Simulation and Analysis of Frequency Hopping Communication Jamming

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Abstract. In modern warfare, the victory of electronic warfare has become one of the key factors affecting the victory of war. It is an important part of electronic warfare that high-efficiency jamming is used to interfere with enemy frequency hopping (FH) communication systems. Firstly, Simulink is used to establish models of a FH communication system, noise jamming, tone jamming, sweep jamming, and follower jamming. Secondly, performance of the four jamming is analyzed. Finally, bit error rate (BER) is used to evaluate and compare the performance of them.

1. Introduction
With the deepening of military informatization, results of communication confrontation increasingly affect results of war. The loser of communication confrontation could lead to the interruption of communication. The Gulf War and the Afghanistan War have proved the necessity of getting advantage in the communication confrontation [1]. The frequency-hopping communication system is the main communication system of our army because of its advance anti-jamming ability. Therefore, it is the main attack target of the interferer. It’s pretty meaningful for us to study FH communication jamming and its performance.

There are four typical communication jamming technologies proposed in [2] and [3]: noise jamming, tone jamming, sweep jamming, and follower jamming. To cause a high bit error rate for FH communication which means communication can not work properly, we need to find the most efficient way to interfere. It can be known from [4] and [5] that the jamming effect would be better if the interferer get the prior knowledge before performing the targeted interference. This article firstly simulates FH communication and its jamming by using Simulink. Then, according to the simulation results, the performance of four jamming technologies is analysed. Finally, in this paper, we analyze the most efficient of them and provide wartime communication confrontation with a theoretical basis.

2. Frequency hopping communication jamming technology

2.1. Noise jamming
There are all kinds of electromagnetic equipment on the battlefield. The electromagnetic diffusion generated by their normal operation and the electromagnetic radiation generated by civilian communications and electrical installations have the characteristics of wide spectrum, strong randomness and weak power constitute noise jamming.
2.2. **Tone jamming**

Single-tone jamming, also known as fixed-frequency jamming, is a kind of targeted jamming, whose frequency is fixed. The power of jamming electromagnetic waves is usually greater than the power of communication signals, because the jammer focuses the power on a certain frequency. Only when the power of jamming is exactly the same as or greater than the signal, the single-tone jamming would effectively interfere with communication process. The efficiency of such jamming is pretty low which was common in early communication confrontation.

Multi-tone jamming is the superposition of several single-tone jamming, that is, the jammer focuses the power on some discrete frequency points. Multi-tone jamming has multiple interference frequencies, and when one of the interference frequencies is the same as the communication signal frequency, it constitutes co-frequency jamming. Single-tone jamming can be a special case of multi-tone jamming. Multi-tone jamming has a great threat to all kinds of radio which is a common interference method currently.

2.3. **Sweep jamming**

Sweep jamming uses a relatively narrow-band signal to sweep in a certain period of time. The narrow-band signal has a narrow bandwidth, which is equivalent to a tone, but it is usually a partial-band signal. At any time in the time period, the center frequency of the jammer is a specific frequency, and the only part of the frequency spectrum affected is within the narrow band area around the frequency. Because the signal is swept, in a short time it can interfere with multiple frequencies in a wide range.

2.4. **Follower jamming**

Follower jamming includes waveform follower jamming, guided follower jamming, and repeater follower jamming. This paper focuses on the repeater follower jamming. After the communication signal is captured, the jammer amplifies the signal and sends it to the receiver. Because of time consumption of the signal processing and transmission, the follower jamming signal always arrives at the receiver later than the communication signal. The jamming has good efficient on low-speed FH communication system and little on high-speed FH communication.

3. **Simulation results and analysis**

3.1. **Simulink simulation**

As is shown in Figure 1, a simulation model including jamming part and FH communication system part is built by using the Simulink. Because FH synchronization is not the focus of this article, the sender and receiver are synchronized by default.

Figure 1. FH communication system and its jamming simulation model.
3.2. Performance of noise jamming
Simulate noise jamming by changing the signal-to-noise ratio (SNR) of the AWGN channel without adding other jamming. The simulation results are shown in Figure 2. It could be inferred from FIG. 2 that as the signal-to-noise ratio of the AWGN channel decreases, the BER of FH communication system increases. If the signal-to-noise ratio decreases to a small number, communication with an excessively high bit error rate would be interrupted.

![Figure 2. Graph of the signal-to-noise ratio and BER.](image)

3.3. Performance of tone jamming
It could be known from FIG. 2 that the BER is 0 when the signal-to-noise ratio of the channel is greater than 0 dB, so the signal-to-noise ratio of the AWGN channel is set to 20 dB. FH carrier frequency is set to $10 + \frac{20}{32}i$ KHz, $(i = 1, 2, ..., 30)$. The parameter of Sine Wave 4, single-tone jamming module, is set from 10000Hz to 13075Hz. Change the signal-to-jamming ratio (SJR) by changing the amplitude value of Sine Wave 3. The simulation results are shown in Figure 3 (a). Then, the SJR is set to 40dB. The frequency of the single-tone jamming module is set from 11250Hz to 12500Hz. Besides, the parameters of Sine Wave 1 and Sine Wave 2, double-tone jamming module, are set from 11250Hz to 12500Hz and 12500Hz to 13750Hz. Finally, three tones jamming consists of Sine Wave 1, Sine Wave 2 and Sine Wave 3 whose parameter is set from 13750Hz to 15000Hz. The simulation results are shown in Figure 3 (b).

![Figure 3. Graph of tone jamming simulation.](image)

As is shown in Figure 3: with the decrease of SJR of single-tone jamming, the bit error rate increases; when the SJR is reduced to a certain level, the bit error rate does not increase; when the single-tone jamming frequency is in the FH frequency range, the bit error rate is high and the interference effect is better; the interference efficiency of multi-tone jamming is better than single-tone jamming.
3.4. Performance of sweep jamming
The SNR of the AWGN channel is set to 20 dB. The output frequency range of VCO 1, part of the sweep jamming module, is the same with the output frequency range of VCO which is part of FH module. We change the SJR by changing the Gain value of Gain 1. The simulation results are shown in Figure 4.

![Figure 4. Graph of the sweep jamming and BER.](image)

As is shown in Figure 4: with the decrease of SJR of sweep jamming, the bit error rate increases; when the SJR is reduced to a certain level, the bit error rate does not increase; when the SJR is constant, with the increase of the scanning frequency of sweep jamming, the bit error rate increases, and the interference effect enhances; however, if the scanning frequency increases to a certain number, the bit error rate would approach a value and not increase significantly.

3.5. Performance of repeater follower jamming
The SNR of the AWGN channel is set to 20 dB, and change the SJR by changing the Gain value of Gain. Besides, change the delay by changing the value of Delay 1. The simulation results are shown in Figure 5. The horizontal axis in FIG. 5 is the ratio of the delay time of the repeater follower jamming to the hop duration, and the -20 dB and -26 dB curves coincide.

![Figure 5. Graph of the repeater follower jamming and BER.](image)

As is shown in Figure 5: with the decrease of SJR of sweep jamming, the bit error rate increases; when the SJR is reduced to a certain level, the bit error rate does not increase; when the delay is 0, that is, when the jamming and the FH signal arrive at the receiver at the same time, the energy of the jamming is concentrated in the FH frequency of the hop, the interference effect is significant; As the delay increases, the interference effect becomes weaker and weaker, and until the delay exceeds one hop duration, the repeater follower jamming could not cause interference to the FH signal.
4. Conclusion

This article uses Simulink to establish a simulation model of the FH communication system and its four kinds of jamming, and simulates and analyzes the interference effects of them. Firstly, under the same SJR, the interference effect of follower jamming is the best, but it also needs the extreme operating conditions. Not only must the interferer grasp the detailed situation of the interfered side such as FH signal and equipment performance, but also the geographical location of the confrontation sides has strict requirements, and it is difficult to implement. Secondly, the interference performance of high-frequency sweep jamming is also very good. But it takes huge energy to achieve the jamming. Thirdly, although the conditions for achieving tone jamming are not so harsh, the interference performance is relatively poor, and it could not cause much trouble to FH system. Finally, if the interferer could spend a huge number of energy to affect the enemy’s electromagnetic environment the enemy would be paralyzed by the inevitable strong jamming. In a word, we should soberly realize that there is no best jamming method, and according to different situation, we must comprehensively consider various conditions to make the best choice of the moment.

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