A Novel Method of Top-Level EMC Design Technology for Large and Complex Electronic Information Systems

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Abstract**—This paper presents a novel method of top-level EMC (EMC) design technology for large and complex electronic information systems, such as aircraft. A Numerical Airplane Model (NAM) with EMC effects and Performance Simulation Models (PSM) of electronic-equipments are made. In order to ensure the NAM and PSM correct, the following information should be concerned: the structure of airplane and equipments, the relative locations of equipments, the specification and operation-principles of the electronic-equipments, and the inputs and outputs of the electronic-equipments, etc. The electromagnetic interference matrix (EIM) are build by a novel method, called "field-circuit hybrid method——ECHM". The EIM is the function of bandwidth, sensitivity, polarization, signal characteristics, non-linear of front-and-end, receiver-antenna, radiation power, characteristics off-bandwidth, harmonious, intermodulation, transmitter antenna, location, and attenuation of cables, etc. Based on the ECHM and EIM and EMI/EMS performance, the safety and EMC performance of plane can be predicated. The top-level EMC specification can be set down. The top-level EMC specification can be disassembled to the sub-systems and equipments. The whole-plane EMC can be evaluated and controlled quantificationally. The methods presented in the paper have been applied to 3 kinds of planes. The validity of the above method has be proved .**

I. INTRODUCTION

With the advancement in the information age, a large group of special complex electronic information systems have been produced. They show four features on the limited space and stage: a high degree of informationization integration, the highly advanced nature of the performance; the high degree of complexity of the environment and model; the decisive feature of EMC on Security. The EMC system problems has become the systems engineering question in the system/ between the system/ EMI coupling between the system and the environment blends. So it becomes one of key questions.to decide modern large-scale complex electronic information system development.

However, EMC problem, specially system-level EMC issues, has the features: complexity, hidden, would like to set very intellectual, assessment of statistical indexes and so on, which are different from the general performance of electrical appliances of electronic information system inherent characteristics. Therefore the top-layer EMC design of the complex electronic information systems has been a difficult problem. Especially for this type of systems of high EMC requirements and more acute problems of "four features", such as airplane, the top-layer EMC design of the full-airplane machine quantitative analysis technology is a major technical problem.

This paper, in the background of airplanes, research and propose a top-layer EMC design of quantitative analysis technology. Proposed a top-layer EMC design of the full-airplane quantitative analysis technology and the entire process quantification control flow, proposed Based on the gray theory "the full-airplane EMC of digital airplane" concept and "EMC Behavioral Simulation Model" of on-board electronic systems concept, proposed establishes electromagnetic interference conjunction Matrix of the full-airplane installed equipment "field-circuit coupling co-analysis method". This method has been successfully applied to 3 types of airplanes on the problems of full-airplane EMC prediction, indexes establishment of top-layer EMC, the EMC index disassembly of subsystems, the quantitative assessment of the full-airplane EMC performance, the reforms of full-airplane EMC problems. Practice tests show that the whole plane has a good EMC, without major EMC problems, and the aircraft design and reform has a one-time success.

II. CHARACTERISTICS AND DIFFICULTIES OF THE FULL-AIRPLANE EMC PROBLEMS

EMC is an electronic information system inherent characteristic, but because of its hidden nature and, making EMC indexes, EMC model, EMC design, EMC examine, evaluation of EMC, and EMC test has its Specificity.

Specificity 1: EMC index is different from other electrical appliances – the index has characteristics of probability statistics. As the full-airplane EMC is the synthetical result of all electronic information system, no matter it is full-airplane EMI characteristics or EMS characteristics, they have probability statistics property. Therefore, the full-airplane EMC data sample, the sample data acquisition methods, and the samples data statistical methods are crucial to identify the index of the full-airplane EMC.

Special 2: EMC design is different from other electrical appliances.Traditional electrical system design can be referred to as "the normal signal design", according to their function that is required to complete the design of electrical appliances. Yet in this paper, EMC Design include two design process-

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"normal signal design process" and " the design process of the normal signal and signal unexpected as the input".The unexpected signal especially indicate the signal from the airplane radio stations installed on the airplane by the sum of the interference signal caused by the plane and the electromagnetic environment signal of airborne radio in the air.

Special 3: EMC test is different from other electrical appliances –the fault diagnosis via the detection exterior phenomena. System-level EMC test, which is a test to the whole plane， achieve the data for the whole work of comprehensive data. Therefore, the aircraft EMC issues to determine is through the appearance of the image to determine the internal problems. One of the main tasks of system-level EMC test is to detect the new EMC problems due to the system intercommunication and coupling with the sub-systems of qualified. This “diagnostic” test drives the full-airplane EMC test complex and important.

Special 4: system-level EMC test is different from the sub-system test - belonging to the large-scale test of the system. From the perspective of the size of the system, EMC problems can be divided into device level, board level, equipment level, subsystem level, system level, the systematic collection level (multi-system’s set), and so on. The system-level EMC test, in both of the index and the methods, has the different nature from the test of the device level, board level and equipment level, sub-system level.

III. EMC Top Quantificational Design Procedure

This paper presents the EMC top quantificational design procedure, as shown in Figure 1. These eight aspects are as follows:

1) System collectivity puts forward the whole top EMC design parameters by top requirements and system-level EMC standards, and then verifies the parameters.

2) System collectivity quantificationally decomposes the whole top EMC design parameters to subsystem progressively.

3) According to the whole EMC numerical model named numerical airplane, system collectivity employs design called “assembling subsystem with system”, and quantificationally estimates subsystem EMC.

4) It comprehensively tests the subsystem EMC before the system collectivity being shaped.

5) System collectivity predicts the influence of subsystem performance on EMC top design parameter by numerical airplane.

6) System collectivity adjusts the subsystem parameters and redesigns the integrated scheme of the complete machine by numerical airplane, and solves the influence of deviation parameter.

7) System collectivity completes the subsystem combined modulation testing of simulated install environment (assembling subsystem with system) by the whole airplane EMC integrated simulation and testing platform(semi-physical simulation platform);

8) System collectivities EMC testing (verifies the validity and check the left hidden danger).

IV. EMC Top Quantificational Design Procedure

In accordance with EMC issues in the development of new aircraft, in the meantime in order to solve the problems of ignoring pre-design in traditional EMC work, the lack of systematic and difficult to solve the problem later exposed, we can employ a " top-down, systemic, EMC quantificational pre-design "approach.

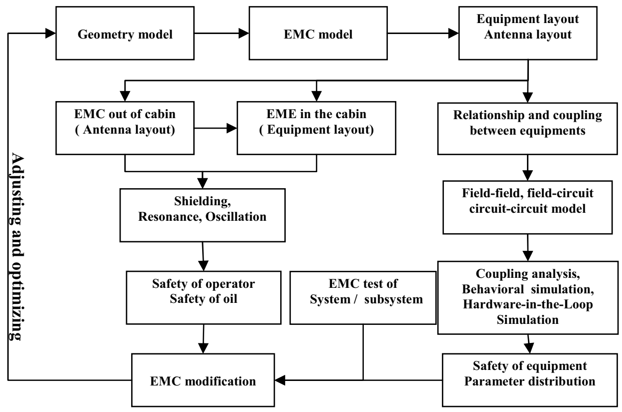

Fig. 1 EMC top quantificational design procedure

The wide work frequency band of total system, intricate and overlapping frequency band of transceiver, great transmitting power of transmitting equipments, high sensitivity of receiving equipment and the great number of antenna lead to extraordinarily complex EMC problems. It is necessary to apply the technology “top-down system-level EMC quantificational pre-design”, and to establish EMC analysis model and associated matrix of all associated equipments. We also take the system design scheme to analyze, design, assess, test, optimize and adjust in way of numerical airplane, semi-physical simulation and cooperate simulation test etc. until the system collectivity achieve satisfying EMC.

The three core technologies of the “top-down, systemic, quantificational pre-design” are numerical airplane, associated matrix of electromagnetic interference and EMC parameters allocation quantificationally. This paper aims at these three points and the others are analyzed in other articles.

V. “Digital airplane”（EMC Digital Model）

“Digital airplane” plays a key role in assessing the EMC of the entire aircraft, and it is the basic platform for forecasting and evaluation. “Digital airplane" is able to analyze the interference relation between various sub-systems on the basis of the whole aircraft system, and establish the character-analyzing model for each sub-system. The linkages between various sub-systems include the design signal flow, the interference signal flow, the circuit-circuit relation, the circuit-field relation, and the circuit-circuit relation. Here, the character-analyzing model is the behavioral simulation model of each sub-system.

The process to establish the " Digital airplane" includes the following steps: 1)to build the parameterized surface model; 2) to build the models for the external antenna and the internal equipment; 3)to build the interference relation between the airborne equipments; 4)to analyze the internal and external electromagnetic environment and the distribution of the interference sources; 5) to build the mathematical description model for the interference relation; and finally 6)to build the "digital airplane".

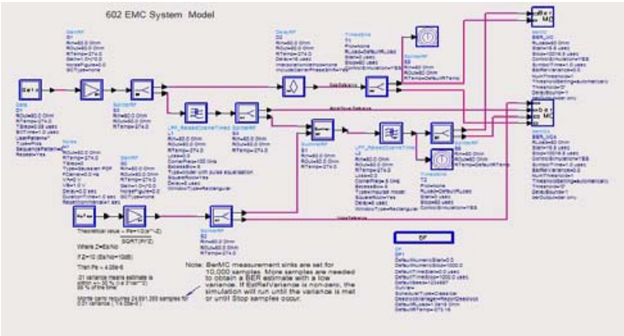

Fig. 2 A "digital airplane"-an EMC Digital Model for an airplane

Figure 2 A "digital airplane"-an EMC Digital Model for an airplane. The behavioral simulation model for the airborne sub-systems and equipments should be built on the basis of their schematic design, schematic operation and EMC data.

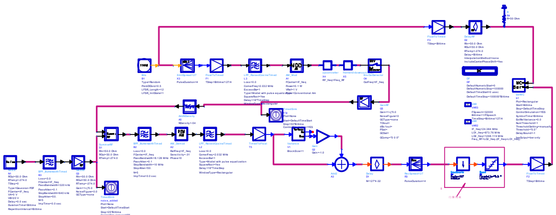

Fig. 3 A behavioral simulation model for the normal and abnormal signals entering the send-and-receive links.

In Figure 3, the unintended signals contain interfere effects of the narrow-band (Gaussian) random process, the effects of the pulse interference on the system, the continuous wave interference of the single-frequency, the interference of the broadband noise on the DS , and the interference of the task radio on the airborne communication radio.

Practice shows that the "digital airplane" and the behavioral simulation model are efficient for accurate analysis of the whole issue of EMC, EMC fault location and reform design of program.Figure 4 Application of the technology to resolve the EMC failure of airborne equipment.

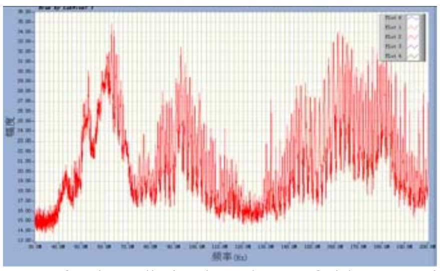

Fig. 4(a) A curve for the radiation launch test of airborne equipment

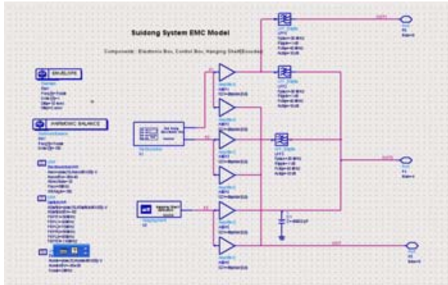

Fig. 4(b) The behavioral simulation model of EMC of the on-board equipment

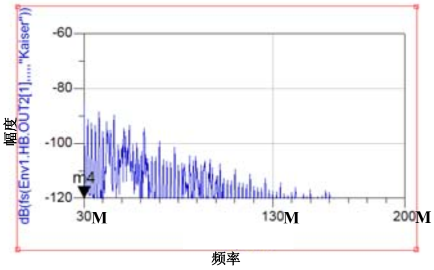

Fig. 4(c) The expected effects of the adoption of the behavioral simulation model to improve the design of EMC (The radiation declined 20dB)

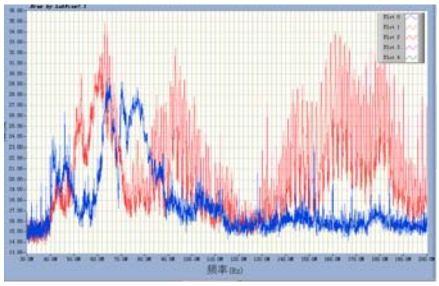

Fig. 4(d) A comparison of the EMC before and after the improvement (Chart shows that, after the improvement, the launch radiation dropped 20dB, and the improved radiation test curve is the same as the expected effect, which proved that EMC reform based on behavioral simulation model are very effective.

VI. The Electromagnetic Interference Associated Matrix of Entire Aircraft System

After analyzing and valuating the EMC of the entire aircraft, we found that the number of the radiation source ports to produce an effective electromagnetic launch, radiation, coupling and the sensitive equipments is usually more than ten times or even some decuple times of the number of actual equipment. For a comprehensive, we describe the association of electromagnetic interference in machine-wide by the mathematical model of correlation matrix with interfere relationship, and establish interferential associated matrix. This method is not only a comprehensive understanding of the interferential relationship of the entire system, but also can analyze the interferential wight of each interferential element. By this way,we can evaluate and optimize the EMC of the entir airplane, distribute the EMC quantitative index for sub-systems [1, 4].

In considering of the one-on-one relationship between launch and receive equipment, to keep the entire system fully meet the requirements of EMC, it must ensure that the receiver can not be disturbed or desensitization. Definite the safety region matrix of antenna isolation at this time

$$\mathbf{A_{compat}}(dB) = (A_{\text{comp}ij}) = (\mathbf{P_t} - \mathbf{L_{tB}} - \mathbf{L_{tf}}) \otimes \mathbf{T_E} - (\mathbf{P_{smin}} + \mathbf{L_{rB}} + \mathbf{L_{rf}} - \mathbf{S_m}) \otimes \mathbf{T_R} \quad (1)$$

Where, for the Kronecker product.

Equation (1) is the best region of EMC design. If this equation is meet, it means that the signal of other device in the airplane will not get through the antenna ports and creat disturb to the receiver. If the equation is not meet, the disturb is not always achieve. To each receiver, if it meet two of the equation (2), it can work, only appear desensitization, and the techno-index will descend accrodingly.

$$P_{sj} /(J_j + N_j) \geq (S/N)_{mj} \text{ 和 } P_{sj} \geq P_{s\min} \quad (2)$$

Among them, P_{sj} is the received signal power of the receiver j; J_j is the received external interference power of the receiver j; N_j, which is a stable value for a particular receiver, is the internal noise power of receiver j .

VII. The Target Decomposition and Quantification Assign of EMC

Based on the entire machine EMC digitization model-digit airplane, we may further complete the entire machine EMC top layer target establishment and quantification decomposition, using the entire machine EMC disturbance incidence matrixs, which indicated the electromagnetic interference relations between board installations.When carrying on the system EMC analysis and appraisal, it's also necessary to integrate the coupling way index into the system of the radiant and sensitive equipment, besides the consideration of the receiveing and dispatcheing equipment and antenna's partial performance parameter.

Among the parameters influenceing system EMC, some are relative independent, don't vary with other parameters, and can be designed by the sub-system manufacturers, such as the emissive power of transmitter, operating band, attenuation of outside-belt launche, sensitivity of receiver, operational frequency, receiveing belt external inhibition, and so on.

Some parameters are in conjunction with the each other. When other parameters act some variation, these parameters will undertake corresponding changes. Take the power gain and polarization characteristic of antenna for example, when the installing position of antenna changes, the parameters such as radiation characteristic, power gain, polarized attenuation between antennas also vary.

Example of Top layer design target establishment:

There are some receiving system R and launching system T in the machine. By the analyses of the opterating band width, polarized characteristic, signal characteristic, front-end nonlinearity, and receiving antennas' characteristic of R, and the analyses of the opterating band width, transmitting power, characteristic of outside-belt stray launche, transmitring antennas' characteristic of T, and the consideration of the probable arrangement of T and R in the airplane, the attenuation characteristic of lines connectting T and R, we get that T and R are mutually compatible when satisfying an isolation of 90dB.

But the 90dB isolation is not the ultimate designing index. Since the installing equipment environment will also have influences to R, it's necessary to analyze the installing equipment environment of T and R. Suppose other transmitting equipment in the plane will also induce 14dB disturbance, and consider a 6dB margin of safety, only up to 110dB isolation can make sure of the compatible between T and R.

VIII. Conclusions

The poaper proposed "EMC quantification design from top to down"is a new method realizing EMC top design and entire machine EMC quantification control, the digital airplane and board equipment's behavior level simulation model are the basic means carrying on the "EMC quantification design from top to down", and "field-circuit coupling synergistic analytic method" is the core technique of accurate analysis of board installation electromagnetic interference relations.

The experiment and practices indicated that, based on the proposed new method in this article, it's possible to realize the entire machine EMC prediction, the top layer EMC target formulation, the subsystem EMC target decomposition, the entire machine EMC quantification appraisal, and achieve the entire machine EMC quantification control. This method in this article has already obtained successful applications in 3 kind of airplane.

Acknowledgment

The authors would like to express thanks to Mrs Wang Yumei, Wang Yujiao, Sun Wei, Mrs Wu Longgang and the other members in EMC Laboratory of Beijing University of Aeronautics and Astronautics for their helpful discussions and encouragements

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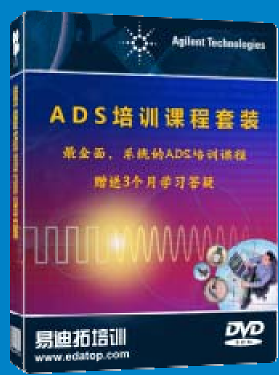

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