Cyclostationary Detection in Spectrum Pooling System of Undefined Secondary Users

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Abstract— **Spectrum sensing continuing to emerge as an essential topic for the cognitive networks where two kinds of users primary and secondary will share the band. This paper proposes a method for real-time detection of secondary users at the base stations. Cognitive Radios may hide themselves in between the primary users and Rental secondary users based on spectrum pooling system to avoid being charged for using spectrum. To deal with such scenario, a cyclostationary Fast Fourier Transform FFT Accumulation Method (FAM) has been used to develop a new scheme for channels users recognition. Channels users are tracked according to the changes in their signal parameters for instance modulation techniques. The Matlab simulation runs three signals transmitted on spectrum pooling system channels. Obtained spectral correlation density functions show successful Differentiation between signals.**

Keywords— Cognitive Radio; Sensing; Cyclostationary Detection; Undefined.

I. INTRODUCTION

Nowadays, wireless systems are based on fixed spectrum allocations, allocated fixed spectral bandwidth to licensed user at any time. Which lead to a useless of scarce and expensivespectral resources and result in inefficiency utilizing spectrum. Dynamic spectrum access techniques secure greater spectral-usage efficiency and enhanced access to frequency spectrum based on spectrum pooling [1]. of Spectrum pooling is a resource sharing strategy which allows the licensed owner to share portion of his licensed spectrum with a rental secondary users [2], cognitive radio users absent until he needs it himself. The goal of the spectrum pooling is to improve spectral efficiency by overlaying new wireless radio systems on a licensed one (the primary users) without interfering to the primary users, and without changing its operations. In order to keep existing and without harmful interference with rental users, cognitive radios technology must have the ability to detect unused spectrum, it is a very important process in spectrum pooling system.

One of the most significant issues in the cognitive radio technology is spectrum sensing, because in cognitive radio system, the systems distinguish the radio environment by the spectrum sensing. If the spectrum sensing does not work accurately, the cognitive radio system will have incorrect information about the radio environment, and the system will try to use the spectrum which a primary user uses and does not use the spectrum which the primary user does not use. It results in the several performance degradation of: the cognitive radio system and the primary user [3].

Traditionally, there are three schemes which are used for spectrum sensing, such as: Matched filter detection, Energy detection and Feature detection [4].

Matched filter detection: When the parameter of the primary user signal is known to the CR user, the optimal detector in stationary Gaussian noise is the matched filter, it maximizes received signal-to-noise ratio. While the matched filter requires a priori characteristics knowledge of the primary user signal, e.g. modulation type and order, pulse shaping, packet format.

Energy detection: If the receiver cannot gather sufficient in formation about the primary user signal, the optimal detector is an energy detector. However, the energy detector measures energy in each narrowband channel and determines the presence of a primary user if the energy detected in a narrowband channel is higher than a certain threshold. However, to achieve high receiver sensitivity, a low threshold has to be used. In some cases, the threshold has to be lower than the noise floor, in which case the detection fails. The problem is even more complex due to the fact that the noise is most likely non-Gaussian because of the presence of CR user's interference.

Feature detection: Most of the signals encountered in wireless communications are cyclostationary inherent, whereas the noise is stationary [5]. The wireless communication signals loaded with sinusoidal carriers, pulse trains, repeating codes, hopping sequences, cyclic prefixes, and signals are cyclostationary because their mean value and autocorrelation function exhibit periodicity. This periodicity trend is used to perform various signal processing tasks that includes detection, recognition and estimation of the received signals [6]. As a result, the cyclostationarity of the primary signals can be used to detect their presence. The cyclostationarity of a

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signal is not reflected in the power spectral density (PSD); however, it is reflected in the spectral correlation density (SCD) function which is obtained by taking the Fourier transform of the cyclic autocorrelation function. Therefore, spectral correlation analysis of the received data can be used to identify the signal. Higher order spectral statistics have also been used to identify weak users [5].

The paper has been organized as follow: the proposed model to be used in this investigation is discussed in Section II. Section III introduces detection method. In Section IV, reports on simulated implementations and analyses of the proposed model. Section V presents concluding remarks.

II. PROPOSED MODEL

The cognitive radios (CRs) are designed to work in a crowded wireless environment. Thus, scarce spectrum may lead selfish cognitive networks to use illegally the spectrum. High reconfigrability specifications of the cognitive radios make them capable to adapt their signal parameters according to their needs and the channels they are working in. Although, CRs designing have passed a long way of development to allow these transceivers to be obtainable in the near future, it is scarcely visible how these services will be monitored. To verify the cognitive network, a supporting sensing network is designed to examination the spectrum. Observed holes suitable to transmit are reported whenever a request to transmit and the occasion are available. We think that: duties for this sensing network should be extended to include the CRs recognition. A wider network may be created by adding awareness abilities to the sensing network to produce a novel robust monitoring system.

The new designed scheme will be capable of noticing the white holes in the spectrum, and also identify each channel user. Such a development requires the amalgamation of the optional monitoring system and information resources for occurrence the Spectrum Broker. The observed data are then being sent instantaneously to the decision makers in the main wireless providers for additional processing.

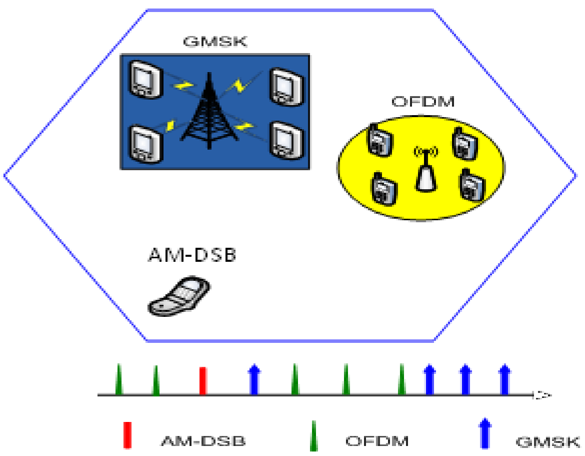

Fig .1 spectrum pooling system

The opportunity that a certain CR may transmit illegally falls outside the current definitions of cognitive networks. These bluffer cognitive radios can use their technical advances to adapt their carrier frequencies to transmit on a certain channel when the primary user is off. However, they still need to transmit using different signal parameters to maintain broadcast dedicated to their end users. This exploit may occur at any time and can be happen rarely or even constantly. The recommended observation scheme will use the FFT Accumulation Method FAM to detect deceptive CRs behaviour instantaneously. FAM is presented as the algorithm for cyclic spectrum analysing. This method is derivative from the cyclostationary technique which is widely acceptable as the most effective sensing procedure for the cognitive radios. This work is a natural expansion of our work in [7] by incorporating the recently suggested spectrum pooling system and different CR users.

III. DETECTION METHOD

The cyclostationary processing theory is proposed here as the algorithm for the developed identification scheme. Most of the communication signals can be modelled as cyclostationary random process. Let say, a zeros-mean discrete time signal x(n) is cyclostationary with periodic T if its autocorrelation function $R_x(n,k)$ is also periodic in T, as shown in Equation 1 [7].

$$R_x\,(n,k) = R_x\,(n+T, k+T) \qquad (1)$$

To gain an intuition into how cyclostationary based detection works, it is beneficial to define the Cyclic Autocorrelation Function (CAF) [7].

$$R_x^{\propto}\,(n.k) = \lim_{N=\infty} \frac{1}{2N+1} \sum_{n=-N}^{N} x(n)\, x^*\,(n - k)\, e^{-i2\pi\propto n}\, e^{i\pi\alpha k} \qquad (2)$$

where $R_x^{\propto}(k)$ is the CAF of discrete time signal x (n) and $\propto$ is the cyclic frequency. The CAF can also be interpreted as the measured amount of correlation between different frequency-shifted versions of a given signal. For different signal, the CAF exhibits different features, which are generally used for detecting the presence of the signal. However, this feature is not easily seen by only observing its CAF, in time domain. For this reason, it is important to determine in the frequency domain the amount of correlation between frequency-shift versions of the signal. By applying the Fourier transform to the CAF,

Giving the cyclic spectral correlation function as shown in equation 3 [7].

$$S_x^{\propto} = \sum_{k=-\infty}^{\infty} R_x^{\propto}\,(k)\, e^{i2\pi fk} \qquad (3)$$

where $S_x^{\propto}(f)$ is called cyclic spectral correlation function or cyclic spectrum of discrete time signal x(n). Notably, if $\propto=0$, the CAF and the Cyclic Spectrum (CS) reduce to the conventional autocorrelation function and power spectral density function, respectively. FAM method is based on modifications of time smoothed cyclic cross period gram which is defined as [7]:

$$S_{xyT}^{\propto}(n.f) = \lim_{N=\infty} \frac{1}{2N+1} \sum_{n=-N}^{N} \frac{1}{T} X_T\left(n, f + \frac{\propto}{2}\right) Y_T^*\left(n, f - \frac{\alpha}{2}\right) \quad (4)$$

where $X_T\left(n, f + \frac{\propto}{2}\right)$ and $Y_T\left(n, f - \frac{\propto}{2}\right)$ are the complex the complex envelopes of narrow band, band pass components of the signals X(n) and Y(n), respectively. These complex envelopes are computed in the following way [7]:

$$X_T(n, f) = \sum_{k=-N'/2}^{+N'/2} \propto(k)\ x(-k)\ e^{-i2\pi f(n-k)^{T_s}} \quad (5)$$

$$Y_T(n, f) = \sum_{k=-N'/2}^{+N'/2} \propto(k)\ y(n-k)\ e^{-i2\pi f(n-k)^{T_s}} \quad (6)$$

where $\propto(k)$ is a data narrowed window of length T = N'Ts seconds and the sampling period Ts. The FAM method is validated by estimating the cyclic spectrum. Fig. 2 illustrates the implementation model of FFT Accumulation Method.

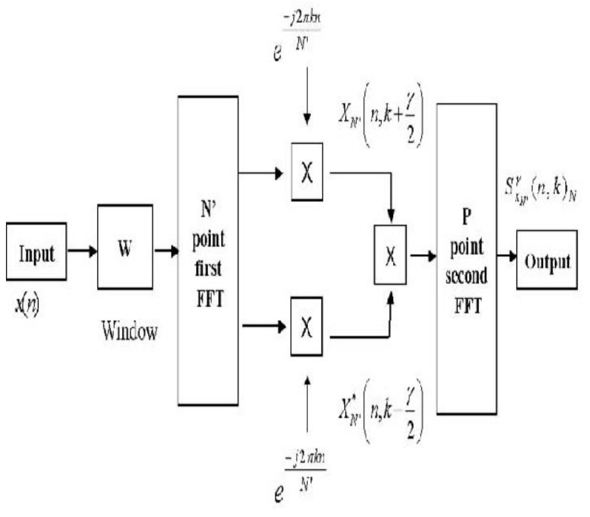

Fig. 2 FFT Accumulation Method

The FAM method works as follow:

- The complex envelops are estimated efficiently by means of a sliding N' point FFT, followed by a downshift in frequency to baseband.
- In order to allow for an even more efficiency estimation, the N' point FFT is hoped over the data in blocks of L samples which means that L data point are skipped between computations of the N' point FFT.
- After the complex envelopes are computed and the product sequences between each one of them and the complex conjugate of the other s are formed, the time smoothing is accomplished by means of a P point FFT.

The value of L was chosen to be equal to N'/4. The value of N' is determined according to the desired resolution in frequency (Δf) used in the algorithm, and is given by [7]:

$$N' = \frac{f_s}{\Delta f} \quad (7)$$

The value of P is determined according to the desired resolution in cyclic frequency$(\Delta\alpha)$, and is given by [7]:

$$P = \frac{f_s}{L\Delta\propto} \quad (8)$$

IV. SIMULATION

A Matlab simulation code was created to generate FAM as the sensing mode for our model. We demonstrate a spectrum pooling example which has a GSM network as primary users and cognitive radio network as rental secondary users and cognitive node as hiding secondary user, respectively based on modulation of GMSK, OFDM and AM-DSB, as illustrated in Fig. 1 three signals were fed into the code and simulation was run at frequency of 805 MHz.

Fig. 3 shows the spectral correlation function for the GMSK signal. The modulation used here to generate this signal is quadrate phase shift keyed modulation. It is easy to decide the modulation sort from the signals profile.

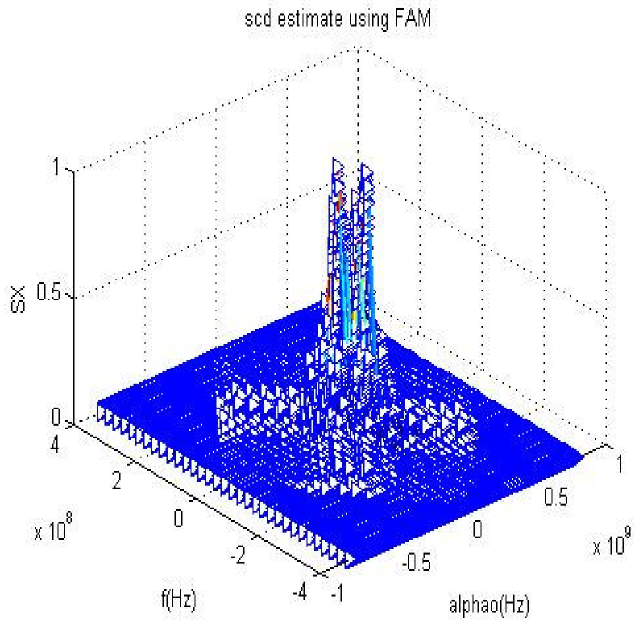

Fig. 3 Cyclic spectrum of the GMSK signal

Fig. 3 shows an overview for the received primary signal

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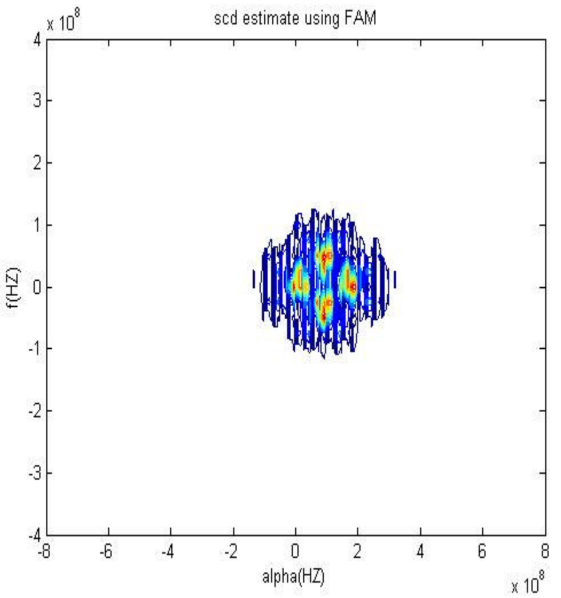

Fig. 4 Contour figure of the GMSK signal

Subsequently, we examine the rental secondary user signal using the same technique. Assuming that the rental CR network transmitted signal in OFDM, the detected waveform is shown in Fig. 4.

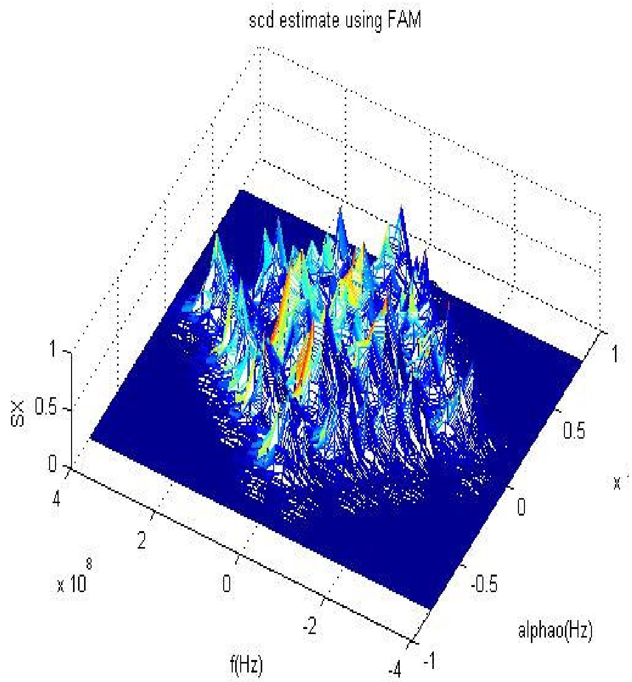

Fig. 5 Cyclic Spectrum of the OFDM signal

It is significant to look at the received signals from diverse sides. This will avoid any ambiguity in the signals modulation source category. Hence, the other outlook for the rental secondary User spectral function is show in Fig. 5.

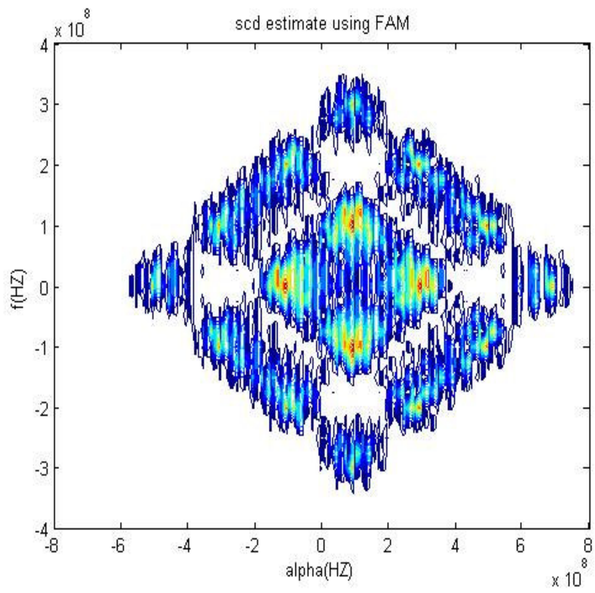

Fig. 6 Contour figure of the OFDM signal

Meanwhile, we examine the hiding secondary user signal using the same FAM technique. Assuming that the hiding CR node transmitted signal in AM signal. The modulation used here is Double side- band Large Carrier DSB-LC, the detect waveform is shown in Fig. 6.

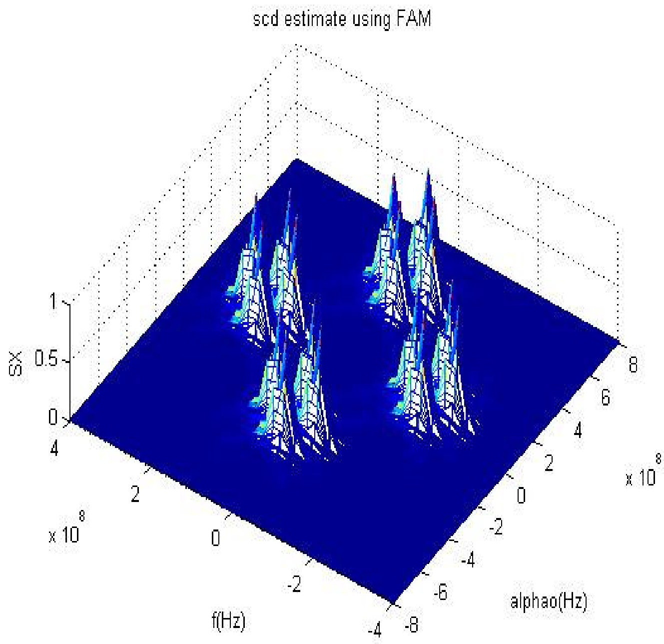

Fig. 7 Cyclic spectrum of the AM-DSB signal

The AM-DSB signal can be reobtainable also in an additional elevation sight to assure the modulation type. Fig. 7 shows overview for the received hiding secondary user signal.

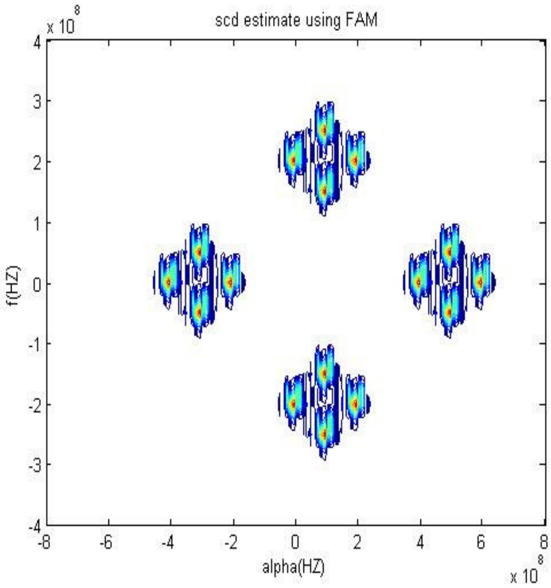

Fig. 8 Contour figure of the AM-DSB signal

It is substantially noticeable the differences between the primary, rental secondary and hiding secondary simulated signals using the FFT accumulative method. These results make this method a preferable choice for this category of signal discovery. Additionally, cyclic spectrum enables accurate examination for the signal periodic changes. Thus, minor functions resulted from wireless environmental changes and interference can be estimated, compared, and identified. The obtained results show the FAM correlation function. Detected signals in time domain are transferred to the frequency domain. Subsequently, other estimations are implemented to define each signal type. Although, this will ensure the accuracy of obtained result, it is not known the effects of the time spend in this process on the detection speed. Reasonable, α changes speed affects on CAF and CS will be critical factor on the results reliability advisability. The simulation was performed assuming perfect transmission conditions without any consideration for the environmental and systematic noise.

Up to our knowledge, no efforts tried to use the FAM characters to make a distinction between different channels signals as this papers presents. We argue that a designed monitoring system can be developed using FAM and enhanced by self learning to recognize any CR prohibited transmission and deal with it at once. The learning features will let the anticipated system more efficient in introducing to various signals. Future work will be undertaken to detect hiding signals with noise by Cognitive Radio users using FAM method.

V. CONCLUSION

A new strategy was presented for detecting the simulation transmission from cognitive radio. Cognitive radios hiding themselves by using primary channels in spectrum pooling system or by using same primary and rental secondary frequencies were detect in this paper. Our matlab simulation process three signals: primary, rental secondary and hiding secondary transmitting on the pooling system channels. The simulated signals were analysed corresponding to the changes in their modulation techniques. FAM used as the analysing algorithm for the scenario studied. Detected signals were recognized in accordance with their frequency domain representations performed by the used method. Primary and two secondary generated signals were examined and detected clearly. The presented modification wills aware managing entities for the future networks on any uncharted transmission whenever it occurs. The suggested model will be required to guarantee the reliability of the charging system.

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