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# Research on Application of Nonlinear System in Communication Jamming

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*Abstract*—**In this paper, the application of chaos in communication jamming is investigated. We first develop a nonlinear system which acts as a guide unit of jamming and the system is in a state of chaos. Then the jamming signal is set to be the output of the chaotic nonlinear system. Jamming effects and jamming levels of the system driven by different enemy communication signals are thus studied and compared with the effects and levels of white noise blanketing jamming. Simulation results show that the jamming signal can cover corresponding enemy communication signal in frequency domain and get fine jamming effects. Finally, we conclude that the jamming effects of the system mentioned above are obviously better than the effects of white noise blanketing jamming. Furthermore, if the frequency points of enemy communication signal are in the pass band of the nonlinear system frequency spectrum, the communication jamming system achieves an optimal effect of jamming.**

***Keywords-chaos; communication jamming; nonlinear system; optimal jamming***

## I. INTRODUCTION

Chaos is a seemingly irregular motion in certain nonlinear system. It is similar to a random behavior without any additional random factors. Chaos extensively exists in fields of physics, chemistry, biology, medicine, electronics and everywhere [1]. Since 1990s, research on chaotic dynamics of nonlinear system has been focused on chaos control, chaos synchronization and other important applications [2]. In recent years, great interests are developed in applying chaotic dynamics of nonlinear system to signal processing and communication problems. Furthermore, considerable attention has been paid to secure communication issues. Various chaos secure communication technologies have been proposed such as chaotic masking, chaotic on-off keying, chaotic shift keying , chaotic parameter modulation, chaotic frequency modulation and so on [3][4].

Widespread applications of nonlinear system in secure communication have inspired people to study its applications in communication countermeasure. Communication countermeasure mainly includes two parts: one is to weaken or destroy enemy radio communication system via communication detection and communication jamming; the other is to protect the normal performance of our own radio communication system, i.e. communication anti-jamming technology [5]. Nonlinear system theory in communication jamming is like a two-edged sword which not only increases the difficulty, but also provides a method [6].

At present, strong white noise is mainly used to suppress enemy communication system for the purpose of paralyzing or interrupting. With the rapid development of modern signal processing technology, kinds of filters are able to reduce the effects of white noise jamming and make the communication system normal in a short duration. Therefore, we are expecting a better jamming method. In this paper, we mainly study the applications of nonlinear system in communication jamming. Chaotic signal attack of nonlinear system gets fine jamming effects and will further raise the defense difficulties of enemy communication systems [7].

The rest of the paper is organized as follows: in Sec. II, the system model is introduced, and its performance as well as the effects of white noise blanketing jamming is discussed in Sec. III. Moreover, an optimal jamming is put forward. Finally, conclusions are drawn from the performance comparison between chaotic jamming of nonlinear system and white noise blanketing jamming in Sec. IV.

## II. COMMUNICATION JAMMING SYSTEM

Communication jamming is the process that people suppress and destroy enemy radio communication by radiating electromagnetic energy mainly to weaken or even block “nerves” and “blood vessels” (e.g. command communication, cooperative communication, intelligence communication and service communication) of enemy

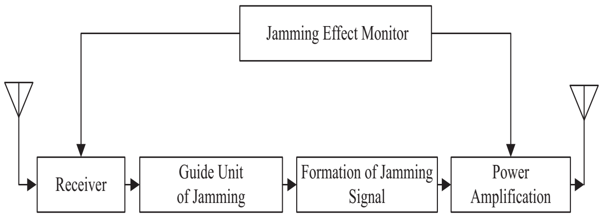



Figure 1. Communication Jamming System

information network system. By jamming pattern, the technology is classified into blanketing jamming, deception jamming and network jamming.

The framework of communication jamming system is demonstrated in Figure 1 [5]. Enemy communication signal is accepted by receiver and processed by guide unit of jamming. Jamming signal is got from formation of jamming signal. After power amplification, jamming signal is radiated to attack enemy communication system. Jamming effect monitor observes and evaluates jamming effect of jamming signal.

In this paper, a chaotic nonlinear system is set as the guide unit of jamming. We research the jamming pattern and study the jamming effect of formed jamming signal. The nonlinear system model we choose is a third-order Düffing oscillator model [8]:

$$x''+\kappa x'+\beta x+\alpha x^3=\gamma s(t) \quad (1)$$

where $\kappa$ is the damping ratio, $(\beta x+\alpha x^3)$ is the nonlinear restoring force, and $\gamma$ is the amplitude of driving power $s(t)$. Although Düffing model is only a nonlinear vibration model derived from a simple physical model, many nonlinear problems in engineering can be transformed into the model. A nonlinear system can work in several states: steady state, one-cycle state, multi-cycle state, critical state, chaotic state and so on. Its manifold nonlinear characteristics and various chaos phenomena all can be presented by the Düffing oscillator model above.

Chaotic state is peculiar to nonlinear system. We determine whether the nonlinear system is in a chaotic state by maximum Lyapunov exponent. As long as the maximum Lyapunov exponent of nonlinear system is positive, the system is in a chaotic state [9].

The connections between maximum Lyapunov exponent and model parameters are demonstrated in Figure 2. When $\kappa=0.3$, $\alpha=1$, $\beta=0$, the relationship between maximum Lyapunov exponent and $\gamma$ is shown in Figure 2 (a). It is seen that when $40<\gamma<50$, the nonlinear system may be in a chaotic state; when $\gamma>50$, nonlinear system has easy access to a chaotic state. Thus $\gamma$ is set to 60 in the simulation.

Figure 2 (b) displays the relationship between maximum Lyapunov exponent and $\beta$ when $\kappa=0.3$, $\alpha=1$, $\gamma=60$. It shows that if $\beta>0$, the system has a hard characteristic: when $0<\beta<10$, it may be in a chaotic state; when $\beta>10$, it is difficult to enter a chaotic state. While if $\beta<0$, the nonlinear system has a soft characteristic: when $-40<\beta<0$, it is able to get into a chaotic state easily; when $-50<\beta<-40$, it may be in a chaotic state; what's more, when $\beta<-50$, the nonlinear system has difficulty in entering a chaotic state.

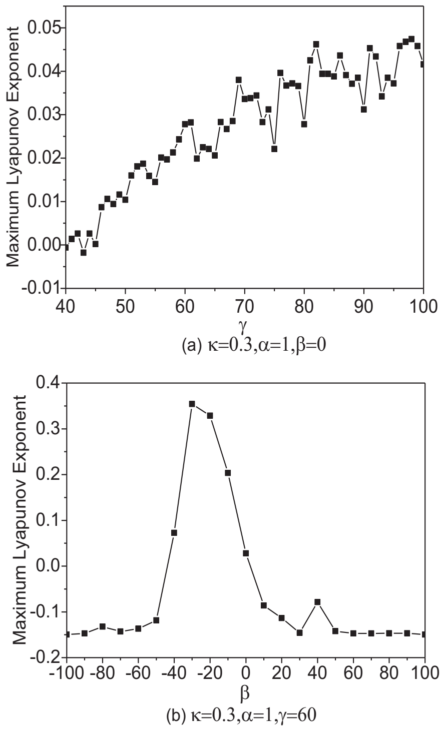



Figure 2. Relationships between Maximum Lyapunov Exponent and Model Parameters

It is inferred from the above two situations that a nonlinear system with a soft characteristic is easier to get into a chaotic state. Hence we set $\beta=-30$. Similarly, it can be proved that if $\kappa=0.3$ and $\alpha=1$, the nonlinear system has easy access to a chaotic state.

In conclusion, the selected parameters of the Düffing oscillator model are $\kappa=0.3$, $\alpha=1$, $\beta=-30$, $\gamma=60$. Then a nonlinear system is achieved with (2).

$$x''+0.3x'-30x+x^3=60s(t) \quad (2)$$

## III. SIMULATION RESULTS AND ANALYSIS OF COMMUNICATION JAMMING

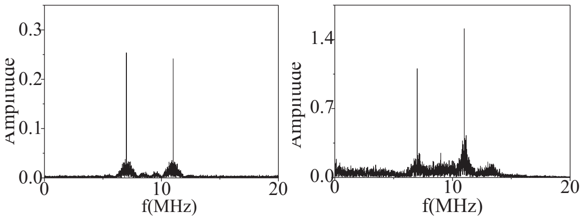
Three groups of 2FSK signals are selected as enemy communication signals s(t) and their bit rates are all 100Mb/s. The center frequency points corresponding to logic 1 and logic 0 are shown in TABLE I, and their frequency spectrums are shown in Figure 3 (a), Figure 4 (a) and Figure 5 (a) respectively.

TABLE I. CENTER FREQUENCY POINTS OF THREE SITUATIONS

| *Situation Number* | *Logic 1* | *Logic 0* |
|---|---|---|
| Situation 1 | 7MHz | 11MHz |
| Situation 2 | 10MHz | 14MHz |
| Situation 3 | 18MHz | 22MHz |

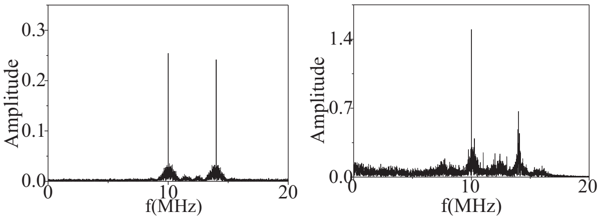
### *A. Chaotic Jamming of Nonlinear System*

When the three groups of signals act as driving power s(t), the maximum Lyapunov exponents of nonlinear system $x''+0.3x'-30x+x^3=60s(t)$ are individually tested to be 0.2969, 0.3540 and 0.4799. They are obviously positive, so the states of the nonlinear system in the three



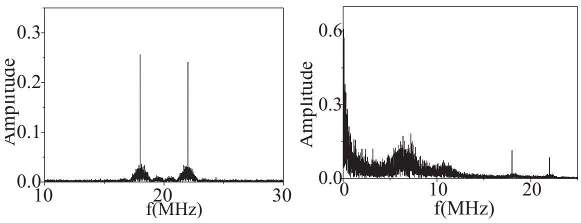
(a) Enemy Communication Signal (b) Jamming Signal

Figure 3. Signal Spectrums in Situation 1



(a) Enemy Communication Signal (b) Jamming Signal

Figure 4. Signal Spectrums in Situation 2



(a) Enemy Communication Signal (b) Jamming Signal

Figure 5. Signal Spectrums in Situation 3

situations are all chaotic.

We individually input the three groups of enemy communication signals to the jamming guide unit constituted by the nonlinear system. The signal spectrums of the output jamming signals can be seen in Figure 3 (b), Figure 4 (b) and Figure 5 (b).

Compare (a) with (b) in the three situations, we find that the two center frequency points of jamming signals are consistent with the ones of enemy communication signals. Therefore, it is easy to achieve the effect of spot jamming in blanketing jamming pattern. Conclusions can be drawn that the jamming signal outputted by a chaotic nonlinear system is able to cover the enemy communication signal in frequency domain, which means the communication jamming system has a good jamming effect.

In order to test the jamming effects of jamming signals, the three enemy communication signals are attacked by corresponding jamming signals. The jamming results are indicated in Figure 6. JSR(Jamming-Signal-Ratio), the power ratio of jamming signal and enemy communication signal, is introduced to quantify the jamming effects:

$$JSR = \frac{P_J}{P_S} \tag{3}$$

where $P_J$ is the jamming signal power and $P_S$ is the enemy communication signal power. $P_e$ in Figure 6 is the error rate.

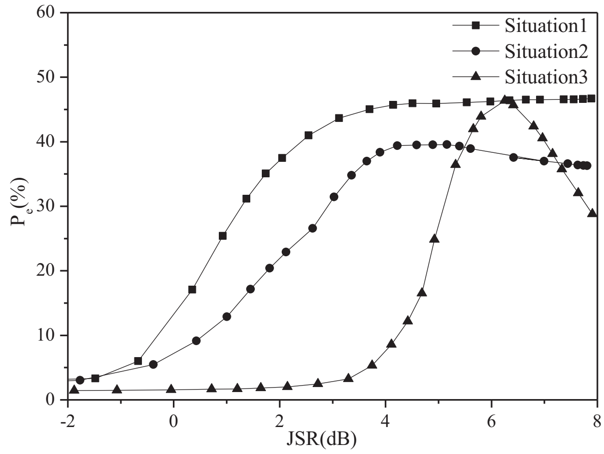


Figure 6. Communication Jamming Effects

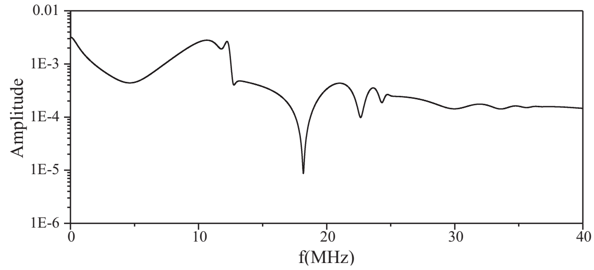


Figure 7. Frequency Spectrum of Nonlinear System

The jamming effects are evaluated by jamming levels. The jamming levels of digital communication system are divided into four levels based on the value of $P_e$ and displayed in TABLE II [5].

TABLE II. JAMMING LEVEL

| *Jamming Level* | *$P_e$ Range* |
|---|---|
| Level 0 | [0,0.05) |
| Level 1 | [0.05,0.12) |
| Level 2 | [0.12,0.2) |
| Level 3 | [0.2,∞) |

It is inferred from Figure 6 that when $JSR \geq 5dB$, the jamming levels in the three conditions all reach level 2 or level 3 and the jamming effects are excellent. Comparing the three lines in Figure 6, we discover that the jamming effects of a communication jamming system change along with the center frequency points of the enemy communication signal.

Figure 7 displays the frequency spectrum of the nonlinear system. Since the center frequency points of the enemy communication signals in Situation 1 and 2 are generally in the pass band of the frequency spectrum, the jamming effects of the system are better than Situation 3 and the jamming levels achieve level 3 if $JSR \geq 5dB$. While the center frequency points in Situation 3 are approximately in the stop band or valley of the frequency spectrum, the jamming effect of the system is slightly worse and the jamming level only reaches level 2 if $JSR \geq 5dB$. Through the analysis of Figure 5 (b), we also find that the power of the jamming signal is not

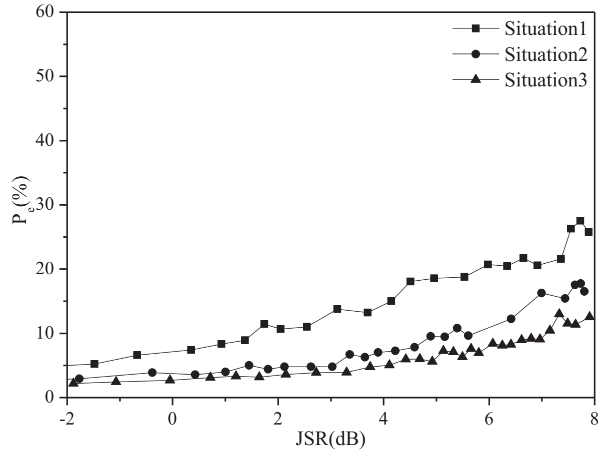



Figure 8. Frequency Spectrum of Nonlinear System

on the two center frequency points and the power utilization rate is relatively low.

Hence, if the nonlinear system is in a chaotic state and the frequency spectrum of the enemy communication signal is in the pass band of the system, the communication jamming system is able to attain an optimal effect of jamming. Meanwhile the power utilization rate is relatively high. Under this circumstance, the communication jamming level achieves level 3 if $JSR \geq 5dB$ .

### B. White Noise Blanketing Jamming

When we attack the three enemy communication signals described above with Gaussian white noise, the jamming effects of the white noise blanketing jamming can be seen in Figure 8. The trends of the three lines are very similar: $P_e$ increases slowly along with the increment of JSR.

Comparing the simulation results in Figure 8 with those in Figure 6, we see that:

1) The $P_e$ of chaotic jamming is significantly higher than that of the white noise blanketing jamming with the same JSR.
2) In order to reach the same jamming level, the JSR of chaotic jamming is less than that of white noise blanketing jamming.
3) Moreover, the jamming level of the white noise blanketing jamming is hard to achieve level 3.

Thus it is safely concluded that jamming effects of chaotic jamming are evidently better than the effects of the white noise blanketing jamming.

## IV. CONCLUSION

In this paper, the jamming effects of communication jamming technology are discussed based on chaotic nonlinear system. In the system model, 2FSK signals and the third-order Düffing oscillator model are served as enemy communication signals and nonlinear system. The simulation results demonstrate that the output signal of the chaotic nonlinear system can cover the corresponding enemy communication signal in frequency domain and get fine jamming effects. If the frequency points of the enemy communication signal are in the pass band of the nonlinear system frequency spectrum at the same time, the jamming system will achieve the effect of spot jamming and reach an optimal jamming.

We compare the chaotic jamming of a nonlinear system with the white noise blanketing jamming. The conclusion can be drawn that the jamming effects and jamming levels of chaotic jamming are obviously better than the effects and levels of the white noise blanketing jamming. The jamming signals of the chaotic jamming system are able to quickly track the variation of the enemy communication signals in frequency domain, and the power utilization can be centralized. Hence, its efficiency is extremely high. Furthermore, the jamming signals can pass through the electronic filtering system to attack enemy communication effectively.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