Key Anti-Jamming Technologies and Their Performance Comparison in Frequency Hopping Communication System

Yuan Yuan

School of Electronics and Information Engineering, Beihang University, Beijing, China, 100191

54892713@163.com

Keywords: Frequency Hopping Communication; Jamming Performance; Simulation; Bit Error Rate

Abstract. Wireless communications have been applied to every aspect of our life with the development of modern communication technologies, which makes the problem of interference more critical. Especially for the frequency hopping (FH) systems, the application scenario of them is very complicated. Developing anti-jamming technologies of FH systems is a valuable research subject. In this thesis, we carry out theoretical analysis and simulation study on jamming performance of frequency hopping communication system, and then we take FH/BFSK system as an example, and give a theoretical analysis of the error rate in the five typical communication interference patterns.

Introduction

The basic characteristic of frequency hopping communication is to change the signal frequency, so as to evade enemy detection or interference, so hopping technology is essentially a reconnaissance interference avoidance technique. The avoidance ability is mainly reflected in the frequency hopping speed and the frequency hopping width. The faster is frequency hopping speed, the wider is frequency hopping width, the system anti jamming performance will be better. However, both of them can't be improved without limits. Currently, most of HF frequency hopping radios adopt sub-band hopping. Therefore, there are still shortcomings and limitations on hopping communication system in terms of anti-jamming performance.

In this context, we carry out theoretical analysis and simulation study on jamming performance of frequency hopping communication system. We analyze the influence of the typical communication jamming on the frequency hopping communication system, including full band jamming, partial band jamming, single-frequency jamming, multi-frequency interference and tracking jamming. Then we take FH/BFSK system as an example, and give a theoretical analysis of the error rate in the five typical communication interference patterns.

Frequency Hopping Communication System Jamming Performance Simulation Model

Combined with simulation model of frequency hopping systems and theoretical analysis of jamming technologies, by adding jamming module and bit error rate (BER) statistics module, we design the frequency hopping communication system jamming performance analysis schematic diagram, as shown in Figure 1:

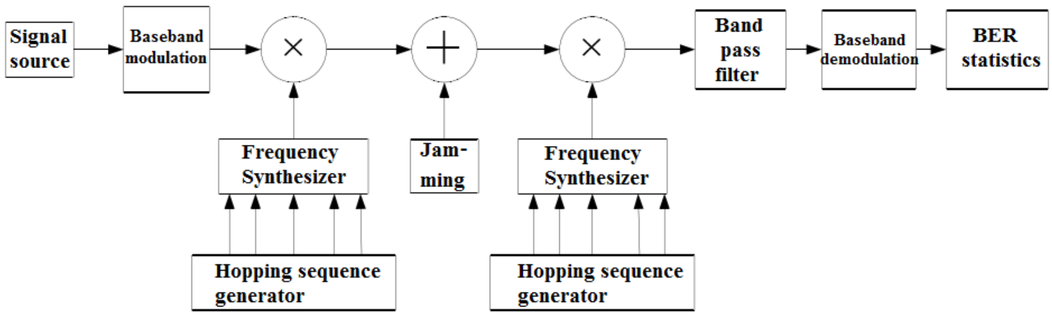

Figure 1. Frequency hopping communication system jamming performance analysis schematic diagram

Based on the schematic diagram above, then we design the FH/BFSK communication system jamming performance simulation model on Matlab/Simulink platform is shown in Figure 2:

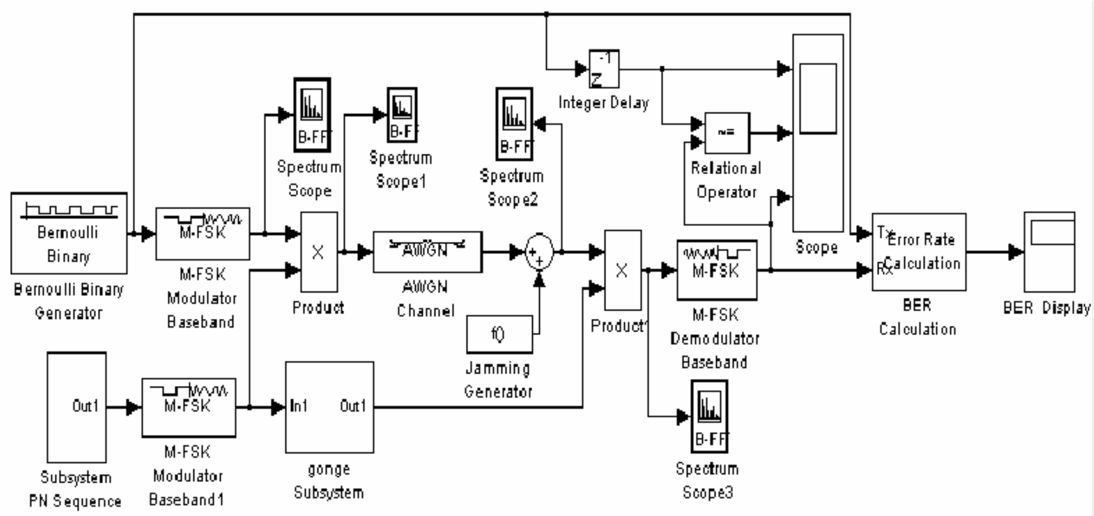

Figure 2. Frequency hopping communication system jamming performance simulation model

In the figure, jamming generator module specifically includes full band jamming, partial band jamming, single-frequency jamming, multi-frequency interference and tracking jamming.

Key Jamming Technologies in Frequency Hopping Communication System

Full Band Jamming. There is a broadband jamming in the channel, so we apply the AWGN module of Simulink to simulate the full band jamming. To change the jamming-signal ratio in the module, we can obtain the BER of the frequency hopping communication system at different jamming-signal ratio. The spectrum of full band jamming on Matlab simulation platform is shown in Figure 3:

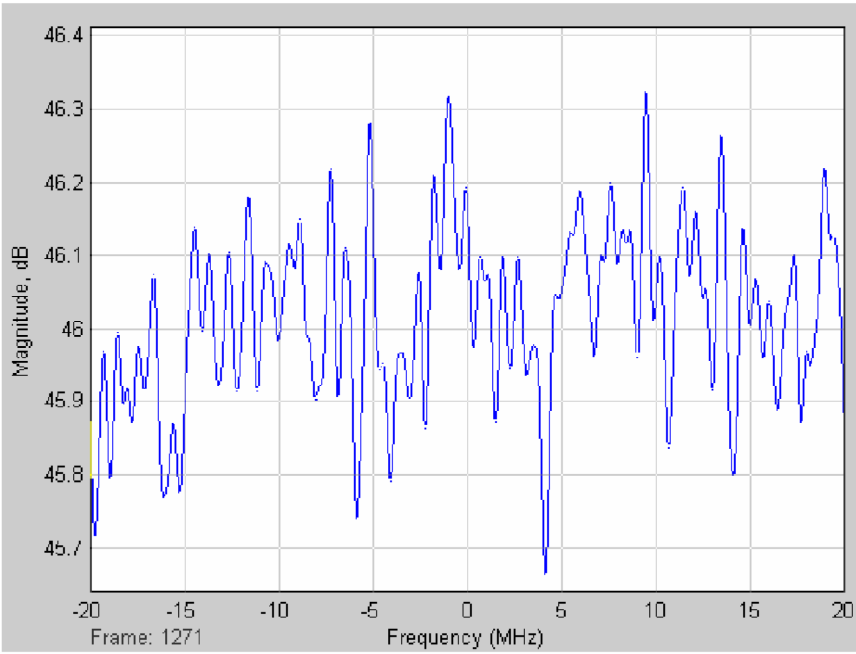

Figure 3. Full band jamming spectrum on Matlab platform

Set the simulation time as 1000s, and maintain other parameters unchanged, and change the jamming-signal ratio, and then we can obtain the diagram of bit error rate (BER) and jamming-signal ratio (JSR), as shown in Figure 4:

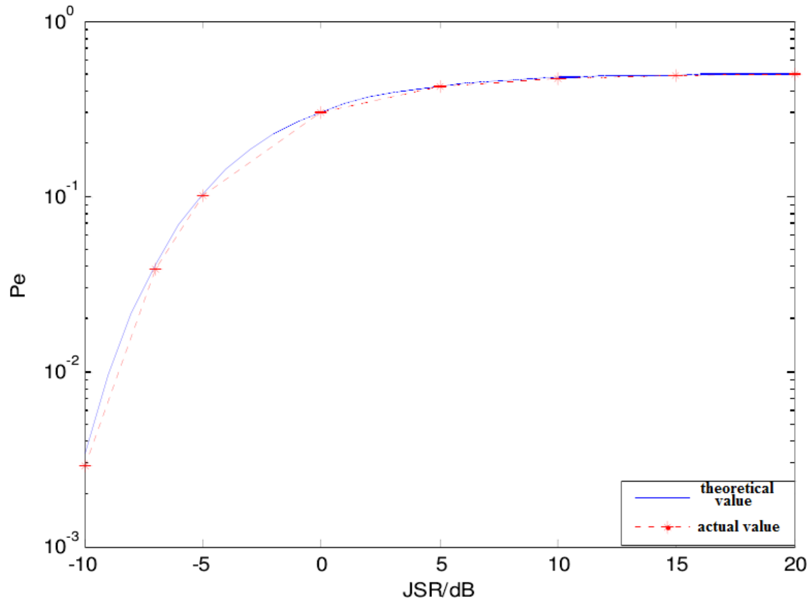

Figure 4. FH/BFSK system BER diagram at full band jamming

By observing the diagram, we can get the following conclusions:

1) Full band jamming is very effective for the frequency hopping communication system. With the increase of the jamming-signal ratio (JSR), BER of frequency hopping communication system will rise sharply. When the JSR is about -10dB, BER is acceptable for a general communication system; when JSR is above -5dB, the obtained BER obviously increases, and the performance of the frequency hopping system is rapidly deteriorating at this time; however, when JSR reaches to 20dB, the system will be completely unable to communicate.

2) By comparing the simulation curve and theoretical curve, we can see that: when JSR is lower than -5dB, the simulation error value of the frequency hopping communication system is lower than the theoretical value; when JSR is above -5dB, the simulation error value is close to the theoretical value at the same JSR. This verifies the correctness of the simulation system from one side. The main factor of inconsistency is because the system is constrained by computer hardware resources and Simulink environment, so it is unable to get enough points to get a more accurate calculation of BER.

Partial Band Jamming. It is produced by a broadband Gaussian noise passing through a bandpass filter module. To change the bandwidth of bandpass filter, we can obtain the appropriate jamming bandwidth. The simulation model is shown in Figure 5:

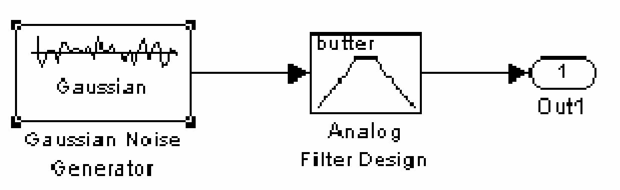

Figure 5. Partial band jamming simulation model

Respectively set the jamming factor as a=1, a=0.5, a=0.3, a=0.1, and then obtain the diagram of BER and JSR of partial band jamming, as shown in Figure 6:

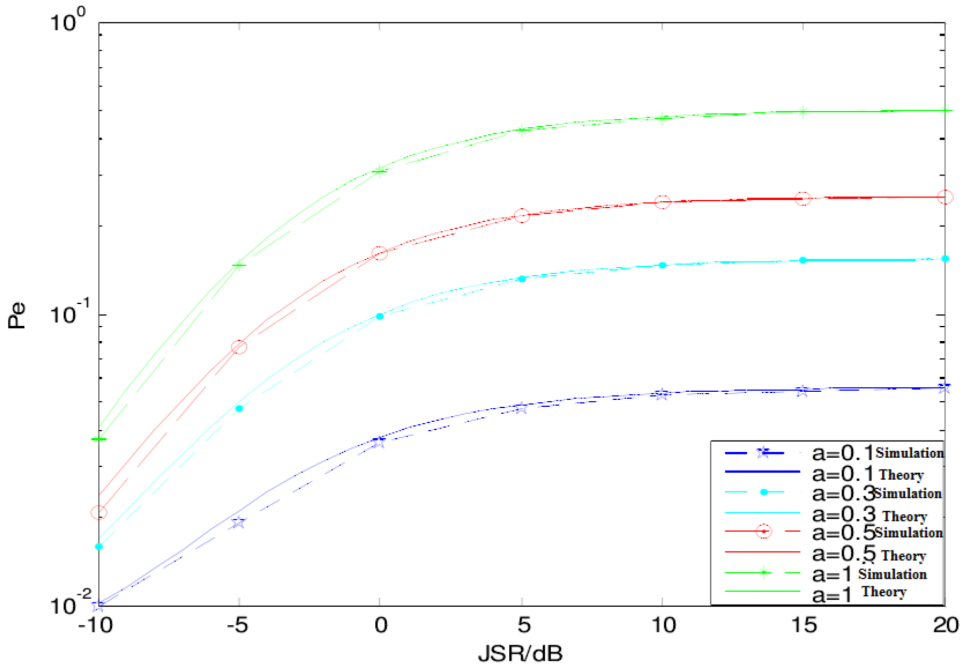

Figure 6. FH/BFSK system BER diagram at partial band jamming

By observing the diagram, we can get the following conclusions:

1) Impose partial band jamming on FH/BFSK communication system, that is, the partial band jamming factor a∈（0,1）. If BER is of the order of 10^{-1}, the jamming will produce impact on the hopping system. That is to say, the interference noise bandwidth should be accounted for 30% of the entire bandwidth to achieve better results.

2) Comparing the two curves of the same color, we can find that the trends of the two curves are basically the same, and the difference is caused by the simulation error.

3) When JSR≥5dB, change of BER is relatively small. If a=0.5, BER will above 0.2, which is enough for most of systems in terms of jamming effect. Therefore, for each partial band jamming factor *a*, there are worst-case partial band interference, when the system BER reaches a maximum, and at this time, increase of interference noise power will produce limited impact on the interference effect.

Single-Frequency Jamming. Use a sine wave generator to achieve single-frequency jamming. To change the frequency and amplitude of the sine wave, we can obtain the impact on frequency hopping system at different frequencies and different intensities. The simulation model is shown in Figure 7:

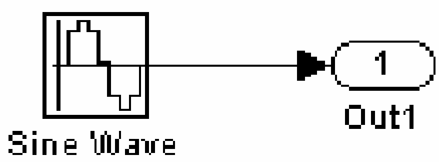

Figure 7. Single-frequency jamming simulation model

The simulation result of single-frequency jamming at SNR=10dB is shown in Figure 8:

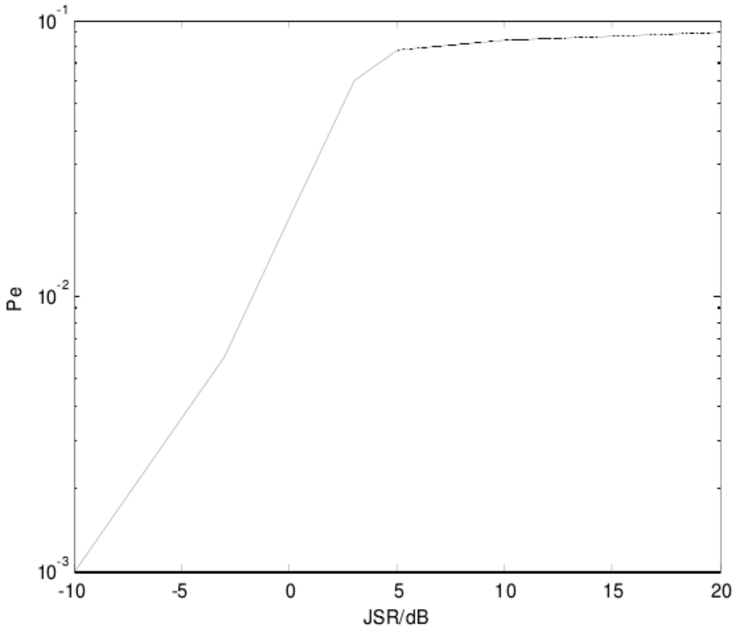

Figure 8. BFSK system BER diagram at single-frequency jamming

We can see from the diagram, single-frequency jamming has limited impact on frequency hopping system, and the BER is always lower than 10^{-1}, so it can not cause effective jamming on frequency hopping systems. Similarly, the main factor of inconsistency is because the system is constrained by computer hardware resources and Simulink environment, so it is unable to get enough points to get a more accurate calculation of BER.

Multi-Frequency Jamming. Use several sine wave generators to achieve multi-frequency jamming. To change the frequency and amplitude of the sine wave, we can obtain the impact on frequency hopping system at different frequencies and different intensities. The simulation model is shown in Figure 9:

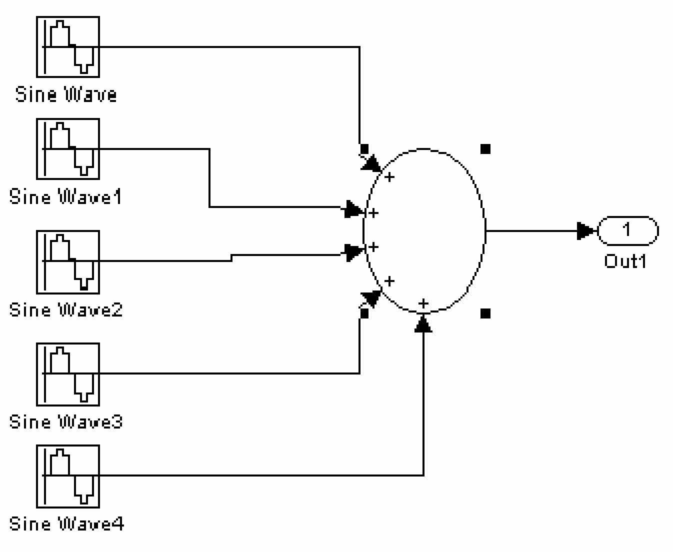

Figure 9. Multi-frequency jamming simulation model

The simulation result of single-frequency jamming at SNR=10dB is shown in Figure 10:

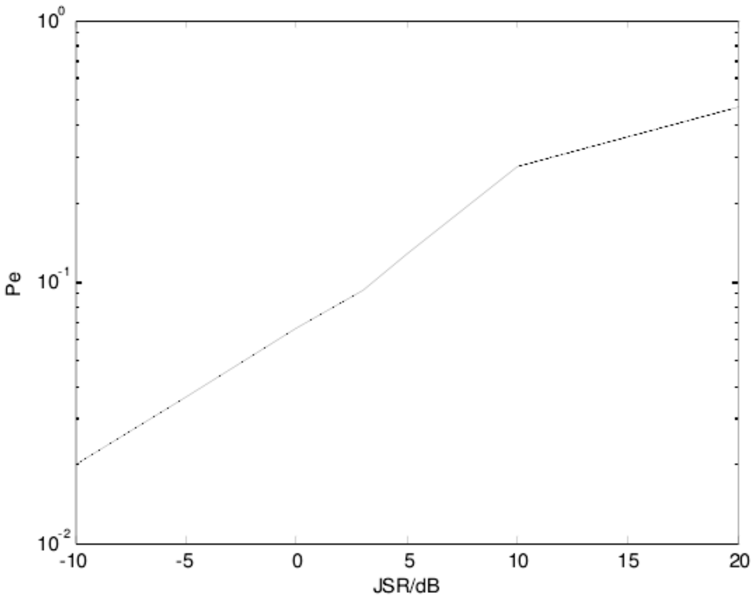

Figure 10. BFSK system BER diagram at multi-frequency jamming

When JSR≥5dB, BER≥10^{-1}, the frequency hopping system has been effectively interfered. It shows that multi-frequency jamming can cause effective jamming on frequency hopping systems.

Tracking Jamming. Tracking jamming is to extract the instantaneous frequency and power of the frequency hopping signal by spectrum analysis, and form corresponding narrowband interference signal. The simulation model is shown in Figure 11:

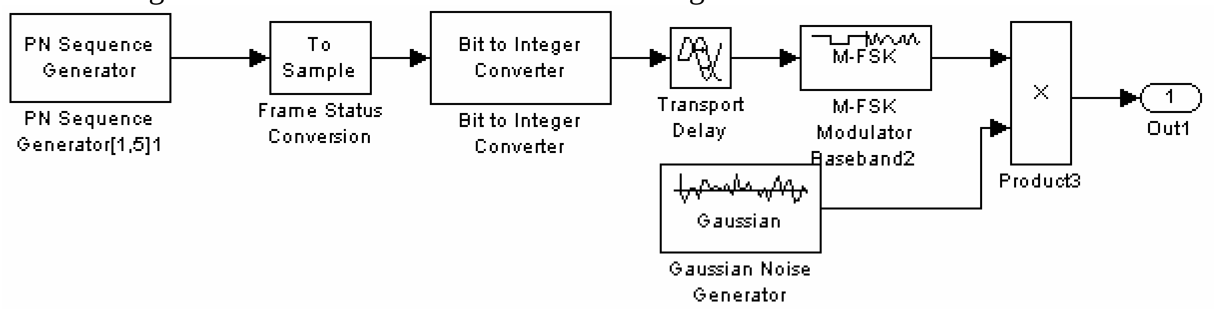

Figure 11. Tracking jamming simulation model

We set SNR=10dB, and carry out tracking jamming simulation on FH/BFSK system, and then obtain the BER curve. And then set jamming-suppression ratio between [0, 1], and maintain the SNR and JSR as 10dB, and then obtain the BER curve as shown in Figure 12:

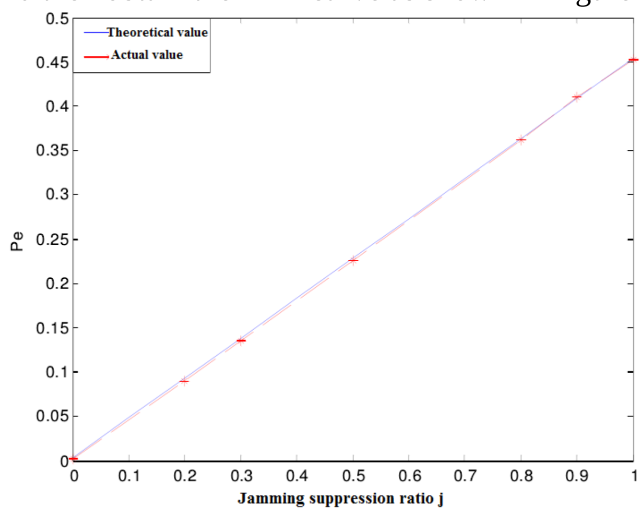

Figure 12. Simulation result of tracking jamming

We can see that, with the increase of jamming-suppression ratio, system BER will also increase, that is, the system performance is gradually deteriorating. In other words, the shorter the time used by the analysis and processing of the interference machine, the jamming effect on frequency hopping system will be better.

Comparison of the Jamming Technologies Performance

We compare the jamming performance of full band jamming, partial band jamming, single-frequency jamming and multi-frequency jamming in FH/BFSK system, as shown in Figure 13:

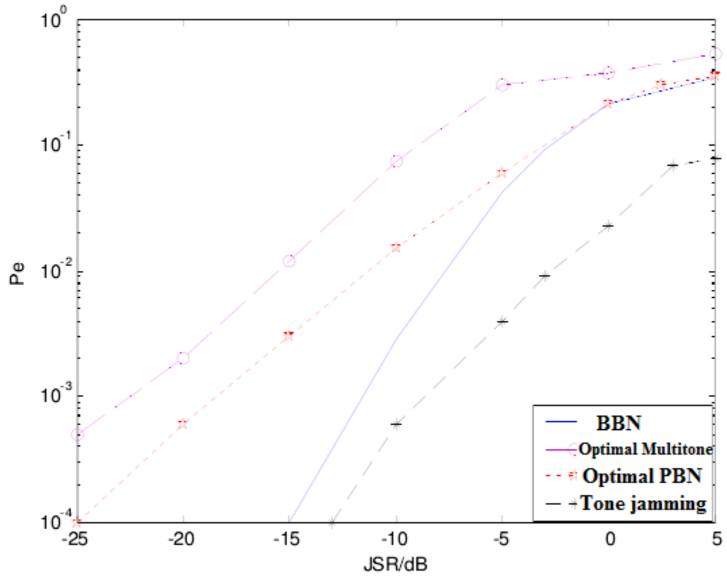

Figure 13. Jamming performance comparison

We can see from the diagram, jamming performance of narrowband noise tracking jamming is relatively good, and meanwhile it requires a high demand for reconnaissance equipment and location of the jamming machine. In addition, pressing time and dwell time of frequency hopping signal will influence the jamming effect. Jamming performance of multi-frequency jamming is also very good, but it requires adequate and sufficient interference audio. While full band noise jamming requires relatively low reconnaissance systems, and it only needs to detect the direction of the frequency hopping receiver. To achieve effective jamming, the transmit power of the broadband jamming machine must be very large, But also may cause jamming on the own communication. When the partial band jammer instantaneous coverage is coefficient goal net operating band for the best time, partial band jamming will have better jamming effect than full band jamming. Therefore, in the actual application of jammer, we should choose the right jammer reasonable under the specific circumstances, so that the jamming effects will have greater improvement.

References

[1] Zhang L, Ren J, Li T. Spectrally Efficient Anti-Jamming System Design Using Message-Driven Frequency Hopping[C]// Communications, 2009. ICC '09. IEEE International Conference on. IEEE, 2009:1-5.

[2] Voglewede P E, Leiby Iii E M, Chamberlain M W, et al. Signal jamming avoidance method for a frequency hopping communication system: EP, US7782986 B2[P]. 2010.

[3] Meng X Y, Tao R, Jia L N. An Intelligent Anti-jamming Frequency Hopping System[C]// Pervasive Computing Signal Processing and Applications (PCSPA), 2010 First International Conference on. IEEE, 2010:1053-1056.

[4] Liang T, Zhang J M, Chen Y. Modeling and Simulation of Frequency Hopping Anti-jamming Communication System. Modeling, Simulation and Visualization Methods (WMSVM), 2010 Second International Conference on. IEEE, 2010:250-253.

[5] Miao Y U, Wang Y H, Wang G F. BSS based anti-jamming method for frequency hopping communication against partial-band noise jamming. Systems Engineering & Electronics, 2013, 35(5):1079-1084.

[6] Wei W, Zhang H, Wang R. Anti-jamming Performance Analysis of High Speed Frequency-hopping Communication System Based on Simulink. Modern Electronics Technique, 2009.

[7] Xin D S. Application and Discussion of Anti-Jamming Technology for HF Communication. Information Security & Technology, 2015.