

NOVEL PILOT ASSISTED SPECTRUM SENSING FOR OFDM SYSTEMS ON CLUSTERED DIFFERENTIAL ESD

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Abstract- A novel pilot-assisted spectrum sensing technique is based on ofdm systems by using the statistical difference for first-order and second-order statistical signals. The presence of spectrum is found based on these statistical differences using an frequency-domain differential operations. The proposed second order statistics technique is compared with other weighted combination and the weighted combination provides upto 2db gain when compared to second order statistics and thus further improved. The second order statistics techniques performance is further improved upto 8db gain. The Performance of the proposed technique is measured using the metrics i.e.; probability of false alarm (PFA) and probability of detection (PD). The spectrum sensing technique outperforms all conventional pilot assisted spectrum sensing techniques and furthermore it is shown that first order statistics based technique can offer better performance (8 db gain) than second order statistics based technique for small normalized Doppler shifts and second order statistics has better performance for the larger normalized doppler shifts .

I. INTRODUCTION

Spectrum sensing is an detection technique used to identify the presence of signal in a noisy spectrum. The spectrum sensing is not only encouraged by the cognitive radio technique where the cognitive radio is the key enabling technology that also known as dynamic spectrum access (DSA) networks, to utilize the spectrum more efficiently without interfering with the primary users. It differs from conventional cognitive radio can equip users with cognitive capability and reconfigurability.

Cognitive capability: It refers to the ability to sense and gather information from the surrounding environment with this capability, secondary users can identify the best available spectrum.

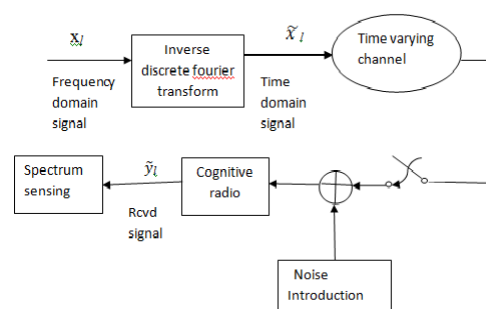
Reconfigurability: It refers to the ability to rapidly adapt the operational parameters according to the sensed information in order to achieve the optimal performance.

OFDM is a subset of frequency division multiplexing in which a single channel utilizes multiple sub-carriers. In addition the sub-carriers in an OFDM system are used to carry a signal and are overlapped to maximize spectral efficiency. However; sub-carriers in an OFDM system are precisely orthogonal to one another. Thus, they are able to overlap without interfering. As a result, OFDM systems are able to maximize spectral efficiency

without causing adjacent channel interference. OFDM communications systems are able to more effectively utilize the frequency spectrum through overlapping sub-carriers. Some of the sub-carriers in some of the OFDM symbols may carry pilot signals for measurement of the channel condition. Pilot signals and training symbols may also be used for time synchronization and frequency synchronization. One key principle of OFDM is that since low symbol rate modulation scheme suffer less from intersymbol interference caused by multipath propagation. Since the duration of each symbol is long, it is feasible to insert a guard interval between the OFDM symbols, thus eliminating the intersymbol interference. That guard interval consist of cyclic prefix, and it is transmitted followed by a symbol with the guard interval, consists of the end of the OFDM symbol copied into the guard interval, and the guard interval is transmitted followed by the OFDM symbol. A cyclic prefix is a repetition of the first section of a symbol that is appended to the end of the symbol.

II. OFDM SIGNAL MODEL

The transmitted data block is considered as frequency domain signal and it is represented as $x_l \triangleq p_l + s_l$, where x , p , and s denotes the data block, pilot block and information bearing symbol block and the subscript l denotes the block index.



The IIFT is used to convert the frequency domain signal into time domain signal and is denoted as \tilde{x}_l .

$$\tilde{x}_l = \begin{bmatrix} F_{cp}^H \\ F_H \end{bmatrix} x_l$$

The time domain transmitted signal \tilde{x}_l is applied to the multipath slowly time varying channel which is modelled as FIR filter along with the CIR filter where it shows that the CIR does not change for one

block duration. After applying into the time varying channel

$$\tilde{y}_l = \Delta_l^{low} + \tilde{x}_l + \Delta_l^{up} \tilde{x}_{l-1} + V_l$$

In this equation \tilde{y} denotes the received signal and v denotes the noise which has zero mean and variance. Here the additive white noise is added to the time domain signal so that the noise performance will be reduced. And after applying into the additive noise the signal goes through cognitive radio which is used to utilize the spectrum more efficiently without any interference. The cognitive radio has three functions:

Spectrum sensing and analysis: It can detect the spectrum white space i.e., a portion of frequency band that is not being used by the primary users, and utilize the spectrum more efficiently.

Spectrum management and handoff: After recognizing the available frequency band by sensing, the CR enables secondary users to choose the best frequency band among multiple bands according to time varying channel to meet quality of service.

Spectrum allocation and sharing: A secondary user may share the spectrum resources with primary users, other secondary users, or both. Hence, a good spectrum allocation and sharing mechanism is critical to achieve high spectrum efficiency.

In the receiver part if the received signal has unknown timing and frequency calculation then the received signal will be in the form of

$$\tilde{y}_l = \Omega_l (\Delta_l^{low} + \tilde{x}_l + \Delta_l^{up} \tilde{x}_{l-1}) + v_l$$

In this equation Ω_l is diagonal carrier frequency offset matrix. Δ_l^{low} is lower triangular channel matrix and Δ_l^{up} is an upper triangular channel matrix. The received signal \tilde{y}_l is finally applied into the spectrum sensing stage. The spectrum sensing is used to identify whether the signal is present or not if signal $\tilde{x}_l=0$ it indicates the presence of signal and $\tilde{x}_l \neq 0$ indicates the absence of signal. The spectrum sensing is done through the sensing device these sensing device will report to the alarm when the signal \tilde{x}_l is absent it indicates to the probability of false alarm. If the signal \tilde{x}_l is present it indicates to the probability of detection.

III. SPECTRUM SENSING TECHNIQUE

The novel pilot assisted spectrum sensing technique is based on the subcarriers which carry the signals and that signal has two different properties.

Then the received signal is represented as

And the presence of signal from the noisy spectrum is found by these different properties.

Algorithm Description

The novel pilot assisted spectrum sensing technique is based on first order and second order statistics signal. First considering the second order statistics signal, it is divided into five steps:

Step 1: Carry out the second order statistics onto the received signal \tilde{y}_l with matrix form then the output is

$$D(\tilde{c}_{\ell 1}) \triangleq 1/\ell - \ell_1 \sum_{\ell=\ell_1}^{\ell-1} D(\tilde{y}_{\ell+\ell_1}^*) D(\tilde{y}_{\ell})$$

Applying the discrete Fourier transform on the $\tilde{c}_{\ell 1}$ then the output will be converted to

$$c_{\ell 1} = F \tilde{c}_{\ell 1}$$

Here $C_{\ell} \triangleq F^H \Lambda_{\ell} F$, Λ_{ℓ} is a diagonal channel matrix with diagonal elements respect to the channel frequency response.

Step 2: The vector $c_{\ell 1}$ is multiplied with its conjugate

$$\tilde{c}_{\ell 1} = D(c_{\ell 1}^*) c_{\ell 1}$$

$$\tilde{c}_{\ell 1}^{(n)} = \frac{1}{(\ell - \ell_1)}$$

$$\sum_{\ell=\ell_1}^{\ell-1} (|\tilde{c}_{\ell}(n)| \Delta p) + |\omega^{(n)}_{\ell 1, s}|^2 + \sigma_{\ell 1}^2 + \epsilon_n$$

In this equation $\sigma_{\ell 1}^2$ represents the noise and the ϵ_n represents the residual noise with zero mean. In this case the carrier frequency offset gets totally ignored so that use to reduce the residual noise.

Step 3: Perform the linear combination to the vector $\tilde{c}_{\ell 1}$. By carrying out the linear combination to this vector the residual noise ϵ_n is reduced.

Step 4: The difference between subcarrier is experimented among the u_1 and u_m . Now applying the frequency domain differential operations among u_1 and u_m . The result will be

$$u_m^{\prime} = u_{m+1} - u_1$$

$$= \bar{u}_{m+1} - \bar{u}_1 + \theta_m^{\prime}$$

The main advantage of applying the frequency domain differential operation is that the noise variance will get totally removed.

Step 5: Finally the decision should be taken to found whether the signal is present or not by considering the $|u'_m|$

$$\tilde{x}_\ell \neq 0, (|u'_m|) > \lambda$$

$$\tilde{x}_\ell = 0, (|u'_m|) \leq \lambda$$

When the threshold λ is greater than the $|u'_m|$ then it shows that the presence of signal and the threshold is less than or equal to the $|u'_m|$ it describes the absence of signal.

Now considering the first order statistics signal it has also five different steps. This step is evaluated to show the performance difference between the statistics difference

Step 1: Performing the first order statistics onto the received signal \tilde{y}_l with matrix form then the output is

$$\tilde{m} \triangleq \frac{1}{\ell} \sum_{\ell=1}^{\ell} \tilde{y}_\ell$$

Applying the discrete Fourier transform on the \tilde{m} then the output will be converted to $m = F\tilde{m}$.

Step 2: The vector \tilde{m} is multiplied with its conjugate

$$m = \frac{1}{\ell} \sum_{\ell=1}^{\ell} (F C_\ell F^H p + \text{diag}(H_\ell X_\ell)) \exp(j2\pi\epsilon(\ell-1)j/N) + \omega\epsilon$$

where the H_ℓ and X_ℓ are the appropriate channel matrix and signal matrix. The $\text{diag}(H_\ell X_\ell)$ is a diagonal matrix and ϵ is a carrier frequency offset which is a major issue corresponding to the performance of the spectrum sensing technique. When the carrier frequency offset ϵ is less than 0.013 then the result will be

$$\tilde{m} = \frac{1}{\ell} \sum_{\ell=1}^{\ell} (\Delta \ell p) + \omega\epsilon$$

So, it shows that the carrier frequency offset ϵ is less than 0.013 then the first order statistics has better performance but if the ϵ is greater than 0.013 then the second order statistics has the better performance.

IV. SIMULATION RESULTS

The carrier frequency offset is caused due to the Doppler shift effects and the mismatching of oscillators. In this paper we mainly consider the Doppler shift effect. Here, the PFA is fixed at 10% and PD at 90%.

Doppler shift effect

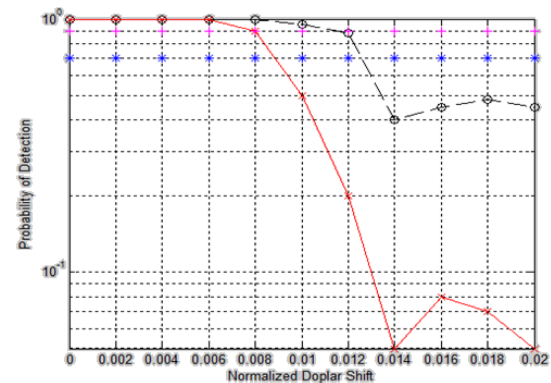


Figure.4.1 The effect of Doppler shift for proposed technique.

The proposed first order and second order technique is evaluated with the different Doppler shifts. In this figure the normalized Doppler shifts are selected from 0 to 0.02, from 0 to 0.012 is considered as a small Doppler shift and from 0.012 to 0.02 is considered as a larger Doppler shift. The above figure 4.1 shows the normalized Doppler shift difference for first order statistics and second order statistics for noise uncertainty 0 and 1.

The second order statistics signal has the same performance for various Doppler shift conditions i.e.; till the smaller Doppler shifts. Then there is a slight loss in the performance of the second order statistics signal for the larger Doppler shifts due to the effect of time varying channel but it doesn't affect the performance of first order statistics. And the first order statistics signal has better performance than second order statistics for the small Doppler shifts (<0.013) as shown in figure 4.1. Then the signals get dropped after 0.012 Doppler shift so the second order statistics signal has been a better performance for larger Doppler shifts.

V. PERFORMANCE EVALUATION

Spectrum sensing is used to sense the presence of signal in noise. PFA (probability of false alarm) and PD (probability of detection) are the parameters used to estimate the performance of spectrum sensing technique.

A. Probability of False Alarm:

The probability of false alarm defines that when there is an absence of signal then the sensing device will report an alarm. To estimate the performance of spectrum sensing in this technique keep the probability of false alarm fixed and then get the probability of detection. To improve the PD for the given PFA the hypotheses test is performed

$$\zeta = \frac{p(\frac{\zeta}{H_1})}{p(\frac{\zeta}{H_0})} > \lambda$$

The $p(\zeta/H_1)$ and $p(\zeta/H_0)$ are the probability density functions under the hypotheses H_1 and H_0 and the PFA is estimated through:

$$PFA \triangleq \Pr((\zeta) > \lambda / H_0) = \int_{\zeta > \lambda} p\left(\frac{\zeta}{H_0}\right) d\zeta$$

The probability of false alarm is estimated using the cumulative density function under the hypothesis test:

$$PFA = 1 - \prod_{m=1}^{M-1} P[u'm | H_0(\lambda)]$$

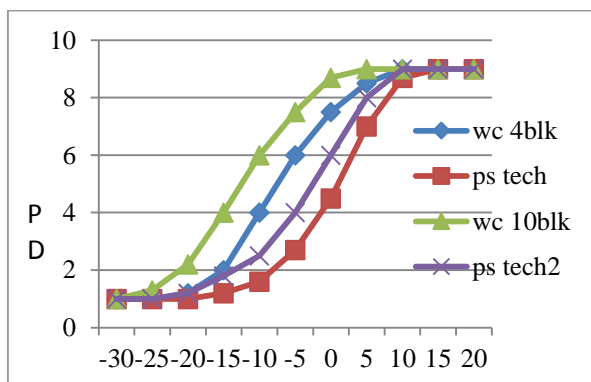


Fig.5.1 Performance comparison graph

The performance is compared between the second order statistics and the other detection techniques like energy detection, matched filter detection and cyclo stationary based detection. In this above fig.5.1 first the second order statistics signal provide upto the 2 db gain when compared to the other techniques and further the performance is improved to the 8 db gain than the other techniques.

B. Probability of Detection

The Probability of detection defines that when the signal is presence then the sensing device will report to an alarm. The probability of detection is estimated via:

$$PD \triangleq \Pr((\zeta) > \lambda / H_1) = \int_{\zeta > \lambda} p\left(\frac{\zeta}{H_1}\right) d\zeta$$

The probability of detection is estimated using the cumulative density function under the hypothesis test:

$$PD = 1 - \prod_{m=1}^{M-1} P[u'm | H_1(\lambda)]$$

The u is/ H_1 is obtained by summing different equal distributed variables and the each variable is evaluated by second order and first order statistics signal.

VI. CONCLUSION

A novel pilot spectrum sensing for ofdm systems is developed by first order or second order statistics difference among the signals. The difference among the statistical signal is achieved by the frequency domain operation. The proposed second order statistics technique is compared with other weighted combination and the weighted combination provides upto 2db gain when compared to other the proposed technique and the second order statistics performance improve upto 8db gain. The performance of the spectrum sensing technique is evaluated using the two different parameters i.e; PFA (probability of false alarm) and Pd(probability of detection). The performance metrics are the main factor for getting the difference between the first and second order statistics. The First order statistics has a better performance for larger normalized Doppler shift and the second order statistics will provide an better performance for small normalized doppler shifts (<0.0.13).

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