Electromagnetic simulation and test based on shielding effectiveness of cabinet shell

Tongguo Gao¹*, Tao Wang¹*, and Deng Li¹, Yu Guan¹

¹Jiangsu Automation Research Institute
* Corresponding author: lvmeimei2006@163.com

Abstract. Electromagnetic simulation technology is an important means to study microwave electromagnetic field and electromagnetic compatibility. The shielding effectiveness of electronic cabinet made of carbon fiber materials is studied by simulation method. The mainstream 3D full wave electromagnetic simulation software CST and modern electromagnetic simulation algorithm are used as research tools to analyze the shielding effectiveness of electronic cabinet made of carbon fiber materials. The simulation results are verified by means of scaled model verification, which greatly reduces the cost of experimental verification and improves the research efficiency.

1. Introduction

Re102 is an electric field radiation emission test item in GJB 151b "requirements and measurement of electromagnetic emission and sensitivity of military equipment and subsystems", which is one of the essential items of electromagnetic compatibility test of military equipment and subsystems. Re102 mainly measures the electric field radiation intensity generated by the tested equipment and subsystem through space propagation and ground reflection. The passing probability of re102 can be improved by improving the shielding effectiveness of the shell. The shell with good electromagnetic shielding effectiveness can cut off the transmission path from the electromagnetic interference source to the equipment, so as to eliminate or weaken the adverse effect of the interference source on the equipment.

The core of electromagnetic simulation technology is to use computer to solve electromagnetic field distribution based on Maxwell equation, field boundary condition and constitutive relation of medium. The shielding effectiveness of product shell can be simulated and analyzed by using this technology. In order to reduce the radiation emission of equipment and improve the shielding effectiveness of equipment shell, it is one of the important means.

2. Selection of simulation algorithm

2.1. Matching analysis of coupling coil

The general electromagnetic simulation problems can be divided into four categories according to the electrical size and simulation bandwidth, namely, the broadband problem of electrical large size, the narrowband problem of electrical large size, the broadband problem of electrical small size and the narrowband problem of electrical small size. According to this, different simulation algorithms can be selected, and the selection of algorithm will affect the calculation amount of simulation and the accuracy of problem analysis.
EMC Simulation is a typical large-scale broadband problem, which is usually solved by time-domain methods, such as finite integral time-domain (FITD). Because the time domain method uses the pulse generator to add the electromagnetic pulse into the system, the convolution of the shock function in the convolution concept can be compared with the convolution of the system function. The output response is obtained at the output end of the system, and then the response of the system in the broadband range is obtained through spectrum analysis. That is to say, using time domain method to analyze the broadband charged magnetic field problem, only one calculation is needed to get the results, which improves the calculation efficiency.

The theoretical basis of finite integral method in time domain is Maxwell equations, which is the discrete form of Maxwell equations on spatial grid. The mesh equation derived from Maxwell’s equations is (1).

\[
\begin{align*}
Ce & = -b \\
\tilde{Ch} & = \tilde{b} + j \\
\tilde{Sd} & = q \\
Sb & = 0
\end{align*}
\]

(1)

Where \( h \) is the magnetic field intensity, \( j \) is the current density, \( D \) is the electric displacement vector, \( e \) is the electric field intensity, \( B \) is the magnetic induction intensity, and \( Q \) is the unit charge.

On this basis, the central difference is used to replace the reciprocal of time to generate the display equation. The following is the time integral equation in the case of no loss (2)

\[
\begin{align*}
& e^{n+1/2} = e^{n−1/2} + \Delta t M^{-1} \left[ CM \rho b^n + j^n \right] \\
& b^{n+1} = b^n - \Delta t Ce^{n+1/2}
\end{align*}
\]

(2)

Where \( h \) is the magnetic field intensity, \( j \) is the current density, \( D \) is the electric displacement vector, \( e \) is the electric field intensity, \( B \) is the magnetic induction intensity, and \( Q \) is the unit charge.

On this basis, the central difference is used to replace the reciprocal of time to generate the display equation. The following is the time integral equation in the case of no loss (2)

Through the above equations, the voltage and flux can be solved alternately on the time axis, and the complete time and space electromagnetic field distribution can be obtained.

### 3. Modeling simulation and experimental verification of carbon fiber shell model

#### 3.1. General setting of simulation model

According to gjb151b-2013 "requirements and measurement of electromagnetic emission and sensitivity of military equipment and subsystems" re102 electric field radiation emission test requirements "figure 56 re102 limits for submarines" frequency range, the simulation frequency band is set to 10kHz ~ 1GHz. At the same time, according to the literature, the conductivity of carbon fiber is 62500 s / m, the dielectric constant is 8.5, and the permeability is 1[3].

#### 3.2. Establishment of simulation mode

The cabinet is generally composed of metal shell, external adapter plate and heat dissipation equipment. All kinds of units can be installed in the form of pulling. At the same time, some types of cabinets also have display and control units, which can facilitate the internal module control management and electronic cabinet function configuration. In the process of model building, we should pay attention to the following points in the CST model creation environment:

1. The size unit of the model should be determined in advance. The lower the unit, such as millimeter (mm), the more accurate the mesh generation in the later stage;
2. The relative position of each detail or module of the model should be close to the actual design requirements as far as possible;
(3) If the material characteristics of each detail or module of the model are not uniform, they should be set separately. For example, if the shell of the model is carbon fiber, but the internal module pulling device and the module delamination interval are metal, the module parameters should be set separately. Based on the above analysis, a certain type of electronic cabinet is selected as the simulation model construction sample, as shown in Figure 1. The model has a comprehensive function module, which represents the common characteristics of similar products in the Institute.

![carbon fiber simulation model](image)

Figure.1. carbon fiber simulation model

In view of the symmetry of the carbon fiber shell model, a vertical polarization electric field intensity monitor and a horizontal polarization electric field intensity monitor are set every 200 mm at the inner center line. In this way, the test model of transmitting and receiving outside the shell and receiving inside the shell is formed. According to the anisotropy theorem of electromagnetic field, the attenuation of shell to external electric field (S12) is the shielding effectiveness of corresponding frequency band.

3.3. Shielding effectiveness simulation results

As mentioned above, the shielding effectiveness simulation results are distinguished according to the frequency range and polarization direction, and the simulation results are shown in Figure 2.

![Simulation results](image)

(a) vertical polarization from 10kHz to 30MHz

(b) horizontal polarization from 30 to 200MHz
The simulation results show that the shielding efficiency of the shell of carbon fiber materials exceeds 60dB in most frequency bands, and cannot be achieved at some frequency points, such as the shielding efficiency of 26mhz-30mhz frequency band is greater than 58db, and that of horizontal polarization shielding in the frequency range of 200MHz to 1GHz is greater than 40dB.

Therefore, the conclusion can be drawn from the simulation results: the shell of carbon fiber material is used as equipment cabinet, and its shielding efficiency meets the requirements of the products in general. The defects of the material itself should be considered in the design in individual positions and frequency bands [4-5].

3.4. Test and verification of shielding effectiveness

The advantages of the method of model verification are to save the production cost and reduce the verification cost. The disadvantage is that the shrinkage model is essentially a simplification of the real shell, which can not fully reflect all the details of the real shell. Therefore, the precision of the simulation is quantitatively verified by the method of the shrinkage model verification only when the shell structure is simple [6-10]. Combined with the test environment and considering the cost of the research and verification, the scale model is chosen to verify.

(1) Preparation of validation model

Because of the linearity of Maxwell equations, when the physical size of the model is reduced by N times, the test frequency band is increased by N times. Assuming n = 2, i.e. select a 1:2 model of carbon fiber materials for testing. According to the simulation proportion parameters, the carbon fiber material shell is made. The material is the market-made T300 carbon fiber board. The shell height is 40cm, the width and length are about 25cm, and the material thickness is 2mm, which basically meets the requirements of 1:2 reduction ratio of cabinet shell, as shown in Figure 3.
(2) Verification test

The test site is arranged according to the test requirements of re102 electric field radiation emission. Firstly, the background electromagnetic environment is tested to determine whether the background is qualified. Then, the electric field intensity without shielding shell is tested by using a broadband emitter and receiving antenna. Finally, the electric field intensity with shielding shell is tested by using a broadband emitter and receiving antenna. The test site is shown in Figure 4.

![Figure 3. Carbon fiber shell](image)

![Figure 4. Test site](image)

(a) Test without shielding shell   (b) Test with shielding shell

(3) Results of test verification

According to the definition of shielding effectiveness, the shielding effectiveness of vertical polarization and horizontal polarization can be calculated, as shown in Figure 5.

![Figure 5. Shielding effectiveness results](image)

(a) Vertical polarization shielding effectiveness

(b) Horizontal polarization shielding effectiveness
3.5. Result analysis and error discussion

From the shielding effectiveness results, the carbon fiber shell has good shielding effect in the test band of 10kHz ~ 1GHz. From the trend, the simulation results are basically consistent with the actual test results, but there are many errors. The main sources of errors are as follows:

(1) Simulation error: simulation error mainly involves simulation model construction, simulation algorithm selection, simulation grid and grid expansion partition. Among these factors, the error caused by simulation grid is the main error, because grid partition directly affects the amount of calculation, and indirectly becomes the measurement index of operation convergence time. When the number of grids reaches a certain level, the error caused by different boundary conditions is accumulated, which eventually leads to the error of simulation results;

(2) Error of scale model: the scale model is essentially a simplification of simulation model or design model, which omits some factors in simulation. At the same time, the frequency conversion in test also involves the limitation of radiation ability of radiation source and antenna;

(3) Error caused by radiation source: in order to install the radiation signal into the shielding shell, a certain type of display is used as the radiation source to ensure the emission of full frequency electromagnetic energy in the test frequency band to the greatest extent. But the radiation source is not an ideal model of antenna and signal source in essence, which can not guarantee the high radiation of each frequency point. When the radiation of some frequency points is too low, the radiation is submerged in the background noise, resulting in the calculation value of the final shielding effectiveness is too small. From another point of view, the limitation of the scale model is explained, that is, when the model size is small, it is impossible to put all the antennas in the scale model and bring test error;

(4) Test system error: the measurement receiver used can meet the definition of EMI measurement receiver in cisper16, but it can't be completely guaranteed that when the actual test is carried out, part of the occasional sexual harassment signals will be sent to the test system.

4. Conclusion

In this paper, the simulation method is used to simulate the electronic cabinet made of carbon fiber materials. The mainstream 3D full wave electromagnetic simulation software CST and modern electromagnetic simulation algorithm are used as research tools to analyze the electric field shielding effectiveness of the electronic cabinet in this case, and some experimental verification work is completed.

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