



# Research on Detection Algorithm of DSSS Signals Under Alpha Stable Distribution Noise

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**Abstract.** The detection algorithm of direct sequence spread spectrum (DSSS) signals based on power spectrum reprocessing will significantly degrade in Alpha stable distribution noise environment, in order to solve this problem, the concept of generalized power spectrum reprocessing was proposed. On the basis of studying the generalized power spectrum reprocessing feature of the DSSS signals, the pulse spectrum was extracted as the detection feature to achieve effective detection. Simulation results show that the performance of this method have good performance both in the Alpha stable distribution noise.

**Keywords:** Signal detection · DSSS signals · Alpha stable distribution noise · Generalized power spectrum reprocessing

## 1 Introduction

DSSS is a channel transmission technology widely used in modern communication, it has very high processing gain. The source signal is often hidden in the noise after direct expansion processing, the special character determines its hard to detect. At present, the commonly used detection methods include auto-correlation accumulation [1], cyclo-stationarity spectral correlation [2], higher-order cumulants [3], cepstrum [4], power spectrum reprocessing [5, 6], etc. Power spectrum reprocessing can be seen as an improved version of cepstrum, its computational complexity is slightly lower than the cepstrum. Cepstrum and the power spectrum reprocessing is used to detect DSSS signals, is the use of periodicity of pseudo-code components in the frequency domain and time domain, through power spectrum reprocessing, the pseudo-time domain or the inverted frequency domain will show up this periodicity, it becomes a useful characteristics of signal detection. Thus, the advantages of cepstrum and power spectrum reprocessing are that it can not only detect the presence of DSSS signals in the noise, and can effectively identify the DSSS signal and normal signal.

Most of previous researches on the detection of DSSS signals employed Gaussian distribution as the model of background noise. With the increasing complexity of channel environment, the Gaussian distribution has been unable to effectively describe some noise, especially some significant short-time impulse noise with large amplitude, such as electromagnetic pulse noise, low-frequency atmospheric noise, multi-user interference, etc. More and more researchers confirmed that the Alpha stable distribution is a more effective noise model, and have done a lot of researches on signal

processing in Alpha stable distribution noise [7–11], therefore, this article studies the detection method of DSSS signals under Alpha stable distribution noise. Alpha stable distribution sequence does not have a second-order statistics and above, this nature determines the above mentioned detection methods of DSSS signals will fail. It can be seen from the Figs. 1 and 2 that the Alpha stable distribution noise destroys the spectral characteristics of the power spectrum reprocessing, and the corresponding DSSS signal detection algorithm will also fail. Aiming at this problem, based on the idea of reference [12], power spectrum reprocessing is extended, and the concept of generalized power spectrum reprocessing is proposed. It is applied to the detection of DSSS signal under Alpha stable distribution noise and achieves good results.

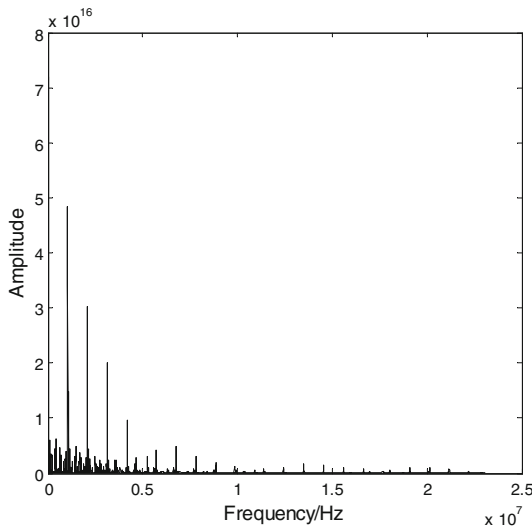


Fig. 1. Power spectrum reprocessing of DS-BPSK with non-noise

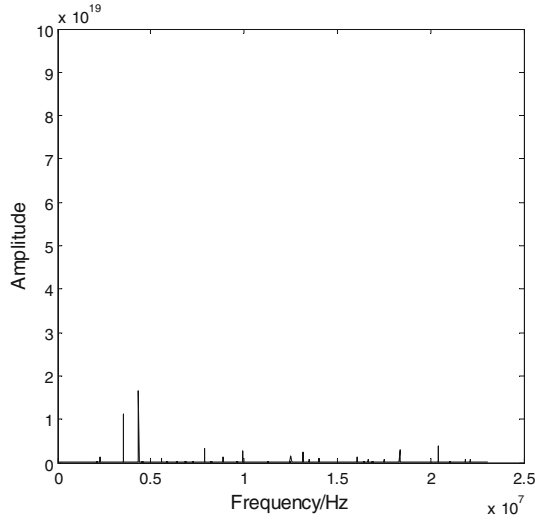
## 2 Algorithm Principle

The generalized auto-correlation function of the signal  $x(t)$  is defined as:

$$GR_x(\tau) = E[f\{x(t + \tau)\}f^*\{x(t)\}] \tag{1}$$

In the above formula,  $f(x) = \frac{\arctan(|x + j\mathbf{H}(x)|)}{|x + j\mathbf{H}(x)|}x$ ,  $\mathbf{H}(\cdot)$  represents the Hilbert transform.

The generalized power spectrum is the Fourier transform of generalized auto-correlation function:



**Fig. 2.** Power spectrum processing of DS-BPSK with Alpha stable distribution noise

$$GP_x(f) = \int_{-\infty}^{\infty} GR_x(\tau)e^{-j2\pi f\tau}d\tau \tag{2}$$

Similarly, assuming that the auto-correlation function of the generalized power spectrum  $GP_x(f)$  is  $G^2R_x(\tau)$ , its generalized power spectrum reprocessing is defined as:

$$G^2P_x(f) = \int_{-\infty}^{\infty} G^2R_x(\tau)e^{-j2\pi f\tau}d\tau \tag{3}$$

In practical applications, the generalized power spectrum reprocessing can be approximated by the following formula:

$$G^2P_x = |FFT|FFT(f(x))|^2 \tag{4}$$

It is mentioned in the reference [11] that the generalized transform does not change the period characteristics of the spread code of DSSS signal. The generalized power spectrum reprocessing must have similar spectral characteristics to the traditional power spectrum reprocessing.

The noisy DSSS signal received by the receiver can be expressed as:

$$x(t) = s(t) + n(t) = Ad(t)p(t) \cos(\omega_c t + \varphi_0) + n(t) \tag{5}$$

In the above formula,  $A$  represents the amplitude of the DSSS signal,  $d(t)$  represents the information code sequence,  $p(t)$  represents the spread code sequence,  $\omega_c$  represents the carrier frequency,  $\varphi_0$  represents the initial phase, and  $n(t)$  represents the Alpha stable distribution noise.

Combined with the Eqs. (4) and (5), the generalized power spectrum reprocessing of DSSS signal can be obtained as follows:

$$\begin{aligned}
 G^2P_s(f') &= \left| \text{FFT} \left[ \frac{(N+1)(\arctan^2 A)}{4\pi N^2} \text{Sa}^2((f-f_c)\pi T_p) \sum_{\substack{k=-\infty \\ k \neq 0}}^{k=\infty} \delta\left(f-f_c-\frac{k}{T_0}\right) \right] \right|^2 \\
 &= \begin{cases} \left| \frac{(N+1)(\arctan^2 A)}{4\pi N^2} e^{-j2\pi df_c} \left\{ \frac{1}{2\pi^2 T_p} \left(1 - \frac{|f'|}{T_p}\right) * \right. \right. \\ \left. \left. 4\pi^2 T_0 \sum_{\substack{k=-\infty \\ k \neq 0}}^{k=\infty} \delta(f'-kT_0) \right\} \right|^2, & |f'| \leq T_p \\ 0, & |f'| > T_p \end{cases} \\
 &= \begin{cases} \left| \frac{(N+1)(\arctan^2 A)}{2\pi N} \sum_{\substack{k=-\infty \\ k \neq 0}}^{k=\infty} \left(1 - \frac{|f'-kT_0|}{T_p}\right) \times \right. \\ \left. e^{-j2\pi df_c} \right|^2, & |f'-kT_0| \leq T_p \\ 0, & |f'-kT_0| > T_p \end{cases} \tag{6}
 \end{aligned}$$

It can be seen from the above equation that in the generalized power spectrum reprocessing, the signal energy is concentrated at some sharp triangular pulse sequences. Figure 3 shows a generalized power spectrum reprocessing graph with the same noise as in Fig. 2. It can be seen from the figure that the spectral characteristics have been greatly improved. Therefore, the generalized power spectrum reprocessing can be used as a detection feature of DSSS signal under Alpha stable distribution noise.

For the generalized power spectrum reprocessing of DSSS signal, after a large number of simulation analysis, the ratio of the maximum value to the mean value in the spectral domain is used to describe the sharp pulse characteristics, and the ratio is used as the detection feature.

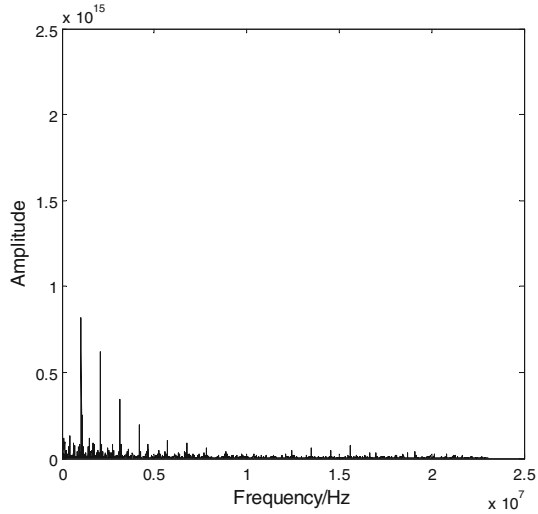
$$th = \frac{\max(G^2P_s)}{\text{mean}(G^2P_s)} \tag{7}$$

According to the simulation experience value, when the decision threshold is 25, the effective detection of the DSSS signal under a certain mixed SNR can be realized.

### 3 Algorithm Step

The detection algorithm steps are as follows:

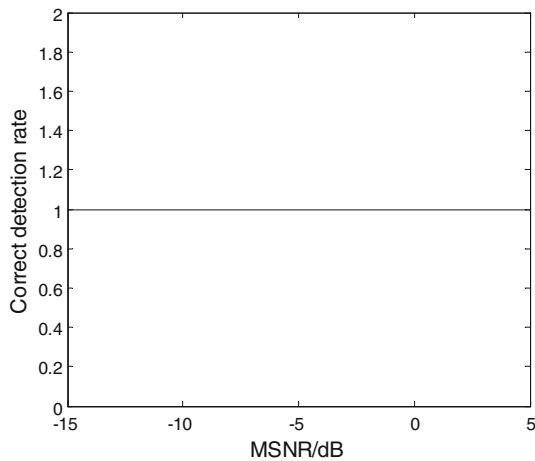
- (1) Calculate the generalized power spectrum reprocessing of the received signal;
- (2) The detected feature value is calculated according to Eq. (7) (In order to avoid the influence of the DC term, the calculation here does not include the zero frequency);
- (3) Decision: if  $th \geq 25$ , there is a DSSS signal; otherwise there is only noise.



**Fig. 3.** Generalized power spectrum reprocessing of DS-BPSK

## 4 Simulation Analysis

- (1) Verify detection algorithm performance based on power spectrum reprocessing. The parameters of DSSS signal are as follows: the modulation type is DS-BPSK, the spread code is Gold, the symbol rate of spread code is 3.84 M bit/s, the spread spectrum gain is 23 dB, the sampling frequency is 46.08 MHz, the carrier frequency is 5 MHz, the number of point is 16384. The detection results are shown in the Figs. 4 and 5.



**Fig. 4.** Correct detection rate

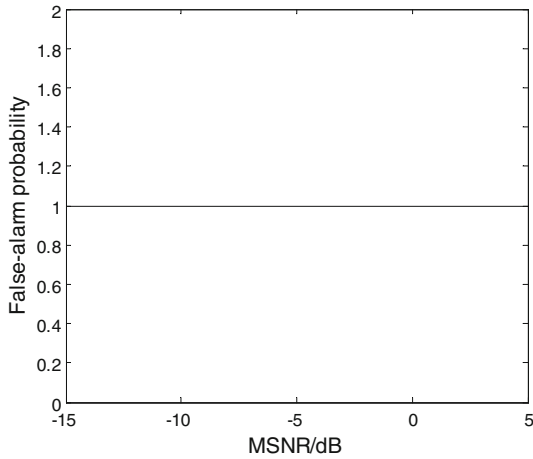


Fig. 5. False-alarm probability

It can be seen from the above figure that under the framework of the proposed algorithm, in the whole mixed SNR range, the correct detection rate and false alarm probability of the algorithm based on the power spectrum reprocessing are both 100%. As can be seen from Fig. 2, regardless of whether there is a target signal, there is an irregular impact line in the power spectrum reprocessing of the received signal, which will cause misjudgment. In other words, the influence of noise dominates the decision process. This shows that the algorithm based on the power spectrum reprocessing has failed.

- (2) Verify detection algorithm performance based on generalized power spectrum reprocessing. The signal parameters are the same as simulation 1. The detection results are shown in the Figs. 6 and 7.

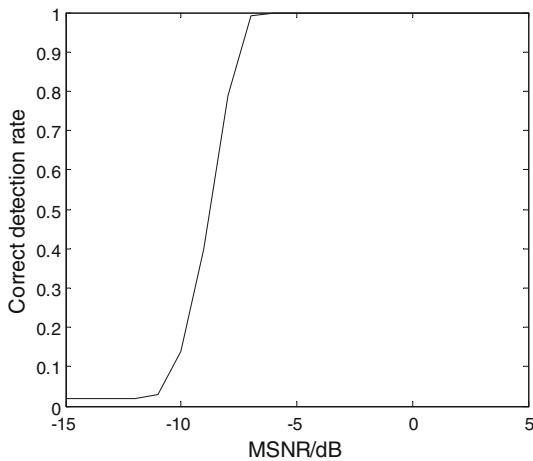
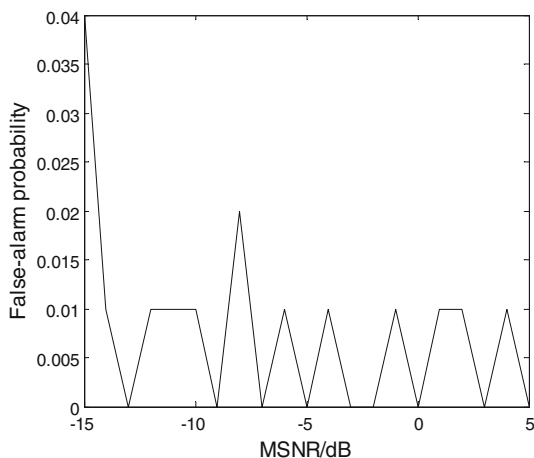


Fig. 6. Correct detection rate



**Fig. 7.** False-alarm probability

It can be seen from Fig. 6 that when the correct detection rate is greater than 90%, and the false-alarm probability is not more than 1%, indicating that the proposed algorithm can achieve effective detection of DSSS signal under a certain mixed SNR.

## 5 Conclusion

In this paper, the concept of generalized power spectrum reprocessing is proposed, which solves the problem of power spectrum reprocessing failure under Alpha stable distribution noise. On this basis, a new detection method of DSSS signal is proposed, which extends the application range of power spectrum reprocessing from Gaussian noise background to the Alpha stable distribution noise.

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