

Simulink Implementation of Frequency-hopping Communication System and Follower Jamming

Xinfeng Fan

National Key Laboratory on Electromagnetic Environment Effects, Army Engineering University
Shijiazhuang, China
1132544091@qq.com

Zhiliang Tan

National Key Laboratory on Electromagnetic Environment Effects, Army Engineering University
Shijiazhuang, China
gilbert_g@126.com

Abstract—Frequency hopping (FH) communication has strong ability of anti-jamming, and it is the most widely used communication method in communication field. Based on the basic principle of frequency hopping communication, this paper built frequency hopping communication system simulation model and follower jamming simulation model by means of MATLAB/Simulink. The model provides visual interface parameter settings, while visually observing the waveform, analyzing the spectrum, and displaying important indicators such as bit error rate. The simulation results show that the frequency hopping communication system simulation model and the follower jamming simulation model work normally and achieve the expected results.

Keywords—simulink simulation, frequency hopping, follower jamming, model

I. INTRODUCTION

Radio communication is widely used in military communications due to its rapid establishment and flexibility. However, traditional radio communication works at a fixed frequency and is easily intercepted or jammed by the enemy. Aimed at this drawback, frequency hopping communication changes the radio transmission frequency back and forth according to a certain law and speed, and let the receiver also receive the signal according to this law. At present, intentional jamming to frequency hopping communication includes barrage jamming and follower jamming, wherein follower jamming can weaken frequency hopping communication like as fixed frequency communication, and becomes the biggest threat to frequency hopping communication [1].

MATLAB has a powerful Simulink dynamic simulation environment that provides a graphical interface for modeling with block diagrams [2]. The simulation model of frequency hopping communication system, built by MATLAB/Simulink in this paper, can dynamically reflect the dynamic working process of frequency hopping communication system, and can perform waveform observation, spectrum analysis and function research. The follower jamming simulation model built actually can reflect the characteristics of follower jamming. And this paper carries out jamming performance analysis, providing certain technical support for anti-follower jamming.

II. THE COMPOSITION AND PRINCIPLE OF FREQUENCY HOPPING COMMUNICATION SYSTEM

Frequency hopping communication means two or more

parties communication is under the control of the same synchronization algorithm and pseudo-random hopping pattern algorithm and the RF frequency is pseudo-randomly and synchronously hopped in the form of discrete frequencies in the agreed frequency table [3]. The principle block diagram of FH communication system is shown in Figure 1.

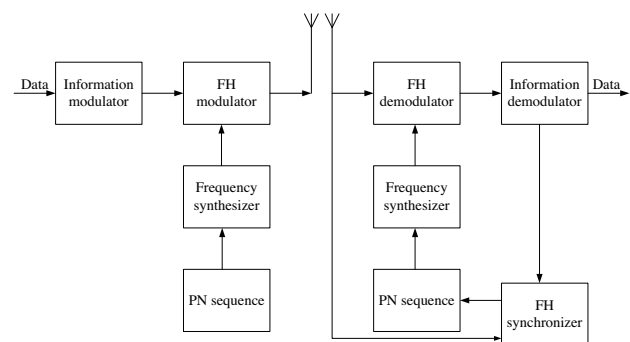


Figure 1. Principle block diagram of FH communication system

At the transmitting end, the input information is first modulated. IF modulated signal is mixed with the hopping RF signal synthesized by the frequency synthesizer to perform frequency shifting. The frequency of the resulting RF signal is constantly changing, and the anti-interception performance and anti-jamming performance are greatly improved.

At the receiving end, the frequency is synchronized first according to the received signal. Then, the system mixes the received signal with the hopping RF signal output by the frequency synthesizer to obtain an IF modulated signal, performing IF demodulation and baseband regeneration to obtain original information [4].

III. SIMULATION MODEL OF FH COMMUNICATION SYSTEM

The simulation model of frequency hopping communication system based on MATLAB/Simulink can reflect the dynamic process of frequency hopping communication system. It also can observe the spectrum of signal before and after system spread spectrum in real time. At the same time, we can perform modern communication simulation on the basis of extended simulation model. Thus, the basic simulation model provides a powerful research platform for further system research and design. The system parameter settings are shown in Table I, and the model is shown in Figure 2. It can observe spectrum and waveform

via corresponding block. To build multiple-user system model, it just needs to connect multiple single-user system in

parallel and let them pass one shared AWGN channel.

TABLE I. SIMULATION PARAMETERS OF FH COMMUNICATION SYSTEM

System bandwidth	Moduation	Data bite	Frequency interval		Number of frequency points	Hopping speed	FH sequence
			FH	2FSK			
200~1800Hz	FH/2FSK	200bps	50Hz	100Hz	32	50	M-sequence

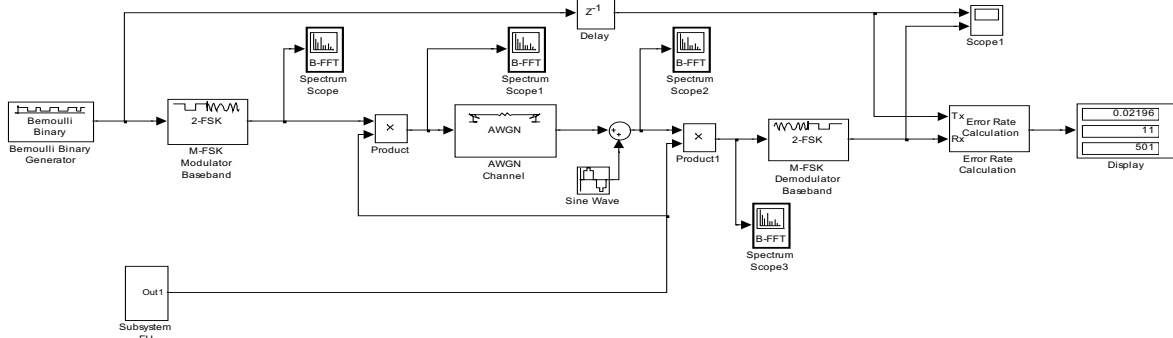


Figure 2. Simulink diagram of FH communication system simulation model

A. System Description

At the transmitter, the Bernoulli Binary Generator block generates random binary data with symbol width of 0.02s. Then the data feeds into the 2FSK Modulator block for baseband modulation. FH subsystem generates FH signal, which mixed with 2FSK signal in the Product block. The frequency-mixed signal is sent to the AWGN Channel.

At the receiver, all users receive multi-user mixed signals in AWGN noise. The frequency hopping signals first pass the Product1 block for dehopping, and then pass through the 2FSK Demodulator block for noncoherent FSK demodulation. The Error Rate Calculation block is used for calculating the bit error rate, and the Display block shows the result. Parameter setting of main related blocks is shown in Table II~III.

TABLE II. THE MAIN PARAMETER OF BERNOULLI BINARY GENERATOR

Parameter name	Probability of a zero	Initial seed	Sample time
Parameter value	0.5	61	0.02

TABLE III. THE MAIN PARAMETER OF 2FSK MODULATOR

Parameter name	Frequency seperation	Samples per symble
Parameter value	100	80

B. Internal diagram of FH subsystem

The internal diagram of FH subsystem is shown in Figure 3. Hopping frequencies are controlled by the VCO block of the voltage controlled oscillator. PN Sequence Generator generates M-sequence with sampling period of 1/250s and samples per frame of 5, so the hopping speed is 50hop/s. The Bit to Integer Converter block convert binary sequence to 32 integers between 0 and $2^5 - 1$, which will control the voltage controlled oscillator to generate 32 FH carrier signals with different frequencies, shown in Figure 4. Parameter setting of main related blocks is shown in Table IV~V. The frequency of the carrier signal is *Quiescent frequency*+ *Input*

*sensitivity***u* [5], where *u* is the converted integer of m sequence.

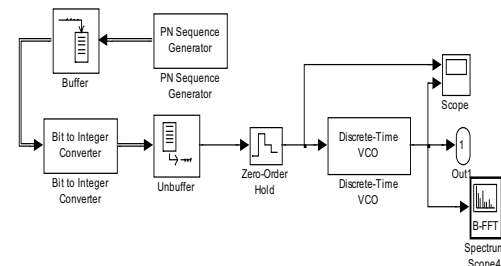


Figure 3. Simulink diagram of FH subsystem

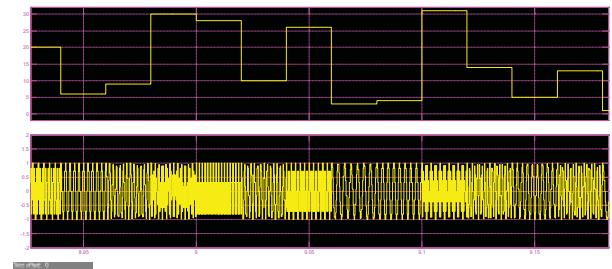


Figure 4. Simulation waveform of FH carrier signal

TABLE IV. THE MAIN PARAMETER OF PN SEQUENCE GENERATOR

Parameter name	Generator polynomial	Initial states	Sample time	Samples per frame
Parameter value	[1 1 1 1 0 1]	[0 0 0 0 1]	1/250	5

TABLE V. THE MAIN PARAMETER OF DISCRETE-TIME VCO

Parameter name	Output amplitude	Quiescent frequency	Input sensitivity	Sample time
Parameter value	1V	200Hz	50	1/4000

IV. SIMULATION MODEL OF FOLLOWER JAMMING

In implementation, the follower jamming performs by

analyzing the frequency hopping signal first, extracting its instantaneous frequency and power, and then forming a corresponding narrowband jamming signal to transmit. Thus, it forms jamming to the frequency hopping signal. A follower jamming signal is still a frequency hopping signal, but it has certain analysis processing delay compared with the normal frequency hopping signal, which is implemented by the Transport Delay block in Simulink. In this block, the delay parameter can be set to change analysis processing delay. The follower jamming model is shown in Figure 5.

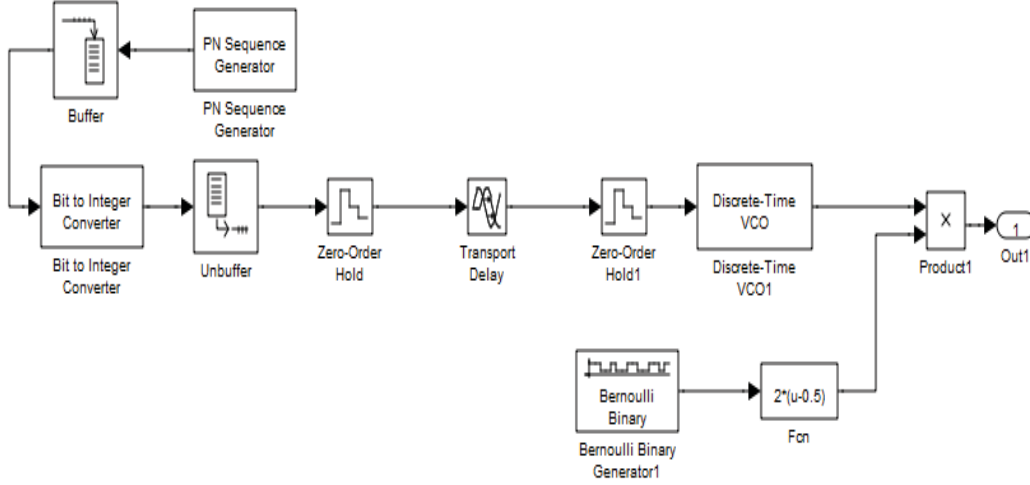


Figure 5. Simulink diagram of follower jamming

The simulation waveform of follower jamming is shown in Figure 6, which shows output waveform of converted M-sequence, frequency hopping carrier signal, delayed carrier signal and final follower jamming waveform from top to

bottom. Use the Transport Delay block to achieve a certain time delay. Since the hopping speed of the built frequency hopping communication system is 50hop/s, the delay should be controlled between 0 and 0.02s. The delayed carrier signal is mixed with jamming signal in Product1 block to form jamming to the frequency hopping communication system. The power of the jamming signal is controlled by adjusting the parameters of the Fcn function. Parameters setting of other blocks are same as blocks built in frequency hopping communication system, except that sample times need to be set to fulfill the observation request.

bottom. Compared to frequency hopping signal, the follower jamming waveform delays 0.002s, which is the same as the parameter setting in the Transport Delay block.

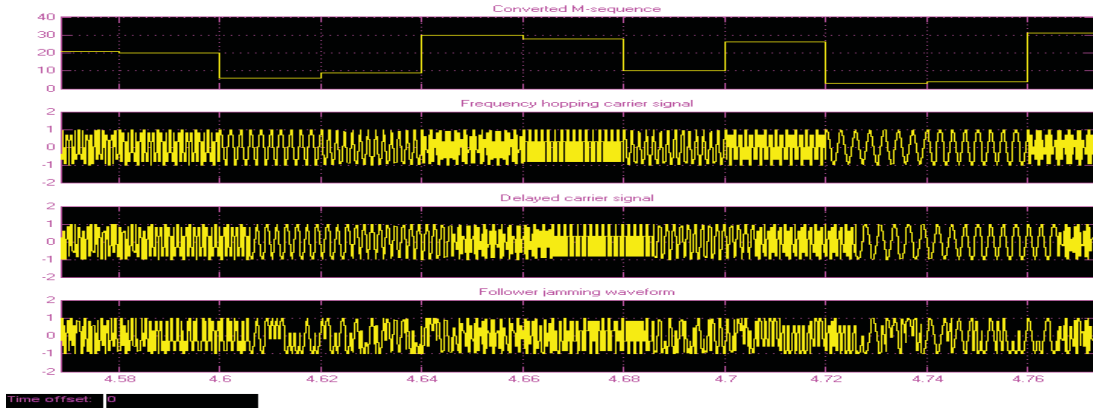


Figure 6. Simulation waveform of follower jamming

V. SIMULATION RESULTS

Follower jamming is the "killer" of frequency hopping communication, here mainly discusses its jamming effect on communication. The dwell time of frequency hopping signal is expressed by T_d , which can be regarded as the frequency hopping period, and the delay of follower jamming is expressed by τ , then the jamming suppression ratio can be expressed as $j = \frac{T_d - \tau}{T_d}$. The follower jamming can affect normal communications on the condition of $0 < j \leq 1$. Under actual conditions, effective follower jamming requires

that jamming time accounts for more than 50% of the dwell time of frequency hopping signal, then there is $\tau \leq 0.5T_d$.

Figure 7 shows simulation results of bit error rate with different jamming intensities on conditions SNR=10dB, and the hopping speed is 50hop/s, and the jamming suppression ratio is in the interval [0.5, 1]. From the results, the bit error rate increases gradually as the jamming suppression ratio increases gradually, and the system performance deteriorates gradually. With the increase of the jamming intensity, the bit error rate also increases gradually, and the system performance also deteriorates gradually.

Figure 8 shows simulation results of bit error rate with

different hopping speed on conditions the jamming suppression ratio is 0.9, and the jamming intensities F_{cn} is set to 5, and SNR is in the interval $[-30\text{dB}, 10\text{dB}]$. From the results, the bit error rate decreases gradually as the SNR increases gradually, and the system performance is gradually optimized. With the gradual increase of the hopping speed, the bit error rate is gradually increased under the fixed

jamming suppression ratio, not contradictory to the theory that increasing the hopping speed can improve the anti-follower jamming performance, and the system performance is gradually deteriorated. When SNR is less than -20dB , the bit error rate reaches the maximum value, and the increase of hopping speed has a limited effect on the bit error rate.

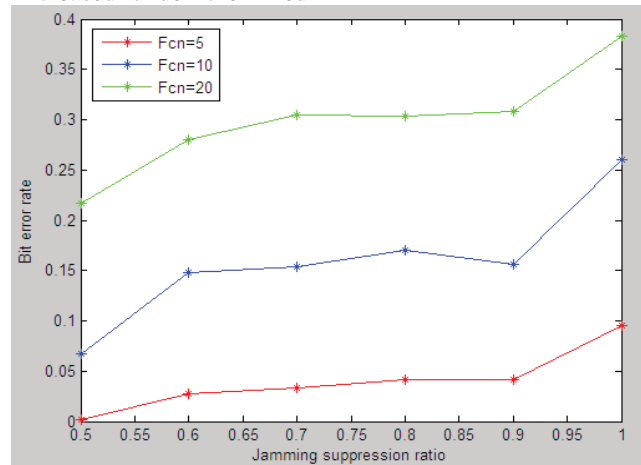


Figure 7. Simulation results of bit error rate with different jamming intensities

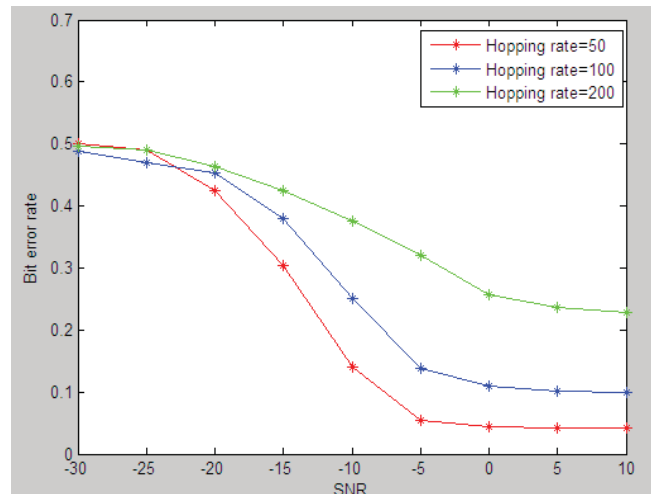


Figure 8. Simulation results of bit error rate with different hopping rates

VI. CONCLUSION

In this paper, on the basis of introduction to principle of FH communication, we have built simulation model of FH communication system with MATLAB/Simulink, which realizes the core components of FH system such as PN sequence generator, frequency synthesizer, and 2FSK modulator. The model can serve as a basic reference model, then we have built model of follower jamming on the basis of it, and discusses jamming effect of follower jamming. The results provide some measures to anti-follower jamming, and lay foundation to further research.

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