Study of an Application of Hybrid Spread Spectrum Technology in Satellite Communication

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***Abstract*—This study is aiming at the application of DS (Direct Sequence)/FFH (Fast Frequency Hopping) hybrid spread spectrum technology in satellite communications. A system model was established and key technologies were analyzed. The DS/FFH synchronization of hybrid spread-spectrum satellite communication system includes two stages, such as acquisition and tracking. In the acquisition stage, the acquisition is based on the parallel waiting through PMF-FFT structure, which can achieve rapid acquisition; in the tracking stage, through the carrier phase lock loop and the pseudo code tracking loop, the accurate alignment of the carrier phase of the received signal and the phase of the direct spread pseudo code is realized respectively. Due to the group delay distortion the carrier phase is no longer continuous, which affects the reception synchronization. This paper proposes group delay equalization for the channel through the analysis of four type of group delay and corresponding cause in the signal transmission process. Finally, comparisons analysis of the anti-interference performance of the system under the conditions of broadband, narrowband, multi-frequency and partial frequency band interference is performed through simulation. The results can provide certain guiding significance for the system anti-interference design and engineering implementation.**

Keywords—DS/FFH hybrid spread spectrum; anti-interference; synchronization; equalization

I INTRODUCTION

Direct sequence spread spectrum (DSSS) has many features such as low spectral density, anti-interception, anti-multipath, and easy implementation of code division multiple access. However, system communication performance or terminal communication may be interfered by narrow-band signals with over-capacity threshold

Fast frequency hopping (FFH) has the characteristics of high frequency hopping rate, wide bandwidth, multiple frequency points, etc. It can resist many kinds of interference such as narrowband interference, tracking and forwarding interference, but it does not have the spreading processing gain of DSSS system[1].

Then the DS / FFH system is a hybrid system that adds carrier frequency hopping to the direct sequence spread spectrum system. Compared with DS and FFH, DS / FFH hybrid spread-spectrum system has stronger anti-interference, anti-fading, anti-interception ability and better multi-access networking performance, is a most typical anti-interference communication system[2 . Therefore, in the field of military communications, the original direct sequence spread spectrum method can be replaced by DS / FFH hybrid spread spectrum technology, which adapts to the harsher electromagnetic environment[3].

II SYSTEM MODEL

The process of DS/FFH hybrid spread spectrum is shown as Figure 1. After encoding the data group, the data is directly spreaded. Then the BPSK modulation of the spread spectrum signal is performed. Finally the modulated signal is up-converted to the frequency hopping carrier.

Since the FFH frequency hopping method is adopted, the information rate R_c is lower than frequency hopping rate Rh. After DS/FFH hybrid spread spectrum, the wider bandwidth of the signal and the larger gain of spread spectrum is obtained, which enhances the anti-interference ability of the signal. At the receiving terminal, the signal is first down-converted by the radio frequency channel and de-hopped. Then BPSK demodulation and de-spreaded is performed. Finally the source information is obtained by decoding. During the transmission and reception process, due to the pseudo-randomness and confidentiality of the direct spreading sequence and the frequency hopping pattern, the transmission signal is difficult to be intercepted by non-cooperative parties.

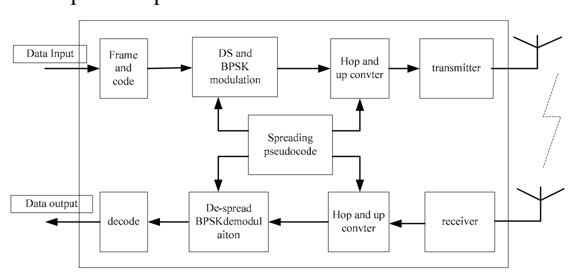

Figure 1 The structure of DS/FFH hybrid spread spectrum system

A. Signal form

After the DS/FFH hybrid spread spectrum signal is transmitted through the channel and down-converted by the receiver, the intermediate frequency signal can be expressed as Equation 1.

$$r(n) = AC(n)\cos(2\pi f_i n + \varphi_i + \theta_{0,\pi}) + N(n)$$

$$\theta_{0,\pi}\begin{cases} = 0, & \text{if } d(n) = 1 \\ = \pi, & \text{if } d(n) = 0 \end{cases} \qquad (1)$$

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DOI 10.1109/CISCE50729.2020.00016

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Where A is the signal amplitude, d(n) is the information R_b is the information rate C(n) is the DSSS sequence; Rc is the pseudo code rate; f_i is the carrier frequency; φ_i is the corresponding frequency-hopping carrier phase, where the i-th hop and the i+1-th hop are continuous; θ0, π are the information BPSK modulation phase; N(n) is the channel noise. Since $R_c<R_h$, the symbol d(n) at the moment is transmitted by R_h/R_c frequency sets, and the frequency set at that moment is determined by the frequency hopping pattern.

The direct-spreading sequence C(n) and the frequency-hopping pattern fi in formula (1) are used for signal mixing spread-spectrum modulation and synchronous reception. The direct-spreading sequence generates long-period pseudo codes by means of nonlinear composite pseudorandom codes, frequency hopping. Meanwhile the frequency hopping pattern is a frequency-hopping sequence generated by chaotic pick-point storage that meets the system cycle length.

B. The effect of Doppler on the signal reception of DS/FFH hybrid spread spectrum system

1) The effect of Doppler on carrier tracking

In the DS/FFH hybrid spread spectrum communication system, due to the relative movement, between the transmission and receiving terminals, and continuous jump of the carrier the carrier frequency, the carrier Doppler frequency is constantly jumping, which makes it difficult to track the carrier frequency. Therefore, it is necessary to perform frequency compensation correction in the carrier tracking module according to the tracking result of the frequency hopping pattern, which can reduce the impact of Doppler frequency deviation hopping on carrier tracking

According to the Doppler expression, the relationship between the Doppler frequency shift in the i-th frequency hopping gap and the Doppler frequency shift in the i−1th is shown in Equation 2

$$f_d(v_i,i)=\frac{v_i f_{li}}{v_{i-1} f_{l(i-1)}} f_d(v_{i-1},i-1) \tag{2}$$

Near the carrier frequency hopping point, the relative movement rate v of the transceiver can be considered to be constant; therefore the relationship between the Doppler frequency shift before and after the frequency jump can be expressed by Equation 3 and Equation 4.

$$f_d(i)=k_i f_d(i-1) \tag{3}$$

$$k_i=f_{li}/f_{li-1} \tag{4}$$

Therefore, according to the tracking result of the frequency hopping pattern, the carrier frequency ratio k_i of the adjacent frequency hopping gap is calculated as the correction factor of the carrier tracking at the frequency hopping point, then the hopping variable of the Doppler frequency shift can be reduced and the carrier tracking reliability can be increased.

2) The effect of Doppler on pseudo code tracking

In the case of high dynamics, the carrier Doppler frequency deviation will cause the expansion or contraction of the pseudo code chip, which is called the pseudo code Doppler. In frequency hopping systems, due to carrier Doppler hopping, pseudo code Doppler hopping is caused, which affects the accurate tracking of pseudo code.

In the case of carrier Doppler frequency shift, the rate of the direct spread pseudo code can be expressed by Equation 5

$$R=(1+f_d/f_l)R_0 \tag{5}$$

Where f_l is carrier frequency, $R_0$is Pseudo-code rate without Doppler.

When the Doppler frequency shift is not large, the impact of the increase variable Δ of the direct spread pseudo code rate which is expressed in equation 6 on tracking can be ignored.

In a highly dynamic environment, the effect of this increment on tracking can reduce the ranging accuracy below the target. In order to ensure good tracking of the pseudo code, carrier assist technology, which feeds back the pseudo code delay offset caused by the Doppler frequency shift within the pseudo code loop update interval to the pseudo code NCO, can compensate the pseudo code Doppler influence.

$$\Delta= R_0 f_d/f_l \tag{6}$$

C. The effect of group delay on signal reception

Because the carrier frequency of the DS/FFH hybrid spread spectrum signal keeps hopping, it will occupy a wider RF bandwidth. However, channel equipment and wireless propagation links (mainly the ionosphere) are difficult to guarantee linear transmission under broadband conditions, and the time delays of different frequency signals received by the receiver are different, which results in group delay of the DS/FFH hybrid spread spectrum signal distortion.

In the DS/FFH hybrid spread spectrum communication system, the factors that cause the group delay distortion include two aspects.

1) the inconsistent group delays of channel devices

Due to the hopping of the carrier frequency, a wider RF bandwidth is required. However, it is difficult for channel devices to guarantee linear transmission under broadband conditions. Then signals at different frequency points have different delays through the measurement device. The value of the group delay distortion is related to the carrier center frequency, frequency hopping bandwidth, and the group delay characteristics of the channel device in the operating frequency band

2) The inconsistent group delay of the signal propagation path

The inconsistent group delay of the signal propagation path is mainly the influence of the ionosphere on the transmitted signal. The number of ions and electrons in the ionosphere is large enough to affect the propagation of radio waves, which will have a delay effect on the propagation of electromagnetic wave signals on the satellite-ground link. The additional propagation delay introduced is calculated in Equation 7

$$\Delta t=\frac{40.3}{cf^2}TEC \tag{7}$$

Where c is the speed of light; f is the frequency of the propagating signal; TEC is the total electron content of the ionosphere, and its unit is TECU=1×1016el/m2. It can be seen from equation (7) that the group delay of the signal passing through the ionosphere is inversely proportional to

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the square of the signal frequency, and the delay of signals passing through the ionosphere at different frequencies is different

Based on the above analysis, the group delay distortion makes the carrier phase no longer continuous and affects the reception synchronization. Therefore, group delay equalization should be performed on the channels so that the group delay of each channel tends to the same value

III RECEIVING SYNCHRONIZATION TECHNOLOGY IN DS/FFH HYBRID SPREAD SPECTRUM

DS/FFH hybrid spread spectrum has become the main anti-jamming technology in the field of communication, but high-speed, long-distance mobile communication targets have problems such as high Doppler frequency, large Doppler frequency change rate and strong link interference, which makes DS/FFH It is difficult for the hybrid spread spectrum system to receive signals.

In the DS/FFH hybrid spread spectrum system, the premise of correct signal reception is synchronization, including direct spread synchronization and frequency hopping synchronization, where direct spread synchronization refers to the same phase of the direct spreading code and the same carrier frequency; and frequency hopping synchronization refers that frequency hopping sequence, the frequency hopping pattern, and the start and end moments of the hopping are the same between the transmitter and transceiver terminals. Synchronization is divided into two stages, acquisition and tracking. The goal of DS/FFH hybrid spread spectrum system acquisition is that the phase difference between the spreading codes at the receiving and transmitting ends is within $T_c/2$; tracking refers to continuously adjusting the difference between the spreading codes at the receiving and sending ends until it reaches zero.

A. Acquisition

In the DS/FFH hybrid spread spectrum system, the acquisition method is PMF-FFT based on the parallel, and the principle is shown in Figure 2

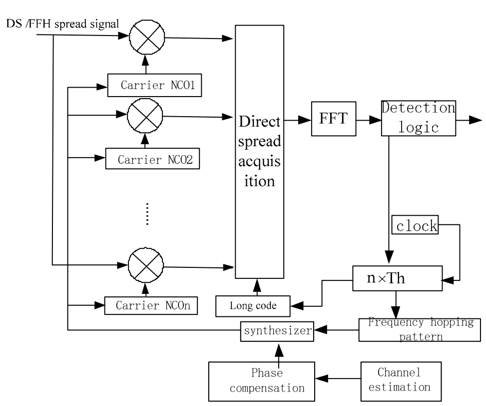


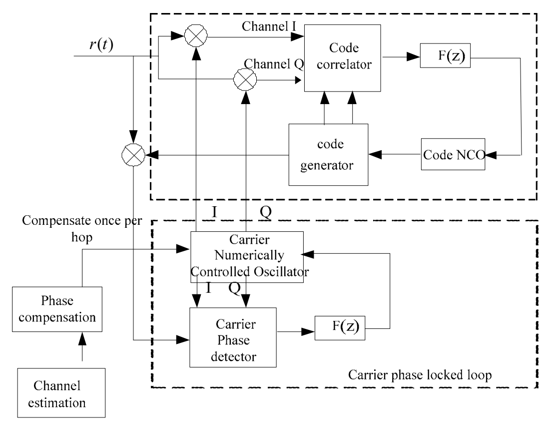
Figure 2 Block diagram of PMF-FFT acquisition based on parallel waiting

At the receiver, down conversion of the frequency-hopping digital is completed first. Then the signal is multiplied by the local pseudo code (when acquiring the signal, the local carrier frequency takes the nominal intermediate frequency, and the local pseudo code rate takes the nominal pseudo code rate). Finally, the signal is sent to the buffer after the integral clearing unit. When the buffered data reaches the number of FFT analysis points, the data is analyzed by FFT.

In the parallel waiting part, there are n local carriers waiting for the received signal. After the signal passes the carrier correlation, it enters the matched filter bank of the direct-spread acquisition unit. If the local pseudo code is not synchronized with the received pseudo code, the correlation peak obtained during FFT analysis is relatively low; if the local pseudo code is basically synchronized with the received pseudo code (the phase difference is less than 1 chip), there will be a relatively high correlation peak at the Doppler frequency on condition of the FFT analysis. When the correlation peak exceeds the acquisition threshold, it is believed that the local pseudo code is synchronized with the received pseudo code, and the pseudo code slip is stopped. Then the local carrier frequency is set to the frequency point obtained by FFT analysis, and the tracking phase is entered. Otherwise, it will keep the relative sliding of the local pseudo code and the received pseudo code, continue to buffer and FFT analysis and judgment.

B. Tracking

The tracking process is divided into carrier tracking and pseudo code tracking. The tracking can achieve accurate alignment of the carrier phase of the received signal and the phase of the direct spread pseudo code, so as to achieve de-hopping, de-spreading, demodulation of DS/FFH hybrid spread spectrum.DS /FFH hybrid spread spectrum signal tracking process is shown in Figure 3



Figur 3 DTracking block diagram of DS/FFH hybrid spread spectrum

When the synchronization time of the local frequency synthesizer leads or lags the frequency hopping time of the input signal, the pseudo code tracking module will provide the frequency adjustment amount to the NCO leadingly or flaggingly, which results that the loop enter the transient process through inputting frequency step signal. When the real time of hopping synchronization comes, the tracking loop is quickly transferred to a steady state. The duration of this transient process expands with the increase of the frequency hopping synchronization time error. When it is increased to a certain extent, it will also affect the entire carrier tracking process.

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IV THE ANTI-INTERFERENCE PERFORMANCE ANALYSIS IN DS/FFH HYBRID SPREAD SPECTRUM

The communication system is in a complex electromagnetic environment and is facing various interferences. The anti-interference performance will directly affect the survivability and availability of the communication system, so the anti-interference performance analysis of the DS/FFH hybrid spread spectrum system is the key to the system research[4].

A. Broadband interference

The FH system is incapable of wideband interference distributed in the entire frequency band bandwidth, especially the comb-band broadband jamming interference; while the DS system can filter out most of the wideband interference through the relevant dispread narrowband filter[5]. Therefore, the bit error rate of the DS/FFH hybrid spread spectrum system against broadband interference is equal to the bit error rate of direct-spread broadband interference[6].

It is assumed that the bilateral power spectral density of broadband interference is expressed in the equation.

$$N_j(f) = \begin{cases} \frac{N_j}{2} & |f - f_0| \le f_c \\ 0 & |f - f_0| > f_c \end{cases} \tag{8}$$

The power spectral density of the bipolar code is expressed as Equation 9.

$$P_s = T_s Sa^2(\pi f T_s) \tag{9}$$

Therefore, the bilateral power spectral density of the interference signal after de-hopping and de-spreading falling near the carrier is approximately expressed as Equation 10.

$$\frac{N_n}{2} = \int_{-f_c}^{f_c} \frac{N_j}{2} T_c \sin^2(\tau T_c) d\tau \approx \frac{N_j}{2} \tag{10}$$

So the bit error rate is shown in Equation 11.

$$\begin{aligned} P_e &= Q(\sqrt{(\frac{S}{N_0})}) \\ &= Q(\sqrt{\frac{2}{N_0 / E_b + (J/P)(R/\omega)}}) \end{aligned} \tag{11}$$

Where E_b/N_0 is signal to noise ratio, J/P is the interference to signal ratio.

While the expression of function Q(x) is shown as Equation 12

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-\frac{t^2}{2}} dt,\ x \ge 0 \tag{12}$$

B. Narrowband interference

High-power narrow-band interference signals have a serious impact on the DS system. For the DS/FFH hybrid spread spectrum system, if the center frequency of the narrow-band interference is different from the signal carrier frequency, the interference has little effect [7].

When the frequency of the hopping signal is within the interference frequency band, the bilateral power spectral density of the interference signal is expressed as Equation 13.

$$N_j(f) = \begin{cases} \frac{N_j}{2} & |f - f_0| \le \frac{\omega_j}{2} \\ 0 & |f - f_0| > \frac{\omega_j}{2} \end{cases} \tag{13}$$

The related dispreading process of the interference signal is equivalent to the process of convolution with the pseudo code in the frequency domain, and the bilateral power spectral density of the intermediate frequency output is calculated as Equation 14.

$$S(f_{IF}) = \int_0^{\frac{\omega_j}{2}} \frac{N_j}{2} T_c \sin c^2[(f_0 - f_j - \tau)T_c] d\tau \tag{14}$$

Since $\omega_j/\omega \le 1$, the integrand can be regarded as a constant in the integration interval, then the above formula 14 can be calculated as Equation 15 instead.

$$S(f_{IF}) = \frac{N_j}{2} T_c \sin c^2[(f_0 - f_j)T_c] = \frac{J}{\omega} \sin c^2[(f_0 - f_j)T_c] \tag{15}$$

If the center frequency of the interference signal is at the carrier frequency, the bilateral power spectral density output at the intermediate frequency reaches the maximum value J/ω, which will gradually decrease as the interference frequency deviates from the carrier frequency. In the worst case, the bit error rate is calculated in Equation 16.

$$\begin{aligned} P_e &= Q(\sqrt{\frac{2}{N_0 / E_b + 2J/\omega}}) \\ &= Q(\sqrt{\frac{2}{N_0 / E_b + 2(J/P)(R/\omega)}}) \end{aligned} \tag{16}$$

When the signal hops into or out of the interference band, the receiver noise is not stable. For slow frequency hopping signals, the quasi-static analysis method is considered. When the frequency hopping signal hops into the noise interference frequency band, the system noise power spectral density is calculated as expression 17.

$$N_n = N_0 + N_j^{eq} \tag{17}$$

Without hopping into the noise interference band, the system noise power spectral density is calculated as expression 18.

$$N_n = N_0 \tag{18}$$

Where N_j^{eq} is the equivalent interference power spectral density; N_0 is the unilateral power spectral density of thermal noise.

Assuming that η is the ratio of the interference signal bandwidth to the useful signal bandwidth, then the average bit error rate of the system is calculated as equation 19.

$$\begin{aligned} \overline{P}_b &= \eta P_b[E_b / (N_0 + N_j^{eq})] + (1-\eta) P_b[E_b / N_0] \\ &= \eta Q(\sqrt{\frac{2}{N_0 / E_b + 2(J/P)(R/\omega)}}) + (1-\eta) Q(\sqrt{\frac{2E_b}{N_0}}) \end{aligned} \tag{19}$$

C. Multi-frequency interference

Single-frequency interference has little effect on the DS/FFH hybrid spread-spectrum system. However, the impact of multi-frequency interference is obvious Multi-frequency interference refers to the presence of multiple interference signals with high interference intensity

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within the spread spectrum bandwidth[8]. Interference signal is expressed by formula 20

$$i(t)=\sqrt{2J}\sum_{i=0}^{N_j}\cos(2\pi f_j t+\varphi_j) \tag{20}$$

When the frequency of hopping signal is within the interference frequency band, the interference signal will pose a threat to the system. The local reference signal can be expressed as equation 21

$$a(t)=2c(t)\cos[2\pi(f_k+f_{IF})t] \tag{21}$$

The interference signal and the local reference signal are multiplied and the value of the intermediate frequency filter is calculated as shown in the formula22

$$[a(t)q(t)]_{IF}=\sqrt{2J}\cos[(f_{IF}+\Delta f)t-\varphi_i] \tag{22}$$

Where Δf=f_k-f_j.

Then after the second mixer and low-pass filter, the signal is expressed as equation 23.

$$x_1(t)=\sqrt{2J}\cos[2\pi\Delta ft-\varphi_j] \tag{23}$$

The normalized integrator output of the interference to the signal component is calculated by equation24.

$$y_1=\sqrt{\frac{2J}{P}}\frac{1}{T_b}\sum_{i=0}^{N-1}c_{1i}\int_{iT_c}^{(i+1)T_c}\cos[2\pi\Delta ft-\varphi_j]dt \tag{24}$$

Finally, the integral value is calculated by equation25.

$$y_1=\sqrt{\frac{2J}{P}}\frac{1}{\pi T_b\Delta f}\sum_{i=0}^{N-1}c_{1i}\cos[\pi\Delta T_c(2i+1)-\varphi_j]\sin\pi\Delta fT_c \tag{25}$$

When N is large enough, assuming a Gaussian distribution with mean 0, the variance is calculated by the formular26.

$$\begin{aligned}\delta_{y_1}^2&=Ey_1^2-E^2y_1\\&=Ey_1^2\\&=\frac{2J}{PT_b^2\pi^2\Delta f^2}\sum_{i=1}^{N-1}\sum_{m=0}^{N-1}E[c_{1i}c_{1m}]\sin^2(\pi\Delta fT_c)E[\sin(\pi\Delta f(2i+1)T_c-\varphi_j)]\end{aligned} \tag{26}$$

Under the condition of independent equal probability of pseudo-random sequence the variance can be expressed by equation 27

$$\begin{aligned}\delta_{y_1}^2&=\frac{2J}{PT_b^2\pi^2\Delta f^2}\sin^2(\pi\Delta fT_c)E[\sum_{i=1}^{N-1}\sin^2(\pi\Delta f(2i+1)T_c-\varphi_j)]\\&=\frac{2J}{PT_b^2\pi^2\Delta f^2}\sin^2(\pi\Delta fT_c)E[\sum_{i=1}^{N-1}(1-\cos[2\pi\Delta f(2i+1)T_c-2\varphi_j])]\end{aligned} \tag{27}$$

The mean value of the cosine term of random phase is zero, and then the equation27 can be written as expression28

$$\begin{aligned}\delta_{y_1}^2&=\frac{2J}{PT_b^2\pi^2\Delta f^2}\sin^2(\pi\Delta fT_c)\\&=\frac{J}{PN}Sa^2(\sin(\pi\Delta fT)_c)\end{aligned} \tag{28}$$

According to the calculation, it is supposed that the normalized frequency of interference is η, then the average bit error rate of the system can be calculated by equation29.

$$\begin{aligned}\overline{P}_b&=\eta Q(\sqrt{\frac{1}{\delta_{r1}^2+\delta_{r2}^2}})+(1-\eta)Q(\sqrt{\frac{1}{\delta_{r2}^2}})\\&=\eta Q(\frac{1}{\sqrt{\frac{J}{PN}Sa^2(\sin(\pi\Delta fT)_c)+\frac{N_0}{2E_b}}})+(1-\eta)Q(\sqrt{\frac{2E_b}{N_0}})\end{aligned} \tag{29}$$

In the worst case, when the interference frequency is equal to the center frequency of the signal, Δf can be zero, and the average bit error rate of the system at this time is expressed in equation30.

$$\overline{P}_b=\eta Q(\frac{1}{\sqrt{\frac{J}{PN}+\frac{N_0}{2E_b}}})+(1-\eta)Q(\sqrt{\frac{2E_b}{N_0}}) \tag{30}$$

D. Partial band interference

Partial band interference refers to the concentration of interference power in a narrower frequency band than the spread spectrum system. Noise interference in some frequency bands is easy to generate, and the power spectral density is high, which has a serious impact on the frequency hopping system.

If the bandwidth of the spread spectrum signal is ω, the interference bandwidth is ω_j. Then the number of interfered frequency M can be calculated by the formula 31.

$$M=[\frac{W_j}{W/d}], \tag{31}$$

If the ratio of the effective interference bandwidth to the system bandwidth is η and the interference power is J, then the interference unilateral power spectral density is expressed by equation32.

$$J/\omega=J/\eta_\omega. \tag{32}$$

So the average bit error rate of the system can be calculated by equation33 [9,10].

$$\begin{aligned}\overline{P}_b&=\eta Q(\sqrt{\frac{2}{N_0/E_b+(J/P)(R/\eta\omega)}})+(1-\eta)Q(\sqrt{\frac{2E_b}{N_0}})\\&=\eta Q(\sqrt{\frac{2}{N_0/E_b+(J/P)(R/\eta 2N)}})+(1-\eta)Q(\sqrt{\frac{2E_b}{N_0}})\end{aligned} \tag{33}$$

E. Analysis

Assuming information rate R_b is 100kbps, DS pseudo-code rate R_c is 20Mchip/s, FFH frequency hopping rate Rh is 100khop/s, frequency hopping bandwidth is 200MHz, and the communication modulation is BPSK, the analysis of average error bit in various four types of interference scene is performed.

The wideband interference performance simulation is shown in Figure 4. When the interference signal ratio JSR is 5dB, 10dB, 15dB, 20dB, according to the change of the signal-to-noise ratio Eb/N0 ,the bit error rate of the DS/FFH hybrid spread spectrum system against broadband interference can be seen is equal to the bit error rate of direct-spread broadband interference. The simulation of narrow-band interference performance is shown in Figure 5 and Figure6. When the interference signal ratio JSR is 5dB, 10dB, 15dB and 20dB, and the interference bandwidth ratio η is 0.2, 0.4, according to the change of the signal-to-noise ratio Eb/N0, it can be seen that the bit error rate varies with the incensement of η. For part of the frequency band interference, when the interference is small, the bit error rate

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decreases with the rise of η, and the interference is allocated to a larger frequency band. At this time, the anti-interference performance of direct spreading is mainly reflected; when the interference is large, the bit error rate increases with the increase of η because the noise tolerance is exceeded by the interference power. Then the anti-interference performance of frequency hopping is mainly reflected at this time. In the case of the same signal-to-noise ratio and interference-to-signal ratio, multi-frequency interference worsens the performance of the system's bit error rate, which has the greatest impact on the system.

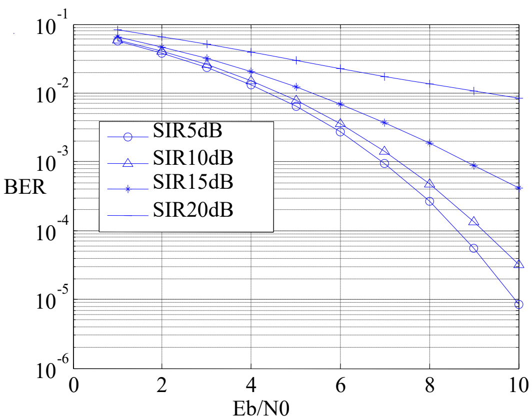

Figure 4 The simulation curve of broadband interference under different conditions

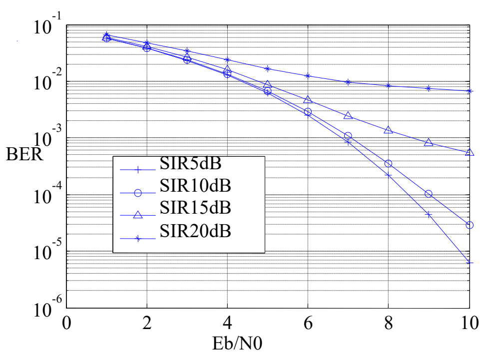

Figure 5 The performance curve of narrowband interference when η is 0.2

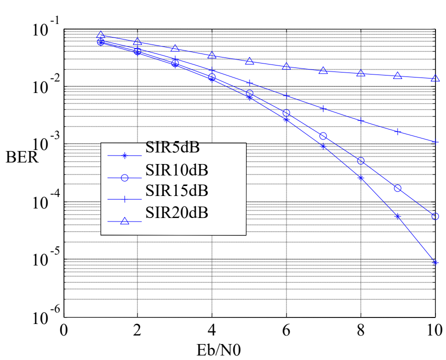

Figure 6 The performance curve of narrowband interference when η is 0.4

V CONCLUSION

This paper proposes the structure of the DS (Direct Sequence)/FFH (Fast Frequency Hopping) hybrid spread spectrum communication system, and analyzes the system signal form and the principles of carrier Doppler and pseudo code Doppler that affect the reception performance. The system reception synchronization includes two stages of acquisition and tracking. It is believed that in the acquisition stage, the acquisition method of PMF-FFT structure based on the parallel waiting can achieve the goal of rapid acquisition; While in the tracking stage, the carrier phase locked loop and the pseudo code tracking loop are used to achieve accurate alignment of the carrier phase of the received signal and the phase of the direct spread pseudo code respectively. Then the analysis of four the types and causes of group delay during signal transmission is carried out and the effect of group delay distortion on reception synchronization is. Finally, the bit error rate formula of the system in the modes of wideband interference, narrowband interference, partial band interference and single frequency interference is derived, and the impact of various interferences on the system under different signal-to-noise ratio and interference-to-signal ratio conditions is investigated through simulation. The result provides reference and theoretical basis for anti-interference design of communication system.

ACKNOWLEDGMENT

This project was sponsored by National Key Research and Development Program of China (2016YFB0500903).

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