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RESEARCH ON IDENTIFICATION METHOD OF WIDEBAND JAMMING IN DSSS SYSTEM

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ABSTRACT

Wideband suppressing jamming is one of the main threats faced by Direct Sequence Spread Spectrum (DSSS) system. The identification of wideband jamming modes and estimation of its parameters provide beneficial reference for applying effective anti-jamming measures. Aiming at familiar wideband jamming modes faced by DSSS, five characteristic parameters are extracted. An automatic identification method of wideband jamming modes based on fractional Fourier transforms (FRFT) and layered decision-making algorithm is proposed. Through the simulation results and analysis, it can be found that the method can effectively identify non-jamming, narrow-band jamming, wideband noise jamming, wideband comb jamming and wideband sweep jamming. It has the advantages of high identification rate, simplicity, short sample time, fine stability and robustness, etc.

Keywords: *Jamming Identification; Direct Sequence Spread Spectrum; Layered Decision-making*

1. INTRODUCTION

Communication reconnaissance is one of the important research content of communications fields. In the traditional methods, the communication reconnaissance services are for electronic war, communication purpose is to provide electronic support the implementation of effective interference by getting the information of characteristics of the communication signal for electronic attack. In fact, defense of communication electronic also needs the support of communication reconnaissance. Through the analysis of the interference signal, the interference pattern identification and estimation of the interference parameters, the receiver can choose the best anti-jamming measures according to different interference signals. So through the method we can change the application of anti-interference means with definite purpose, and improve the ability of anti-jamming communications equipment effectively.

Direct Sequence Spread Spectrum system (referred to as "DS" or DSSS) has strong the anti-jamming capability and characteristic of low probability of intercept, and it has been getting the applications of a wide range in the civilian and military purpose [1-3]. The broadband interference is one of the common effective interference of the DS system, when the strong interference is beyond the DS system the interference tolerance limit, the system performance will seriously be deteriorated. Identification and parameter estimation methods of DS system will provide a useful reference in the adopting of appropriate anti-jamming measures according to common broadband interference. The paper [2-5] adopts the hierarchical decision classification algorithm based on the spectrum and the radon transform in the automatic identification of the broadband interference, but there are also exists the disadvantages, e.g., the complexity of computation and long time of signal sampling. In the paper, according to the model of the common broadband interference of spread spectrum systems, we propose a wideband interference identification method based on fractional Fourier transform, and simulation results and related analysis are also presented.

2. INTERFERENCE MODEL

The broadband interference can be divided into the broadband noise interference; broadband lines sweep interference and broadband comb spectrum interference [6,7].

2.1 Interference of broadband noise

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Broadband noise is a random noise signal in certain frequency bands with certain bandwidth, namely that it is equal to add a Gaussian noise with the power spectral density of $N_j = J/\omega_{ss}$ at the receiving end, where J is the average noise power, ω_{ss} is the spread spectrum bandwidth. In the actual project application, we can produce the certain bandwidth of noise, and then modulate it onto the required frequency band. Its characteristics are the signal energy can be distributed uniformly among the entire frequency band; when observed either from time domain or frequency domain, there are no energy aggregations.

2.2 Broadband comb spectrum interference

The broadband comb spectrum interference is a kind of narrow-band interference on a certain range of frequencies which modulated in some way. The comb spectrum interference is similar to broadband noise interference when frequency bandwidth is greater than or equal to the frequency interval. Narrowband interfering signal generation method in each frequency point can adopt the modulation interference or key interference method.

2.3 Broadband lines sweep interference

Broadband lines sweep interference is an effective interference way against DS communication, the relationship between the instantaneous frequency and time is a linear transformation, just as shown in Fig.1.

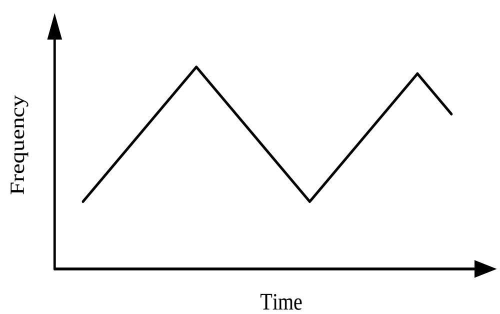

Fig. 1 Instantaneous Frequency Of The Line Sweep Interference Signal

According to changes of the frequency in the speed, the line sweep interference can be further divided into the fast line sweep interference and slow line sweep interference, and the sweep bandwidth of interfere can cover the entire bandwidth of the spread spectrum communication system, or only cover part of it, the mathematical expression is as Eq.(1).

$$j(t) = \sqrt{2J}\cos\left(\int_0^t \omega(\tau)d\tau + \theta\right) \qquad (1)$$

Where J represents the average power of the interference signal; $\omega(\tau)$ represents the instantaneous frequency with linear variation. From Fig.1, it can be found that if the description of the line sweep interference within a certain period of time, the sweep frequency (i.e., the slope of the line), and the initial phase should be known.

3. FRACTIONAL FOURIER TRANSFORM

Fractional Fourier transform (FRFT) is a generalized form of the Fourier transform, in recent years it has developed into a powerful tool in the analysis and processing of non-stationary signals and time-varying system. The fractional Fourier transform is defined as follows [8].

$$X_p(u) = F_p[s](u) = \int_{-\infty}^{+\infty} s(t)K_p(t,u)dt \qquad (2)$$

Where

$$K_p(t,u) = \begin{cases} \sqrt{(1-j\cot\alpha)}e^{j\pi(t^2\cot\alpha - 2ut\csc\alpha + u^2\cot\alpha)} & \alpha \neq n\pi \\ \delta(t-u) & \alpha = n\pi \\ \delta(t+u) & \alpha = (2n+1)\pi \end{cases} \qquad (3)$$

Where $a = p\pi/2$, p represents the fractional Fourier transform order; F_p represents the fractional Fourier transform operator. It can be found that the cycle of order p in the fractional Fourier transform is 4, and when $p = 4n+1$, the fractional Fourier transform becomes the traditional Fourier transform.

The definition of the fractional Fourier transform from the intuitive view it can be looked as the chirp-based decomposition, but essentially the fractional Fourier transform provides a comprehensive description of the signal from the time domain to the frequency domain in the whole process, with the continuous growth of order from 0 to 1, fractional Fourier transform show the gradual variation in the signal from the time domain to the frequency domain. Thus, the fractional Fourier transform actually reflects a unified time-frequency concept between the time domain and frequency domain in the signal frequency analysis method, and it provides more choices in time-frequency analysis.

The calculation of the fractional Fourier transform can be divided into two categories: one is a fast approximation algorithm, commonly referred

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to as discrete sampling algorithm, the algorithm is the direct discretization of the continuous fractional Fourier transform formula; another class of discrete fractional Fourier transform is an algorithm make the definition of DFRFT based on the discrete Fourier transform matrix Eigenvalue decomposition method. Expression of discrete sampling algorithm is based on the continuous fractional Fourier transform, the FRFT decomposition for signal convolution adopts the FFT method to calculate the fractional Fourier transform, so its speed is almost the same as FFT, and it is computationally faster kind of FRFT numerical calculation method, and it is very suitable for real-time signal FRFT numerical calculation, so we apply this algorithm in actually engineering implementation [9-11].

4. CHARACTERISTIC PARAMETER EXTRACTIONS

In order to effectively distinguish non-interference, narrowband interference and broadband noise the comb spectrum interference and line sweeping interference parameters, in the paper, we extract the following five characteristics.

4.1 Normalize The 3db Bandwidth Of The Spectrum Of B_ω

The first step is to calculate the normalized spectrum of the base band signal

$$S_u(n) = S(n)/\max(s(n)) \quad (n = 0,1,\ldots \quad N-1) \tag{4}$$

$S_u(n) = |FFT(x(n)|$ represents the spectrum modulus value of the digital baseband signal , N represents the data length , B_ω can be expressed as (5):

$$B_\omega = \frac{m_R - m_L + 1}{N} \tag{5}$$

Among them, the $m_R = \min\limits_{S_u(n)>S_t}(n)$ $m_R = \max\limits_{S_u(n)>S_t}(n)$, S_t is the threshold value set. Through B_ω , we can Distinguish between the narrowband interference and broadband interference .

It can be seen that B_ω can be calculated through FFT, it reflects the frequency domain characteristic of the received signal. Through the B_ω , we can distinguish narrowband interference and broadband interference, the calculation work of B_ω has smaller amount of operations, so we can distinguish strong narrowband interference firstly; while the spectrum without interference and broadband interference are hard to distinguish only from the frequency domain, it should use the PN code in the time-frequency domain and the priori knowledge in the judgment.

4.2 Coefficient R_c Of The Sliding Revolving PN Code

The broadband noise interference in the interference bandwidth range is uniformly distributed, its energy is also uniformly distributed in the whole time-frequency plane, so whether it is from the frequency domain or time-frequency domain to distinguish between the broadband noise interference and the DSSS communication signal are relatively difficult. We can take advantage of the characteristics of the DSSS signal to detect whether the presence of broadband noise interference.

The received baseband signal and the known PN code for the sliding correlator, through the DSSS signal generation mode and the auto-correlation characteristics of the PN code, through the sliding correlator ,it can obtain a sequence of time intervals and there will be a correlation peak, if we adopt the absolute value of this sequence , i.e., in order to eliminate the impact of the DSSS signal message code, then in every one PN code cycle, there will be an impulse, then we make the FFT operation after obtain the absolute value, then the result will appear uniformly spaced discrete spectral lines, the spectral line number is equal to the length of the PN code, shown as Fig.2.

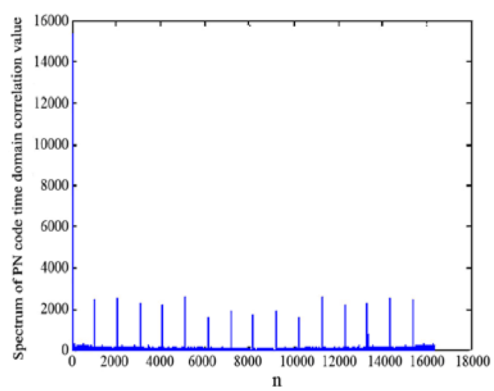

Fig.2 Spectrum Of Absolute Value Of Sliding Pn Code

R_c is equal to the discrete spectrum when zero-frequency lines are got rid of , the mean and the spectrum remaining part of the ratio of the mean, R_c reflects the energy ratio between the digital baseband signal, the DSSS signal energy ,the background noise and interference. In the case of the presence of interference, the value of R_c is

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reduced with the increase of the dry signal ratio as shown in Fig.3. From the Fig.3, the R_c can be adopted to determine whether the presence of interference. It should be noted that the value R_c is related to the selection of the PN code, and when we adopt the different PN code, the corresponding values will also be different in size. Obviously, R_c reflects the information of received signal in time domain.

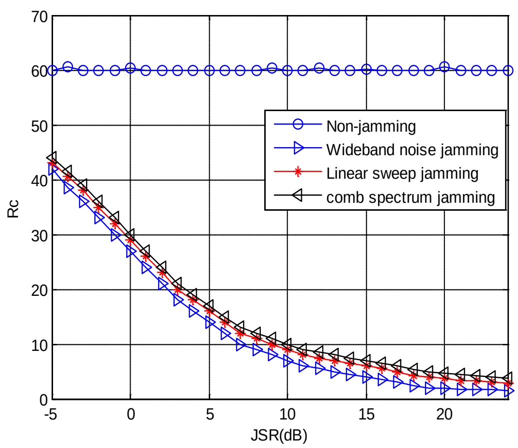

Fig. 3 Relationship Between R_c And JSR

4.3 Normalize The Power Spectral Similarity Coefficient Q_{ss}

Calculate the power spectrum of the received signal $P_\omega(n)$, and the normalization of the mean value is just as (6).

$$P_{u\omega}(n) = P_\omega(n) / m_p \qquad (6)$$

Where m_p is the mean value of $P_\omega(n)$. Q_{ss} can be calculated through (7).

$$Q_{ss} = \frac{\sum_{n=0}^{M-1} P_{u\omega0}(n) P_{u\omega}(n)}{\sqrt{\sum_{n=0}^{M-1} P^2_{u\omega0}(n) \sum_{n=0}^{M-1} P^2_{u\omega}(n)}} \qquad (7)$$

Among them, $P_{u\omega o}(n)$ represents the normalized spectrum of the DS baseband signal power according to the PN code obtained in advance without interference noise. Through the equation (7), it can be found that $Q_{ss} \le 1$, the larger value indicates the spectral of spectrum envelope of the received baseband signal is more similar to the DSSS signal, so it can be used to identify the presence or absence of interference. In the Fig.4, the relationship between the Q_{ss} and Jamming-to-Signal power Ratio (JSR) when the received signal simulation without interference, and with all kinds of interference are presented, respectively (each point is 500 times in the average).

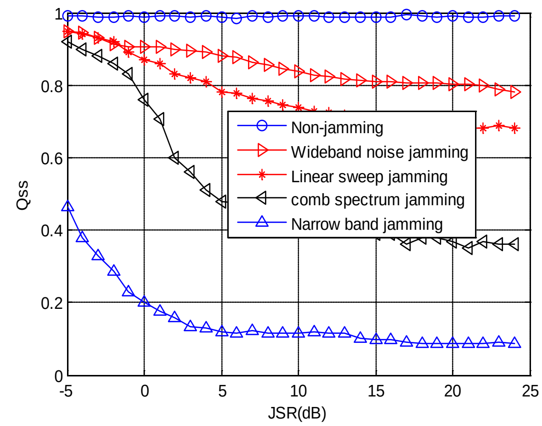

Fig.4 Relationship Between The Q_{ss} And JSR

4.4 Normalize The Standard Deviation σ_{pns} Of The Impulse Power Spectrum

$$\sigma_{pns} = \sqrt{\frac{1}{M}\sum_{n=0}^{M-1}(P_{pu}(n) - P_{pu}(n))^2} \qquad (8)$$

$$P_{pu}(n) = P_{u\omega}(n) - \frac{1}{2L+1}\sum_{i=-L}^{L} P_{u\omega}(n+i) \qquad (9)$$

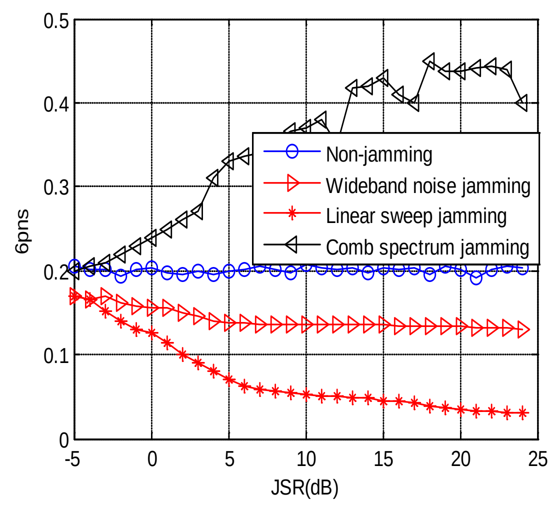

Fig.5 Relationship Between The σ_{pns} JSR And SNR

Among them, the second item in the right side of equation (9), represents the using of the moving average filter in the filtering process of $P_{u\omega}(n)$, therefore, $P_{u\omega}(n)$ represents the normalized power spectrum of the impulse portion, so it is the standard deviation of the normalized power spectrum impulse portion. In the Fig.5, the different

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values of σ_{pns} according to the different value of the JSR are give out. It can be seen from Fig.5, that the obvious difference between the broadband comb-like spectrum interference and a variety of other broadband interference are obtained.

4.5 Crest factor R_{m2m} on FRFT transform domain

First we make the fractional Fourier transform of the digital baseband signal, the transformed matrix $X(u_k, p)$ is obtained. Where p represents the different transform order, the value is changed from 0 to 2, and u_k represents the discrete values of the transform domain in different order of fractions; its length is the same as the analysis of the sequence length. And then calculate kurtosis of the each order of FRFT, and then kurtosis sequence of FRFT can be obtained.

$$K(p) = \frac{E\left\{X^4(u_k, p)\right\}}{\left\{E\left\{X^2(u_k, p)\right\}\right\}^2} \qquad (10)$$

R_{m2m} can be obtained through the following formula (11).

$$R_{m2m} = \frac{\max(K(p))}{\overline{K(p)}} \qquad (11)$$

Where $\overline{K(p)}$ represents the average value of the kurtosis sequence in transform domain, and the maximum value of $K(p)$ corresponds the order peak of the $p_{\max}$.

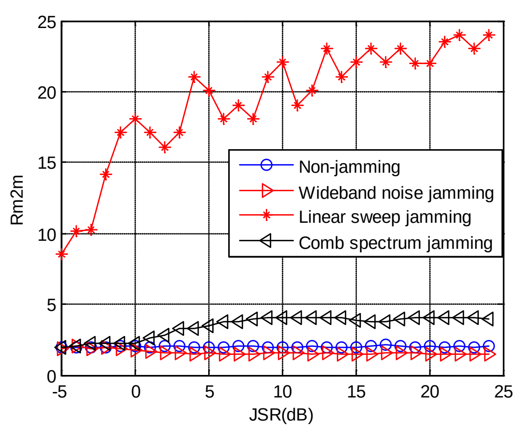

Fig.6 Diagram Of The Relationship Between R_{m2m} JSR, And SNR

Generally speaking, when the presence of narrowband interference or comb spectrum interference, the $X(u_k, p)$ will reach the kurtosis maximum value at $p \neq 1$, and the value of R_{m2m} is also smaller; while with the presence of line sweep interference , $X(u_k, p)$ will reach the kurtosis maximum value at $p \neq 1$, and value of R_{m2m} is large. In the Fig.6, the relationship between the R_{m2m} and the value change of the JSR, and SNR are given out. As can be seen from Fig.6, from the R_{m2m} , we can distinguish the existence of the broadband line sweep interference and other broadband interference.

5. IDENTIFICATION ALGORITHM AND SIMULATION

The interference pattern recognition is a pattern recognition problem. The analysis of the signal pattern recognition in the field of signal processing, generally includes a signal preprocessing, feature extraction and features comprehensive, as shown in Fig. 7.

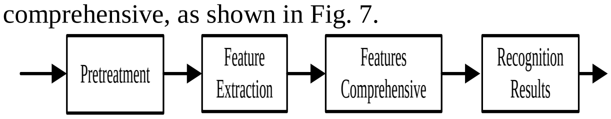

Fig.7 Block Diagram Of The Signal Pattern Recognition System

The task of the signal preprocessing turn the received signal into a suitable form, includes the frequency down-conversion, filtering, amplification, A / D conversion, etc, The main purpose of the feature extraction is using the small number of features and the classification error probability characteristics to describe the significant class differences in information mode. Obtaining the group of "fewer but better" classification feature, namely that obtaining the vector data set as small as possible in order to improve the efficiency of recognition and reduce the amount of calculation. The third step of the signal pattern recognition is the feature consolidation (classification identification), which are classified according to the rules of a classification judgment given by the eigenvectors represented an input mode to an appropriate mode categories, and then make the conversion from the feature space to the decision-making space, and ultimately make the realization of the classification and identification of the mode.

The characteristic function modules are to complete the pattern recognition algorithm, which is based on a certain type of classification and discrimination rules given by the eigenvectors, the input mode is categorized to the appropriate mode

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from the feature space to decision-making space mapping. And the classification and identification of the final completion of the model are realized. Therefore choosing the appropriate judgment rule, structure classification and identification are the important research content. A hierarchical decision classification algorithm based on statistical decision theory is very mature now, the main features of this classifier are a simple structure, most convenient, and therefore also are widely used in pattern recognition of engineering. So if we choose the better stability of feature vectors to determine the appropriate discrimination threshold and classification structure, good recognition performance can be obtained. Based on the analysis of the characteristic parameters above, in the paper, we adopt a hierarchical decision classification algorithm [5], and the automatic identification algorithm on parameters broadband interference mode is as shown in Fig.8.

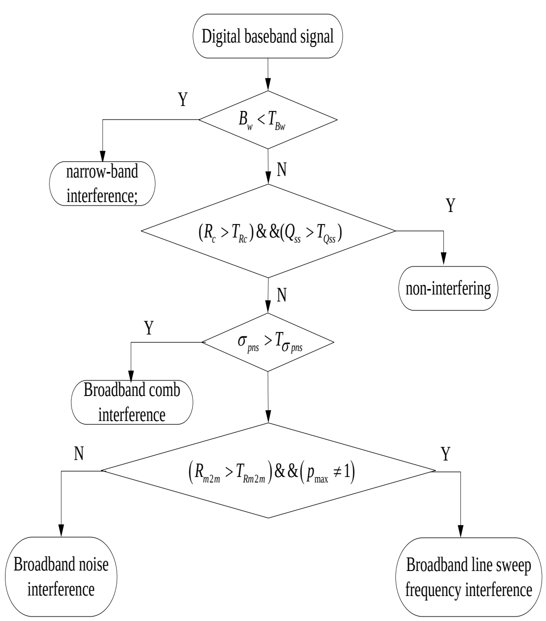

Fig.8 Recognition Of The Wideband Interference Pattern

According to the identification process showed in Fig.8, we make the following simulations. The direct sequence spread spectrum signal is generated through using the random sequence as a modulated signal source, modulation method is BPSK, the PN code is generated by the m-sequence and the length is 31, the information symbol rate is about 1Kbits/s, the IF frequency is 128KHz and the sampling frequency is1024KHz. Signal-to-noise ratio (SNR) is from -2dB to 15dB and is chosen arbitrarily. Jam-to-signal ratio (JSR) steps from-5dB to 25dB. Interference center frequency signal is based on the IF of the communication, and the deviation is within 6KHz. When the system generates the various kinds of interference and its parameters are selected from the list of parameters as shown in Table 1. Simulation length is 128 information symbols. The thresholds of $T_{B\omega}$, T_{Qss}, T_{Rc}, $T_{\sigma pns}$ and $T_{R_{m2m}}$ are 0.06, 0.95, 26, 0.16 and 2.6 ,respectively, which are obtained through 500 times independent simulations. The Fig.9 is probability of correct identification with various broadband interferences and the different values of JSR.

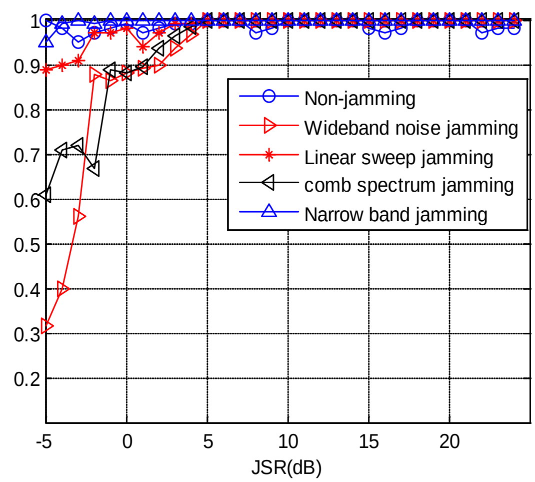

Fig.9 Recognition Rate With Different Jsr Under Broadband Interference

Table.1 Parameter In The Various Interference Simulations

types of interference		Interference parameters
Wide Band Noise	Cover bandwidth	Signal bandwidth ± 17 KHZ
Broadband line sweep	Cover bandwidth	Same broadband noise interference
	Sweep frequency	(2,4,8,16,32,64) x bandwidth
Broadband comb	Cover bandwidth	Same broadband noise interference
	Comb number	(4,5,6,8,10)
	Modulation mode	any of the Narrow band interference

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Narrow-band interference	Audio interference Modulation interference Keying interference	Tone (CW) (AM, FM) 2FSK,BPSK,QPSK, 2ASK,4FSK,4ASK

As it can be seen from the simulation results, when the JSR is greater than 0dB, the overall recognition rate is over 90%, and with good stability and robustness. When the JSR is less than 0dB, the main decision error occurs with the presence of broadband noise. As the DSSS signal spectrum has the same characteristics as white noise, so when the low power Gaussian noise is added, the effect on the spectral characteristics will be small, so when the JSR is very low, the broadband noise can be easily judged as non-interference situation. In practical applications, due to the anti-jamming ability of the spread spectrum system itself, so it actually requires high power of the interference in order to reach the expected effect, therefore the above algorithm has practical application value. The high recognition rate of the algorithm, the characteristic parameters of the algorithm are small, the process of identification is simple, and the using of fractional Fourier transforms to detect lines sweep interference, so the signal sampling requirements are greatly reduced.

6. CONCLUSIONS

Broadband oppressive interference is one of the serious threats of the direct-sequence spread-spectrum system. The identification and parameter estimation of broadband interference style targeted anti-jamming measures will provide a useful reference for the DS system. In the paper, through extracting the parameter values of the five characteristics of a fractional Fourier transform, we propose the hierarchical decision classification algorithm based broadband interference identification method, and give out the simulation results and related analysis. The simulation results show that this method has many advantages such as the high recognition rate, simplicity, short sampling length, good stability and robustness etc,. Through the method, we can effectively identify non-interference, narrowband interference, broadband noise, broadband comb spectrum interference and broadband lines sweeping Interference. And the narrowband interference can be made the further identification and classification through applying the modulation scheme of communication signal.

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