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An Improved Synchronization Acquisition Method of Fast Frequency Hopping Signal

Minghao Tian, Fang Liu and Yongxin Feng

School of Information Science and Engineering, Shenyang Ligong University, Shenyang 110159, China
tianlucky@163.com

Abstract

The synchronization technology is one of the key technologies in fast frequency hopping communication system. The performance of synchronous loop will directly affect the whole performance of the fast frequency hopping communication system. In view of the deficiency of synchronization time and synchronization anti-interference in the existing synchronization methods, an improved synchronization acquisition method is put forward, that is double judgment circular correlation method. The test results show that the improved synchronization acquisition method can effectively improve synchronization speed, increase synchronization anti-interference performance and reduce the complexity of synchronization loop.

Keywords*: Fast frequency hopping; Synchronization acquisition; Synchronous speed; Anti-interference; FFT*

1. Introduction

The fast frequency hopping communication system developed rapidly in fields such as satellite communication. The synchronization technology is very important in fast frequency hopping communication system. The quality of synchronization loop performance will directly affect the whole performance of the fast frequency hopping communication system [1-3]. The synchronization time and the anti-interference in the process of synchronization are the major factors to measure the effectiveness of the synchronized methods. The performance requirement of fast frequency hopping communication technology increases with the requirement of application system, and the existing fast frequency hopping signal synchronization method has been difficult to meet requirement. Therefore, it is significant to analyze the shortcomings and improve the existing synchronization methods [4-5].

The acquisition of synchronization information in fast frequency hopping signal is called coarse synchronization. Coarse synchronization is alignment process between the frequency hopping sequence generated locally and the received frequency hopping sequence in a frequency hopping interval. There are three traditional acquisition methods: serial acquisition, parallel acquisition and series-parallel combination acquisition.

In serial acquisition technology, the correlation calculation is calculated between the reference signal at the receiving end and the received signal. By calculating the correlation value within the given time and comparing whether it meet the requirements of system threshold, it will be determined whether the frequency hopping signal synchronization is successful. The synchronization time of this technology is longer, and the application is limited in some systems which have not much frequency points and require small size.

In the parallel acquisition technology, there are n band-pass filters in synchronization loop which process synchronous information. The synchronous information received by the receiving end is filtered through the n band-pass filters, then get sum and compare the

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result with the threshold value. If the result meets the threshold value set in synchronization loop, the frequency hopping signal synchronization is successful. This technology can continuously make correlation calculation, so the time is short for processing. This technology has the characteristics of frequency diversity and its anti-interference ability is remarkable. However, the synchronization loop needs more hardware, which causes the system volume to be relatively large [6-9].

The series-parallel combination acquisition technology combines the serial and parallel acquisition method, which divides the synchronization information into two parts: short sequence part and long sequence part. The short sequence part is captured by the parallel acquisition technology, and another part of long sequence is captured by serial acquisition technology. The parallel acquisition module completes the synchronization of frequency hopping signal at start time, and then controls the startup of serial acquisition module. This technology has advantages of testing reliability in serial acquisition method and fast speed in parallel acquisition method. However, in practice, the complexity of the system will increase and the cost is higher [10-12].

In view of the existing problems for the traditional synchronization acquisition methods: long synchronization time or high system complexity, a double judgment circular correlation method is put forward. This method can effectively improve synchronous speed and reduce the system complexity, which is based on the existing serial sliding correlation synchronization method and adopts fast Fourier transform.

2. An Improved Synchronization Acquisition Method

The existing serial sliding correlation belongs to linear correlation. In the improved acquisition method, the fast Fourier transform is adopted to calculate correlation value between local signal and received signal, which is in the form of circular correlation to replace the original linear correlation. Contrasting circular correlation with linear correlation, the rate of synchronous calculation will increase significantly, so as to make the system synchronization time reduce greatly, and better meet the requirements of the system synchronization time.

In the improved method, a double judgment circular correlator is introduced, which includes two circular correlation deciders to judge correlation results. There will be a lot of times that the state is not synchronized judged by calculation result when correlator begins correlation calculation in synchronization loop, because only one correct phase can be judged synchronization in the synchronization information sequence, and other phases are not synchronization phase. This will cause many times excrescent correlation calculation in the synchronization loop. In order to shorten the average synchronization time, a double judgment circular correlation method is put forward. Firstly, use a short part of synchronization information to calculate circular correlation value, which need short time, and then put the result into decider T1 to judge. If the result is greater than the preset threshold, the judgement is pre-synchronization. Secondly, use the whole synchronous information to calculate circular correlation value, and then put the result into decider to judge. The judgement is synchronization until all the outputs of deciders are greater than the corresponding threshold. Among them, the first circular correlation decider T1 only provides a rough valuation of the spread spectrum code sequence, through which to determine whether to need to adjust the local signal phase deviation; On this basis, according to the result of correlation calculation, the second circular correlation decider T2 judge whether the acquisition is successful and whether step into the synchronous tracking loop. The Figure 1 shows the flow chart of the double judgment circular correlation acquisition method.

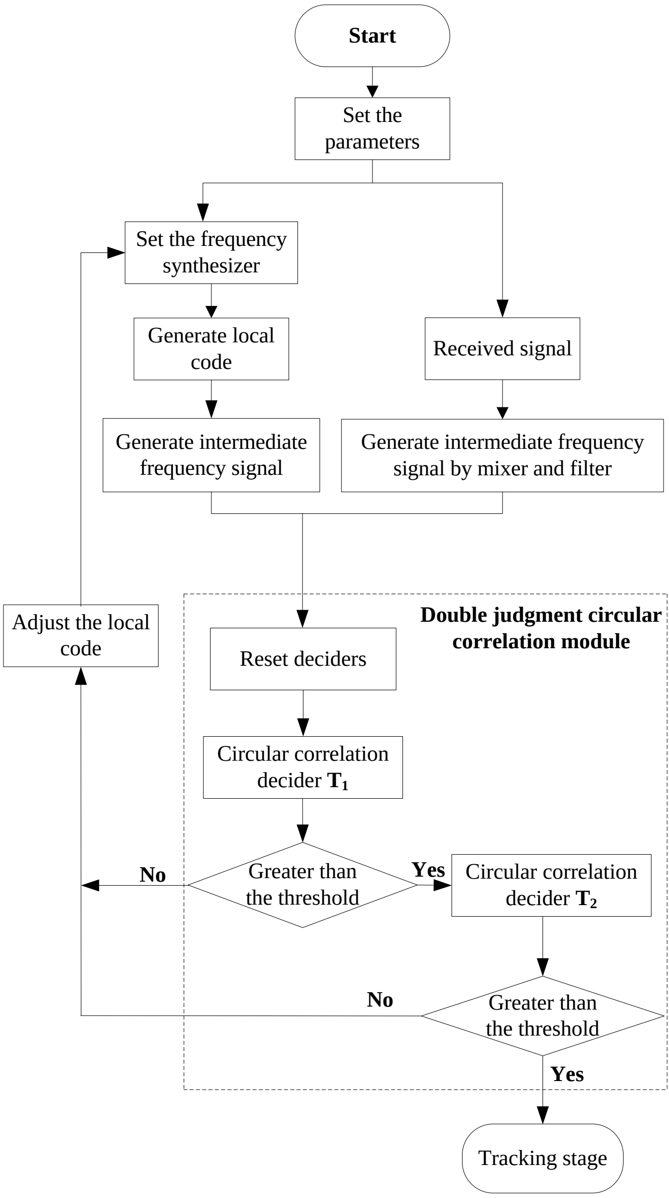

Figure 1. Flow Chart of Double Judgment Circular Correlation Acquisition Method

For double judgment circular correlation acquisition method, the specific steps are:

Step1: sets the parameters of the signal receiving end before acquisition stage begins. According to frequency of the received frequency hopping signal, the receiving end controls the frequency synthesizer to generate corresponding local carrier frequency;

Step2: the receiving end generates corresponding local pseudo random code, mixes with the local carrier frequency, and generates local intermediate frequency signal. At the same time, the received signal is processed by mixer and filter to generate intermediate frequency signal;

Step3: sets the ratio peak thresholds of two circular correlation deciders in the double judgment circular correlation module;

Step4: inputs the local intermediate frequency signal and received intermediate frequency signal into double judgment circular correlation module;

Step5: calculates circular correlation between a section of local signal and a section of received signal, then inputs the ratio peak value into the first circular correlation decider

T1. Judge whether the ratio peak value is greater than the threshold. If the ratio peak value is less than the threshold, adjusts the local code clock frequency and then repeat the step;

Step6: If the ratio peak value is greater than the threshold, calculates circular correlation of all synchronization information codes, and then inputs the ratio peak value into the circular correlation decider T2. Judge whether the ratio peak value is greater than the threshold. If the ratio peak value is greater than the threshold, judge synchronization acquisition is successful and then step into tracking stage, which means the ratio peak value meets the requirement of the threshold. Otherwise, adjusts the deviation of local signal phase, and then repeats the step 5.

3. Simulation and Performance Analysis

Simulation is carried out in the MATLAB platform. In simulation, the specific parameters settings of fast frequency hopping signal are: the speed of leading sequence is 8 MBPS, the sampling frequency is 8GHZ, the number of frequency hopping point is 100 within the band of 1GHZ~2GHZ, and the speed of carrier frequency jump is 16000 hops/s. The center frequency of carrier wave is controlled by frequency control word. According to the speed of pseudo random sequence, the sampling frequency and the speed of carrier frequency jump, the number of sampling every hop points is 500000. The signal modulation method adopts BPSK modulation and the signal amplitude of the carrier wave is set to 1.

After the fast frequency hopping signal enters the receiving end from transmission channel, the receiving end begins the signal synchronization acquisition stage. In signal acquisition loop, first of all to determine the frequency of fast frequency hopping signal by searching frequency, and then carries on the double judgment circular correlation acquisition. The sliding energy accumulation of leading sequence is stored in form of ratio peak (the ratio of the maximum peak and the average peak), which will be used in the double threshold decision. In this system, the ratio peak threshold is set to 7. When the first circular correlation decider T1 works, it judges whether the ratio peak value is greater than 7 and then selects an operation. If the ratio peak value is less than 7, the local code clock frequency need be adjusted and then correlation calculation need be repeated. Otherwise, the circular correlation of all synchronization information codes is calculated, and then the ratio peak value inputs into the circular correlation decider T2, which judges whether the ratio peak value is greater than 7 and then selects an operation. If the ratio peak value is greater than 7, the receiving end steps into tracking stage, which means the ratio peak value meets the requirement of the threshold. Otherwise, the deviation of local signal phase need be adjusted, and then correlation calculation need be repeated.

3.1. Analysis of Synchronization Acquisition Time

The acquisition time of serial sliding correlation method and improved method are showed in Table 1.

Table 1. Acquisition Time of Serial Sliding Correlation Method and Improved Method

Method / *Sequence*	*Sliding correlation method*	*Improved method*
1	8.055251s	*0.641951s*
2	7.825461s	*0.668547s*
3	8.124736s	*0.643854s*
4	8.095467s	*0.623584s*
5	7.945728s	*0.611578s*
6	7.942168s	*0.619658s*
7	7.869784s	*0.623698s*
8	8.054286s	*0.635847s*
9	8.084679s	*0.627455s*
10	8.102548s	*0.652147s*
Average	*8.010011s*	*0.634832s*

As seen in Table 1, the average runtime of the serial sliding correlation method exceeds ten times of that improved method costs. Therefore, the double judgment circular correlation method is faster than the serial sliding correlation method, and its performance is superior.

3.2. Influence Analysis of Channel Interference Ratio to Synchronization Methods

When communication signal is interfered by interference signal effectively, the relativity between the received signal and the local signal will be impacted significantly. With the increase of interference signal energy, the impact on the correlation peak value will be more and more obvious. The phenomenon is the correlation peak value decreases gradually.

Two different synchronization methods are tested respectively under different channel interference ratio. The specific test method is to test interference to signal ratio that conduced to acquisition failure under different channel interference ratio. The test is carried on in the MATLAB simulation platform, and the test results are showed in Table 2.

As seen in Table 2, the change trend of interference to signal ratio that conduced to acquisition failure is similar between serial sliding correlation method and improved method under different channel interference ratio. When the channel interference coefficient is 0.6, the interference to signal ratio is lower, which means anti-jamming capability is relatively weak at this situation. When the channel interference coefficient is same, interference to signal ratio that conduced to acquisition failure for improved method is greater than that of the serial sliding correlation method about 2 db. As a result, the simulation data shows that fast frequency hopping system has better anti-interference performance, which adopts the double judgment circular correlation synchronization method.

Table 2. Anti-Interference Test of Two Synchronization Methods under Channel Interference Ratio

Interference coefficient \ *Method*	*Sliding correlation method*	*Improved method*
	J/S_{false} (dB)	J/S_{false} (dB)
0.1	9.11	11.50
0.2	8.67	11.42
0.3	8.28	10.77
0.4	6.48	8.95
0.5	6.72	8.96
0.6	6.68	8.38
0.7	7.86	10.13
0.8	9.53	11.50
0.9	8.12	10.93
1.0	10.48	12.77

3.3. Influence Analysis of Different Interference Signal to Synchronized Methods

The two different synchronization methods are tested by joining respectively broadband interference signal, partial frequency band interference signal and pectinate interference signal in the transmission channel.

(1) Influence of broadband interference signal to synchronization acquisition loop

When the interference is broadband interference, the influence of different interference signal to synchronization acquisition loop is showed in Figure 2. Along with the increase of interference to signal ratio, the acquisition ratio peak value are both gradually reduced for serial sliding correlation acquisition method and improved method. Under the influence of broadband interference signal, when the synchronization loop adopts the serial sliding correlation method and the interference to signal ratio increased to 27.44 dB, the ratio peak value can't meet the requirement of the threshold, which means acquisition fails. However, if the improved method is adopted, the acquisition is still successful until the interference to signal ratio increased to 29.77 dB.

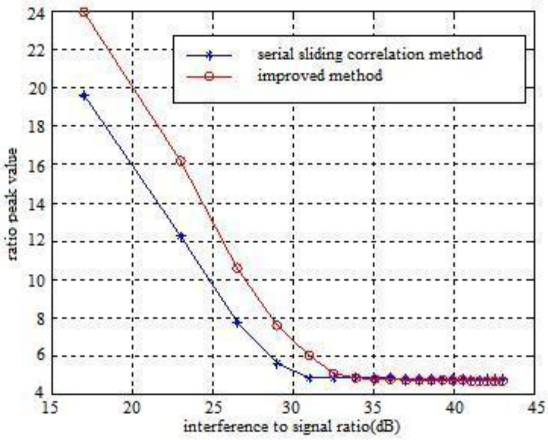

Figure 2. The Ratio Peak Value under Broadband Interference

(2)Influence of partial frequency band interference signal to synchronization acquisition loop

When the interference is partial frequency band interference, the influence of different interference signal to synchronization acquisition loop is showed in Figure 3. Along with the increase of interference to signal ratio, the acquisition ratio peak value are both gradually reduced for serial sliding correlation acquisition method and improved method. Under the influence of partial frequency band interference signal, when the synchronization loop adopts the serial sliding correlation method and the interference to signal ratio increased to 6.29 dB, the ratio peak value can't meet the requirement of the threshold, which means acquisition fails. However, if the improved method is adopted, the acquisition is still successful until the interference to signal ratio increased to 9.06 dB.

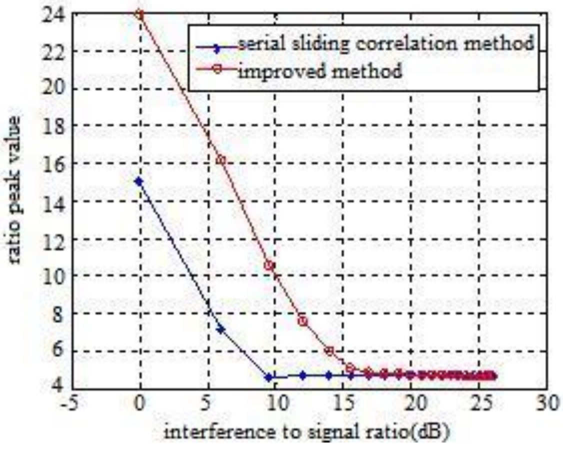

Figure 3. The Ratio Peak Value under Partial Frequency Band Interference

(3) Influence of pectinate interference signal to synchronization acquisition loop

When the interference is pectinate interference, the influence of different interference signal to synchronization acquisition loop is showed in Figure 4. Along with the increase of interference to signal ratio, the acquisition ratio peak value are both gradually reduced for serial sliding correlation acquisition method and improved method. Under the influence of partial frequency band interference signal, when the synchronization loop adopts the serial sliding correlation method and the interference to signal ratio increased to 10.48dB, the ratio peak value can't meet the requirement of the threshold, which means acquisition fails. However, if the improved method is adopted, the acquisition is still successful until the interference to signal ratio increased to 12.78dB.

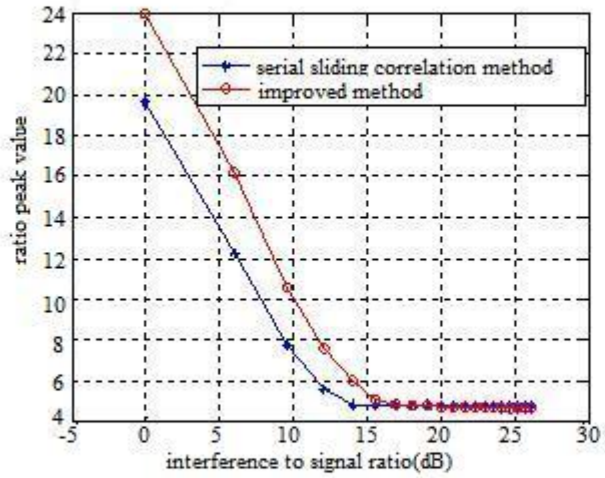

Figure 4. The Ratio Peak Value under Pectinate Interference

The simulation results show that, compared with the existing serial sliding correlation acquisition method, the improved method has better anti-interference performance.

4. Conclusions

An improved synchronization method is put forward: double judgment circular correlation method. Compared with the traditional synchronization method, the double judgment circular correlation synchronization method can improve synchronization speed, increase synchronization anti-interference performance and reduce the complexity of synchronization loop. The simulation data validates the advantages of the improved synchronization method, which provides the basis for the improvement of the performance to fast frequency hopping frequency synchronization loop in future.

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Authors

Minghao Tian, He received the PhD from Nanjing University of Science and Technology in 2008. He is an associate Professor in the School of Information Science and Engineering in Shenyang ligong University. His research interests include spread spectrum communication, frequency hopping communication and signal processing.

Fang Liu, She received the PhD from Nanjing University of Science and Technology in 2010. She is an associate Professor in the School of Information Science and Engineering in Shenyang ligong University. His research interests include spread spectrum communication and frequency hopping communication.

Yongxin Feng, She received the PhD from Northeastern University in 2003. She is a Professor in the School of Information Science and Engineering in Shenyang ligong University. His research interests include spread spectrum communication and frequency hopping communication.

