Scientific Research

Study on the Electromagnetic Environmental Effects for the Detection and Evaluation of Electronic Equipment

YU Daojie, LIN Xin, CUI Weiqun, GUO Yuhua

China National Digital Switching System Engineering and Technological Research Center, Zhengzhou, China

Email: ydj2008@126.com

Abstract: The electromagnetic environmental effects (E3) for the detection and evaluation of electronic equipment are studied systematically. The key index parameters and system model of the detection and evaluation on E3 for electronic equipment are present. And the current developement and tendency of the future on the study of E3 are summrized. The emphasis on the E3 research should be focused on the following areas:multi-classifier fusion method, artifiial intelligence based on probability statistics method and the analytical procedures of system engineering and etc.

Keywords: electromagnetic environmental effects; electronic equipment; methods of evaluation; complex electromagnetic environment

1 Introduction

The common purposes of the study on E3 focus on the determinant factors and relationship between E3 and these factors for the purpose of improving and enhancing the E3 of electronic platforms, systems, subsystems, or equipment. As for this, Goode and Machol have stated firstly: "Decision-making should be on the basis of efficiency evaluation, including predecision-making, practicing decision-making and carrying out decision-making."[1] The sense of the efficiency lies in serving-for-decision-making efficiency evaluation. Without efficiency evaluation, efficiency is nothing but a common blurry conception. So, in 1963, based on the partition of system state and the ideology model of conditional transfer probability, Weapon System Efficiency Industry Advisory Committee of America (WSEIAC) puts forward the following definition of E3: System efficiency is a measurement under the expectation that one system is to fulfill a given tast. It is a function on the availability, dependability and inherent capability of the system.

The definition of E3 given by GJB1346-92 is like this: "It is the capacity to achieve the objectives of the requirement under the required conditions, a multivariant measurement to military electronic equipment and it will posses different specific connotation with the study of the different point of views."

2 Category Descriptions of Efficiency

We can draw the conclusion based on the above definitions that under certain conditions, the efficiency of electronic equipment owns some specific connotation, as a result, the evaluation is to submit to specific requirement. According to different requests, the common-used categories accepted in large-scale regions of E3 on electronic equipment can be classified as follows:

Firstly, Self-Efficiency & Efficiency of Use.

Self-Efficiency refers to the self contained beneficial effect of the electronic equipment, it is a relative performance of static. Efficiency of Use is the beneficial effect that the electronic equpment performed under the actual environment of electronic warfare.

Efficiency of Use involves more relevant factors, thus its model is more complicated.

Secondly, Efficiency of Performance Index & Monomial Efficiency.

Efficiency of Performance Index refers to the measurement to the relevant factors which effect efficiency, like MTBF, Speed measurement, firepower measurement and etc.

Monomial Efficiency can not only be regarded as efficiency of performance index but also a more advanced placement. It mainly stresses the state that the electronic equipment operates in a certain condition, in order to achieve a single task, a corresponding monomial task will be in action, such as strategic mobility and protection capability of Armor Weapon.

Thirdly, System Efficiency & Combat Efficiency.

At present, there has not been a unified definition on System Efficiency. The followings are a few kinds of them:

Radio Research Board of American Airlines defines it as: under specified conditions, when using system, how is

its probability to meet the demands of complain in a fixed time.

United States Navy defines it as the target of fulfilling the task in a specified condition and a fixed time or a probability to meet the demands of a campaign in a specified condition and a fixed time.

A.H.Levis and his colleagues from Massachusetts Inst Tech(MIT) USA define it as the fit score of the system and the mission.

WSEIAC defines it as this: System efficiency is a measurement under the expectation that one system is to fulfill one given tast; It is a function on the availability, dependability, and inherent capability of the system.

From the above definitions, we can see the effectiveness of electronic equipment should be a measurement to meet a specific task in a specified condition and a fixed time; it can be measured by the function of probability or validity, reliability and capability.

The Mission Efficiency of electronic equipment often refers to the measurement to meet the expected target using the electronic equipment to carry out a specified mission in a specified battle environment. Obviously, Mission Efficiency is the one that come upon when electronic equipment is in operation under a certain condition by a given person, a result of combined actions of electronic equipment, person and environment. It is a special System Efficiency considering person and environment, or we can call it "person- environment-electronic-equipment efficiency."

Compared to efficiency of performance index, System Efficiency and Mission Efficiency, thanks to their high degree of integrated, are much easier to facilitate decision-making but more difficult to analysis and assessment.

On the whole, considering E3 is an objective assessment index, it is much reasonable to define E3 as "an extent in which electronic equipment is used to fulfill a specified mission in a fixed time and environment". In addition, considering the evaluating complication of E3, taking probability model to measurement efficiency is certainly more favorable to mathematical modelling, data processing and the expression and understanding of results. It is more convenient to use statistical methods and artificial intelligence methods for the contributing to

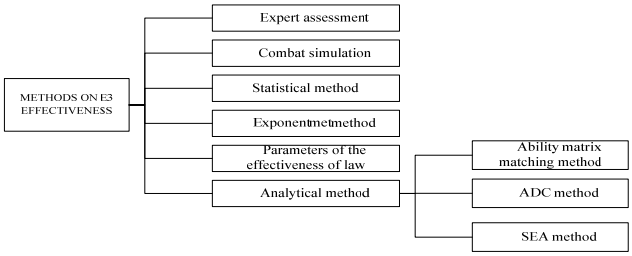

Figure 1. Overview of the methods on the research of e3 efficiency

the use of data presented by means of machine learning, rules extracting and data updating.

3 Development and Tendency on the Study of E3 Home and Abroad

Too many ways of evaluating efficiency of electronic equipment have been put forward to meet different aims and environment, mainly including Monomial Efficiency and System Efficiency. Figure1 shows the Overview of different methods on the research of E3 efficiency.

The evaluating of Monomial Efficiency involves mainly shooting, target searching, battlefield mobility, availability and dependability[2–4]. The assessment and evaluation methods of the performance of corresponding E3 efficiency is much more perfecter and simpler.

System Efficiency can be classified into two main groups: Performance indicators based on more comprehensive assessment and Performance assessment methods based on the people-environment-electronic equipment, which is also the current focus of theory and application. The former can mostly be attributed to decision-making problems in theory, typical methods include comprehensive assessment of the probability, fuzzy Comprehensive evaluation, effect of multi-attribute analysis, evaluation and analysis based on Gray Theory, principal component analysis and theory of nonlinear systems and etc. The latter mainly related to operational performance issues, its main methods are laid out in figure1. Among them, the ADC method of transition probability based on the system state and conditions given by WSEIAC in 1963 and the SEA(System Efficiency Analysis) method given by A.H.Levis and his colleagues from Massachusetts Inst Tech(MIT) USA between the eraly 1970s and late 1980s are the most representative. These two methods are successfully used both at home and abroad[5–7]. Typical methods include ADC method and SEA method.

Electromagnetic Environmental Effects defined in ADC method as: System efficiency is a measurement under the expectation that one system is to fulfill one given tast; it is a function on the availability, dependability, and inherent capability of the system. According to the definition, Electromagnetic Environmental Effects can not only be divided into three factors like availability, dependability and capability, but also through appropriate combination, indicate the final overall system performance of a monomial performance measure of electronic equipment. If we use the efficiency of using vector A to represent the possible initial state of carrying out a mission, the credibility of the system by the expression matrix D to represent the random state of carrying out the mission. Inherent ability using vector C or matrix, the system performance can be expressed as the product of these three vectors: $E = ADC$.

The advantage of ADC method is as follows: It uses only three parameters to describe the efficiency of the use of electronic equipment systems at different steps of the process, thus it is much simpler and more convenient for the efficiency evaluation and assessment.

The disadvantage of ADC method is: It is difficult to get a more overall comprehensive system response of the electronic equipment to meet a set of specific tasks.

The Correction Models of ADC method shows different forms, such as: ARC probability model, QADC model and KADC model and etc.

ARC model is a probability model. Here system efficiency E is defined as:

$$E = \text{ARC} \tag{1}$$

Where A is the probability of electronic system in armed state and reliable work state; R is the probability of electronic system in reliable state in the case of in use, C is the probability of fulfilling task for electronic system under the reliable conditions in use .

QADC model considers the impact of the efficiency of other weapons. Here system efficiency E is defined as:

$$E = \text{QADC} \tag{2}$$

where $Q=P_a+(1-P_a)(1-\overline{PR})$,P_a is the probability of shooting priority of the weapon system for one-side and another side. R is the probability of reliability of the former's weapon system. P is the kill probability of the latter's weapon system.

KADC model considers the quality of the system operators. System efficiency E is defined as:

$$E= E=A_pD_pC_p \tag{3}$$

The basic idea of SEA is that the system performance itself is a hybrid concept including different factors such as technique, economy and human behavior, then allowing the system to get a more reasonable assessment of the efficiency of the systems' response to the user needs, systems technology and systems environment and its changes. As to this, A.H.Levis puts forward the idea of system's performance analysis framework combining system, environment and mission. SEA method is mainly based on six basic concepts: system, mission, environment, original data, MOP (Measures of Performance) and system performance. The key idea of this method is to establish the mapping function between a set of system parameters and system performance. Mapping function is defined as:

$$\{\text{MOP}_i\}_s=f_s(X_1,X_2,\ldots,X_i) \tag{4}$$

And the mapping function between system and mission:

$$\{\text{MOP}_i\}_m=f_m(Y_1,Y_2,\ldots,Y_n) \tag{5}$$

Then system locus L_s and mission locus L_m on space of $\{\text{MOP}_i\}$.Thus in the set of different state, the probability of system in the task-accomplishment state shows the ability of system to accomplish task. System efficiency E is defined as:

$$E = \int_{L_s \cap L_m} h(s)ds \tag{6}$$

SEA's advantages as follows:

Firstly, the method has stronger ability of systematic analysis.

Secondly, it can compare system capabilities and missions on the same MOP space, thus achieving the evaluation ability of the system's fulfilling tasks. Then the definition of system efficiency E is much clearer.

Thirdly, running from the working state of system, analysis of system performance, it can help get a comprehensive description of the system, mission and environmental effect on system efficiency.

The disadvantage and difficulty of SEA method is the difficulty of its applications. The originality innovation of SEA method lies in the extraction of MOP_i, the establishment of the system mapping function f_s and the

foundation of mission mapping function f_m. System element, structure, behavior and performance character must be considered and quantized in order to gain f_s. Thus the establishment of f_s is the emphasis and difficulty of the method.

The basic idea of SEA method is to run the system in the operational environment in order to analyze the extent of mission systems. Strictly speaking, it is a methodological framework of the measurement system's completing the task. At present, only in large-scale systems do we get some success experience, but for individual electronic equipment or small-scale system, further study is expected.

In addition, the assessment on the performance of complex systems and theory can be attributed to the complexity of decision-making. Applied researches focus on the combination of multi-agent technology and Bayesian Networks of the complex task of modeling and solving assessment[8], and the complex task of evaluating based on Petre network, Colored Petri nets and etc[9–13].

4 Description of the Efficiency of Electronic Equipment in Complex Electromagnetic Environment

Complex electromagnetic environment can have great effect on the performance of electronic equipment working on the principle of electromagnetic theory partly or completely. The effect can be described by E3. As a result, it can be called Electromagnetic Environmental Effects based on E3, in short Electromagnetic Environmental Effects for electronic equipment: E3. Any electronic equipment working on the principle of electromagnetic theory partly or completely can be incorporated into the scope of Electromagnetic Environmental Effects: E3.

However, for a long time, the assessment of the efficiency of electronic equipment mainly concentrates in the field of the design, procurement and maintenance management of electronic equipment. Thus the corresponding methods and theories are more mature[14]. But for the assessment of the efficiency of electronic equipment based on the operational environment, especially under the complex electromagnetic environment, which involve the description of the battlefield electromagnetic environment, electromagnetic protection and electronic countermeasures(ECM) and many other subjective and objective factors, the assessment will involve many issues and the correlative research is complicated. So the related study is still at development stage. Although many new methods have been put forward partly considering the E3 performance assessment, and a certain application to certain electronic equipment or electronic equipment have been realized[15]. It is very difficult to adapt to information technology under the conditions of combined operations and training in need of electronic equipment and it is much more difficult to keep up with the pace of research, development and upgrading in the time-validity, adaptability and system integration capabilities.

Given the degree of complexity, we believe that only by fully taking the advantages of multi-disciplinary cross, as well as the use of systems engineering and artificial intelligence methods can we research effectively to overcome and avoid one-sidedness and limitations, and then establish ultimately the systematized model, methods and standard evaluation system of the performance electromagnetic environment of the battlefield, E3 analysis and E3 efficiency, a triplicity E3 electronic equipment.

5 E3 Electronic Equipment Efficiency Evaluation Methodology

First of all, the E3 performance of electronic equipment should reflect individually and systematically the complexity of electronic equipment under the complex electromagnetic environment to complete a given task. "Performance assessment" of electronic equipment contains "E3 performance assessment" in theory. In other words, "the E3 electronic equipment performance assessment" is "the assessment of electronic equipment working on the principle of electromagnetic theory partly or completely ".

Based on the above understanding, the existing theory and methods to assess the performance of electronic equipment can be used in principle for electronic equipment to assess the efficiency of the E3. And the specificity of E3 must be taken into account. The key problem lies in the establishment, selection and design of performance assessment methods of the efficiency assessment which involves the complex electromagnetic

environment analysis and modeling, E3-related performance parameters of electronic equipment system and the establishment of the model.

"complex analysis and modeling of electromagnetic environment" and "electronic equipment related to the performance parameters E3 model system and the establishment of model " have been explained systematically. On "the choice of performance evaluation and design", the efficiency of specific types are closely related with the types of electronic equipment (centralized or distributed). Based on the different aims and requirements of monomial performance, system efficiency and operational efficiency evaluation, there are a large number of assessment methods to choose. However, when based on the performance assessment of the complexity and specificity of specific issues, there is no a method which can be used in a broad field. The selection of performance evaluation must be consistent with target selection and reasonable efficiency assessment. Considering the specificity and complexity of the electromagnetic environmental monitoring, detection and modeling analysis, the E3 performance assessment of electronic equipment is still at development stage at home and abroad especially in the assessment of the theory, methods and applications. A large number of work are carried out or in study in Europe and America[16–20].

6 Conclusions

Study on the performance evaluation of electronic equipment must base on the model of complex electromagnetic environment and electromagnetic environmental effects (E3). Research in detail is to establish the E3-related key parameters and system model model-based on the existing model of the complex electromagnetic environment. Further research can be put in practice on E3 electronic equipment performance evaluation under the direction of the model and method, such as the ability of E3 performance analysis and summary of the existing performance evaluation methods, the exploration and study of new evaluation method. Taking into account the outstanding ability and achievement of the multi-classifier fusion method, artificial intelligence based on probability statistics method and the analytical procedures of system engineering in solving the complex problem of decision-making[21–23], the emphasis of the new efficiency assessment methods should be placed on these fields.

References

[1] Goode, Harry H., and Robert E. Machol, System Engineering, An Introduction to the Design of Large-scale Systems [M], New York: McGraw-Hill Book, 1957.

[2] Military electronic equipment system performance analysis, optimization and simulation [M], Beijing: National Defense Industry Press, 2000.

[3] Chengpan Pan. The efficiency of weapons systems firing [M], Beijing: Ordnance Industry Press, 1994.

[4] Lam Wai Wah. Statistical method used to assess the probability of the missile intercepted the target [J]. electro-optical and Control, 2001 (2).

[5] Li Wei, Mao Ning, Pan Wei.The Efficiency Evaluation Model of Radar Jamming System Based on WSEIAC Model.

[6] Harris F J, Dick C, Rice M.Digital receivers and transmitters using polyphase filter banks forwireless communications [J]. IEEE Trans. on MTT, 2003, 51(4): 1395-1412.

[7] Wu Xiaofeng, zhouzhichao. SEA system performance analysis methods: Operational efficiency evaluation [M]. Beijing: Military Science Press, 1996.

[8] YANG Shan-lin,HU Xiao-jian.Complex task of modeling and decision-making method [M]. Beijing: Science Press, 2007.

[9] M. K. Molloy, "Performance analysis using stochastic Petri nets" [J], IEEE Trans. on Comp., vol. C-31, 1982, pp. 913-917.

[10] A. Movaghar, "Stochastic activity networks: a new definition and some properties" [J], Scientia Iranica, vol. 8, no. 4, 2001, pp. 303-311.

[11] W.H.Sanders et al.,"The UltraSAN modeling environment" [J], Performance Evaluation, Elsevier, vol. 24, 1995, pp. 1-33.

[12] W.D. Obal II and W.H. Sanders, "Measure-adaptive state-space construction methods" [J], Performance Evaluation, Elsevier, vol. 44, no. 2001, pp. 237–258.

[13] Mohammad A A, Ali M. Efficient Evaluation of CSAN Models by State Space Analysis Methods [J]. Proceedings of the Intern-ational Conference on Software Engineering Advances (ICSEA '06), 2006.

[14] Millard D P, Woody J A. System E3 platform evaluation [J]. IEEE International Symposium on Electromagnetic Compatibility, Aug, 1990, p 607-611.

[15] Howard D S, Persons B K. Electromagnetic Environmental Effects (E3) Technical Performance Measures (TPMs) [J]. IEEE International Symposium on Electromagnetic Compatibility, v 1, 2005 International Symposium on Electromagnetic Compatibility, EMC 2005, 2005, p 152-156.

[16] Haider H, Neubauer G, Kollar M. EMF measurement tasks and frequency selective evaluation methods for RF-communication facilities[J]. Electromagnetic compatibility and Electromagnetic Ecology, 2005, IEEE 6th International Symposium on, 2005, 179-182.

[17] Dixon D S. Military use of commercial-off-the-shelf (COTS) equipment: Updated E3 concern[J]s. IEE Conference Publication, 1997, n 445, p29-32.

[18] Song Zu-Xun, Yu Bian-Zhang. Study on the evaluation and criteria of electromagnetic environment effects for UAV[J]. Xitong Fangzhen Xuebao / Journal of System Simulation, 2004,16(12): 2801-2804+2808 in Chinese.

[19] David L.Hall, James Llinas. Handbook of Multisensor data fusion [M], CRC Press LLC, 2001.

[20] Zadeh L A.The Key Roles of Information Granulation and Fuzzy Logic in Human Reasoning[J].IEEE International Conference on Fuzzy Systems, September 8-11,1,1996.

[21] Vasant D, Roger S. Intelligent decision support methods [M]. The Science of Knowledge Works, Printice Hall, 1997:171-180.

978-1-935068-04-4 © 2009 SciRes.