SNR values 0, -10 and -20, respectively. While in the case of FFT, the values are 0.118, 0.12 and 0.149 for SNR values of -10, -20 and 0, respectively. From the curves, it can be inferred that selecting a suitable coefficient number value of 0.9998 and retaining a fix value for cyclic prefix at 1/32 improved the detection performance. As presented in Table 1, for the proposed method, decreasing the average variance of DCT allows obtaining the detection probability, Pd, at 0.3453 compared with the average variance of FFT for the previous method at 2157.7. The trade-off method

Table 1: The values of the variance and the averages variance in 16-QAM modulation for four scenarios

SCE.	σ^2_1 (DB)	σ^2_2 (DB)	σ^2_3 (DB)	σ^2_4 (DB)	σ^2_5 (DB)	σ^2_6 (DB)	σ^2_7 (DB)	σ^2_8 (DB)	σ^2_9 (DB)	σ^2_{10} (DB)	σ^2_{11} (DB)	AV. VAR. (DB)	Coe. no.
SCE.1 DCT	0.3410	0.3341	0.3489	0.3212	0.3493	0.3407	0.3244	0.3197	0.3400	0.3430	0.3769	0.3400	0.9999
FFT	2531.1	2528.6	2525.7	2407.4	2575.5	2449.7	2466.5	2400.9	2515.0	2554.5	2718.2	2515.8	0.9999
SCE.2 DCT	0.3429	0.3517	0.3302	0.3356	0.3595	0.3583	0.3391	0.3566	0.3379	0.3523	0.3342	0.3453	0.9998
FFT	2156.2	2227.8	2040.3	2168.7	2205.4	2164.9	2132.2	2186.0	2103.9	2232.1	2117.0	2157.7	0.9998
SCE.3 DCT	0.3570	0.3526	0.3610	0.3543	0.3516	0.3486	0.3567	0.3546	0.3660	0.3622	0.3511	0.3560	0.99999
FFT	10269	10334	10262	10268	10145	10058	10219	10391	10230	10405	10291	10262	0.99999
SCE.4 DCT	0.3490	0.3479	0.3475	0.3562	0.3588	0.3456	0.3498	0.3524	0.3382	0.3547	0.3477	0.3499	0.99997
FFT	8499.0	8526.6	8307.2	8484.4	8640.3	8229.1	8375.7	8540.8	8225.7	8439.8	8461.1	8430	0.99997

Table 2: Variance for different periodograms and modified periodograms methods

Type of spectrum estimation		Variance
Other Works	Periodogram	3.86E+04
	Welch	82.12 (Blackman)
	Multitaper	52.16
Propose Method	Bartlett based on DCT	0.3478

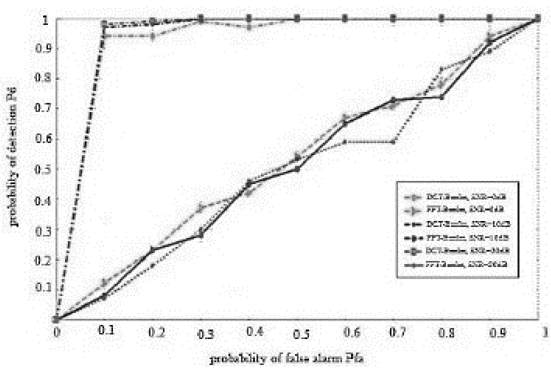

Fig. 5: ROC in AWGN channel, 16-QAM modulation for Pd and Pfa with number of segments = 2, SNR (0, -10, -20) dB, CP = 1/32, Coefficient Number = 0.99997, 8k mode

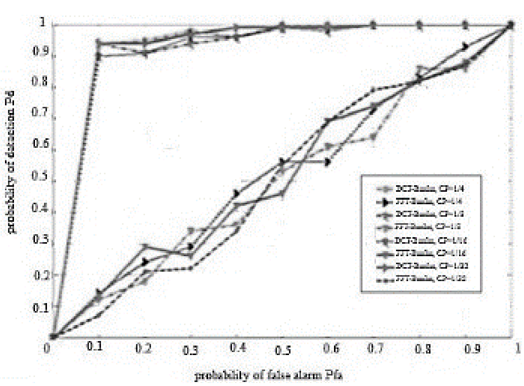

Fig. 6: ROC in AWGN channel, 16-QAM modulation for Pd and Pfa with number of segments = 2, CP is (1/4, 1/8, 1/16, 1/32), SNR =-20dB, Coefficient Number = 0.99999, 8k mode

between Pd and Pfa is employed to determine the coefficient numbers to enhance the performance of detection in both the highest value for Pd and the lowest value for Pfa. Therefore, it is inferred that the performance can be enhanced even with the smallest value of CP by selecting a suitable value for the coefficient number.

Scenario 3: In this scenario, the 8k mode in 16-QAM is employed with different values of the SNR at (0, -10, -20) and fixed cyclic prefix value at 1/32. Figure 5 depicts the receiver operational characteristic (ROC) curves for this scenario.

The figure presents the relationship between the probability of detection (Pd) and the probability of false alarm (Pfa) for NS = 1,000. When Pfa is 0.1, the probability of detection values employing the DCT is found to be 0.94, 0.97 and 0.98 for SNR values 0, -10 and -20, respectively. While in the case of FFT, the values are 0.07, 0.08 and 0.12 for SNR values of -20, -10 and 0, respectively. From the curves, it can be inferred that selecting a suitable coefficient number value of 0.99997 and retaining a fix value for cyclic prefix at 1/32 improved the detection performance. As presented in Table 1, for the proposed method, decreasing the average variance of DCT allows obtaining the detection probability, Pd, at 0.3499 compared with the average variance of FFT for the previous method at 8430. The trade-off method between Pd and Pfa is employed to determine the coefficient numbers to enhance the performance of detection in both the highest value for Pd and the lowest value for Pfa. Therefore, it is inferred that the performance can be enhanced even with the smallest value of CP by selecting a suitable value for the coefficient number.

Scenario 4: In this scenario, the 8K mode in 16-QAM modulation is employed with varied cyclic prefix values at 1/4, 1/8, 1/16 and 1/32 and SNR fixed value kept at -20. Figure 6 shows the Receiver Operational Characteristic (ROC) curves for this scenario. It also presents the relationship between the probability of detection (Pd) and the probability of false alarm (Pfa) for the number of Monte Carlo simulations (NS) = 1,000. When the Pfa is 0.1, the probability of detection values based on the DCT would be 0.9, 0.94, 0,94 and 0.94 for the cyclic prefix 1/16, 1/4, 1/8 and 1/32, respectively. The values based on the FFT are 0.07, 0.12, 0.13 and 0.14 for the cyclic prefix 1/32, 1/8, 1/16 and 1/4, respectively. Thus, it can be concluded that with a suitable value of coefficient number 0.99999, the performance can be improved by enhancing the detection probability Pd for the proposed method. This is because for the proposed method, the average variance of the DCT is decreased to 0.3560 compared with the previous method's average variance of the FFT at 10262 as presented in Table 1. The trade-off method between Pd and Pfa coefficient numbers is selected to get better detection performance for Pd with high value and Pfa with low value. Thus, it can be inferred that the performance of the method can be improved even under conditions where SNR has the lowest value (at -20) only if suitable value for coefficients number is selected.

Table 1 illustrates the values for all the variance employed and the average variance values for four scenarios with 2 k and 8 k modes 16-QAM modulation. The detection performance can be determined by varying the probability of false alarm from 0 to 1.0 (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1) and finding the probability of detection. Performance is also analyzed with the ROC plot. Therefore, eleven values of the variance are obtained. From the simulation results, it can be observed that the presented algorithms do not depend on the signal structure information, the only assumption being here is the information related to the CP and the transmission mode. Simulation results show DCT provides better spectral estimation than DFT and has less variance (Vendelin *et al*., 2005). This is mainly due to DCT being real transform and possess energy compaction property (Youn *et al*., 2007). The leakage effect is not there for DCT as compared to DFT (Kumari *et al*., 2013). Also, the simulation model shows that the selection of the appropriate value for the coefficient vector is imperative to achieving the right result. Therefore, the coefficient vector has a significant impact on the determination of the accurate result. This simulation shows that the difference in the complexity between the two methods. Therefore, to prove the complexity, it can be seen the number of mathematical operations in the traditional Bartlett's periodogram depends on the original stream length, whereas the number of mathematical operations in the proposed Bartlett's periodogram depends on the new stream length. Thus, the second type is lower complexity than the first type since the new stream length is smaller than the original stream length.

By using DCT in Bartlett periodogram is considered as a simple method in the implementation and stimulator design for energy detector. Table 2 above shows that the periodogram method based on DCT as less variance compare to other methods (Kumari *et al*., 2013), hence it is considered preferable than other methods.

CONCLUSION

The cognitive radio was introduced to improve the use of spectrum by efficiently employing the unused spectrum in a bid to reduce spectrum scarcity. The simulations demonstrated that employing ED in the frequency domain using the Bartlett's periodogram method based on DCT enhanced the detection performance by lowering the variance without affecting the signal resolution. Also, it provides a higher probability of detection Pd and a lower probability of false alarm Pfa. The detector's performance analysis is conducted for independent random process in AWGN channels by employing Mont Carlo simulations.

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