Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(7):535-542

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Effectiveness evaluation of electronic warfare command and control system based on grey AHP method

QI Zong-feng[1] and Wang Guo-sheng[2*]

[1]The State Key Laboratory of Complex Electromagnetic Environment Effects on Electronics and Information System (CEMEE), Luoyang, China
[2]Department of Control Engineering, Academy of Armored Forces Engineering, Beijing, China

---

ABSTRACT

The grey AHP effectiveness evaluation problem of electronic warfare command and control system (EWCCS) under complex electromagnetic environment is investigated. First, the evaluation hierarchy structures of EWCCS under complex electromagnetic environment are put forward and can be classified into target hierarchy, rule hierarchy and scheme hierarchy. Then, the grey AHP Algorithm is given as a preliminary knowledge to evaluate the effectiveness evaluation of EWCCS under complex electromagnetic environment. Finally, an effectiveness evaluation example of three EWCC systems under complex electromagnetic environment is considered by using the grey analytic hierarchy process (AHP) Algorithm, and the grey comprehensive evaluations for the three EWCC systems under complex electromagnetic environment and their grades of the grey comprehensive evaluation are proposed.

Key words: Electronic warfare command and control system; complex electromagnetic environment; grey AHP; comprehensive effectiveness evaluation

---

INTRODUCTION

The electronic warfare equipments are more and more important in modern information battles. With the development of the new computer technology, the electronic warfare equipments become more and more complex, pregnable and damageable such that it is difficult to evaluate the performance and effectiveness of the electronic warfare equipments. Cai et al establish the anti-jamming efficiency evaluation model of the tactical communication net and evaluate the anti-jamming efficiency of the tactical communication net by GEM and GAHP in [1]. Cui et al determine the different grey fuzzy weights for different factors by using analytical hierarchy process, and construct grey fuzzy relation matrix by grey fuzzy weight, membership, point grey in [2]. In order to solve the disadvantages for the efficiency evaluation of the underwater acoustic countermeasure，resulting from the underwater information fuzzy and data scarcity, Tang et al propose the gray analytic hierarchy evaluation method in [3]. Yin et al introduce a new grey hierarchy evaluation method ，used for evaluating of EW performance in multiple airborne platform system, establish the complete performance evaluation index system EW performance in multiple airborne platforms system，and give the definition and calculation formula of each index in [4].

Shi et al study the Fuzzy-AHP in evaluation of ECM command effectiveness to calculate the influence degree of each ingredient and evaluate the ECM command effectiveness in [5]. According to its characteristics of insufficient information and uncertainty, Yu et al evaluate the EW system operation effectiveness by using the method of grey hierarchy evaluation in [6]. Chen et al calculate the effectiveness of instructed EW system by using analytic hierarchy process, the weighted coefficient of each guideline is defined, and the effectiveness of instructed EW system is calculated in [7]. Liu et al build an effectiveness evaluation index system of airborne ECM system which can reflect the airborne ECM system capacity generally and impersonally in [8].

As one of important electronic warfare equipments, an electronic warfare system under complex electromagnetic environment plays an important role in the modern information battle. Therefore, the effectiveness evaluation problem of electronic warfare command and control system (EWCCS) under complex electromagnetic environment has become a popular topic in the investigation of modern battle theory. Thus in this paper we will investigate the effectiveness evaluation of electronic warfare command and control system under complex electromagnetic environment by using the grey AHP method. First, the evaluation hierarchy structures of EWCCS under complex electromagnetic environment are proposed. Then, the detail grey AHP algorithm is put forward as preliminaries for the effectiveness evaluation of EWCCS under complex electromagnetic environment. And then, the effectiveness evaluation example of three EWCC systems under complex electromagnetic environment is designed by using AHP and the simulation result shows that the grey AHP method is effective and simple for effectiveness evaluation of EWCCS under complex electromagnetic environment.

EVALUATION HIERARCHY STRUCTURES OF EWCCS

According to the features of EWCCS under complex electromagnetic environment, many factors which are related with the performances of EWCCS under complex electromagnetic environment can be found out and can be classified into the target hierarchy, the rule hierarchy and the scheme hierarchy.

The target hierarchy or the first hierarchy for effectiveness evaluation of EWCCS under complex electromagnetic environment can be denoted by A. The rule hierarchy of EWCCS under complex electromagnetic environment includes scouting and detecting ability C1, command and control ability C2, communicating and safeguarding ability C3, and battlefield electromagnetism environment C4.

For simplicity, we only select two scheme specifications for every component in the rule hierarchy of EWCCS under complex electromagnetic environment. The scheme hierarchy of scouting and detecting ability C1 includes scouting and detecting method C11 and scouting and detecting range C12. The scheme hierarchy of command and control ability C2 include ability of auxiliary decision C21 and decision delay C22. The scheme hierarchy of communicating and safeguarding ability C3 include covering range C31 and communicating capacity C32. The scheme structure of battlefield electromagnetism environment C4 includes quality of electromagnetism radiant point C41 and density of electromagnetism signal C42.

Based on the above analysis of EWCCS under complex electromagnetic environment, we can give the hierarchy structure with the target hierarchy, the rule hierarchy and the scheme hierarchy in Fig. 1.

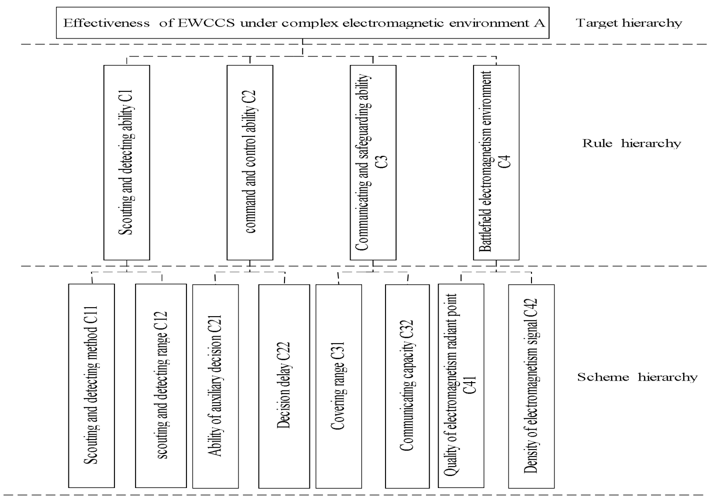

Fig. 1 : The hierarchy structure of EWCCS under complex electromagnetic environment

GREY AHP METHOD

AHP is a decision making support tool developed in the 1970s by Thomas Saaty, a mathematics lecturer from the University of Pittsburgh, US. The process requires the establishment of a hierarchy of criteria which is important to achieve the goal of the decision problem. AHP provides a rational framework for decision making by breaking down the process into components with respect to an overall goal. Based on the classic AHP method, many generalized AHP methods and their applications are studied. As one of generalized AHP methods, Evangelos et al and Ke et al investigate the detail algorithm of grey AHP in [9] and [10]. Based on the above references, we can list the Grey

AHP method as follows:

Step 1. Establish the hierarchy structure of the effectiveness evaluation system. The effectiveness evaluation system is usually decomposed into different hierarchies, such as the goal or target hierarchy, the rule hierarchy and the scheme hierarchy, which are denoted by the ladder structure.

Step 2. Establish the pair-wise judgment matrix. Comparing the different factors in the same hierarchy with one of rules in the above hierarchy, we can obtain their important degrees and the corresponding judgment matrices. The values of the pair-wise comparisons in the AHP are determined according to the scale introduced by Saaty. According to this scale, the available values for the pair-wise comparisons are members of the set: {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9}.

Step 3. Extract the relative importance implied by the previous pair wise comparisons. Calculate the corresponding maximum left eigenvector of the judgment matrix is approximated by using the geometric mean of each row and the numbers are normalized by dividing them with their sum.

Step 4. Test the consistency of the relative importance. In the AHP, the pair wise comparisons in a judgment matrix are considered to be adequately consistent if the corresponding consistency ratio (C.R.) is less than 10%.

The C. R. coefficient is calculated as follows:
1) The consistency index (C.I.) needs to be estimated. This is done by adding the columns in the judgment matrix and multiply the resulting vector by the vector of priorities (i.e., the approximated eigenvector) obtained earlier. This yields an approximation of the maximum eigenvalue, denoted by $\lambda_{\max}$.

2) The C. I. value is calculated by using the formula: C.I. = ($\lambda_{\max}$ -n)/(n-1). Next the consistency ratio CR is obtained by dividing the C. I. value by the Random Consistency index (R. I.) as given in Table 1.

Table 1: R.I. values for different values of n

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54	1.56	1.58	1.59

Step 5. Calculate the relative weight of the compared components to their hierarchy, and calculate the relative weight w of the components in the rule hierarchy and the relative weight w_i of the components in the scheme hierarchy to the goal hierarchy.

Step 6. Determine the evaluated swatch matrices for the specifications in the scheme hierarchy. Assume that the number of the evaluated systems is p and the number of the specifications under the rule hierarchy C_i is k, thus the evaluated swatch matrix can be written by

$$D_i = \begin{bmatrix} d_{i11} & d_{i12} & \cdots & d_{i1p} \\ d_{i21} & d_{i22} & \cdots & d_{i2p} \\ \vdots & \vdots & \cdots & \vdots \\ d_{ik1} & d_{ik2} & \cdots & d_{ikp} \end{bmatrix} \tag{1}$$

Step 7. Assume that there are four evaluated grey species, and their evaluated grades are “excellent, good, common and bad”, which are denoted by $e = 1, 2, 3, 4$, respectively. According to the analysis of the evaluated system, the grey number $\otimes_i$ ($i = 1, 2, 3, 4$) and the whitenized weight function $f_i(x)$ $\otimes_i$ ($i = 1, 2, 3, 4$) of the grey species as follows

$$\begin{cases} \otimes_1 = [0.7, 0.9, 1.0] \\ f_1(x) = \begin{cases} \dfrac{x-0.7}{0.2}, & x \in [0.7, 0.9] \\ 1-x, & x \in [0.9, 1.0] \\ 0, & x \notin [0.7, 1.0] \end{cases}, \text{ when } e = 1 \end{cases} \tag{2}$$

$$\begin{cases} \otimes_2 = [0.5, 0.7, 0.9] \\ f_2(x) = \begin{cases} \dfrac{x-0.5}{0.2}, & x \in [0.5, 0.7] \\ \dfrac{0.9-x}{0.2}, & x \in [0.7, 0.9] \\ 0, & x \notin [0.5, 0.9] \end{cases} \end{cases}, \text{ when } e = 2 \tag{3}$$

$$\begin{cases} \otimes_3 = [0.3, 0.5, 0.7] \\ f_3(x) = \begin{cases} \dfrac{x-0.3}{0.2}, & x \in [0.3, 0.5] \\ \dfrac{0.7-x}{0.2}, & x \in [0.5, 0.7] \\ 0, & x \notin [0.3, 0.7] \end{cases} \end{cases}, \text{ when } e = 3 \tag{4}$$

$$\begin{cases} \otimes_4 = [0, 0.3, 0.5] \\ f_4(x) = \begin{cases} \dfrac{x}{0.3}, & x \in [0, 0.3] \\ \dfrac{0.5-x}{0.2}, & x \in [0.3, 0.5] \\ 0, & x \notin [0, 0.5] \end{cases} \end{cases}, \text{ when } e = 4 \tag{5}$$

where the grey number stands for the grade associated with the specification x, the value of the grey number stands for the interval of the score, the middle value stands for the best scoring value.

Step 8. Determine the evaluated weight matrices. Denote the grey evaluated weight associated with the e-th grey specie by r_{ije}, which can be obtain by $r_{ije} = c_{ije}/c_{ij}$, where $c_{ije} = \sum_{t=1}^{p} f_e(d_{ijt})$ is the grey evaluated coefficient of the system specification C_{ij}, and $c_{ij} = \sum_{e=1}^{4} c_{ije}$ is the total grey evaluated coefficient. Thus the grey evaluated weight vector which is composed of every grey evaluated weight r_{ije} for C_{ij} can be written by

$$r_{ij} = [r_{ij1}, r_{ij2}, r_{ij3}, r_{ij4}] \tag{6}$$

Therefore, the grey evaluated matrix R_i can be obtained from the grey evaluated weight vector r_{ij} for the specification C_{ij} which belongs to C_i as follows

$$R_i = \begin{bmatrix} r_{i1} \\ r_{i2} \\ \vdots \\ r_{ik} \end{bmatrix} \tag{7}$$

Based on the weight vector w_i of the specification C_{ij} which belongs to C_i, the comprehensive evaluation for the specification C_{ij} which belongs to C_i can be given by

$$B_i = w_i R_i \tag{8}$$

From (8), we can obtain the grey evaluated matrix for the total specification A as

$$B = \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_k \end{bmatrix} \quad (9)$$

Step 9. Determine the grey comprehensive evaluation. The value for the grey comprehensive evaluation is

$$E = wBC \quad (10)$$

where $C = [90 \quad 70 \quad 50 \quad 30]^T$ stands for the vector that consists of the score value corresponding to the grey evaluated species.

A NUMERICAL EXAMPLE

Based on the Evaluation hierarchy structure of EWCCS under complex electromagnetic environment in Fig. 1, the AHP algorithm and the grey algorithm, we will calculate the effectiveness evaluation of EWCCS under complex electromagnetic environment.

Assume that the experts give the relative importance of the criteria in the pair-wise judgment matrices of the EWS under complex electromagnetic environment. The corresponding pair-wise judgment matrix among complex electromagnetic environment include scouting and detecting ability C1, command and control ability C2, communicating and safeguarding ability C3, and battlefield electromagnetism environment C4 can be given by the following table 2. And the weight vector of C1, C2, C3 and C4 is $[0.553 \quad 0.1313 \quad 0.2704 \quad 0.0454]^T$, $C.R. = 0.0883 < 0.1$ shows that the relative importance of the pair-wise judgment matrix is consistent.

Table 2: The pair-wise judgment matrix among C1, C2, C3 and C4

A	C1	C2	C3	C4	w
C1	1	5	3	7	0.553
C2	0.2	1	0.3333	5	0.1313
C3	0.3333	3	1	6	0.2704
C4	0.1429	0.2	0.1667	1	0.0454
$\lambda_{\max} = 4.2359$		$C.I. = 0.0786$		$C.R. = 0.0883 < 0.1$	

The corresponding pair-wise judgment matrix between scouting and detecting method C11, and scouting and detecting range C12 in scouting and detecting ability C1 can be given by Table 3. And the weight vector of C11 and C12 is $[0.3333 \quad 0.6667]^T$, $C.R. = 0 < 0.1$ shows that the relative importance of the pair-wise judgment matrix is consistent.

Table 3: The pair-wise judgment matrix among C11 and C12

C1	C11	C12	w1
C11	1	0.5	0.3333
C12	2	1	0.6667

The corresponding pair-wise judgment matrix between ability of auxiliary decision C21, and decision delay C22 in command and control ability C2 can be given by can be given by Table 4. And the weight vector of C21 and C22 is $[0.25 \quad 0.75]^T$, $C.R. = 0 < 0.1$ shows that the relative importance of the pair-wise judgment matrix is consistent.

Table 4: The pair-wise judgment matrix among C21 and C22

C2	C21	C22	w2
C21	1	0.3333	0.25
C22	3	1	0.75

The corresponding pair-wise judgment matrix between covering range C31 and communicating capacity C32 in communicating and safeguarding ability C3 can be given by Table 5. And the weight vector of C31 and C32 is $[0.6667 \quad 0.3333]^T$, $C.R. = 0 < 0.1$ shows that the relative importance of the pair-wise judgment matrix is consistent.

Table 5: The pair-wise judgment matrix among C31 and C32

C3	C31	C32	w3
C31	1	2	0.6667
C32	0.5	1	0.3333

The corresponding pair-wise judgment matrix between quality of electromagnetism radiant point C41 and density of electromagnetism signal C42 in battlefield electromagnetism environment C4 can be given by Table 6. And the weight vector of C41 and C42 is $[0.8333 \quad 0.1667]^T$, $C.R. = 0 < 0.1$ shows that the relative importance of the pair-wise judgment matrix is consistent.

Table 6: The pair-wise judgment matrix among C41 and C42

C4	C41	C42	w4
C41	1	5	0.8333
C42	0.2	1	0.1667

From Table 3, we can know that the weight vector of C1, C2, C3 and C4 $w = [0.553 \quad 0.1313 \quad 0.2704 \quad 0.0454]^T$ can be shown by Fig. 2. From Fig. 2, we can directly find that the sort order of the relative importance among C1, C2, C3 and C4 is "C1»C3»C2»C4", where "»" implies that the former is more important than the later.

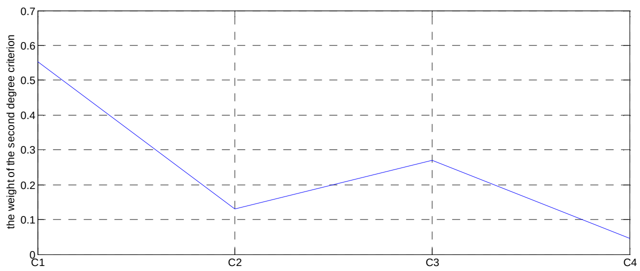

Fig. 2: The relative importance among C1, C2, C3 and C4

From the result for the relative importance among C1, C2, C3 and C4, we can know that the importance of scouting and detecting ability C1 is 0.553. Thus we can know that in order to improve the effectiveness of EWCC systems under complex electromagnetic environment, the scouting and detecting ability C1 is first considered, and the other performances are simultaneously considered. In the scouting and detecting ability C1, the relative importance of scouting and detecting range C12 is 0.6667.

Based on the above results of AHP algorithm, we continue to consider the effectiveness evaluation of three EWCC systems under complex electromagnetic environment by using the grey algorithm.

Assume that the scores of the above specifications for three EWCC systems under complex electromagnetic environment S1, S2, and S3, are given in Table 7 and the scores after undimensionalized by the maximum value are given in Table 8.

Table 7: The scores of specifications in the scheme herichacy

	C1		C2		C3		C4	
	C11	C12	C21	C22	C31	C32	C41	C42
S1	70	65	80	75	89	92	65	74
S2	83	74	60	87	78	90	68	58
S3	90	87	95	69	85	76	87	60

Table 8: The scores after undimensionalized by the maximum value

	C1		C2		C3		C4	
	C11	C12	C21	C22	C31	C32	C41	C42
S1	0.7778	0.7471	0.8421	0.8621	1	1	0.7471	1
S2	0.9222	0.8506	0.6316	1	0.8764	0.9783	0.7816	0.7838
S3	1	1	1	0.7931	0.9551	0.8261	1	0.8108

From Table 8, we can establish the evaluated swatch matrices for S1, S2 and S3 as

$$D_1 = \begin{bmatrix} 0.7778 & 0.9222 & 1 \\ 0.7471 & 0.8506 & 1 \end{bmatrix}, \quad D_2 = \begin{bmatrix} 0.8421 & 0.6316 & 1 \\ 0.8621 & 1 & 0.7931 \end{bmatrix}$$

$$D_3 = \begin{bmatrix} 1 & 0.8764 & 0.9551 \\ 1 & 0.9783 & 0.8261 \end{bmatrix}, \quad D_4 = \begin{bmatrix} 0.7471 & 0.7816 & 1 \\ 1 & 0.7838 & 0.8108 \end{bmatrix}$$

For C11 of S1, from (2)-(5) we can obtain the whitenized weight value of the grey species as

$$e = 1, \quad c_{111} = f_1(0.778) = 0.39, e = 2, \quad c_{112} = f_2(0.778) = 0.61$$
$$e = 3, \quad c_{113} = f_3(0.778) = 0, e = 4, \quad c_{114} = f_4(0.778) = 0$$

Thus the total grey evaluating weight vector for C11 is $r_{11} = [0.39 \quad 0.61 \quad 0 \quad 0]$.For C12 of S1, from (2)-(5) we can obtain the whitenized weight value of the grey species as

$$e = 1, \quad c_{121} = f_1(0.7471) = 0.2355, e = 2, \quad c_{122} = f_2(0.7471) = 0.7645,$$
$$e = 3, \quad c_{123} = f_3(0.7471) = 0, e = 4, \quad c_{124} = f_4(0.7471) = 0$$

Thus from (6) we can obtain the total grey evaluating weight vector for C12 of S1 as

$$r_{12} = [0.2355 \quad 0.7645 \quad 0 \quad 0]$$

Thus from (7) we can obtain the grey evaluating matrix for C1 of S1 as

$$R_1 = \begin{bmatrix} 0.39 & 0.61 & 0 & 0 \\ 0.2355 & 0.7645 & 0 & 0 \end{bmatrix}$$

Similarly, we can obtain the grey evaluating matrices R_2, R_3 and R_4 for C2, C3, and C4 of S1, respectively, as follows

$$R_2 = \begin{bmatrix} 0.7105 & 0.2895 & 0 & 0 \\ 0.8105 & 0.1895 & 0 & 0 \end{bmatrix}, \quad R_3 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}, \quad R_4 = \begin{bmatrix} 0.2355 & 0.7645 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

From (8), we can obtain the comprehensive evaluation for the specification C1, C2, C3 and C4 of S1, respectively, as

$$B_1 = [0.287 \quad 0.713 \quad 0 \quad 0], \quad B_2 = [0.7855 \quad 0.2145 \quad 0 \quad 0], B_3 = [0 \quad 0 \quad 0 \quad 0], B_4 = [0.1962 \quad 0.6371 \quad 0 \quad 0]$$

From (9), we can obtian the grey evaluated matrix for the total specification A of S1 as

$$B = \begin{bmatrix} 0.287 & 0.713 & 0 & 0 \\ 0.7855 & 0.2145 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0.1962 & 0.6371 & 0 & 0 \end{bmatrix}$$

Finally, from (10) we can obtain the value for the grey comprehensive evaluation of S1 as $E_1 = 55.9643$ .Similarly, we can obtain the values for the grey comprehensive evaluation of S2 and S3, respectively, as $E_2 = 77.4825$, $E_3 = 32.0936$. From the above values for the grey comprehensive evaluation of S1, S2 and S3, we can know that the EWCC system under complex electromagnetic environment S1 is “common”, the EWCC system under complex electromagnetic environment S2 is “good”, and the EWCC system under complex electromagnetic environment S3 is “bad”. The evaluating results of the EWCC systems under complex electromagnetic environment S1, S2 and S3 by using the grey AHP method can be shown in Table 9.

Table 9: The comprehensive evaluation results by the grey AHP method

Parameters	Three EWCC systems		
	S1	S2	S3
Value for the grey comprehensive evaluation	55.9643	77.4825	32.0936
Grade for the grey comprehensive evaluation	common	good	bad

CONCLUSION

In this paper we consider the grey AHP effectiveness evaluation problem of EWCCS under complex electromagnetic environment is investigated. By using the grey AHP method, an effectiveness evaluation example of three EWCC systems under complex electromagnetic environment is considered, and the grey comprehensive evaluations and their grades of the grey comprehensive evaluation are proposed. In the next research, we will investigate grey synthetically associated analysis method to evaluate the effectiveness evaluation problem of EWCCS with insufficient information.

Acknowledgments
This work was financially supported by the Open Project Foundation of the State Key Laboratory of CEMEE (CEMEE2014K0305B).

REFERENCES

[1] Cai Y. J., *Fire Control & Command Control*, vol. 37, pp. 106-108, **2012.**
[2] Cui J. G., Fu K. Y., Chen X. C., QI Y. W., Jiang L. Y., *Acta Aeronautica et Astronautica Sinica*, vol. 34, pp. 1-9, **2013.**
[3] Tang Z. , Sun C. , Liu Z. W., Meng D., *Acta Armamentarii*, vol. 33, pp. 432-436, **2012**.
[4] Yin H. T. , Wang X. Y. , Gu X. J. , Wu J. B., *Journal of Northwestern Polytechnical University*, vol. 30, pp. 350-355, **2012**.
[5] Shi R., Han C. J. , Huang J., *Command Control & Simulation*, vol. 28, pp. 59-64, **2006**.
[6] Yu H., Lu G. X., Chen Y., Zhou L., *Radio Engineering*, vol. 39, pp. 61-64, **2009.**
[7] Chen G. Z., Xue Y. F., *Electronic Warfare*, vol. 106, pp. 26-34, **2006**.
[8] Liu Z. Y., Ping D. F., Wang L., *Ship Electronic Engineering*, vol. 32, pp. 68-71, **2012**.
[9] Evangelos T., Stuart H. M., *International Journal of Industrial Engineering, Applications and Practice*, vol. 2, pp. 35-44, **1995**.
[10] Ke H., Ke K., *Mathematic in Practice and Theory*, vol. 41, pp. 155-162, **2011**.