Testability Modeling and Analysis of Extended D-Matrix for Electronic Equipment

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Abstract — While the development of computer and electronic technology improve equipment performance and operational capability, they also greatly increased the complexity of the system. It has brought many problems to test and diagnosis the electronic equipment. The paper carried out testability modeling analysis of modern electronic equipment by the extension D_matrix. It studied the testability analysis methods at present stage. In the Testability Engineering and Maintenance System (TEAMS) software D_matrix is in a single module associated with multiple function of functional fault which cannot be accurately defined, to ensure the root cause of the fault. By analyzing database of TEAMS software it puts forward to a kind of method from the multi-signal model to extended D_matrix, which improves the reusability of extended D_matrix data. Finally, it applied the extended D_matrix modeling on a certain type of electronic equipment, and is obtained the result of testability analysis which validates the theoretical research work.

Keywords – component, Testability Engineering and Maintenance System, extended D-matrix, electronic equipment

I. INTRODUCTION

With the wide application of computer technology and large scale integrated circuit, it improves the performance of weapon equipment at the same time, and also greatly increases the complexity of the system itself. In the modern important systems and equipment, the testability and diagnosis capability of the complex system is obvious more and more significant. The influence of the reliability, maintainability and availability, and life cycle cost has a direct or indirect impact on them. To carry out the testability analysis and application study, is to enhance the level of test and reduce the times of the fault diagnosis of gear system, and to improve equipment integrity in wartime. In addition, good ability of test and diagnosis can reduce maintenance resources, thus reduce the use of equipment and ensure cost.

Testability is an important feature which refers to the equipment can be timely and accurately determine its status, isolate its internal fault. It is a feature likely the maintainability, reliability, which is inherent in the equipment itself. While the equipment has the well testability, it means that the equipment has good ability of fault detection and fault diagnosis, can fulfill levels of testing and fault diagnosis task in a relatively short period of time with a lower price.

Electronic equipment is the core and foundation to realize combat effectiveness. In order to promote the testability and diagnosis capability of electronic equipment, our army introduce the foreign commercial test aided design and evaluation of TEAMS software, the software has played an important role and good effect in testing of electronic equipment diagnosis engineering,. But TEAMS also exposed many problems in the process of practical application, such as electronic equipment is different from the mechanical and electrical equipment, its internal module implements the function of the complex, functional failure types also presents diversity, using modeling TEAMS tend to appear is not in conformity with the characteristics of electronic equipment which is results in the error analysis of conclusion.

TEAMS at this stage of ship electronic equipment has been widely used in test and diagnosis, which obtained large military and economic benefits in the field of ship electronic equipment. TEAMS is the use of the process through the graphical modeling method of multi-signal model data input, generated by multi-signal model in the D_matrix, and then on the basis of D_matrix to optimize testability index calculation and test sequence and output testability analysis and diagnosis strategy.

With the constant improvement of the system integration degree and the complexity, function of modern electronic equipment is more and more, and function failure tends to be more complex. And the general D_matrix can only to define a single module to a functional failure, which do not tally with the actual situation. When TEAMS is often wrongly on the function of the module failure in the application of D_matrix analysis of the process, it results in fault isolation. And only defines a functional failure is no longer practical to a module. In order to overcome the existing problems, the paper puts forward a kind of extended D_matrix, with TEAMS, comparing the simulation results proved by the extension D_matrix the effectiveness to solve the problem of functional fault misjudgment in order to ensure that the correct fault isolation.

TEAMS software is within a closed, unable to export the middle results of testability analysis D_matrix, limits the reusability of D_matrix data. TEAMS of software in the process of analysis is performed dynamically generated D_matrix, on the basis of D_matrix analysis test indicators and test sequence optimization, D_matrix without saving, restricted the TEAMS interact with other software testability analysis. In order to obtain the intermediate results of testability analysis, to improve the reusability of D_matrix data, the development of an open platform for the testability analysis, method for generating the TEAMS database the D_matrix is studied, using the example of the method is verified, the last it is proposed based on the multi-signal model access to expansion D_matrix method.

Fault Detection Rate (FDR) and Fault Isolation Rate (FIR) is the main indicator of testability analysis. On the basis of D_matrix analysis can develop the indicators of testability. The definition of FDR and FIR was divided into two ways. One was not considering the influence of the probability, and another is to consider the definition of probability.

$$\mathrm{FDR}(1)=\frac{N_D}{M}\times 100\% \quad \mathrm{FIR}(1)=\frac{N_L}{N_D}\times 100\%$$

Where, N_D is fault number by correctly detected. M expressed the total fault number existing in the system. N_L was the number of failures correct isolation to replaceable unit in the fuzzy set is not more than L.

Another way of defining FDR and FIR is in the following.

$$\mathrm{FDR}(2)=\frac{\sum_{i=1}^{N_D} P_{D_i}}{\sum_{i=1}^{M} P_i}\times 100\%, \quad \mathrm{FIR}(2)=\frac{\sum_{i=1}^{N_L} P_{L_i}}{\sum_{i=1}^{N_D} P_{D\,i}}\times 100\%$$

Where, P_{D_i} is probability of the ith failure in the number of correctly detected. P_i expressed probability of ith failure in system. If failure probability is not previously set value, the failure probability is 1 / (M + 1). P_{L_i} was probability of ith failure by correctly isolation to replaceable unit in the fuzzy set is not more than L.

II. MULTI-SIGNAL MODEL

Somnath Deb and K. R. Pattipati at the University of Connecticut is put forward multi-signal Model in 1994. The modeling method of multiple signal Model (Mutil-signal model) only on the system testability analysis and fault diagnosis is to extract the important information, and avoid a lot of redundant information, by reducing the cost and difficulty of the simulation. It has good application in large-scale complex system, which has been introduced into TEAMS software of the QSI company.

In multi-signal model, system fault consists of function failure and failure. Function failure refers to the expected impact module function failure. because of a result of the function is multi-dimensional, the function of fault is multidimensional, for example, a sine wave signal, which functions include frequency, phase and amplitude. If the sine signals functional failures, it may be deviation of frequency, phase and amplitude. General fault refers to the information flow can block all via caused by failure of a system crash.

Multi-signal model uses by the directed graph representation. Nodes of graph represent the system unit or variable, and edge of to figure reflects the system function. Because the model is straightforward, it is easy to match the fault and the actual unit. It mainly includes the following elements.

m (module): Constitute a system which has the function of independent and relatively complete replaceable modules.

s (signal): It can clearly describe the features of the system functionality properties in system transmission characteristics. Between different signals has the independence.

t (test): At some point in the system, from which the stand or fall of specific signal can be detected.

tp (test point): test points by containing in test, generally a test contains multiple test.

E(edge): directed line segment from some group to another group, which represents the module or functional dependencies between the test point.

AND NODE: it is redundant connections, which is often used in fault-tolerant model modeling mode. If any module A and module B failure occurs at the same time, the only failure module C, you need to use and node to model analysis.

In multi-signal model, the node and the switch node is optional. By adding the vote nodes in the model and the beginning of the node can make the model be more close to the actual equipment, to improve the accuracy of modeling and testing accuracy

The advantages of multi-signal model are in the following.

(1) Signals in the model were independent of each other, more similar to the structure model, based on the superposition of several information flow model, which is inherited the information flow model and structure model of a lot of advantage, overcome the shortcomings.

(2) And qualitative reasoning model compared with the accurate simulation model, only need to determine the dependencies between test and fault, without much simulation work, simple modeling process.

(3) Compared with mixed diagnosis model, its modeling is not required to be considering a specific failure mode, only needs to determine the important function of attributes, and the fault modeling space, which greatly reduced the difficulty of modeling.

It is reason that make multi-signal model can meet the needs of the large complex equipment testability modeling. It becomes the mainstream of testability modeling method in China.

Either in the information flow model or the signal model, system modeling for the purpose of D_matrix (fault-testing depends on matrix), then on the basis of D_matrix on testability analysis work, the D_matrix is the basis of test analysis, is also the main basis of testability index calculation. Fault-testing depends on matrix (D) - matrix was based on the matrix way dependencies between fault and testing.

D _matrix may be expressed in the following.

$$D = \begin{array}{c} \\ F_1 \\ F_2 \\ \vdots \\ F_m \end{array} \begin{array}{c} \begin{array}{cccc} t_1 & t_2 & \cdots & t_n \end{array} \\ \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{m1} & d_{m2} & \cdots & d_{mn} \end{bmatrix} \end{array}$$

The test sequence optimization analysis can be carried out on the basis of D_matrix, then fault diagnosis tree is generated. Before the test sequence optimization, it needs to reduce of the D- matrix. In the case of a single failure, the reduction includes recognition not detect failure analysis, fuzzy set analysis and redundancy test analysis.

III. METHOD FROM MULTI-SIGNAL MODEL TO EXTENDED D_MATRIX

A. Selecting a Template (Heading 2)

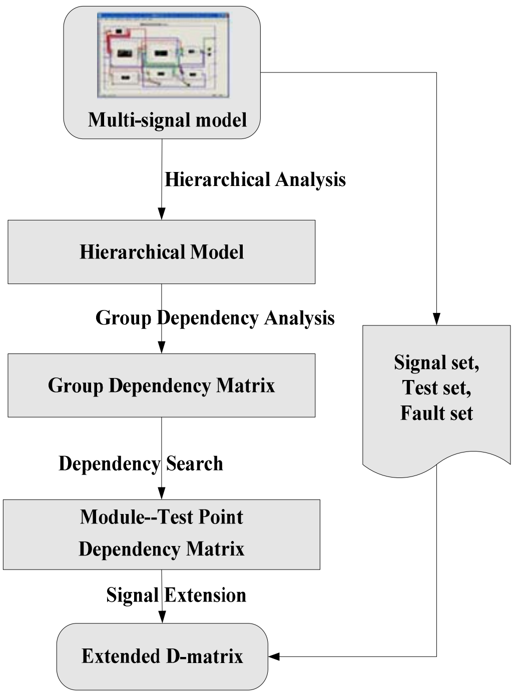

Fig.1 Implementation process from the multi-signal model to extended D_matrix

It studied a kind of method from the multi-signal model to extended D_matrix. The method of implementation process is shown in Figure 1, which can be connected four steps by hierarchical analysis, group dependency analysis, search and signal extension from the multi-signal model to extended D_matrix .

Multi-signal model is generally divided into three layers: the first layer is the Subsystem (Subsystem) layer, the second layer is LRU (field replaceable units) layer, and SRU replacement units is the third layer. The system equipment is generally the LRU layer analysis. According to the analysis of the selected level, the simplification of multi-signal model, which ignore the next layer of modules and test points, at the same time ignore the father of level module.

In multi-signal model the edge (E) represents the dependencies between modules and test points. Between modules and test points for the row and column may be build matrix, at the beginning of matrix element is set to 0. Considering to the attachment, the attachment from group i to group j, express group i function depends on the group j, then it is the matrix element dij. For group neglected parent module, external wired connection relationship is same with the parent module.

In the last section based on function dependence matrix by dependence searching, it can establish dependence matrix for module-test point. Module-test point depends on the behavior module set of the dependence matrix, as a test point set, where matrix elements of the initial value is set to 0. Using from module searching method, search out all of the test point for the module dependencies point. If the module i points to test point j, the matrix element dij sets to 1. Once one element happens twice in the search path, then the search is into the infinite loop, which terminates the path search.

According to the function associated module and various test contains by test points, extend the module-test point dependence matrix. The line extended matrix is all faults (each correlation signal of module is set to a fault, expressed as ci). Column is all test, the matrix elements set initial value 0. If in the module-test point dependence matrix line is module i, a value of 1 of test point k in column, and in the extended matrix line is the failure contained in module i, as a test point k subordinate test sub-matrices. Signal associated with the test in the column of the fault with lines of signal intersection, the value sets to 1.

Now using the above method of multi-signal model to graphical model is shown in Figure 2.

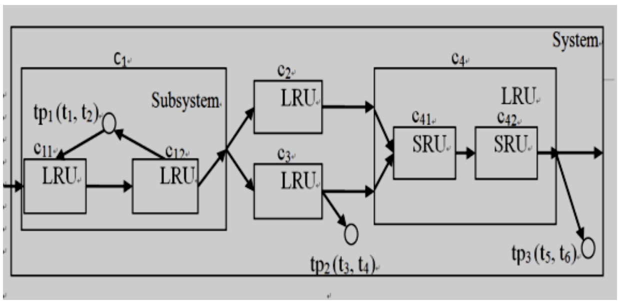

Fig.2 Example of Mutil-signal Model

In the multi-signal model on the Fig.2, Module c1 belongs to subsystem, Module c2 , c3 and c4 belongs to LRU, Module c41 and c42 belongs to SRU. Signals associated each module in each module is shown in Fig. 2. Test point tp1 concludes test t1 and t2, which tests signal s1 and s2. Test point tp2 concludes test t3 and t4, which tests signal s2. Test point tp3 concludes test t5 and t6, which test signal s1 and s3.

In multi-signal model, the relationship between the fault and test is by the definition module associated signals associated with test link to reflect, and based on matrix related to the tectonic fault-test (i.e., D - matrix) for testability analysis.

TABLE I EXTENDED D-MATRIX

	tp1 (s1,s2)		tp2(s1,s2)		tp3(s1, s3)	
	t1(s1)	t2(s2)	t3(s1)	t4(s2)	t5(s1)	t6(s3)
normal	0	0	0	0	0	0
c11(s2)	0	1	0	1	0	0
c12(s1)	1	0	1	0	1	0
c12(s2)	0	1	0	1	0	0
c2(s1)	0	0	0	0	1	0
c2(s3)	0	0	0	0	0	1
c3(s2)	0	0	0	1	0	0
c4(s1)	0	0	0	0	1	0
c4(s3)	0	0	0	0	0	1

The extended D_matrix of the available is as shown in Figure 3. The extension D_matrix merged on line the same fault status.

	A	B	C	D	E	F	G
1		t1	t2	t3	t4	t5	t6
2	c11(s2) c12(s2)	0	1	0	1	0	0
3	c12(s1)	1	0	1	0	1	0
4	c2(s1) c4(s1)	0	0	0	0	1	0
5	c2(s3) c4(s3)	0	0	0	0	0	1
6	c3(s2)	0	0	0	1	0	0

Fig.3 Testability analysis by extended D-matrix

IV. MOEDLING AND ANALYSIS FOR EXTENDED D_MATRIX OF ELECTRONIC EQUIPMENT

A certain type of electronic equipment consists of transmitter, receiver, frequency synthesizer, remote terminal/central Ⅰ/central Ⅱ, microcomputer monitoring and the detection system in machines, power supply and other parts.

Transmitter includes acoustic board, VHF/UHF power amplifier, power amplifier voltage regulator, filter, such as directional coupler module. In the receiver concludes high frequency amplifier, low frequency amplifier circuit, control circuit of three parts; Remote terminal/central Ⅰ/central Ⅱ are optional module. Microcomputer monitoring and machines since the detection system consists of a transmitter, a receiver front panel on the front panel, frequency synthesizer front panel and main panel four front panel component and a BITE (built-in test equipment) components. In the receiver by high frequency amplifier, low frequency amplifier circuit, control circuit of three parts. Power supply includes AC/DC input circuit and regulated power supply board. Multi-signal model is different in system structure based on the superposition of information flow model, so the analysis of the structure and the mastery of information flow to the success of modeling played a crucial role. Determined by way of analyzing the equipment system hierarchy is divided into three, LRU (field replaceable units) for 40, electronic equipment realizes the function of eight, communication power supply, AM launch (VHF, VHF), FM (UHF, ultra high frequency), AM receiving (VHF), FM receiver (UHF), frequency setting, DC power supply and communication functions.

Reference the requirement of "equipment test outline" (GJB2547-95), test indicators for the equipment is in the following.

(1) FIR is not less than 85%.
(2) FDR for fault isolation within two LRU (field replaceable units) is not less than 65%.
(3) FDR for fault isolation within three LRU (field replaceable units) is not less than 75%.

Using the testability analysis software to a certain type of electronic equipment was used to model the multi-signal model. For testability analysis report of electronic equipment is shown in the Fig.4.

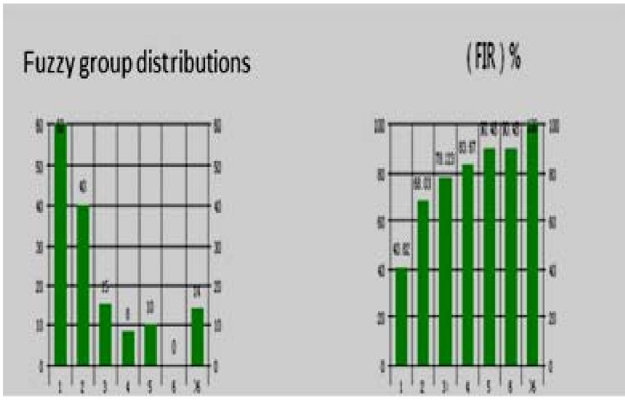

Fig.4 Testability analysis report

FDR of eight system function is 100%.The FIR of AC power supply is 100% (L = 2). FIR of AM (VHF) is 62.5% (L = 2). FIR of FM (UHF) is 58.1% (L = 2). FIR of AM receiving (VHF) is 36.6% (L = 2). FM receiver (UHF) of FIR is 100% (L = 2). FIR of frequency setting is 100% (L = 2). FIR of DC power supply is 100% (L = 2). FIR of the secret words communication function is 100% (L = 2). FDR of System is 100% on average, FIR is 68.03% (L = 2) and 78.23% (L = 3), which is in accordance with established indicators.

Sorted by the importance of the system function, in order to ensure the priority of important function isolation, set up the function of isolation order to AC power supply, DC power supply to FM emission (UHF), FM receiver (UHF) - > AM launch (VHF) - > AM receive (VHF) -> secret message communication ->frequency setting. The generated fault diagnosis tree was conducted in accordance with the order of the system function fault isolation. The resulting test process is simple, and the advantage of avoiding the situation of all kinds of function of test cross, isolation of easier operation, more in line with the actual equipment test in the diagnosis of operation requirements.

After analysis is performed, it can generate diagnosis tree for the diagnosis of equipment needed fault, which will be divided into eight children diagnosis tree, respectively corresponding to the eight related functions of the system. Each functional diagnosis tree generated by the system fault diagnosis tree, child diagnosis tree order to meet user needs can be arbitrarily set. Diagnosis strategy is the function of the system fault isolation, individually isolated directivity is clear to avoid the happening of all kinds of functional test cross, and reduce the isolation operation difficulty. This type of equipment fault diagnosis strategy has been used in test diagnosis engineering.

V. CONCLUSION

The paper studied some testability analysis methods, in order to solve the software TEAMS in D_matrix in a single module associated with multiple function of functional fault which cannot be accurately defined, to ensure that the correct fault isolation. Through TEAMS of software database are analyzed, and put forward to from the multi-signal model to extended D_matrix method, to improve the reusability expanded D_matrix data. On the basis of extended D_matrix to solve the problems of all kinds of tests conducted in diagnosis strategy, reduces the computational complexity. And applied to the modeling of a certain type of electronic equipment, the testability analysis is obtained as a result.

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