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Second order cyclostationarity of LTE OFDM signals in practical Cognitive Radio Application

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Abstract-Today's wireless networks are characterized by a fixed spectrum assignment policy. However, a large portion of the assigned spectrum is used sporadically and geographical variations in the utilization of assigned spectrum ranges from 15% to 85% with a high variance in time. The limited available spectrum and the inefficiency in the spectrum usage necessitate a new communication paradigm to exploit the existing wireless spectrum opportunistically. This new networking paradigm is referred to as Cognitive Radio. A cognitive Radio is a radio that can change its transmission parameters based on interaction with the environment in which it operates. This paper focuses on a Cognitive Radio Approach based on a non cooperative spectrum sensing technique. In this paper the LTE signal in terms of cyclic autocorrelation function and cyclic frequency is studied also the ROC curve is simulated and analyzed.

KEYWORDS- Cognitive Radio, Spectrum Sensing , LTE.

INTRODUCTION

Primary users are licensed users having higher priority onthe usage of part of spectrum and secondary users are unlicensed users. Cognitive radio is a promising solution to this spectrum underutilization problem. Federal Communication Commission (FCC) has issued a Notice of Proposed Rulemaking regarding cognitive radio that requires rethinking of the wireless communication architecture so that emerging radios can share spectrum with primary users without causing interference to them [1]. The term cognitive radio is coined by Dr Joseph Mitola in his doctoral thesis [2]. The word "Cognition" means the mental process of acquiring knowledge through thought, experience and the senses. Cognitive radio enables the users to determine portion of the spectrum available and detect the presence of licensed users when a user operates in licensed bands. There are four main cognitive tasks: spectrum sensing, spectrum management, spectrum mobility and spectrum sharing. Spectrum sensing aims to determine spectrum availability and the presence of the licensed users. Spectrum management is to predict how long the spectrum holes are likely to remain available for use to the unlicensed users (also called cognitive radio users or secondary users). Spectrum sharing is to distribute the spectrum holes fairly among the secondary users bearing in mind usage cost. Spectrum mobility is to maintain seamless communication requirements during the transition to better spectrum. Spectrum sensing is key element in cognitive radio communication. It enables cognitive radio to adapt to its environment by detecting spectrum holes. A spectrum hole (also known as white space) is a band of frequencies licensed to a primary user but at a particular time and specific geographical location that particular band is not utilized by that user. Several spectrum sensing methods are proposed in literature among them we will focus on few like matched filtering, energy Detector, Periodogram, Welch's, cooperative and multiple antenna spectrum sensing methods. In this paper we evaluate the results about spectrum sensing using LTE signals and find the ROC curve.

2. Architechture of cognitive radio Transceiver

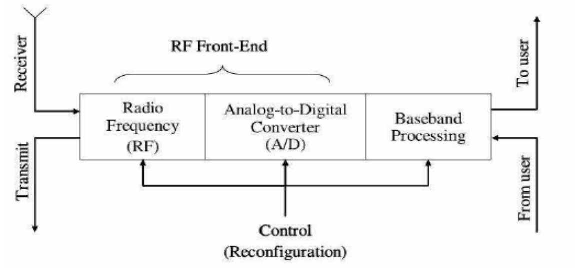


Fig. 1 Cognitive Radio Transceiver architecture

The wideband signals are received through the RF front end and then are sampled using the high speed analog-to-digital (A/D) converter and furthermore different measurements are done for detection of licensed user signal. But in real applications, RF antenna receives signal from various transmitters operating at different power levels,bandwidths and locations which makes it hard to detect weak signals in that kind of range. So there should be multi-GHz speed A/D converter with high resolution but it is practically infeasible to implement.. Another approach can be the usage of multiple antennas. The key challenge of the physical architecture of the cognitive radio is an accurate detection of weak signals of licensed users over a wide spectrum range. Hence, the implementations of RF wideband front-end and A/D converter are critical issues in xG networks.

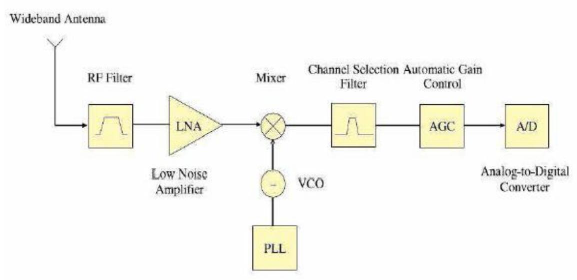


Fig.2 Cognitive Radio RF Front End

The components of a cognitive radio RF front-end are as follows [3]:

1. RF filter: The RF filter filters the received RF signal with a band-pass filter and selects the desired band.
2. Low noise amplifier (LNA): The LNA amplifies the desired signal while minimizing noise component at the same time.
3. Mixer: In the mixer, the received signal is mixed with locally generated RF frequency and converted to the baseband or the intermediate frequency (IF).
4. Voltage-controlled oscillator (VCO): The VCO generates a signal at a specific frequency for a given voltage to mix with the incoming signal. This procedure converts the incoming signal to baseband or an intermediate frequency.
5. Phase locked loop (PLL): The PLL ensures that a signal is locked on a specific frequency and can also be used to generate precise frequencies with fine resolution.
6. Channel selection filter: The channel selection filter is used to select the desired channel and to reject the adjacent channels. There are two types of channel selection filters. The direct conversion receiver uses a low-pass filter for the channel selection On the other hand, the super heterodyne receiver adopts a band pass filter.
7. Automatic gain control (AGC): The AGC maintains the gain or output power level of an amplifier constant over a wide range of input signal.

III. Various spectrum sensing methods

Cognitive radio is an exciting technology that has potential of dealing with the stringent requirement and scarcity of the radio spectrum. Spectrum sensing refers to the action of monitoring the characteristics of received signals which may include RF energy levels if particular band is occupied. Ideal characteristics of Cognitive Radio are: intelligence, reliability, awareness, adaptability, efficiency and excellent quality of service. To improve the detection probability, many signal detection techniques can be used in spectrum sensing. Signal processing is concerned with improving the quality of signal at the top of measurement systems and its main aim is to attenuate the noise in the signal that has not been eliminated by careful design of measurement system. With the advancement in signal processing, we are able to think about cognitive radio technology. In this section, we give an overview of some well-known spectrum sensing techniques.

Generally, the spectrum sensing techniques can be classified as transmitter detection, cooperative detection, and interference-based detection as shown in fig -

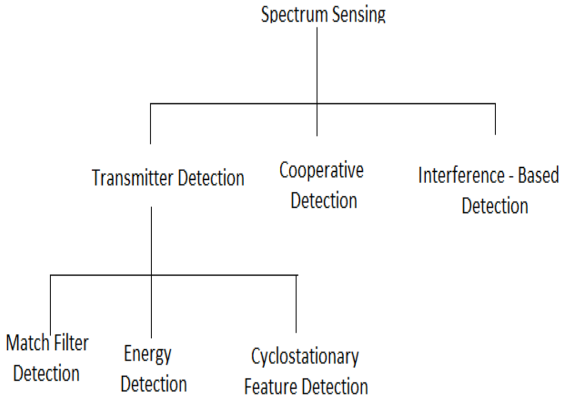


Fig3. Classification of Spectrum Sensing Techniques

3.1 Transmitter Detection

Transmitter detection approach is based on the detection of the weak signal from a primary transmitter through the local observations of users. Basic hypothesis model for transmitter detection can be defined as follows [19]-

$$\mathbf{x_i}\,(\mathbf{t}) = \begin{cases} \mathbf{n_i(t)}, & \mathbf{H_0} \\ \mathbf{h_i(t)s(t) + n_i(t)}, & \mathbf{H_1} \end{cases}$$

H_0 = Primary User Absent
H_1 = Primary User Present

where n: 1, 2, 3,…N;
N: sampling interval;

$n_i(t)$: additive white Gaussian noise;
$x_i(t)$: transmitted Signal

where x(t) is the signal received by the CR user, s(t) is the transmitted signal of the primary user, n(t) is the AWGN and h is the amplitude gain of the channel. H0 is a null hypothesis, which states that there is no licensed user signal in a certain spectrum band. On the other hand, H1 is an alternative hypothesis, which indicates that there exist some licensed user signal.

There are various classical spectrum sensing techniques in literature. A statistical hypothesis test is a method of making statistical decisions using experimental data. Many techniques were developed in order to detect the holes in the spectrum band. Generally used techniques of this kind are matched filtering, energy detection, cyclostationary, and wavelet and covariance techniques. These techniques provide basic concept of spectrum sensing which is further used in various emerging spectrum sensing techniques. In order to avoid the harmful interference to the primary system, the cognitive radio needs to infer about the availability of the spectrum.

3.1 Matched Filtering Method

Matched filtering is known as optimal method for detection of primary users when the transmitted signal is known. It is a linear filter designed to maximize the output signal to noise ratio for given input signal. It is obtained by correlating a known signal, with an unknown signal to detect the presence of the known signal in the unknown signal. This is equivalent to convolving the unknown signal with a time-reversed version of the signal. Convolution is at the heart of matched filters. Convolution does essentially with two functions that it places one function over another function and outputs a single value suggesting a level of similarity, and then it moves the first function an infinitesimally small distance and finds another value [4]. The end result comes in the form of a graph which peaks at the point where the two images are most similar. The matched filter is the optimal linear filter for maximizing the signal to noise ratio (SNR) in the presence of additive white stochastic noise. Matched filtering requires cognitive radio to demodulate received signals. Hence it requires perfect knowledge of the primary users signalling features such as bandwidth, operating frequency, modulation type, pulse shaping and frame format. A matched filter compares two signals and outputs a function describing the places at which the two signals are most like one another. This is carried out by taking Fast Fourier Transform (FFT) of two signals, then multiplying their coefficients and after that taking Inverse Fast Fourier Transform (IFFT) of the result, the output can be find out [4].

Major advantages and disadvantage of matched filter are illustrated below:-

- Advantage of matched filter is that it needs less time to achieve high processing gain and probability of false alarm and missed detection due to coherent detection [5].
- Disadvantage of matched filter is that it would require a dedicated sensing receiver for all primary user signal types.
- It requires the prior information of primary user signal which is very difficult to be available at the CRs.
- Another disadvantage of matched filtering is large power consumption as various receiver algorithms need to be executed for detection.

3.2. Energy Detection Method

Energy detection is a non coherent detection technique in which no prior knowledge of pilot data is required. Goal of this paper is to provide a comprehensive study supported with experimental data that addresses the following issues in spectrum sensing based on energy detection :

1. Required sensing time needed to achieve the desired probability of detection and false alarm.
2. Limitations or energy detector performance due to presence of noise uncertainty and background interference.
3. Performance improvements offered by network cooperation.

Depending on the application, the signal to be detected can be either unknown or known. In most of the applications, the signal information is not available for the detector. The detection is based on some function of the received samples which is compared to a predetermined threshold level. If the threshold is exceeded, it is decided that signal(s) is (are) present otherwise it is absent. Energy detectors (radiometers) are often used due to their simplicity and good performance. The energy detection method performs the signal measurements and determines the vacant channel candidates by comparing the power estimated to the predefined threshold levels. Two deterministic type of signal are considered: sine wave (pilot tone) and modulated signal with unknown data. In this case a suboptimal energy detector is adopted which can be applied to any signal type.

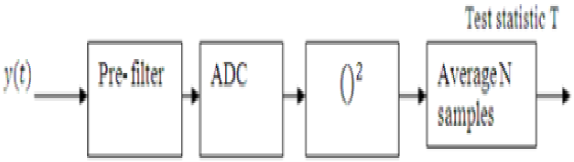


Figure 4: Implementation of energy detection with analogue pre-filter and square law device.

The detection is the test of the following two hypotheses:

H_0:Y[n]= w[n]; signal is absent.
H_1: Y[n]= s[n]+w[n]; signal is present

Where n=1…….N.

where N is observation interval. Here noise is assumed to be additive white Gaussian noise (AWGN) with zero mean and variance σ_w^2. In the absence of coherent detection, the signal samples can also be modelled as Gaussian random process with variance σ_g^2 .Decision statistic for energy detector is:-

$$T = \Sigma_N (Y[n])^2$$

This implementation is quite inflexible in case of narrowband signals and sine waves

3.3 Cyclostationary feature detection

In cyclostationary Feature Detection method modulated signals are coupled with sine wave carriers, pulse trains, repeated spreading, hopping sequences, or cyclic prefixes. This results in built-in periodicity. These modulated signals are characterized as cyclostationary because their mean and autocorrelation exhibit periodicity. This periodicity is introduced in the signal format at the receiver so as to exploit it for parameter estimation such as carrier phase, timing or direction of arrival. These features are detected by analyzing a spectral correlation function. The main advantage of this function is that it differentiates the noise from the modulated signal energy. This is due to the fact that noise is a wide-sense stationary signal with no correlation however modulated signals are cyclostationary due to embedded redundancy of signal periodicity. Analogous to autocorrelation function spectral correlation function (SCF) can be defined as:

$$S_x^\alpha(f) = \lim_{T\to\infty}\lim_{\Delta t\to\infty}\frac{1}{\Delta t}\int_{-\Delta t/2}^{\Delta t/2}\frac{1}{T}X_T(t,f+\alpha/2)X_T^*(t,f-\alpha/2)dt$$

where the finite time Fourier transform is given by:

$$X_T(t,v) = \int_{t-T/2}^{t+T/2} x(u)\,e^{-j2\pi vu}\,du$$

Spectral correlation function is also known as cyclic spectrum.

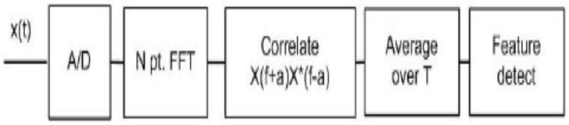


Fig.5. Block diagram of cyclostationary feature detection

While power spectral density (PSD) is a real valued one dimensional transform, SCF is a complex valued two dimensional transform. The parameter α is called the cycle frequency. If α = 0 then SCF gives the PSD of the signal. Because of the inherent spectral redundancy signal selectivity becomes possible. Analysis of signal in this domain retains its phase and frequency information related to timing parameters of modulated signals. Due to this, overlapping features in power spectral density are non overlapping features in cyclic spectrum. Hence different types of modulated signals that have identical power spectral density can have different cyclic spectrum. Because of all these properties cyclostationary feature detector can perform better than energy detector in discriminating against noise. However it is computationally complex and requires significantly large observation time.

cyclostationary feature detection has several advantages such as;

- Cyclostationary feature detection is more robust to changing noise level than energy detection.
- Cyclostationary detectors can work in lower SNR compared to energy detection because feature detectors exploit information embedded in the received signal.
- Drawbacks of the cyclostationary feature detection is that it requires prior knowledge on the primary user's signal and is very complex to implement.

V. PRINCIPLE OF CYCLOSTATIONARITY

Modulated signals have built-in periodicity, characterized as cyclostationary. This information can be used for detection of a random signal with a particular modulation type in the presence of background noise and other modulated signals. Cyclostationary signals exhibit correlation between widely separated spectral components due to the spectral redundancy caused by periodicity. A signal process x(n) is said to be cyclostationary in a wide sense if its mean and autocorrelation are periodic with a period T_0, i.e.,

$Mx(t+T_0)= Mx(t)$ ……….(1)

$Rx((t+T_0, \tau)=Rx(t, \tau)$…….(2)

For all t and τ Therefore, by assuming that the Fourier series expansion of Rx(t, τ),we can write

$$R_x(t,\tau) = \sum_{n=-\infty}^{+\infty} R_x^{\frac{n}{T_0}}(\tau)e^{i2\pi\left(\frac{n}{T_0}\right)t} \qquad (3)$$

$$R_x^{\frac{n}{T_0}}(\tau) = \frac{1}{T_0}\int_{-T_0/2}^{T_0/2} R_x(t,\tau)e^{-i2\pi(n/T_0)t}dt \quad (4)$$

where the Fourier coefficients are referred to as cyclic autocorrelation functions and the frequencies {n/T0}n€Z are called cycle frequencies. Let α represent cycle frequency when the spectral correlation function (SCF) is defined:

$$S_x^\alpha(f) = \int_{-\infty}^{-\infty} R_x^\alpha(\tau)e^{-i2\pi f\tau}d\tau \qquad (5)$$

There are generally two methods to estimate the signal SDC: frequency smoothing and time smoothing. Time smoothing algorithms are considered to be more computationally efficient for general cyclic spectral analysis. Given the signal x(n), all time smoothing algorithms are based on the time smoothed cyclic cross periodogram

$$s_x^\alpha(n,f)_{\Delta t} = \frac{1}{T} < X_T\left(n, f+\frac{\alpha}{2}\right)X_T^*(n, f-\frac{\alpha}{2}) >_{\Delta t} \quad (6)$$

where XT(n, f + α/2), also called complex demodulators, is the spectral components of signal X(n) . Mathematically, computation of the complex demodulators is expressed as

$$X_{T(n,f)} = \sum_{r=-N'/2}^{N'/2} a(r)x(n-r)e^{-i2\pi f(n-r)T_s} \quad (7)$$

where a(r) is a data tapering window of length T=N'T_s seconds, T_s is the sample interval, and f_s is the sampling frequency.

After the complex demodulate has been computed, it is correlated with its conjugate over a time span of Δt seconds

The correlation operation is expressed as

$$s_x^{\alpha}(n,f)_{\Delta t} = \sum_{r=0}^{N-1} X_T(r,f_1)X_T^{*}(r,f_2)g(n-r) \quad (8)$$

where g(n) is a data tapering window of width Δt=NTs second. It is shown in [10] that the time smoothed cyclic cross periodogram converges to the spectral correlation function in the limit, as Δt→∞ followed by Δf→ 0, if the time windows a(n) and g(n) are properly normalized .therefore if

$$\sum_n a^2(n) = \sum_n g^2(n) = 1,$$

we have

$$\lim_{\Delta f \to 0} \lim_{\Delta t \to \infty} s_x^{\alpha}(n,f)_{\Delta t} = S_x^{\alpha}(f) \qquad (9)$$

IV. Long Term Evolution

The 3GPP Long-term evolution (LTE), whose radio access is called Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), is designed to be a flexible radio interface and expected to substantially improve end-user experience (low user plane latency, high sector capacity) with full mobility. At the center of its flexibility is the fact that LTE is designed to be 1) an all-IP technology; providing support for IP-based traffic with end-to-end Quality of service (QoS), 2) scalable; allowing flexibility in deployment, in terms of spectrum availability. Universal Mobile Telecommunications System (UMTS) Long Term Evolution (LTE) Release 8 provides high peak data rates of 300 Mb/s on the downlink and 75 Mb/s on the uplink for a 20 MHz bandwidth, and allows flexible bandwidth operation of up to 20 MHz. Currently, enhancements are being studied to provide substantial improvements to LTE Release 8, allowing it to meet or exceed International Mobile Telecommunications- Advanced (IMT-A) requirements [1].

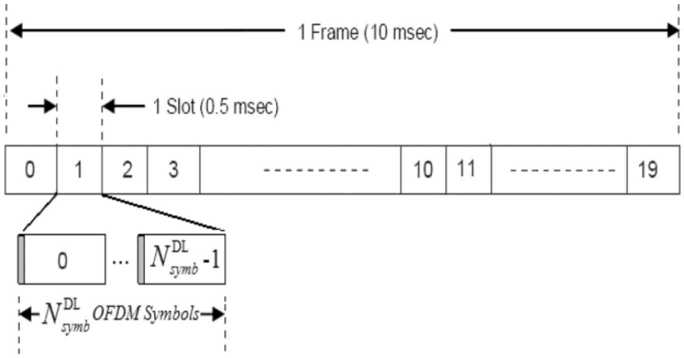
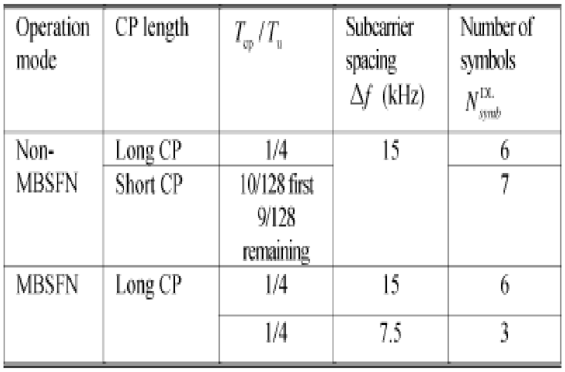


Fig.6. FDD DL frame structure in the LTE OFDM-based systems [6].

Fig. 6 shows the frequency division duplex (FDD) DL frame structure used in the LTE systems [6]. The frame time duration is 10 ms, and each frame is divided into 20 slots, with the slot duration equal to 0.5 ms. Each slot contains N_{symb}^{DL}OFDM symbols, where N_{symb}^{DL}depends on the CP length and useful symbol duration (equal to the reciprocal of the subcarrier frequency spacing) parameters of the OFDM signal. The LTE standard allows multimedia broadcast multicast services be performed either in a single cell mode or in a multi-cell mode. For the latter, transmissions from different cells are synchronized to form a multicast broadcast single frequency network (MBSFN) [6].Here, we consider the case where a single operational mode is employed in each cell, i.e., either MBSFN or non-MBSFN [6]. The LTE operation modes, along with the values of their parameters,i.e. Δf , N_{symb}^{DL} , T_{CP}/T_U are summarized in Table.



Operation mode	CP length	T_{cp}/T_u	Subcarrier spacing Δf (kHz)	Number of symbols N_{symb}^{DL}
Non-MBSFN	Long CP	1/4	15	6
	Short CP	10/128 first 9/128 remaining		7
MBSFN	Long CP	1/4	15	6
		1/4	7.5	3

Table1: lte operation modes and associated signal parameters

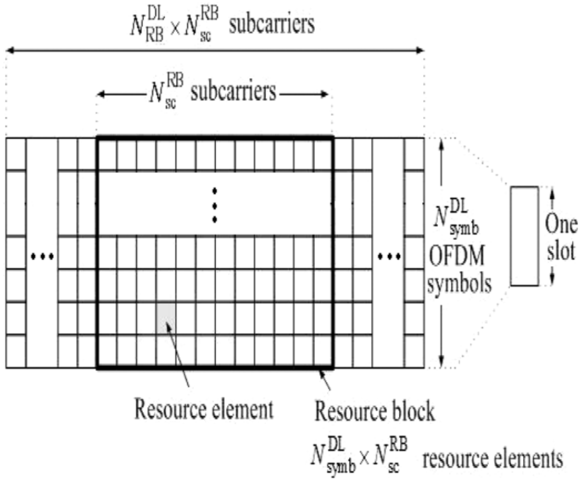


Fig.7. Slot structure and resource grid in the FDD DL frame [6].

The slot structure and associated resource grid used in the FDD DL frame are illustrated in Fig. 9. The slot can be represented as a two dimensional resource grid consisting ofN_{symb}^{DL}OFDM symbols in time domain and K=$N_{RB}^{DL}N_{SC}^{RB}$ subcarriers in frequency domain, with N_{RB}^{DL} as the number of resource blocks andN_{SC}^{RB} as the number of subcarriers in a resource block. Note that represents the number of subcarriers in an OFDM symbol. A resource block is defined as N_{symb}^{DL} consecutive OFDM symbols in time domain and N_{SC}^{RB} consecutive subcarriers in frequency domain. N_{SC}^{RB} equals 12 and 24 for the LTE signals with Δf= 15 kHz and 7.5 kHz subcarrier spacing, respectively. N_{RB}^{DL} then depends on the signal bandwidth; for possible values of this parameter the reader is referred to [25]. The smallest entity of the resource grid is called resource element; a resource block consists of $N_{symb}^{DL} \times N_{SC}^{RB}$ resource elements.

Reference signals (RSs) are embedded in the resource blocks of the transmission frame for channel estimation and cell search/ acquisition purposes [6]. An RS is assigned to each cell of the network and acts as a cell identifier. Therefore, the RS repeats each DL frame. Here we study two types of RSs: the cell-specific RS associated with the non MBSFN mode and the MBSFN RS associated with the MBSFN mode. Note that the terminology used here is according to [6]. The RSs are interspersed over the resource elements, usually transmitted on some of the subcarriers of one or two non-consecutive symbols in each slot. Fig. 10 shows the distribution of the cell-specific RS for short CP over one resource block and two consecutive slots (N_{symb}^{DL}=7 OFDM symbols per slot and N_{SC}^{RB} =12 subcarriers per resource block): the cell-specific RS is transmitted on the first and seventh subcarriers of the first OFDM symbol and on the fourth and tenth subcarriers of the fifth OFDM symbol in each slot. For the distribution of other RSs, one is referred to [6].

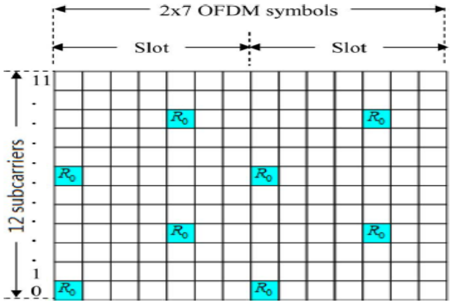


Fig8. Resource element mapping of cell specific RS in LTE signals.

we express the received LTE OFDM signal with short CP and corresponding RS distribution, which is affected by additive Gaussian noise as

$$\begin{aligned}
r(n) = a & \sum_{\substack{l=-\infty \\ l \bmod N_z=\beta=0}}^{\infty} \sum_{\substack{k=-K/2, k\neq 0 \\ k\notin \mathcal{A}_1}}^{K/2} b_{k,l} g_1\left(n - l N_z^{-1} D_z\right) \\
& \times e^{j2\pi k\left(n - l N_z^{-1} D_z\right)/D_{\mathrm{u}}} \\
& + a \sum_{\substack{l=-\infty \\ l \bmod N_z=\beta=0}}^{\infty} \sum_{\substack{k=-K/2, k\neq 0 \\ k\in \mathcal{A}_1}}^{K/2} c_{k,l} g_1\left(n - l N_z^{-1} D_z\right) \\
& \times e^{j2\pi k\left(n - l N_z^{-1} D_z\right)/D_{\mathrm{u}}} \\
& + a \sum_{\substack{l=-\infty \\ l \bmod N_z=\beta=4}}^{\infty} \sum_{\substack{k=-K/2, k\neq 0 \\ k\notin \mathcal{A}_2}}^{K/2} b_{k,l} \\
& \times g\left(n - \left\lfloor l N_z^{-1} \right\rfloor D_z - 3D - D_1\right) \\
& \times e^{j2\pi k\left(n - \left\lfloor l N_z^{-1} \right\rfloor D_z - 3D - D_1\right)/D_{\mathrm{u}}} \\
& + a \sum_{\substack{l=-\infty \\ l \bmod N_z=\beta=4}}^{\infty} \sum_{\substack{k=-K/2, k\neq 0 \\ k\in \mathcal{A}_2}}^{K/2} c_{k,l} \\
& \times g\left(n - \left\lfloor l N_z^{-1} \right\rfloor D_z - 3D - D_1\right) \\
& \times e^{j2\pi k\left(n - \left\lfloor l N_z^{-1} \right\rfloor D_z - 3D - D_1\right)/D_{\mathrm{u}}} \\
& + a \sum_{\substack{l=-\infty \\ l \bmod N_z=\beta\neq 0,4}}^{\infty} \sum_{k=-K/2, k\neq 0}^{K/2} b_{k,l} \\
& \times g\left(n - \left\lfloor l N_z^{-1} \right\rfloor D_z - (\beta-1)D - D_1\right) \\
& \times e^{j2\pi k\left(n - \left\lfloor l N_z^{-1} \right\rfloor D_z - (\beta-1)D - D_1\right)/D_{\mathrm{u}}} + w(n)
\end{aligned}$$

Where α is the amplitude factor equal to $1/\sqrt{K}$,$N_Z$is the repetition period for the RS distribution (in number of OFDM symbols), which equals 7 in this case and corresponds to the number of OFDM symbols in a slot,$A_1=\{0,6\}$ and $A_2=\{3,9\}$are the sets of subcarriers on which the RS is transmitted in corresponding OFDM symbols,$g_1(n)$ is the transmit pulse shape window (associated with the first symbol in the slot) and the impulse response of the receive filter in cascade,g(n) is the transmit pulse shape window (associated with remaining symbols in the slot) and the impulse response of the receive filter in cascade,D_1,D and D_Z are the duration of the first OFDM symbol in the slot, the duration of the remaining OFDM symbols in the slot, and the duration of the slot, respectively, $b_{k,l}$ and $c_{k,l}$ are the data and RS symbols transmitted on the k_{th} subcarrier and within the l_{th} OFDM symbol, respectively, and w(n) is the additive zero-mean Gaussian noise.

The OFDM parameters for LTE signals are presented in Table III. As one can notice, the FFT size is scalable with the bandwidth: when the available bandwidth increases, the FFT size also increases such that the useful symbol duration and the subcarrier spacing are fixed.

Channel bandwidth (MHz)	1.25	2.5	5	10	15	20
FFT size	128 256	256 512	512 1024	1024 2048	1536 3072	2048 4096
Subcarrier spacing Δf (kHz)	15 7.5					
Useful symbol duration T_u (μs)	66.67 133.33					

Table 2: OFDM parameters for the LTE signals

VI. SIMULATION RESULTS

The signals are simulated with 5 MHz double sided bandwidth. For LTE signal, the number of subcarriers is 64, For the LTE signal T_{CP}/T_U equals 1/4. Here we use 64 FFT with 1/4 CP.QAM with 16 points and unit variance of the signal constellation is used to modulate the data subcarriers. The simulaton is done in MATLAB.

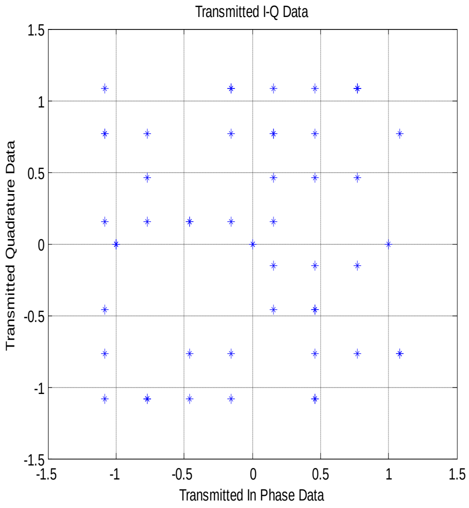


Fig.9 Constellation Diagram of Transmitted Signal

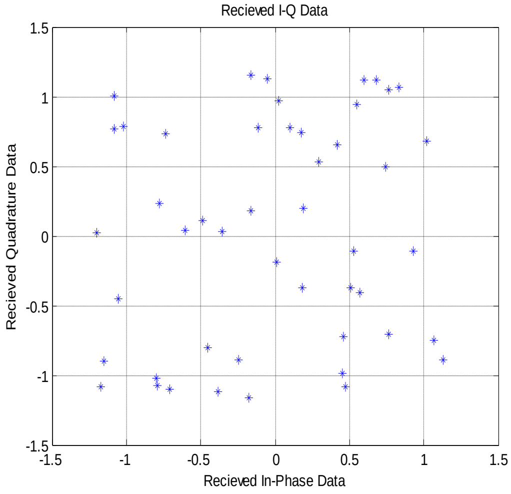


Fig.10Constellation Diagram of Received signal

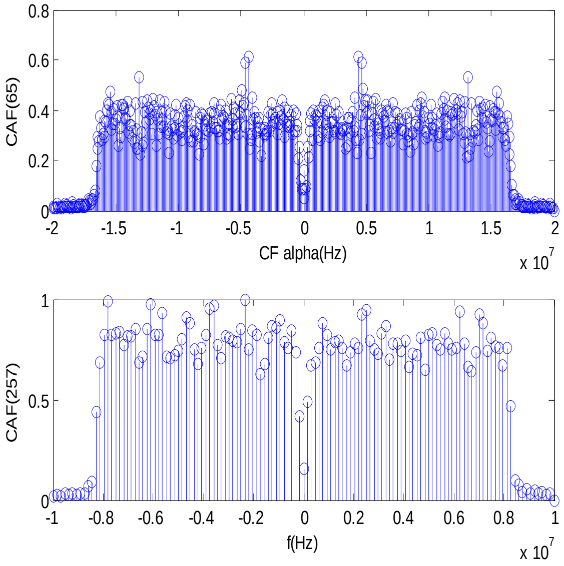


Fig11. Plot of Cyclic Autocorrelation Function with Frequency and Cyclic Frequency

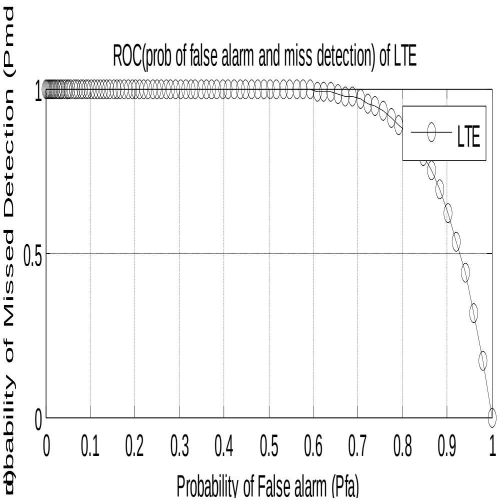


Fig12. ROC curve for LTE signal

VII. COCLUSION

Since the introduction of cognitive radio in 1999, there have been many high-level discussions on proposed capabilities of cognitive radios. Cognitive radio technology is advancing in a very fast way. Standardization is the key to the current and future success of cognitive radio. This paper proposed an overview of Technical aspect for Cognitive Radio networks technology by focusing on the basic overview and architecture design. Cognitive Radio networks technology play equally important roles in the future of wireless networks. In this paper, spectrum sensing using LTE signal is described and studied in terms of cyclic autocorrelation function and ROC curve is simulated.

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