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Research on Synchronization Technology of Frequency Hopping Communication System

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Abstract. Frequency Hopping (FH) communication is a technology of spread spectrum communication. It has strong anti-interference, anti-interception and security capabilities, and has been widely applied in the field of communications. Synchronization technology is one of the most crucial technologies in frequency hopping communication. The speed of synchronization establishment and the reliability of synchronous system directly affect the performance of frequency hopping communication system. Therefore, the research of synchronization technology in frequency hopping communication has important value.

Key words: Frequency hopping communication; anti-jamming; synchronization technology.

INTRODUCTION

Spread spectrum communication means that the spectrum of input information is expanded to become a wide band signal by a specific function, through the channel transmission, and then get the transmitting information of communication system [1]. The bandwidth of the spread spectrum is much larger than the input bandwidth, and the signal is more difficult to be jammed. It has been widely applied to military and civilian communications. Frequency hopping (FH) communication is a communication mode that changes the carrier frequency of both the transmitting and receiving signals according to the predetermined rules. Compared with the conventional communication methods, FH communication can effectively avoid interference and improve the communication quality by hopping the information frequency within the specified bandwidth [2]. Compared with conventional fixed frequency communication, FH communication has been widely applied in modern military communication because of its outstanding

Anti- interference and interception capability, which can ensure the concealment and reliability of communication. In addition, FH communication can effectively combat the multipath interference that is caused by signal fading and signal delay. Therefore, FH technology is also used in the field of civil communications such as Global System for Mobile Communication (GSM), Wireless Local Area Networks (WLAN), satellite communications, Bluetooth, and radar.

FREQUENCY HOPPING SYNCHRONIZATION METHOD

Synchronization technology is one of the most crucial technologies in frequency hopping communication. Only FH communication can be synchronized, both sides of the communication can carry out normal information transmission. The performance of the frequency hopping system is directly affected by synchronization. The synchronization process of frequency hopping system can be divided into two stages: acquisition synchronization and tracking synchronization.

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During the communication of frequency hopping system, the synchronization system is working all the time. The frequency hopping synchronization state is detected and the phase error is adjusted. Once the out of synchronization is found, it will immediately turn into the synchronization acquisition state and quickly establish the new synchronization. The diagram is shown in Fig. 1

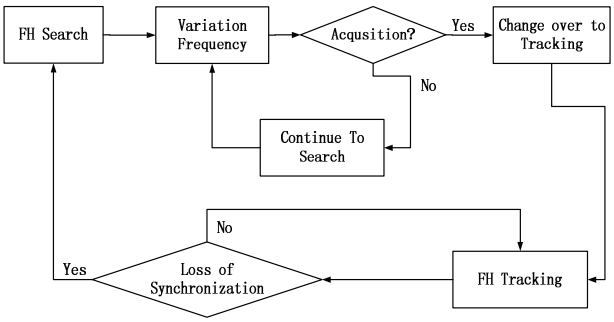

FIGURE 1. The basic flow diagram of the synchronization process in the frequency hopping communication.

At present, the commonly used synchronization methods are mainly divided into two categories: self-synchronization method and external synchronization method. The self-synchronization method is synchronized by inserting synchronized information in the transmitted information, while the external synchronization methods include the reference clock method and the synchronization prefix method [3].

The Reference Clock Method

The reference clock method is a method of synchronization by assigning a common time-base to the communication network and using the common time-base to realize synchronization. By assigning time-base of high precision, the communication nodes in the network can use the same clock and the common time-base to control the local frequency, so that the synchronization between nodes can be realized. The reference clock method can achieve fast synchronization, but it requires high accuracy and stability of the clock. The most commonly used time-base is GPS.

The Synchronization Prefix Method

The synchronization prefix method is a method which communication parties realize synchronization by the information in the prefix. Synchronization prefix refers to a sequence that contains the generated hopping sequence information. The receiver uses the synchronization information that is extracted from the received signal to adjust the local pseudo-random code generator. And then the synchronization process is realized. The advantage of the synchronous prefix method is that it can realize fast synchronization and has simple structure. The disadvantage is that the anti-interference and concealment of synchronization prefix are poor.

The Self-Synchronization Method

The self-synchronization method is a method of realizing synchronization that the discrete information is inserted in the frequency hopping signal and the receiver adjusts the parameters such as frequency by extracting information. The advantage of the self-synchronization method is that the synchronization information is hidden and is not easy to be interfered. Because it does not need to send synchronization information independently, the communication efficiency can be improved. But the synchronization time is longer which is not suitable for systems with wide bandwidth or fast frequency hopping.

THE ACQUISITION SCHEME OF FREQUENCY HOPPING SYNCHRONIZATION

The Serial Acquisition Scheme

The frequency output of the local dds has exactly the same rule of the frequency jump of the transmitter. Then the frequency is mixed. According to the output of the envelope detector ,we can judge the frequency hopping point of the transmitter and receiver, the same as "1"and the difference is "0".Finally, the judgement results of a frequency hopping cycle are added ,and the search instructions are controlled according to the judgement results. If the output of the counter exceeds a predetermined threshold value, it is considered that the acquisition process is successful and frequency hopping communication enters the tracking state. If the output of the counter is lower than the threshold value, the frequency jump rule of the local frequency synthesizer is different from the sender. The local frequency hopping sequence is phased through the search instruction, which usually phase shift 1/2 frequency gapping until the acquisition is successful, as shown in Fig.2.

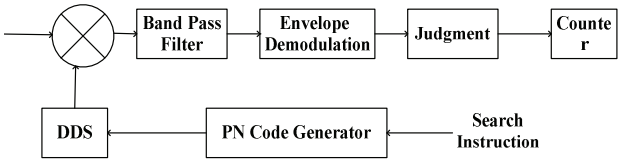

FIGURE 2. The schematic diagram of the serial acquisition scheme

The Parallel Acquisition Scheme

The length of frequency hopping sequence cycle is L, so there are L band- pass filters corresponding to each hopping frequency point of frequency hopping system. The center frequency of the band-pass filters is controlled by the local search controller. The output signal of the matched filters is delayed and the cumulative result is judged. If each center frequency of matched filters in the L frequency gappings is corresponding to the frequency of the transmitter. The predetermined threshold value will be exceeded by the accumulated value. The synchronization acquisition is successful, otherwise continuing to control the center frequency of each matched filter until the acquisition is completed. The schematic diagram is shown in Fig. 3.

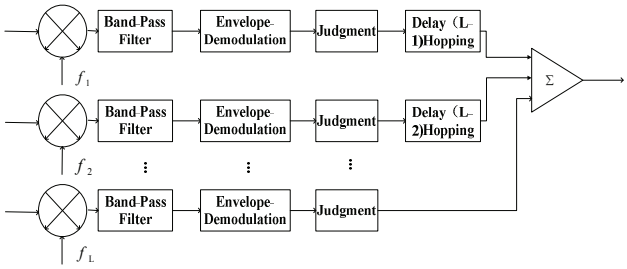

FIGURE 3. The schematic diagram of the parallel acquisition scheme

The Waiting Acquisition Scheme

Frequency hopping sequence generator of receiver and transmitter has the same frequency hopping sequence. The frequency in the frequency table between receiver and transmitter is different from a fixed intermediate frequency. The receiver FH sequence generator is set in a predetermined state, and the frequency synthesizer output a fixed frequency. When the corresponding frequency hopping signal in the waiting transmitter is searched, the two frequencies of receiver and frequency synthesizer are conducted correlation operation in the correlator and we will receive a fixed frequency. Finally, a synchronization acquisition signal is obtained after envelope detection. When it is larger than the synchronous acquisition threshold, a clock pulse is released and trigger the frequency hopping

sequence generator which makes the local frequency synthesizer output the frequency hopping signal .If the received frequency hopping signal does not correspond, the frequency hopping sequence generator keeps the original output state and the frequency synthesizer continues to wait. The schematic diagram of waiting acquisition scheme is shown in Fig. 4.

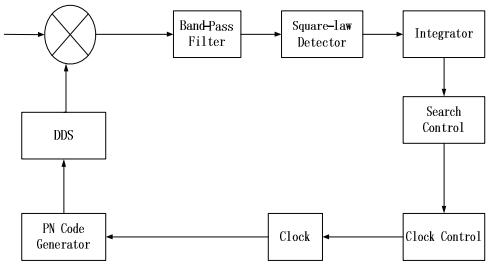

FIGURE 4. The schematic diagram of the waiting acquisition scheme

THE TRACKING SCHEME OF FREQUENCY HOPPING SYNCHRONIZATION

Synchronization tracking means that the time error between the transmission FH sequence and the local FH sequence is further reduced after synchronization acquisition, so that it is precisely aligned with the synchronization. The synchronization tracking process of frequency hopping is usually accomplished by phase-locked loop [4]. The error feedback loop makes the receiving frequency hopping sequence keep the precise alignment with the local frequency hopping sequence.

In the process of frequency hopping sequence tracking, the single frequency hopping period is divided into two parts, and the spectrum energy values of the two parts are calculated respectively. When the received signal is completely synchronized with the local frequency hopping sequence, the signal is constant envelope. In other words, the energy of the two halves of the signal in one hop period is equal, and the difference between the two parts is 0. When the received frequency hopping signal leads the local frequency hopping sequence, the signal has higher energy in the first half of the hop period. When the received frequency hopping signal lags behind the local frequency hopping sequence, the energy of latter part is higher than the first half of the energy. Therefore, the frequency spectrum difference between the two parts will show a linear relationship with the time difference. The time difference can be calculated by the maximum likelihood criterion, and accurate synchronization will be realized. Finally, the synchronization tracking process is completed, as shown in Fig. 5

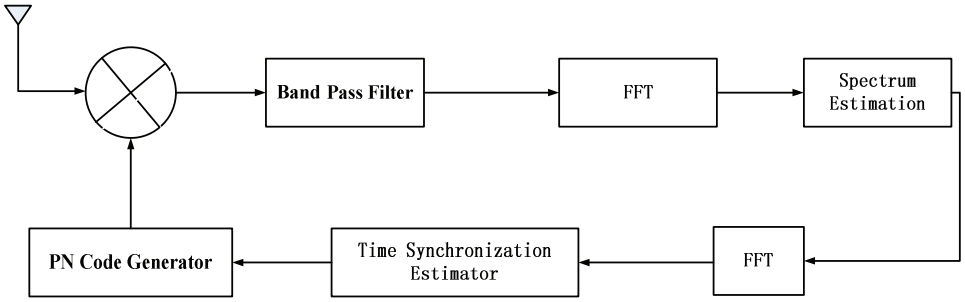

FIGURE5. The schematic diagram of frequency hopping synchronization tracking

The Delay-Locked Loop Scheme

The PN code sequence generator in the loop controls the frequency synthesizer that generates the frequency ahead of the received FH signal frequency and the frequency later than the received FH signal frequency. The signals of the two branches are processed by a band-pass filter and a square-law detector respectively, and obtain the voltage

difference between the early branch and the late branch. The error signal is used to control the VCO that adjusts the local clock to complete the synchronization tracing [5-7].The schematic diagram is shown in Fig. 6

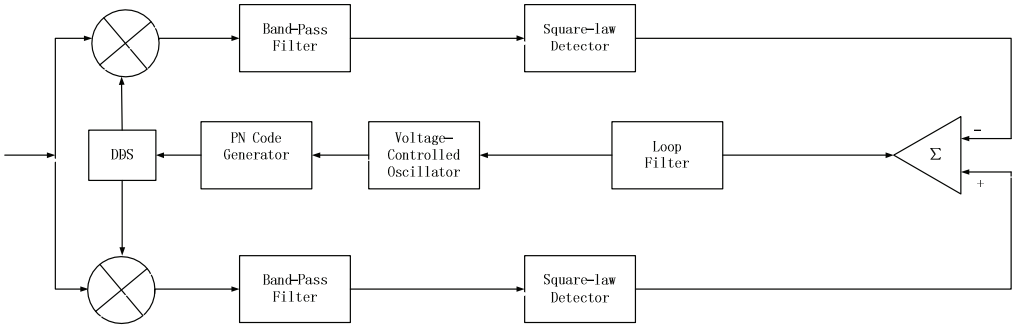

FIGURE 6. The schematic diagram of delay-locked loop scheme

The Tau-Dither Loop Scheme

The clock that controls the local frequency hopping sequence jitters in a very small amplitude τ , τ generally takes as a fraction of the hop period length, and the local frequency hopping sequence is moved forward or backward by the jitter of the clock to achieve synchronization, as shown in Fig. 7

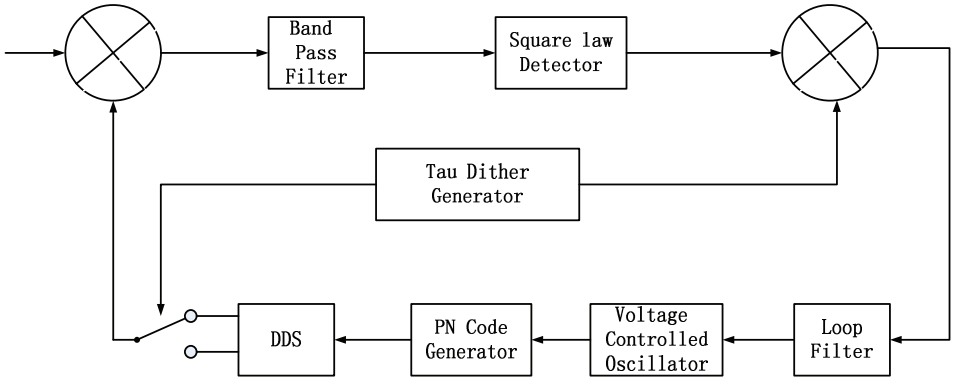

FIGURE 7. The schematic diagram of tau-dither loop scheme

The Comparison of Two Kinds of Phase-Locked Loops

The synchronous tracking principle of delay-locked loop and tau-dither loop scheme is very similar. All use the early and late branch to generate error signals, but the methods of generating the error signal are different. Two unrelated correlators are needed to calculate the error signals in the DLL. The tau-dither loop uses only one correlator to detect the error signal.

CONCLUSION

This paper is about the study of the strategy of synchronization process. In other words, the topic is in which condition the hopping frequency in the receiver and transmitter can be identified.From the theoretical point of view, the more uniform frequency between the transmitter and the receiver, the more probability that the process can be accurately judged that the frequency has been synchronized.This paper focuses on the analysis and comparison of the

different frequency hopping synchronization methods.Synchronization has been a difficult and hot issue in frequency hopping communication systems,and the frequency hopping is moving in the direction of a higher jumping speed.

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