A Novel Effectiveness Inference Method of Communication Jamming Based on Combination Factors

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Abstract. This paper presents a method of communication jamming effectiveness based on jamming equipment, combat target and propagation environment, in order to solve the problem of limited external field test resources for comprehensive evaluation support. “Collect the real jamming signal and communication signal of typical test station environment, in order to simulate the jamming ability of jamming equipment under different propagation environment (terrain, object, meteorology), communication combination parameters (distance, power, modulation mode) and jamming combination parameters (power, bandwidth, type).”

1. INTRODUCTION
At present, the evaluation of electronic jamming equipment design typing is often based on the simulation of the construction of combat target links, and then tests the interference distance (range) of the electronic suppression of the target by the tested equipment. In the actual assessment process, due to the limitations of site, weather, funds, cycle, manpower, safety and other factors, there are often three problems: First, traversing all kinds of transmission environment conditions is not easy to achieve, mainly manifesting in different geographic environment test sites are not easy to find and exhaust, various extreme weather conditions appear randomness and periodicity, and various dynamic changes of natural electromagnetic radiation background are not well controlled, etc; secondly, the parameters of power and modulation modes of the same kind of equipment of the combat target are diverse, and the distributed deployment of different combat units is characterized by the disparity of distance; Thirdly, some interference bandwidth settings are random and not exhaustive. In short, it is often difficult to meet the above test environment and conditions. Therefore, the actual operation is usually carried out only by sampling from typical test sites, and it is impossible to test all the above conditions. However, the reliability of such test results is low, and can not meet and support the scientific and effective evaluation of the equipment under test.

The main purpose of this paper is to use the limited resources of field test, such as the typical test station, the real signal transmission environment and the electromagnetic environment, to collect data including the capability information of jamming equipment and target equipment during the test process, so as to further simulate and deduce its jamming effectiveness and expand the content of typical field test. It can be divided into four parts: First, change the propagation environments of the test equipment in different terrains and meteorology, deduce the interference performance of the interference equipment under various propagation combinations; Second, according to the operational mission of jamming equipment, the scale, area and type of equipment of combat target are envisaged, and the interference performance of the interference equipment changes according to the change of the operational opponent is derived. Third, the comprehensive interference ability of the tested equipment...
under different combination parameters (interference power, interference bandwidth, interference mode) was tested. In this paper, the jamming experiment of ground-to-ground conventional communication is taken as an example, and a multi-factor environment deduction method based on measured data is proposed to answer and solve the above problems.

2. THE DEDUCTION PRINCIPLE OF JAMMING EFFECTIVENESS

In a typical field test site, after jamming equipment effectively suppresses communication links, the spectrum monitoring equipment is used to test the received signal level of communication links and the received signal level of jamming links in real time, and then the suppression coefficient is obtained. Then The jamming capability of jamming equipment is deduced when various factors change. The method is as follows:

(1) Redundancy of jamming effectiveness: When various factors change, the signal level of the jammer and the transmitter to the receiver shows certain fluctuation. It can be expressed by formula (1).

\[ \Delta \Delta P_{rj} = P_{rj} - P_{rt} - k \]  

\( \Delta \Delta P_{rj} \) is the interference performance redundancy of interference equipment after the change of various factors, \( P_{rt} \) is the interference signal level of the receiving point of the communication link, \( k \) is the suppression factor.

(2) Under the condition of field test station distribution, according to the propagation mode corresponding to the propagation distance \( D_j \) of interference link, the transmission loss \( L_{Dj} \) of interference link is calculated by using the interference receiving and receiving power and antenna gain, and then the transmission loss \( L_{Dj} \) of interference link is calculated by using the interference efficiency redundancy when the parameters change. See (2) for the calculation formula:

\[ L_{Dj} = \Delta \Delta P_{rj} + L_{Dj} \]  

\( L_{Dj} \) is the link transmission loss corresponding to the maximum interference distance \( D_{jmax} \) caused by various factors, \( \Delta \Delta P_{rj} \) is the redundancy of jamming effectiveness caused by various factors, \( L_{Dj} \) is the transmission loss of interference link corresponding to the distance \( D_j \) of outfield interference.

(3) According to the different propagation modes and corresponding propagation models of the envisaged interference link and target link, the maximum interference distance \( D_{jmax} \) in the corresponding propagation mode of the equipment is reversed by \( L_{Dj} \).

According to the above-mentioned interference performance derivation principle, on the basis of the measured data of the interference link and the communication link receiving level of the typical external field test, the jamming capability of the jammer and the communicator can be deduced when the parameters of the jammer and the communicator change. The following describes the derivation method of the corresponding interference performance when the link propagation mode, communication transmitter parameters, and interference parameters of the test equipment are changed.

3. THE DEDUCTION METHOD OF INTERFERENCE EFFECTIVENESS OF COMBINED FACTORS

3.1. Propagation mode change deduction method

The propagation mode is closely related to communication and to communication confrontation. According to the spatial relationship, communication services can be divided into three categories: ground (sea) / air communication services, satellite communication services and scattering communication services. Among them, ground (sea) / air communication services can also be divided into land fixed services (short-wave ground wave, short-wave sky wave, ultra-short-wave/microwave), land mobile services (short-wave ground wave, short-wave sky wave, and scattering communication services). Ultra-short wave/microwave, maritime mobile service (Ground-sea Mobile, Sea-sea Mobile), aviation mobile service (Ground-air Aviation, Sea-air Aviation, Air-air Aviation) and other sub-services; satellite communication service can also be divided into satellite-ground fixed service,
satellite-ground mobile service, satellite-ground aviation mobile service, satellite-ground maritime mobile service, satellite-ground-land service. Mobile services, etc. Scattering communication services can be divided into tropospheric scattering communication services and ionospheric scattering communication services. Propagation mode plays an important role in all kinds of communication and communication countermeasure models. The application scenario of communication service propagation mode is shown in Figure 1. Communication countermeasure changes with communication.

![Figure 1. Schematic diagram of the composition of the radio wave propagation mode](image)

The differences of transmission modes are mainly manifested in the differences of transmission media, which leads to different transmission losses of links. The interference efficiency of other propagation modes can be deduced from the test results of communication receiving level and interference receiving level under known modes. The general methods are as follows:

1. Calculating the redundancy of scenario mode jamming effectiveness: Based on the test results of communication receiving level, interference receiving level and suppression coefficient in known propagation mode, the redundancy of interference efficiency in scenario propagation mode is converted and can be accomplished by formula (3):

\[
\Delta P_{yrj} = (P_{yrj} + L_{Dj} - L_{Dj} - P_r) - k
\]

(3)

\(P_{yrj}\) is the interference signal level of the receiving point obtained by experiment under known propagation mode, \(L_{Dj}\) is the transmission loss of interference link corresponding to interference distance \(Dj\) in known propagation mode, \(L_{Dj}\) is the transmission loss of interference link in another propagation mode corresponding to interference distance \(Dj\), \(P_r\) is the received point communication signal level tested under known propagation mode, \(L_{Dj}\) is the transmission loss of communication link in known propagation mode corresponding to communication distance \(Dj\). \(k\) is the compression coefficient.

2. Under the condition of the actual distribution of stations, according to the propagation mode corresponding to the propagation distance \(Dj\) of interference link, the transmission loss \(L_{Dj}\) is calculated by using the transmit and receive power and antenna gain. Using the interference efficiency redundancy, the transmission loss \(L_{Dj}\) corresponding to the maximum interference distance \(D_{yjmax}\) in scenario propagation mode is inferred by \(L_{Dj}\) in another propagation mode is calculated, as shown in Formula (4).

\[
L_{Dj} = \Delta P_{yrj} + L_{Dj}
\]

(4)

3. Based on the difference propagation model between the measured propagation mode and the scenario propagation mode, \(L_{yDj}\) infers the maximum interference distance \(D_{yjmax}\) in the scenario propagation mode by \(L_{yDj}\).
3.2. Derivation Method of Communication Party's Parameter Change

3.2.1. Change in Communication Distance
The interference distance test for a certain communication distance is carried out under the condition of typical measured station distribution. In battle scenario, the communication distance between different battle units (such as brigade, battalion, battalion, company and platoon) is generally different. For other communication distance tests which are different from the actual measurement, the conversion deduction can be made by formula (5).

\[ P^* = P_r + L_{tr} - L_{rt} \]  

\( P_r \) is the converted receiving point communication signal level, \( L_{tr} \) is the communication signal level of the measured receiving point, \( L_{rt} \) is the transmission loss of communication link, \( L_{rt} \) is the transmission loss of communication links corresponding to the measured \( R_t \) of different communication distances.

3.2.2. Change in Communication Transmitter Power
In battle scenario, there are many types of communication stations among different battle units, and the transmitting power of each type of radio station is generally different. For another type of transmitting power different from the measured power, if the antenna used and the working frequency point are the same, it can be deduced by formula (6).

\[ P^* = P_r - 10 \log \frac{W_1}{W_2} \]  

\( P^* \) is the converted receiving point communication signal level, \( P_r \) is the communication signal level of the measured receiving point, \( W_1 \) is the measured transmitter power, \( W_2 \) is the envisaged transmitter power.

3.2.3. Change in Modulation Mode of Transmitting Station
The change of the modulation mode of the transmitter mainly affects the suppression coefficient of the receiver, that is, the suppression coefficient \( K \) of different communication modulation modes is often different under the same interference mode.

For example, under the interference of normal white noise, the reference values of the suppression coefficients of different communication modulation modes are shown in Table 1.

| serial number | communication mode | modulation mode | Suppression coefficient K |
|---------------|--------------------|-----------------|--------------------------|
| 1 | voice communication | DSB | 3.2 |
| 2 | voice communication | SSB | 1.6 |
| 3 | voice communication | VSB | 1.6 |
| 4 | voice communication | AM | 1.1 |
| 5 | voice communication | FM | 4.8 |
| 6 | data communication | 2ASK coherent detection | 0.56 |
| 7 | data communication | 2ASK non-coherent detection | 0.2 |
| 8 | data communication | 2FSK coherent detection | 0.7 |
| 9 | data communication | 2FSK non-coherent detection | 0.55 |
| 10 | 2PSK coherent detection | 1.4 |
| 11 | 2DPSK differential detection | 1.1 |

Remarks: When suppressing effectively, the bit error rate of digital communication is greater than or equal to 0.2. For voice communication, the error rate of taking monosyllabic words is greater than or equal to 0.5.

After obtaining the results of the above-mentioned changes in the parameters of the communicator, the conversion results of the communication signal level at the receiving point and the K factor are respectively substituted into the corresponding calculation formulas to calculate the level redundancy of the interference signal, the loss of the interference link and the maximum interference distance.

3.3. Derivation Method for Parameter Change of Disturbing Parties

3.3.1. Change in interference bandwidth

The jamming equipment has different aiming bandwidth and blocking bandwidth. Under the condition that the total interference power is constant, the jamming bandwidth (aiming bandwidth and blocking bandwidth) different from the experimental results can be converted by formula (7).

\[ P_r = P_{rj} + 10 \log \frac{B_1}{B_2} \]  

where \( P_r \) is the converted receiving point interference signal level, \( P_{rj} \) is the interference signal level of the test receiving point, \( B_1 \) is the interference bandwidth of the real test, \( B_2 \) is the envisaged interference bandwidth.

3.3.2. Change in interference power and interference pattern

Refer to the method of converting the change of transmitting power to the level of receiving point communication signal, converting the change of interference power to the level of receiving point interference signal. The change of jamming mode mainly affects the suppression coefficient of the receiving station, that is, the suppression coefficient \( K \) of different jamming modes for a certain modulation mode is different.

After obtaining the results of the above-mentioned parameters of the interferer, the converted results of the interference signal level of the receiving point and the K factor are substituted into the corresponding calculation formulas to calculate the level redundancy of the interference signal, the interference link loss and the maximum interference distance.

4. SIMULATION RESULTS AND ANALYSIS

4.1. Jamming effectiveness simulation

4.1.1. Measured content

The test stations of the tested objects are shown in Figure 2. The transceiver and receiver work in fixed frequency and frequency hopping communication modes respectively, the jamming equipment is jammed and suppressed separately. The spectrum analyzer and the receiving station are located at the same point. The same antenna and antenna are selected to be placed in the same direction. \( D_t \) is the communication distance, \( D_j \) is the interference distance. The receiving levels of communication link and interference link are tested by spectrum analyzer. Receiving point communication signal level is \( P_{rt} \), measure the average value of the sending station.
n at different times. When converting to frequency hopping communication, the spectrum analyzer is set to maintain state and the level of the concerned frequency points is measured. The receiving point interference signal level is Prj, measure the mean value of jamming equipment at different time. When the interference is blocking, the frequency spectrum analyzer measures the point frequency level. If the integral level within the interference bandwidth is measured, it is converted to the level within the interval of the fixed frequency communication channel.

Fig. 2. Time Series Relation between Communication Signal and Interference Signal

4.1.2. Simulation based on receiving level interference performance deduction method

In Figure 2, the outdoor transmitter's transmit power is set to 5W, the frequency is 100MHz, the distance from the receiving station is 5km, the transmitting and receiving antenna height is 10m, the interference equipment interference power is set to 20W, the antenna height is 20m, and the aiming interference is used, the distance from the receiving station is 8km, the terrain is medium undulating terrain and the line of sight is maintained, the received power of communication is -78.3dbm and the received power of interference suppression is -79dbm measured by spectrum analyzer at the reception station. After completing the above work, using the method of simulation and deduction, the communication parameters of the sender, the interference parameters of the jammer and the maximum interference distance of the jamming equipment after the propagation environment changes are deduced respectively. Because of the limitation of length, only the simulation results of the change of the communication parameters of the sender are provided. Fig. 3-5 are the simulation results of the maximum interference distance caused by the change of the communication distance, transmission power and modulation mode of the sender.

Fig. 3. Simulation results of maximum interference distance varying with communication Distance
Fig. 4. The simulation results of maximum interference distance varying with communication transmission power

Fig. 5. Simulation results of maximum interference distance varying with communication modulation mode

The simulation results show that the maximum interference distance will change correspondingly after the sender parameters change, and the deduction results are in line with expectations, and are verified in the corresponding test tasks.

4.2. Advantages and disadvantages of deduction method based on receiving level

From the above deduction and simulation analysis, it can be seen that the deduction method based on receiving level has some advantages, mainly in:

(1) It does not need too much prior knowledge, and does not need to take into account the antenna gain of the receiving station in different directions. The error introduced in the model and parameter setting is small, and the deduction results are relatively realistic and credible.

(2) If the maximum interference distance and the field test interference distance are the same channel propagation model, the difference between them can offset the systematic error of transmission loss calculation caused by improper setting of topographic features and ground electrical parameters, and can improve the reliability of interference distance deduction.

The inadequacy of this deduction method: the maximum interference distance of the deduction depends on the propagation model in the scenario propagation mode, and the calculation accuracy of the model affects the reliability of the deduction. Therefore, in order to improve the accuracy of simulation results, it is necessary to use a high precision propagation model or locally modified propagation model in the deduction.

5. CONCLUSION

Based on the test data and some prior knowledge of typical test sites, this paper presents a method for deducing the effectiveness of communication jamming based on jamming equipment, combat targets and propagation environment, which solves the problem that the limited field test resources are difficult to support comprehensive evaluation. In the process of research, the starting point is to collect the real interference signal and communication signal in the typical test station environment, the simulation deduces the jamming capability of jamming equipment under different terrain,
meteorological and other propagation environments, different scenario communication combination parameters and jamming combination parameters, the deduction results are relatively realistic and credible. The work of this paper has certain reference significance for electronic equipment test assessment, overall demonstration and design, test effect calculation and evaluation.

Reference
[1] Chen Shangsong. Electronic Measurement and Instrument [M]. BeiJing: Publishing House of Electronics Industry. 2004.08.
[2] James Bao-Yen Tsui. Fundamentals of Global Positioning System Receivers A Software Approach (2nd Edition) [M]. BeiJing: Publishing House of Electronics Industry. 2007.09.
[3] A path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands [J], ITU-R P.1812-4 2015.07.
[4] Xie Yixi. Principle and Application of Radio Wave Propagation [M]. BeiJing: Posts & Telecom Press. 2008.07. P275～295