Proceedings of the 6th WSEAS International Conference on Multimedia Systems & Signal Processing, Hangzhou, China, April 16-18, 2006 (pp105-108)

The detection methods of DSSS/QPSK signal based on the fourth-order moment

ZHAO ZHIJIN, WU JIA, XU CHUNYUN
School of Telecommunication
Hangzhou Dianzi University
Hangzhou, Zhejiang 310018, CHINA

Abstract: - An accumulation detection method based on the fourth-order moment $m_{4x}(0,0,\tau)$ in time domain for the DSSS signal is proposed. Experimental results show that the detection performance of the accumulation method is better than that of the non-accumulation method. It can effectively detect the DSSS signal modulated by QPSK at SNR -16dB. The computation complexity of the method is low and it is easy to implement.

Key-Words: -Direct-sequence spread-spectrum (DSSS); Uncoded detection; Higher order statistics; The fourth-order moment; Accumulation; Threshold

1 Introduction

Some detection methods of DSSS signal modulated by BPSK, such as energy method[1]、autocorrelation method[2] 、 cycle spectrum method[3] and the cepstrum method[4], have been presented. These methods hardly meet the requirement to detect the DSSS signal modulated by QPSK(DSSS/QPSK), which is widely used in the digital CDMA cellular system. So a further research for detection of DSSS/QPSK signal is urgent.

Analyzed the DSSS/QPSK signal's fourth-order moment, the detection methods based on $m_{4x}(0,0,\tau)$ without accumulation and with accumulation are presented. Their operation is rather simple and the detection performance is better.

2 Theoretical analysis

Suppose the DSSS/QPSK signal model

$$s(t) = \sqrt{P}c_i(t)\cos(2\pi f_0 t + \varphi) + \sqrt{P}c_q(t)\sin(2\pi f_0 t + \varphi) \qquad (1)$$

where P represents the signal power, ϕ is a random phase distributed in (0,2π) evenly, $c_i(t)$ 、 $c_q(t)$ are information sequences by spread spectrum and statistically independent each other, as well as they are statistically independent of the carrier component.

On the foundation of the statistics characteristics, the first to fourth-order moments of DSSS/QPSK signal are as follows.

$$m_{1s} = E[s(t)] = 0 \qquad (2)$$

$$m_{2s}(\tau) = E[s(t)s(t+\tau)] = PR_c(\tau)\cos(2\pi f_0 \tau) \qquad (3)$$

$$m_{3s}(\tau_1, \tau_2) = E[s(t)s(t+\tau_1)s(t+\tau_2)] = 0 \qquad (4)$$

$$m_{4s}(\tau_1,\tau_2,\tau_3)=E[s(t)s(t+\tau_1)s(t+\tau_2)s(t+\tau_3)]$$
$$=\frac{1}{4}P^2R_c(\tau_1,\tau_2,\tau_3)[\cos 2\pi f(\tau_1+\tau_2-\tau_3)+$$
$$\cos 2\pi f(\tau_1+\tau_3-\tau_2)+\cos 2\pi f(\tau_2+\tau_3-\tau_1)] \quad (5)$$

From Eqn（2）to Eqn（5）， it's apparent that the fourth-order moment contains richer information.

Additive noise is Gaussian white noise with zero mean and independent with $s(t)$. The first to fourth-order moments of the Gaussian noise are

$$m_{1n}=E[n(t)]=0 \quad (6)$$
$$m_{2n}=\sigma_n^2\delta(\tau) \quad (7)$$
$$m_{3n}(\tau_1,\tau_2)=0 \quad (8)$$
$$m_{4n}(\tau_1,\tau_2,\tau_3)=[\delta(\tau_1)\delta(\tau_3-\tau_2)+$$
$$\delta(\tau_2)\delta(\tau_3-\tau_1)+\delta(\tau_3)\delta(\tau_2-\tau_1)]\sigma_n^4 \quad (9)$$

The received signal is $x(t)=s(t)+n(t)$, its fourth-order moment is given by

$$m_{4x}(\tau_1,\tau_2,\tau_3)=E[x(t)x(t+\tau_1)x(t+\tau_2)x(t+\tau_3)]$$
$$=E\{[s(t)+n(t)][s(t+\tau_1)+n(t+\tau_1)]$$
$$[s(t+\tau_2)+n(t+\tau_2)][s(t+\tau_3)+n(t+\tau_3)]\}$$
$$=m_{4s}(\tau_1,\tau_2,\tau_3)+m_{4n}(\tau_1,\tau_2,\tau_3)$$
$$+m_{2s}(\tau_1)m_{2n}(\tau_3-\tau_2)+m_{2s}(\tau_2)m_{2n}(\tau_3-\tau_1)$$
$$+m_{2s}(\tau_3)m_{2n}(\tau_2-\tau_1)+m_{2n}(\tau_1)m_{2s}(\tau_3-\tau_2)$$
$$+m_{2n}(\tau_2)m_{2s}(\tau_3-\tau_1)+m_{2n}(\tau_3)m_{2s}(\tau_2-\tau_1) \quad (10)$$

Eqn（10）is too complicated to apply the moments estimated directly. Considering the realization difficulty, we only study one kind of fourth-order moments $m_{4x}(0,0,\tau)$（$\tau\neq 0$）to enable effective detection.

When the DSSS/QPSK signal is being, the received signal's fourth-order moment is given by

$$m_{4x}(0,0,\tau)=m_{4s}(0,0,\tau)+m_{4n}(0,0,\tau)+3m_{2n}(0)m_{2s}(\tau)$$
$$=[\frac{3}{4}P^2R_c(0,0,\tau)+3\sigma_n^2PR_c(\tau)]\cos(2\pi f_0\tau) \quad (11)$$

When the DSSS/QPSK signal is not being, the received signal's fourth-order moment is given by

$$m_{4x}(0,0,\tau)=3m_{2n}(0)m_{2s}(\tau)=3\delta^2(\tau)\sigma_n^4=0 \quad (12)$$

Compared Eqn（11）with Eqn（12）, the fourth-order moment of the received signal is not equal to zero when DSSS/QPSK signal exits, and it is equal to zero when only jammed noise exits. So the fourth-order moment $m_{4x}(0,0,\tau)$ can be applied to detect the DSSS/QPSK signal.

3 Detection methods

According to above analysis, the detection method based on the fourth-order moment $m_{4x}(0,0,\tau)$ without accumulation is as following:

When $|m_{4x}(0,0,\tau)|\geq H_T$, DSSS/QPSK signal exits, and vice versa, DSSS/QPSK signal does not exit.

The detector structure is shown as Fig.1.

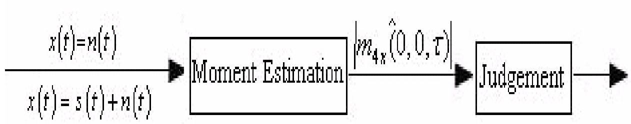

Fig.1 The detector structure without accumulation

Set the false alarm probability to 1%, the threshold H_T can be obtained and it is not altered with the change of the delay τ. The detection performance is simulated.

Original signal datum collects from CDMA signal source modulated by QPSK, information rate is 19.2kHz, length of the PN code is 2^{15}=32768 and its rare is 1.2288MHz, sample number in a code element N is 50, and sampling frequency is 2457.6MHz, additive noise is Gaussian white noise. A great deal of research indicates when τ is equal to even multiple of $N/4$, detection performance is the best, the other way, when τ is equal to odd multiple of $N/4$, the detection performance is the worst. Trading off the detection performance and the realization difficulty, let delay τ $N/2$. Taking 100 groups of signals to be detected, the detection performance of the non-accumulation method is shown in Table.1.

Table.1 Detection performance without accumulation

SNR (dB)	-14	-13	-12	-11	-10	-8
Detection Probability	33%	43%	64%	83%	99%	100%

The detection probability can achieve 64% when SNR reaches -12dB. The detection performance becomes very bad if SNR is lower than - 14dB. As we know, the information obtained from multi-groups of the DSSS signal is nearly the same, while that of the jammed noise is statistically independent each other. Using this property, if accumulation is used, the SNR is enhanced and detection performance can be improved. The detection method with accumulation can be described in the following Fig.2.

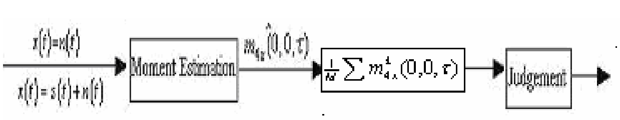

Fig.2 The detector structure with accumulation

When the false alarm probability is 1% and signal datum is the same as above, the detection performance is simulated.

With the rise of accumulation time M, the detection probability is increased and computation complexity is also increased. But when M is larger than 15, the probability is nearly unaltered. M is chosen 15, the simulation results of the detection performance are shown in Table.2.

Table.2 Detection performance with accumulation

SNR/dB	-19	-18	-17	-16	-15	-13
Detection Probability	35%	47%	64%	90%	97%	100%

Compared Table 1 and Table 2, it can be found that the detection performance with accumulation is better than that without accumulation, and the SNR is improved 5dB.

4 Conclusion

The detection methods of DSSS/QPSK signal based on fourth-order moment $m_{4x}(0,0,\tau)$ with accumulation and without accumulation have been presented. They belong to the uncoded detection. Simulations indicate that the detection performance with accumulation is better than that without accumulation. The implementation of these methods is simple.

References:

[1] Urkowitz, H., Energy Detection of Unknown Deterministic, *Proc IEEE.*, Vol.55,No.4, 1967, pp. 523-531

[2] Yuan, L., Liu, J.A., and Wen, Z.J., A Detection Method for DSSS Signal in the Low SNR Condition, *Modern Electronics Technique*, No.5, 2005, pp. 50-55

[3] Zhang, X.L., Xu, J.T., and Chen, Y.S., Detection of BPSK DS signal based on cyclic spectrum correlation technology, *Information Technology*, Vol.28, No.8, 2004, pp. 30-32

[4] Zhang, J.L., Detection of DSSS signal, *Radio Engineering*, No.2, 1994, pp. 19-21