Efficient Signal Feature Detection method using Spectral Correlation Function in the Fading channel

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ABSTRACT

The cognitive radio communication is taking the attentions because the development of the technique came to be possible to analyze wireless signals. In the IEEE 802.22 WRAN Systems[1], how to detect a spectrum and signals is continuously studied. In this paper, we propose the efficient signal detection method using SCF (Spectral Correlation Function). It is easy to detect the signal feature when we are using the SCF. Because most modulated signals have the cyclo-stationarity which is unique for each signal. But the fading channel effected serious influence even though it detects the feature of the signal. We applied LMS(Least Mean Square) filter for the compensation of the signal which is effected the serious influence in the fading channel. And we analyze some signal patterns through the SCF. And we show the unique signal feature of each signal through the SCF method. It is robust for low SNR(Signal to Noise Ratio) environment and we can distinguish it in the fading channel using LMS Filter.

Keywords: *SCF, LMS, WRAN, CR*

1. INTRODUCTION

In the IEEE 802.22 WRAN(Wireless Regional Area Networks) systems[1] the CR(cognitive radio) has been taking the attention because of the limited spectral resources. So the plan to use the frequency efficiently is therefore studied.

Basic technique of the CR is a spectrum sensing[2]. Through spectrum sensing we can know which band is using. The fundamental technique of spectrum sensing is signal feature detection. The signal feature detection method uses SCF. The spectral correlation is an important characteristic property of modulated signals if it is cyclo-stationary. It exhibits as correlation between pairs of the spectral components whose difference of the central frequencies is called cyclic frequency. The utilization of this spectral redundancy in the spectral correlation transformed space enables substantial performance improvement in the signal parameter estimation. The fading makes serious influence at SNR of the signal as well as AWGN(Additive White Gaussian Noise). So we must consider the fading with the noise when we analyze consequently the signal.

In this paper, we study cyclic autocorrelation and spectral correlation function for CR system. And we simulate the modulated signals for signal feature detection. Also we detected the feature of the signal taking the influence of Rayleigh fading channel. So we used LMS filter and compensated the signal to be distorted by the influence of the fading.

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2. SPECTRAL CORRELATION FUNCTION

A modulated signal of primary user is containing generally original periodic things. So the transmitted data has a stationary random process personality. Also modulated data has the cyclo-stationarity because of statistical periodic between its mean and autocorrelation. Generally for a signal analysis of a stationary random process, we use autocorrelation function and a power spectrum density function. Otherwise in regard to cyclo-stationary signal we can use a spectral correlation function because the correlation of frequency factor exists due to his periodic characteristic.

In general, a complex received signal $x(t)$ is said to exhibit second-order cyclo-stationarity. Its autocorrelation is defined as

$$R_{xx}(t,t+\tau)=E\{x(t)\cdot x(t+\tau)\} \quad (1)$$

$R_{xx}(t,t+\tau)$ is a function of two independent variables,

t and τ. It is periodic in t with period T for each value of τ. It is assumed that the Fourier series representation for this periodic function converges. So that $R_{xx}(t,t+\tau)$ can be expressed as

$$R_{xx}(t,t+\tau)=\sum_{\alpha} R_{xx}^{\alpha}(\tau)e^{j2\pi\alpha t} \quad (2)$$

α is called the cycle frequency parameter.

And then the cyclic autocorrelation defined as [3]

$$R_{xx}^{\alpha}(\tau)=\lim_{T\to\infty}\frac{1}{T}\int_{-T/2}^{T/2} R_{xx}(t,t+\tau)e^{-j2\pi\alpha t}dt. \quad (3)$$

The Spectral Correlation Function is the Fourier transforms of the cyclic auto-correlation[3].

$$S_{xx}^{\alpha}(f)=\int_{-\infty}^{\infty} R_{xx}^{\alpha}(\tau)e^{-j2\pi f\tau}d\tau. \quad (4)$$

2.1 SCF of the BPSK Signal

Generally BPSK modulation signal defines as follows.

$$x(t)=a(t)\cos(2\pi f_0 t+\phi_0)\ \ \phi_0\in(0,\pi) \quad (5)$$

$a(t)$ is amplitude and ϕ_0 is phase.

SCF of BPSK signal is as follows[4].

$$S_{xx}^{\alpha}(f)=\begin{cases}\frac{1}{4T_c}Q(f+\frac{\alpha}{2}\mp f_0)Q^*(f+\frac{\alpha}{2}\mp f_0)e^{-j[2\pi(\alpha\mp f_0)t_0\mp 2\phi_0]}, & \alpha=\pm 2f_0+\frac{k}{T_c}\\ \frac{1}{4T_c}Q(f+\frac{\alpha}{2}-f_0)Q^*(f-\frac{\alpha}{2}-f_0) & \\ \quad +\frac{1}{4T_c}Q(f+\frac{\alpha}{2}\mp f_0)Q^*(f+\frac{\alpha}{2}\mp f_0), & \alpha=0\\ 0, & otherwise\end{cases}$$

(6)

where $Q(f)=\dfrac{\sin(\pi f T_c)}{\pi f}$.

2.2 SCF of the QPSK Signal

Generally QPSK modulation signal defines as follows.

$$x(t)=a(t)\cos(2\pi f_0 t+\phi_0),$$
$$\phi_0\in(\pi/4,3\pi/4,-3\pi/4,-\pi/4) \quad (7)$$

$a(t)$ is amplitude and ϕ_0 is phase.

SCF of QPSK signal is as follows[4].

$$S_{xx}^{\alpha}(f)=\begin{cases}\frac{1}{4T_c}Q(f+\frac{\alpha}{2}-f_0)Q^*(f-\frac{\alpha}{2}-f_0) & \\ +\frac{1}{4T_c}Q(f+\frac{\alpha}{2}\mp f_0)Q^*(f+\frac{\alpha}{2}\mp f_0), & \alpha=0 \\ 0, & otherwise\end{cases} \quad (8)$$

where $Q(f)=\dfrac{\sin(\pi f T_c)}{\pi f}$.

3. EFFICIENT SCF SCHEME UNDER THE FADING CHANNEL

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. It assumes that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables[5].

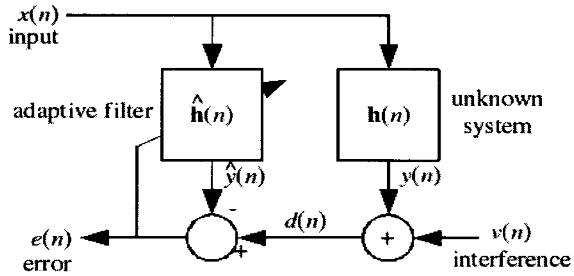

Fig. 1. LMS Filter

Most linear adaptive filtering problems can be formulated using the block diagram above. That is, an unknown system is to be identified and the adaptive filter attempts to adapt the filter to make it as close as possible to, while using only observable signals x(n), d(n) and e(n) (y(n), v(n) and h(n) are not directly observable.

The received signal in a Rayleigh fading environment reduced greatly about SNR. Therefore the detection of the signal is not easy. So we drew a plan in the paper to see consequently LMS filter[6] of the best suited which considers a Rayleigh fading channel.

4. SIMULATION

In this chapter, we showed that modulated signal can be distinguished by the unique signal feature using SCF if that signal is in the fading channel.

Common parameters to use in this paper are as follows[7].

Table 1. Main Simulation Parameters

Parameter	Value
Carrier frequency	125MHz
Bandwidth	20MHz
Sampling Frequency	800MHz

Fig. 2 is structure of this SCF generation which we consider in this paper.

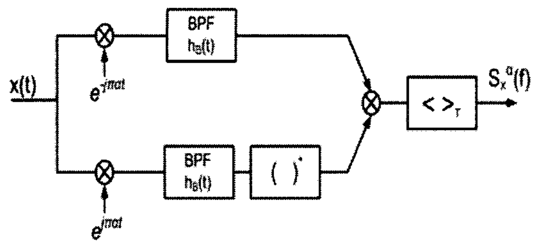

Fig. 2. Spectral Correlation Function Generation

Fig. 3 shows BPSK Signal Feature using SCF. When α is 0, signal feature is detected where f_c is $\pm$ 125MHz. Also when $f_c = 0$, the signal feature was detected where α is $\pm$ 250MHz which is the exactly twice of f_c. It is the relation between α and f_c.

QPSK signal feature using SCF is showed by Fig 4. When α is 0, signal feature is detected where f_c is $\pm$ 125MHz. But when $f_c = 0$, the signal feature was not detected where α is $\pm$ 250MHz which is the twice of f_c. It is unique feature's characteristic of the QPSK signal.

Though these Figs, we can exactly know the difference between BPSK signal and QPSK signal.

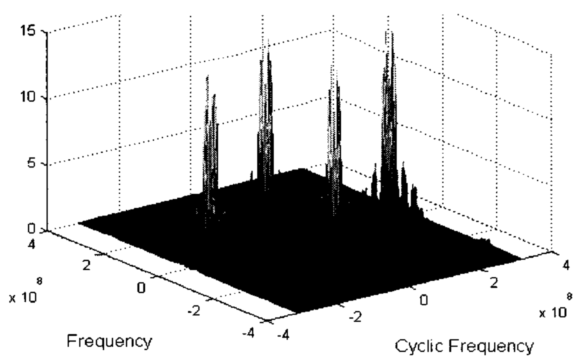

Fig 3. Signal Feature Detection of BPSK signal using Spectral Correlation Function.

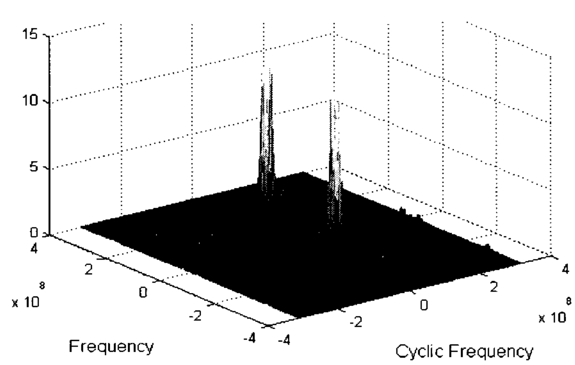

Fig 4. Signal Feature Detection of QPSK signal using Spectral Correlation Function.

In Fig. 5 and Fig. 6, we apply Rayleigh fading channel to each signal. It reduced the amplitude of transmitted signals. So the signals suffer easily from noise. The fading channel's factor use Doppler Frequency 100Hz.

Fig. 5 shows that signal feature of BPSK signal in Rayleigh fading channel. Compared to Fig. 3, it is similar. But its amplitude is much smaller. Fig. 6 shows that signal feature of QPSK signal in Rayleigh fading channel. Compared to Fig. 4, it is similar except its amplitude.

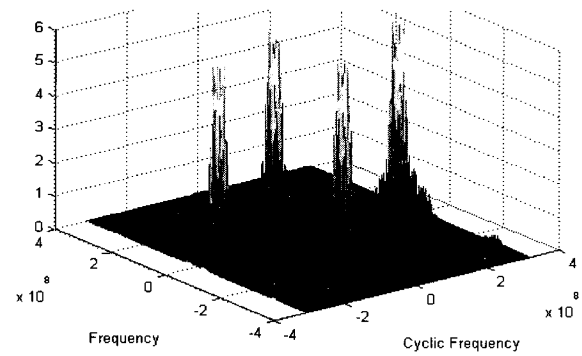

Fig. 5. Signal Feature Detection of BPSK signal in Rayleigh fading channel(Doppler Frequency : 100Hz)

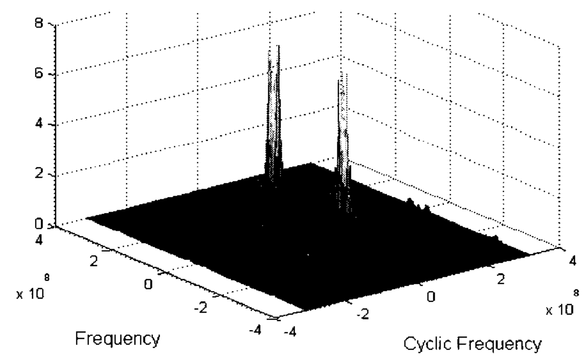

Fig. 6. Signal Feature Detection of QPSK signal in Rayleigh fading channel(Doppler Frequency : 100Hz)

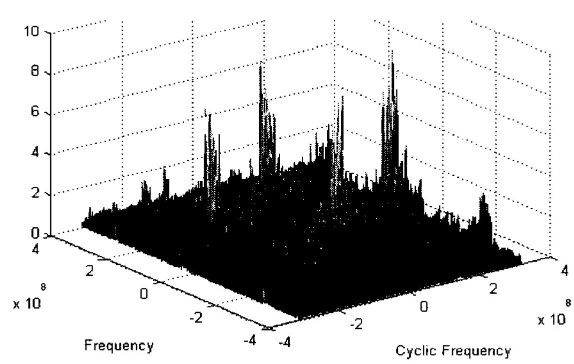

Fig. 7. Signal Feature Detection of BPSK signal with AWGN(0dB) in Rayleigh fading channel (Doppler Frequency : 100Hz)

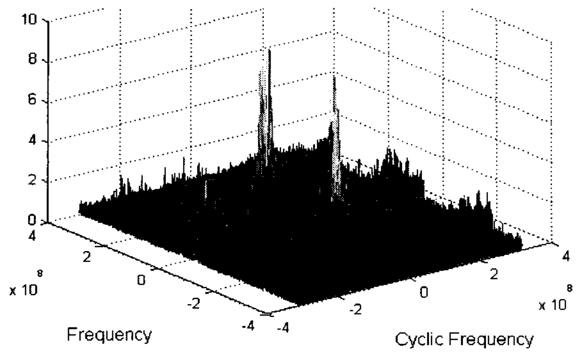

Fig. 8. Signal Feature Detection of QPSK signal with AWGN (0dB) in Rayleigh fading channel (Doppler Frequency : 100Hz)

Fig. 7 shows that signal feature of BPSK signal with AWGN(0dB) in Rayleigh fading channel. It took as a whole the influence of the noise. But the level of signal grew bigger. Also the difference of the level arose more between the signal and noise compared to Fig. 5. So we can know that is robust noise when we use auto- correlation. It is similar to QPSK signal in Fig. 8.

Fig. 9 shows that signal feature of BPSK signal with AWGN(0dB) in Rayleigh fading channel using LMS filter which uses 8-weights and 0.01-step size[4]. It is almost similar to Fig. 3. It shows that the noise was eliminated by using LMS Filter. So we can distinguish the signal and know signal's information in the worst channel. Also it applied QPSK signal in Fig. 10.

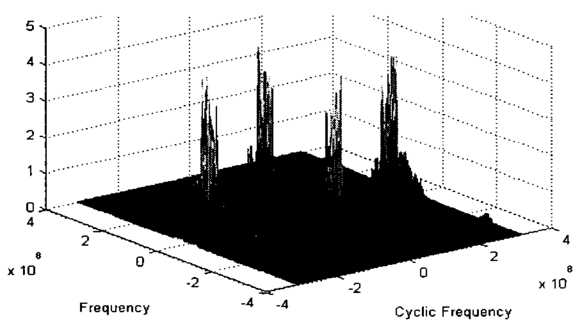

Fig. 9. Signal Feature Detection of BPSK signal with AWGN (0dB) in Rayleigh fading channel(Doppler Frequency : 100Hz) Using LMS Filter(8 weight, 0.01 step-size)

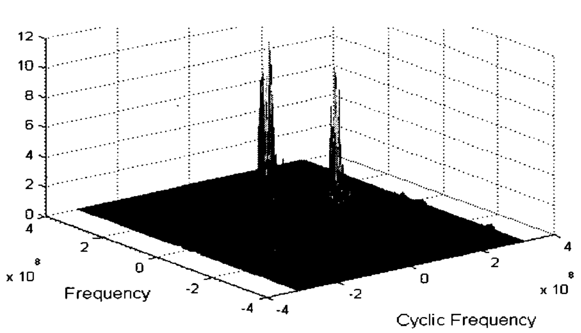

Fig. 10. Signal Feature Detection of QPSK signal with AWGN(0dB) in Rayleigh fading channel(Doppler Frequency : 100Hz) Using LMS Filter(8 weight, 0.01 step-size)

5. CONCLUSION

We applied SCF and detected each signal to be forged. We can know the characteristic of the signal which is modulated. It has many advantages about signal detection and analysis that we applies SCF in CR system. We considered a Rayleigh fading to implement the feature of SCF with reality. The signals which suffer a Rayleigh channel generally reduced SNR. It is difficult to know the characteristic of the signal through analyzing the signal detection result. We used LMS filter to increase SNR of the signal to suffer consequently the fading channel. We can know from the result of the simulation that the signal which is affected a Rayleigh fading appling LMS filter can reduce the noise. We predict the improved results compared to existing method if we consider the method to propose consequently in this paper at a sensing part of CR system. So we recommend this method for the spectrum sensing in the Rayleigh fading channel.

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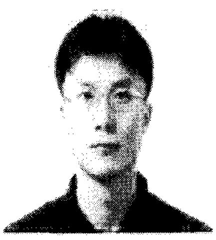

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