Efficiency Evaluation for Ship-borne UHF Communication Equipment Based on AHP

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Abstract: By taking the capacity of anti-interference communication for ship-borne UHF radio as the evaluation target, choosing the specific parameters of Equipment, the efficiency evaluation system of DSSS, DS/FH and FH is established. And by using AHP efficiency evaluation model, quantizing the expert evaluation data, the resisting disturbance communication capacity is analyzed.

1. Research background

With the development of information technology, modern naval warfare must have the ability of joint operation and whole area operation based on network information system. As the link of the overall combat effectiveness, the communication system undertakes the tasks of information transmission and distribution, such as command, intelligence and support. At sea, the ship communication capability is one of the key factors affecting the combat capability of the whole formation. Therefore, how to give full play to the equipment communication capability and improve the development of communication equipment is also very important. Communication effectiveness is an effective measure of the communication capability of military communication equipment. Its effectiveness evaluation can provide important support for the demonstration, development, test and operational use of communication system.

Ship ultrashort wave communication equipment is an important equipment for surface ship formation command communication and ship air cooperative communication. It has the advantages of good communication effect and simple structure, and has a variety of anti-interference technical means such as direct spread spectrum, spread hop and pure hop. There is no scientific basis for how to apply electromagnetic interference in the complex battlefield, but it can't be applied in the actual battlefield. By establishing the anti-jamming index evaluation model of ship ultrashort wave communication equipment, this paper quantitatively analyzes the anti-jamming communication ability of different anti-jamming means, so as to provide scientific auxiliary decision-making for commanders.

2. Evaluation index system

In order to help commanders choose anti-jamming means scientifically and intuitively, this paper intends to study the anti-jamming effectiveness by establishing an anti-jamming evaluation system and quantitatively analyzing the anti-jamming effectiveness. Analytic hierarchy process (AHP) is a systematic and hierarchical decision analysis method combining qualitative and quantitative methods to solve multi-objective complex problems [1-3]. Analytic hierarchy process can be used to analyze the anti-jamming effectiveness of ship ultrashort wave communication equipment.

The decision-making process of selecting anti-jamming effectiveness evaluation of ship ultrashort wave equipment can be summarized as follows:

(1) The evaluation index system of anti-jamming effectiveness is divided into three layers: target layer, standard layer and decision-making scheme layer;

(2) Determine the weight of each standard to the target and the weight of each anti-interference decision-making scheme to each standard through mutual comparison;

(3) Synthesize the above two groups of weights to determine the weight of each anti-interference decision-making scheme to the target.

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2.1 Establishment of evaluation index system

Taking the typical ship ultrashort wave communication equipment as an example, its anti-jamming means mainly include direct spread, pure hop and spread hop modes, and the corresponding evaluation indexes must be reasonably selected to evaluate the anti-jamming effectiveness of the three modes [4-5]. According to the requirements of objectivity, testability, independence and completeness [6-8], and according to the actual situation of the equipment, the relevant parameters that can be operated and set are mainly selected as the evaluation index. "Anti-jamming effectiveness of ship ultrashort wave equipment" as the target layer; The radio parameters "frequency interval", "frequency stability", "transmitting power", "receiving sensitivity", "modulation distortion", "spread spectrum code type", "frequency hopping pattern", "frequency hopping speed", "frequency hopping table number", "modulation system", "anti-interference tolerance" and "same step time difference" are used as the standard layer; "Direct expansion", "pure jump" and "expansion jump" are taken as the decision scheme level, as shown in Figure 1.

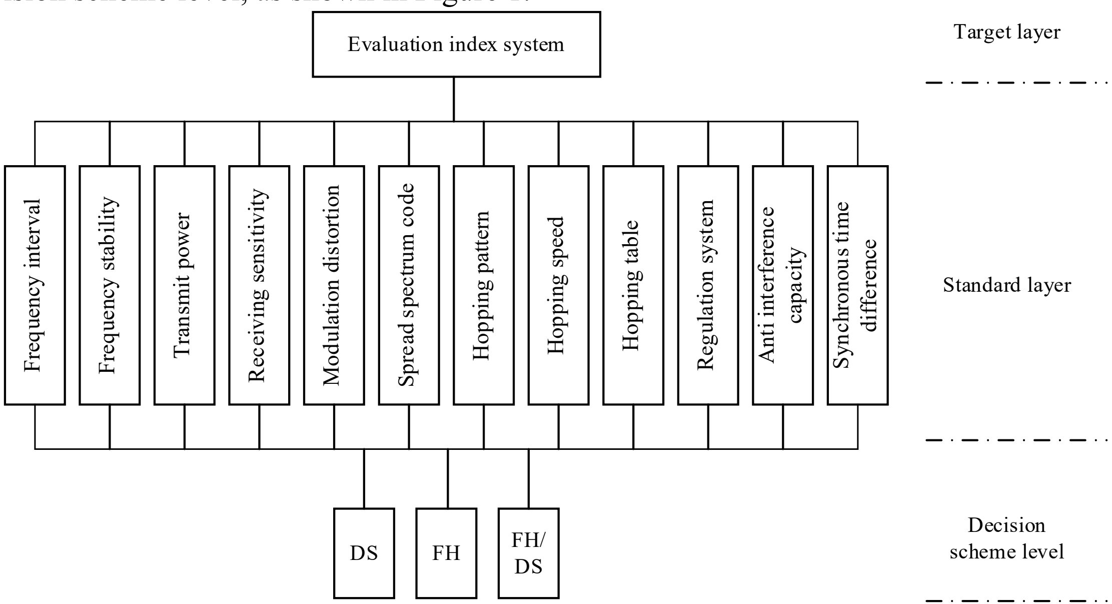

Figure 1 Evaluation index system of anti-jamming effectiveness of ship ultrashort wave communication equipment

2.2 Calculation of AHP index weight

Compare and judge the similar criteria of the standard layer, and get the relative weight of the evaluation criteria. The main process is to first compare the importance of one criterion with that of another criterion, obtain the judgment matrix, and finally obtain the weight of each criterion by calculating the matrix eigenvector [9-11].

(1) Criterion weight scale model

Using 1 ~ 9 scale method to compare the importance of two criteria in the same layer.

(2) Weight scale of target layer and standard layer

According to the established evaluation index system, the influence of multiple index parameters of ship ultrashort wave communication equipment on anti-jamming performance is analyzed, so as to obtain the weight scale of target layer and standard layer, as shown in Table 1.

Table 1 Weight scale of target layer and standard layer

Standard	Absolutely important	Median	Very important	Median	More important	Median	Slightly important	Median	Equal
	9	8	7	6	5	4	3	2	1
Frequency interval							√		
Frequency stability					√				
Transmit power	√								

Receiving sensitivity			√							
Modulation distortion					√					
Spread spectrum code					√					
Hopping pattern					√					
Hopping speed			√							
Hopping table										√
Regulation system										√
Anti-interference capacity	√									
Synchronous time difference							√			

(3) Criterion weight judgment matrix

According to the weight scale model, the weight judgment matrix of target layer and standard layer is obtained as follows:

Table 2 Judgment matrix BE

B_E	u1	u2	u3	u4	u5	u6	u7	u8	u9	u10	u11	u12
u1	1	1/3	1/7	1/5	1/3	1/3	1/3	1/5	3	3	1/7	1
u2	3	1	1/5	1/3	1	1	1	1/3	5	5	1/5	3
u3	7	5	1	3	5	5	5	3	9	9	1	7
u4	5	3	1/3	1	3	3	3	1	7	7	1/3	5
u5	3	1	1/5	1/3	1	1	1	1/3	5	5	1/5	3
u6	3	1	1/5	1/3	1	1	1	1/3	5	5	1/5	3
u7	3	1	1/5	1/3	1	1	1	1/3	5	5	1/5	3
u8	5	3	1/3	1	3	3	3	1	7	7	1/3	5
u9	1/3	1/5	1/9	1/7	1/5	1/5	1/5	1/7	1	1	1/9	1/3
u10	1/3	1/5	1/9	1/7	1/5	1/5	1/5	1/7	1	1	1/9	1/3
u11	7	5	1	3	5	5	5	3	9	9	1	7
u12	1	1/3	1/7	1/5	1/3	1/3	1/3	1/5	3	3	1/7	1

Feature vector:

[0.027, 0.057, 0.226, 0.119, 0.057, 0.057, 0.057, 0.119, 0.014, 0.014, 0.226, 0.027]T

Weighted sum vector:

[0.027, 0.048, 0.253, 0.104, 0.048, 0.048, 0.048, 0.104, 0.019, 0.019, 0.253, 0.027]T

Based on the index of ship ultrashort wave radio, for each standard level, establish the judgment matrix of each scheme at the decision-making scheme level. The judgment matrix of each scheme is:

$$B1=\begin{bmatrix}1 & 1 & 7\\ 1 & 1 & 7\\ 1/7 & 1/7 & 1\end{bmatrix},\quad B2=\begin{bmatrix}1 & 1/5 & 1/2\\ 15 & 1 & 3\\ 2 & 1/3 & 1\end{bmatrix},\quad B3=\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix},\quad B4=\begin{bmatrix}1 & 1 & 5\\ 1 & 1 & 5\\ 1/5 & 1/5 & 1\end{bmatrix},$$

$$B5=\begin{bmatrix}1 & 2 & 5\\ 1/2 & 1 & 3\\ 1/5 & 1/3 & 1\end{bmatrix}, B6=\begin{bmatrix}1 & 9 & 9\\ 1/9 & 1 & 1\\ 1/9 & 1 & 1\end{bmatrix}, B7=\begin{bmatrix}1 & 1/9 & 1/7\\ 9 & 1 & 3\\ 7 & 1/3 & 1\end{bmatrix}, B8=\begin{bmatrix}1 & 1/9 & 1\\ 9 & 1 & 9\\ 1 & 1/9 & 1\end{bmatrix}, B9=\begin{bmatrix}1 & 1/9 & 1/7\\ 9 & 1 & 3\\ 7 & 1/3 & 1\end{bmatrix},$$

$$B10=\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}, B11=\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}, B12=\begin{bmatrix}1 & 1/9 & 1/9\\ 9 & 1 & 1\\ 9 & 1 & 1\end{bmatrix}$$

For each criterion, the maximum eigenvalue $\lambda_{\max}^{i}$ and its corresponding eigenvector Pi of the judgment matrix Bi (I = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12) are solved respectively, and the consistency test is carried out, i.e

P1=[0.467, 0.467, 0.067]

λ_{1max}=2.998, CR1=0.002<0.1;

P2=[0.111, 0.667, 0.222]

λ_{2max}=3.004, CR2=0.003<0.1;

P3=[0.333, 0.333, 0.333]
λ_{3max}=3, CR3=0<0.1;
P4=[0.455, 0.455, 0.091]
λ_{4max}=3, CR4=0<0.1;
P5=[0.581, 0.309, 0.11]
λ_{5max}=3.004, CR5=0.003<0.1;
P6=[0.818, 0.091, 0.091]
λ_{6max}=2.9999, CR6=0<0.1;
P7=[0.057, 0.649, 0.295]
λ_{7max}=3.0812, CR7=0.07<0.1;
P8=[0.091, 0.818, 0.091]
λ_{8max}=2.9999, CR8=0<0.1;
P9=[0.057, 0.649, 0.295]
λ_{9max}=3.0812, CR9=0.07<0.1;
P10=[0.333, 0.333, 0.333]
λ_{10max}=3, CR10=0<0.1;
P11=[0.333, 0.333, 0.333]
λ_{11max}=3, CR11=0<0.1;
P12=[0.053, 0.474, 0.474]
λ_{12max}=2.9999, CR12=0<0.1;
Where Pi is the weight of each standard deviation parameter to the final decision scheme.

2.3 Comprehensive weight

Calculate the comprehensive weight of three anti-interference methods:
E=[0.236, 0.324, 0.439]

This shows that when the ship ultrashort wave radio encounters interference, for the three anti-interference communication modes of direct spread spectrum, frequency hopping and frequency hopping, the anti-interference efficiency of frequency hopping communication is the best.

3. Evaluation and analysis

The above evaluation conclusion conforms to the basic principles of three anti-interference communication. "Direct spread spectrum" refers to the spread spectrum modulation of the information to be transmitted through the broadband spread spectrum code, which widens the signal bandwidth and reduces the signal amplitude at the same time, and is transmitted through RF modulation. "Frequency hopping" is to load the information to be transmitted on a random and fast hopping carrier frequency, so that the enemy's reconnaissance and jamming can't touch and keep up with the random hopping carrier frequency, so as to achieve the purpose of "avoiding" the enemy's jamming. "Spread hop" is the working mode of "direct spread" and then "frequency hopping" of the transmitted information. The first mock exam is a combination of two modes, and it should be better than the single mode. Combined with the evaluation conclusion, we analyze the practical application of anti-interference communication of ship ultrashort wave radio:

In DSSS mode, because the power spectral density of the transmitted signal is relatively high, it is difficult to "hide" the signal in the noise environment. According to the actual application records, after the enemy obtains the DSSS power spectrum signal through detection, the high-power interference near the central frequency can cause effective interference to the DSSS signal. Therefore, the anti-interference effect of the "DSSS" method of the actual ship ultrashort wave radio is poor.

In frequency hopping mode, through many anti-interference tests, the ship ultrashort wave radio has small frequency hopping interval, large bandwidth, many frequency points and fast hopping speed, so it has strong anti-interference ability. Moreover, the signal power spectrum during frequency hopping is relatively small and has little impact on other stations. It is suitable for peacetime and training.

In the spread hop mode, although its anti-interference performance is the best through evaluation and analysis, the power spectral density after spread spectrum is high, and the jump of signal in the corresponding frequency band will have a great interference impact on the whole working frequency band, which may lead to the failure of other ship ultrashort wave radios working at the same time. Therefore, the "extended jump" working mode of ship ultrashort wave radio is only used in confrontation drills or special tasks.

4. Conclusion

This paper analyzes the comprehensive effectiveness evaluation of three typical anti-jamming modes of ship ultrashort wave radio. Combined with the settable parameters of specific equipment, the specific evaluation model and evaluation system are established. The analytic hierarchy process is selected to analyze the anti-jamming performance, and the comprehensive weights of different anti-jamming modes are obtained. The evaluation results are consistent with the facts. Based on the established effectiveness evaluation model, the preliminary influence relationship between various indicators of the radio and communication effectiveness can be analyzed, so as to improve the performance of the radio and promote the rational use of tactics.

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