Analysis of Communication Characteristics of Projectile-Carried Communication Jamming Object

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Abstract: In order to facilitate the construction of projectile-carried communication jamming system model, this paper used the methods of literature search, classification and summary, and details sorting, deeply analyzing the communication characteristics of projectile-carried communication jamming object from seven aspects, including communication modulation mode, antenna type, antenna length, antenna transmission gain, sensitivity calculation, jamming tolerance, initial synchronization process and its characteristics. Then, the boundary conditions of projectile-carried communication jamming object were determined. In other words, the modulation mode of projectile-carried communication jamming object was 2FSK, the antenna type was whip antenna, the antenna length was 2 m or 2.4 m, the short wave antenna transmission gain was -10.5912 dBi, the ultra- short wave antenna transmission gain was -1.383 dBi, the jamming tolerance was 32% of the available frequency, and the initial synchronization time was calculated as 182 ms. The relevant conclusions lay a foundation for the follow-up study of projectile-carried communication jamming performance.

Key words: Projectile-carried communication jammer, jamming object, frequency hopping radio, communication characteristics.

1. Introduction

Projectile-carried communication jammer refers to an electronic equipment [1], [2] that uses projectile as a carrier and is launched near the enemy target area to complete communication jamming tasks. The projectile-carried communication jammer mainly jams the enemy frequency hopping communication radio [3]-[5]. When we study the performance of projectile-carried communication jamming, we need to analyze and sort out the communication characteristic parameters of projectile-carried communication jamming object, namely frequency hopping radio, so as to lay the foundation for the subsequent construction of projectile-carried communication jamming system model.

2. Communication Modulation Mode of Projectile-Carried Communication Jamming Object

We had listed and classified the existing references:

According to the reference [6] and reference [7], the common modulation methods of digital frequency hopping communication radio were 2FSK and 2DPSK. Reference [8]-[16] told us that 2FSK was the most commonly used communication modulation mode of military digital frequency hopping communication radio. Therefore, 2FSK could be selected when the communication modulation mode of projectile-carried communication jamming object was selected.

3. Antenna Type of Projectile-Carried Communication Jamming Object

For digital frequency hopping communication radio, it is necessary to define the type of transmitting antenna of the radio station. Because different antennas have different propagation mechanism, they also have different emphasis in the description of subsequent simulation model. From the tactical level, digital frequency hopping communication radio mainly refers to shortwave or ultra-short wave frequency hopping communication radio.

Among them, ultra-short wave communication because of high frequency, short wavelength, antenna can be made very small, usually vertical whip antenna. Because of the low frequency of HF communication, the antenna must be large enough to work effectively.

The simple rule is that when the length of the antenna reaches 1/2 of the frequency used, the efficiency of the antenna is the highest. Short wave antenna is divided into two categories: ground wave antenna and sky wave antenna. The ground wave antenna includes whip antenna, inverted L-shaped antenna and T-shaped antenna. The electromagnetic wave emitted by this kind of antenna is omni-directional and mainly propagates around in the form of ground wave, so it is called omni-directional ground wave antenna, which is often used in short-range communication.

In short wave propagation, the basic principle of antenna selection is [17]:

Short distance fixed communication: selecting ground wave antenna or sky wave high elevation antenna.

Point to point communication or directional communication: selecting sky wave directional antenna, etc.

Networking communication or omni-directional communication: selecting sky wave omni-directional antenna;

Vehicle communication or personal communication: selecting small whip antenna.

In our practical research, from the perspective of operability, as long as it is convenient to study the performance of projectile-carried communication jamming, generally speaking, the antenna type of projectile-carried communication jamming object is whip antenna.

4. Antenna Length of Projectile-Carried Communication Jamming Object

For frequency hopping communication radio, the height of antenna can determine whether the signal transmission quality is good or bad. Sometimes the antenna is too short, the communication quality of the radio can not be guaranteed, not to mention the specific jamming effect.

Here we also sort out the existing references:

References [18] and [19] took Shaanxi Fenghuo Communication Group Co., Ltd. as an example to introduce some short wave and ultra-short wave radio products,

For example:

The whip antenna length of XD-D9B1 shortwave SSB radio was 2.4 meters;

The whip antenna length of XD-D11 shortwave SSB frequency hopping adaptive radio station was 2.4 meters;

The whip antenna length of xd-d9a small short wave SSB radio was 2.4 meters;

The whip antenna length of xd-d9g short wave SSB radio was 2.4 meters;

The whip antenna length of xd-d9v short wave SSB radio was 2.4 meters;

The whip antenna length of xd-d12a shortwave frequency hopping adaptive radio station was 3 meters;

The whip antenna length of prc-188 knapsack VHF frequency hopping radio was 1.5 meters;

The whip antenna length of prc-2188 knapsack VHF frequency hopping radio was 1.5 meters or 3 meters.

Therefore, in the actual study of projectile-carried communication jamming performance, we could take 2.4 meters and 2 meters for the antenna length of short wave frequency hopping communication radio station and ultra-short wave frequency hopping communication radio station respectively.

5. Antenna Transmission Gain of Projectile-Carried Communication Jamming Object

There are many calculation methods of antenna transmission gain [20]:

1) The narrower the main lobe width, the higher the gain. For general antennas, the gain can be estimated by the following formula:

$$G(dBi) = 10\lg(32000 / (2\theta_{3dB,E} \times 2\theta_{3dB,H})) \tag{1}$$

In formula (1), $2\theta_{3dB,E}$ and $2\theta_{3dB,H}$ are the width of the antenna's lobes in two main planes; 32000 is the statistical empirical data.

2) For parabolic antenna, the gain can be approximately calculated by the following formula:

$$G(dBi) = 10\lg(4.5 * (D/\lambda_0)^2) \tag{2}$$

In formula (2), D is the paraboloid diameter; λ_0 is the central working wavelength; 4.5 is the statistical empirical data.

3) For the vertical omni-directional antenna, there is an approximate formula:

$$G(dBi) = 10\lg(2L/\lambda_0) \tag{3}$$

In formula (3), L is the antenna length and λ_0 is the central working wavelength.

For the whip antenna, we used equation (3) to calculate the antenna transmission gain. For short wave, the frequency band is 3-30MHz, the wavelength is 10-100 meters, the central wavelength is 55 meters, and the antenna length is 2.4 meters. After calculation, the antenna transmission gain was -10.5912 dBi;

For ultra-short wave, the frequency band is 30-300MHz, the wavelength is 1-10 meters, the central wavelength is 5.5 meters, and the antenna length is 2 meters. After calculation, the antenna transmission gain was -1.383 dBi.

6. Sensitivity Calculation of Projectile-Carried Communication Jamming Object

Different references have different explanations for sensitivity calculation, such as:

Reference [21]: When the communication distance of the enemy receiving and transmitting radio station is the maximum Rmax, the power signal-to-noise ratio of the receiving antenna of the communication receiver is its minimum receiving signal-to-noise ratio $S_{N(\min)}$, that is, sensitivity.

Reference [22]: the minimum received power measured at the antenna port of the user terminal when the bit error rate does not exceed a certain value.

However, when calculating the receiver sensitivity mentioned in references [21] and [22], the receiver bandwidth should be known in advance, so the calculation was not very convenient. We could consider the receiver sensitivity from another angle.

Under the condition of free space transmission, the jamming signal power received by the receiver [23] is:

$$P_j = \frac{P_{Tj} G_{Tj} G_{Rj}}{L_j} \tag{4}$$

Among them:

P_{Tj} — jammer output power;

G_{Tj} — antenna gain in the receiver direction;

G_{Rj} — antenna gain of receiving antenna in jammer direction;

L_j — path loss from jammer to receiver.

Equation (4) is expressed in decibels:

$$P_j(dBm) = P_{Tj} + G_{Tj} + G_{Rj} - L_j \tag{5}$$

where, $P_j(dBm)$ is the minimum detectable jamming signal power at the receiving end, P_{Tj} is 40dBm, G_{Tj} and G_{Rj} are -15dB and -10.5912dB respectively. L_j is the path loss formula in free space, L_j =32.45 + 20lgf (MHz) + 20lgr (km). It can be calculated that L_j = 50.28dB (Suppose f = 3MHz, $r = 3km$), so

$$P_j(dBm) = 40\text{-}15 - 10.5912 - 50.28 = \text{-}35.8712 dBm.$$

The calculation showed that when the average output power of jammer was 40dbm, as long as the receiving power of the communication radio station was greater than $-35.8712dBm$, the jamming signal could be received and the normal communication of the enemy radio station could be jammed.

This method could avoid the need to calculate different receiver bandwidth due to different communication system characteristics of different receivers.

7. Jamming Tolerance of Projectile-Carried Communication Jamming Object

As we know, the jamming tolerance M_j is defined as the actual anti-jamming ability of the spread spectrum communication system which can maintain the normal operation of point-to-point (the minimum output signal-to-noise ratio meeting the normal demodulation requirements)

The expression [24] is:

$$M_j = G_P - [L_S + (S/N_0)_{out}] \tag{6}$$

where, G_P is the processing gain of the spread spectrum communication system; $(S/N_0)_{out}$ is the minimum signal-to-noise ratio required by the receiver demodulation output; L_S is the inherent processing loss of the spread spectrum communication system, which is caused by the signal damage caused by the error in the spread spectrum signal processing and engineering practice. For practical systems, the values of the parameters in formula (6) are related to the modulation type of the system and the corresponding channel parameters.

According to engineering experience, L_S is generally 1-2.5dB, the maximum should not exceed 3dB, and $[L_S + (S/N_0)_{out}]$ is generally 5dB.

For frequency hopping communication, according to the general technical level of frequency hopping receiver, assuming that the number of frequency hopping is N, the inherent loss of frequency hopping processing is 2.5dB, and the threshold value of minimum demodulation output signal-to-noise ratio required by frequency hopping is 2.4dB. Substituting into the formula (6), the frequency hopping jamming tolerance is 0.32N, which indicates that the jamming tolerance of conventional frequency hopping is 30% - 40% of the available frequency.

However, in order to achieve the jamming tolerance of 30%-40% of the available frequency, the premise is to use error correction coding mechanism. If it is a simple conventional frequency hopping communication system, no anti-jamming measures are adopted in the signal transmission process, then the jamming tolerance is difficult to reach 30%-40% of the available frequency. Because the simple frequency hopping communication system itself does not adopt any error correction mechanism, the actual frequency hopping communication system generally adopts error correction coding mechanism, which is used to reduce the minimum output signal-to-noise ratio requirement of frequency hopping communication system demodulation, so as to improve the frequency hopping jamming tolerance.

8. Initial Synchronization Process and Characteristics of Projectile-Carried Communication Jamming Object

If frequency hopping radio wants to realize reliable frequency hopping communication, both sides of communication must carry out frequency hopping according to certain rules. This process of communication according to certain rules is called synchronization. The synchronization process includes two stages: initial synchronization and service synchronization [25].

8.1. Initial Synchronization

The so-called "initial synchronization" refers to that the frequency hopping radio transmits synchronization information at the beginning of sending information, so that the receiver and transmitter can realize synchronization rapidly. When the radio station is used for frequency hopping communication, it is necessary to press the call key for about 0.5s, and a "beep" appears in the headset, and then the call can be conducted. Within about 0.5s of pressing the call key, the radio station has completed the "initial synchronization" of frequency hopping communication, while the "beep" in the headset indicates that the "initial synchronization" has been established. In the process of "initial synchronization", the receiver extracts the synchronization information from the received frequency hopping signal, and then starts synchronous frequency hopping according to the instruction of synchronization information, thus completing the establishment of "initial synchronization" of radio frequency hopping communication.

8.2. Realization of Service Synchronization

In the process of frequency hopping communication, in order to ensure the continuous synchronization in the communication process, it is necessary to carry out "service synchronization". The so-called "service synchronization" refers to the synchronization established by searching the synchronization calibration information inserted into the FH network data stream to ensure that the synchronization between the transmitter and the receiver can be maintained in a hop to hop manner after the "initial synchronization" is established. Through the "service synchronization", the local clock of the receiver can be constantly corrected to make it consistent with the clock of the transmitter, so as to ensure that the frequency hopping law and jump rate of the receiver and transmitter are consistent. Different from the "beep" in the headset when the "initial synchronization" is established, the operator is not aware of the "service synchronization" process during the call.

8.3. Specific Establishment of Initial Synchronization

It is assumed that the initial synchronization information consists of 20 bit TOD [26], [27] information, 2 bit synchronous hop/service hop flag and 2 bit check code. The initial synchronization information is transmitted with one set of frequencies.

At the same time, it is assumed that the initial synchronization information is divided into two groups. The first group transmits the first two bits of the initial synchronization information, and the second group transmits the last 22 bits of the initial synchronization information, which are recorded as TOD 1 and TOD2 respectively.

The distribution of information transmitted by each group is as follows:

TOD 1: 2 bit synchronous hop/service hop flag;

TOD 2: TOD information and 2 bit check code, 22 bits in total.

Further hypothesis: the number of frequency sets used is 256 [28]. In transmission, a group of frequencies is used, a total of 15 frequency points are used for information transmission.

First of all, the 15 frequency points are used to send 7 times in a total of 5 hops, and the transmitted information is TOD 1. Among them, the purpose of transmitting 7 times is to make the receiver have enough time to receive the content transmitted by the transmitter, so as to ensure the probability of synchronization. As the initial synchronization/service identification, the first two bits should transmit several times more to ensure that the receiver can achieve the initial synchronization or service synchronization in time. Then, with these 15 frequencies, the system circulates three times, with a total of 86 hops, and the transmitted information is TOD 2. Considering the factors such as high probability of synchronization and short synchronization time, the 15 frequencies are transmitted three times. So 91 hops are used to transmit the initial synchronization information.

The generation and replacement of the initial synchronization frequency is determined by the partial value of TOD, check code and key. The initial synchronization frequency is selected from the frequency table, and the frequency selection is controlled by PN code. Both the transmitter and the receiver have the same frequency table and the same PN code.

The initial synchronization information is transmitted in 91 hops, assuming that the rate of frequency hopping is 500 Hops/s, and the frequency hopping period is 2 ms (= 1/500 Hops/s), so the initial synchronization time t is:

$$t = 91 \text{ jumps} \times 2 \text{ ms} = 182 \text{ ms}$$

According to the reference [6], the initial synchronization time of VHF frequency hopping radio should be less than 0.6s, so the synchronization head designed here meets this standard. Moreover, if the synchronization time is too short, the receiver can not receive the initial synchronization information, which can not reach the ideal information synchronization probability.

9. Conclusions

By analyzing the communication characteristics of the projectile-carried communication jamming object, we set the boundary conditions of the jamming object which need to be set in the process of building the projectile-carried communication jamming system model. In the follow-up research work, according to the communication characteristics of the projectile-carried communication jamming object, we can construct the corresponding projectile-carried communication jamming object model according to the communication characteristics of the projectile-carried communication jamming object, which lays the foundation for further research on the projectile-carried communication jamming performance.

Conflict of Interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript.

Author Contributions

Jie Zhang: be responsible for the conception of the outline and the design of the core content, as well as the writing of the article.

Haixia Shao: be responsible for text-proofreading and chapter material arrangement of the article.
Haijun Wang: be responsible for formula proofreading and data verification of the article.

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