Research on design of electromagnetic compatibility shielded anechoic chamber

Guo Shichao1*, Guo Dandan2, Zhang Qiongyu1, Wu Nankai1

1Beijing Institute of Spacecraft Environment Engineering, Beijing, 100094, China
2Beijing Institute of Spacecraft System Engineering, Beijing, 100094, China
*Corresponding author’s e-mail: 357464199@qq.com

Abstract. The electromagnetic compatibility (EMC) shielded anechoic chamber is a necessary place for the equipment to conduct electromagnetic compatibility testing. This article introduces the reasons for building an EMC anechoic chamber, and elaborates the problems that need attention in the construction of the shielded room. In particular, the key parts of the shielding shell design, the design of the absorbing material, and the electrical performance indicators were discussed in detail, and the construction of the anechoic chamber size requirements, ground installation, lighting system, and filter settings were prompted. At the same time, this article briefly introduces the use of anechoic chamber after completion.

1. Introduction
The CISPR standard requires electromagnetic compatibility (EMC) testing to be performed in an Open Area Test Site, but this method has several disadvantages.

a) It cannot be operated 24/7 due to unpredictable weather factors.

b) In the case of very serious electromagnetic pollution, it is almost impossible to find an open field with an electromagnetic environment level lower than the EMC standard limit.

The emergence of an EMC shielded darkroom solves this problem. The darkroom itself is a fully shielded housing with a good total reflection floor. The surrounding walls and ceiling are hung with absorbing materials to isolate the electromagnetic fields in the inner and outer space. Therefore, in the working frequency band, the anechoic chamber can absorb electromagnetic waves, so that the room is basically kept free of reflections, and the conditions of the open field are simulated to test the radiation effects of the equipment on the surrounding environment or equipment without having to spend a lot of money to build and maintain the open site[1].

2. Planning of special parts of shielded darkroom

2.1. Size requirements
EMC anechoic chamber can be divided into two types: Semi Anechoic Chamber (SAC) and Fully Anechoic Chamber (FAC). The half-anechoic dark room is affixed with absorbing materials on five sides, and the ground is a metal reflecting surface. It mainly simulates the open test field, which can greatly reduce the impact of the site and electromagnetic environment on the test. The six inner surfaces of the all-wave anechoic chamber are equipped with electromagnetic wave absorbing materials as an alternative site for free space[2].
The EMC anechoic chamber can be divided into 3m method, 5m method, 10m method, etc. from the test distance (test object envelope).

2.2. Shielded housing design
a) The size of the shielding shell must ensure the clear space of the EMC anechoic chamber. The length and width of the clear space of the EMC anechoic chamber are both the tip-to-tip distance of the absorbing material, and the height is the distance from the tip of the absorbing material to the ground.

b) The structure of the shielded shell is regular and the joint surface is neat. The entire shielded shell should be anti-rusted.

c) The outer surface of the top of the shield shell is equipped with a passage for maintenance personnel, and the maintenance area should support personnel passage.

d) The design of the shielded shell should consider the structural load bearing, deformation factors, and the supporting capacity of the absorbing material and related facilities. Pay particular attention to the interface between the shielded shell and the civil engineering.

e) The shielding shell should be guaranteed not to rust, deform, and reduce the shielding effectiveness within 10 years. The service life of the shield case is greater than 20 years.

f) The shielded shell is solid and its seismic resistance should meet the requirements of the current national design code. Seismic fortifications shall meet the requirements of resistance to magnitude 7 earthquakes.

2.3. Ground design
a) The height of the EMC anechoic chamber floor is consistent with the floor of the logistics passage outside the anechoic chamber door, and the height difference from the floor of the logistics passage is not more than ± 1mm.

b) The floor load of the anechoic chamber needs to be calculated according to the maximum mass of the measured object and the bearing method to give the unit load requirement, such as 3 tons / square meter. The entire EMC anechoic chamber floor must not undergo permanent deformation due to load bearing.

c) The non-load-bearing floor of the EMC anechoic chamber is composed of an elevated anti-static floor, and the floor size is 600mm × 600mm. The height of the raised floor shall meet the requirements for cable passing and installation of underground equipment, and shall also meet the general requirements of SJ / T10796-2001 anti-static raised floor.

d) The entire surface of the EMC anechoic chamber floor should be provided with a reflective surface made of metal with a thickness of not less than 2mm. The surface resistance is less than 0.1m Ω, and the lap resistance between the entire ground panel blocks is less than 0.01Ω. The reflective surface of the non-load-bearing ground part can be covered with a metal plate on the raised floor, but it must ensure the flatness, the lap resistance and the convenience of maintenance and disassembly in the later stage[3].

e) EMC anechoic chamber floor flatness requirements: within 1000mm range does not exceed ± 1.5mm, within 2000mm range does not exceed ± 3mm, and within 10000mm range does not exceed ± 3.5mm. No protrusions are allowed on the ground, and the height difference between all interfaces, bolts, and the ground is not more than ± 1mm.

f) The ground installation clearance of the EMC anechoic chamber is not more than 1.5mm, and the gap between the ground interface, the gap between the gate and the channel should be not more than 2mm.

2.4. Design of electric filter for anechoic chamber
a) The power line filter should be set according to the voltage and current parameters of the power supply line of the actual system with appropriate margins. Its performance should meet the requirements of MIL-F-15733. The insertion loss of the filter should meet the requirements of relevant
technical parameters in CSIPR 17, MIL-STD-220A, GJB / Z132-2002, and the insertion loss in the range of 10k ~ 40GHz is not less than 100dB.

b) The output of the power line filter should be three-phase balanced.

2.5. Grounding requirements
a) The anechoic chamber is equipped with a grounding box. The grounding box should include a signal grounding box and a cabin shell grounding box. Each grounding box is independently grounded and equipped with two grounding posts, and the grounding resistance is less than 1 Ω[3].

b) The grounding resistance of the shielded case, power supply ground, and protective ground in the anechoic chamber should be less than 1 Ω.

2.6. Lighting requirements
a) The illuminance in the anechoic chamber from 1.5m to 2m is not less than 200Lux, and the remaining range is not less than 150Lux[4].

b) The anechoic chamber top lighting fixtures are all liftable, which is convenient for daily bulb replacement. The lighting cable should be laid in the tube on the back of the absorbing material.

c) The lighting fixture should be able to work normally in the electromagnetic environment of 200V / m. When the lighting fixture is turned on and off, there should be no emission signal that affects the detection, and its radiated and conducted emissions should be 10dB lower than the US military standard limit and meet the environmental radiation limit requirements[5].

2.7. Absorbing material requirements
a) EMC anechoic chambers are installed on all five sides except the ground, and the absorbing materials are installed by hanging. The installation of the absorbing material must be firm and reliable, to ensure that 100% will not fall off within 20 years.

b) The floor of the EMC anechoic chamber is covered with movable absorbing materials to realize the conversion of half-wave and full-anechoic anechoic chambers. The height of the movable absorbing materials does not need to exceed 700mm.

c) The absorbing material must ensure high flame retardancy and meet the three test requirements in NRL-8093. Under the experimental conditions required by the GB / T2406-93 plastic combustion performance test method-oxygen index method test standard, the oxygen index is not less than 26%, and the GB8624-1997 construction material combustion performance classification method reaches no less than B2 level requirements.

d) The absorbing material must have moisture-proof performance. Under the condition of 90% humidity, the absorbing material does not absorb moisture and does not deform. At the same time, the weight gain does not exceed 15% within 240 hours.

e) The absorbing material should be able to withstand a continuous field strength of 500V / m and an instantaneous field strength of 1000V / m.

f) The absorption performance of the EMC anechoic chambers absorbing material in the vertical and horizontal polarization directions under normal incidence conditions must meet the requirements shown in Table 1[6].

| Frequency (Hz) | Minimum reflection loss attenuation(dB) |
|---------------|----------------------------------------|
| 30M-1G        | ≤-6dB                                  |
| 1G-18G        | ≤-20dB                                 |

2.8. Environmental requirements
a) The EMC anechoic chambers should meet the cleanliness conditions required by the product.

b) The environmental conditions of the EMC anechoic chambers are required to be a temperature of 20 ± 5 ℃ and a humidity of 30% to 60%. This is conducive to the normal operation of the equipment and to avoid moisture absorption of the absorbing material.
3. Electrical performance index of electromagnetic compatibility anechoic chambers

The electrical performance indicators of the EMC anechoic chambers should be considered from five aspects: shielding effectiveness, background noise, normalized site attenuation, site voltage standing wave ratio, and site uniformity.

3.1. Shielding effectiveness
a) The test frequency range meets 9kHz-40GHz.
   b) The test standards meet GB12190-2006 "Measurement methods for shielding effectiveness of electromagnetic shielding rooms", GJB5792-2006 "Classification and measurement methods for electromagnetic shields of military secret information systems", GJB2926-97 "Electromagnetic Compatibility Testing Laboratory Accreditation Requirements", EN50147-1 "Anechoic chambers Part1: Shield attenuation measurement" and IEEE Std 299 "IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures".
   c) The anechoic chambers shielding resonance point will have a greater impact on the test data, so the frequency band near the resonance point is not tested. The resonance frequency of the hexahedral cuboid structure is shown in formula (1), and the lowest resonance frequency is shown in formula (2).

\[ f_{r_{mb}} = 150 \sqrt{\left( \frac{m}{a} \right)^2 + \left( \frac{n}{b} \right)^2 + \left( \frac{k}{c} \right)^2} \]  
\[ f_r = f_{110} = 150 \sqrt{\left( \frac{1}{a} \right)^2 + \left( \frac{1}{b} \right)^2} \]  

3.2. Background noise
a) The test frequency range meets 10kHz-40GHz.
   b) The test standard meets GJB 151B-2013 "Electromagnetic emission and sensitivity requirements and measurement of military equipment and subsystems", CSIPR 22 "Information technology equipment--Radio disturbance characteristics--Limits and methods of measurement", MIL-STD-461F "Requirements for the control of electromagnetic interference "and" Characteristics of subsystems and equipment ".

3.3. Normalized site attenuation
a) The test frequency range meets 30MHz-1GHz.
   b) The test standard meets GB / T 6113.104-2008 "Specifications of radio disturbance and immunity measurement equipment and measurement methods-Part 1-4: radio disturbance and immunity measurement equipment auxiliary equipment radiation disturbance", GB9254-2008 "Information technology equipment Radio disturbance limits and measurement methods ", CISPR16-1-4" Specification for radio disturbance and immunity measuring apparatus and methods-Part 1-4: Radio disturbance and immunity measuring apparatus-Ancillary equipment -Radiated disturbances "and GJB2926-97" Electromagnetic Compatibility Testing Laboratory Accreditation Requirements[7].

3.4. Site voltage standing wave ratio
a) The test frequency range meets 1GHz-18GHz.
   b) The test standard meets CISPR 16-1-4 "Specification for radio disturbance and immunity measuring apparatus and methods-Part 1-4: Radio disturbance and immunity measuring apparatus-Ancillary equipment-Radiated disturbances".
   c) The limit is required to meet SVSWR not greater than 2: 1 or SVSWR not greater than 6dB[7].
   d) The schematic diagram of the field voltage standing wave ratio is shown in Figure 1 below.
3.5. **Site uniformity**

a) The test frequency range meets 1GHz-18GHz.

b) The test standard meets GB / T 17626.3 "Electromagnetic compatibility test and measurement technology radio frequency electromagnetic field radiation immunity test", IEC 61000-4-3 "Electromagnetic compatibility (EMC) -Part 4-3: Testing and measurement techniques-Radiated, radio- frequency electromagnetic field immunity test, IDT "and GJB 2926-97" Electromagnetic Compatibility Testing Laboratory Accreditation Requirements ".

c) In the determined imaginary vertical plane, 75% of the electric field strength amplitude deviation should be within -0 ~ +6dB. After removing the 25% maximum deviation point, the field strength deviation at the retention point is within ±3dB.

4. **Conclusion**

This article discusses the necessity of building an electromagnetic shielding room. Through research and design, the external structure of the anechoic chamber, the design of the shell, the design of the absorbing material are described in detail, and the system indicators such as the ground and lighting are briefly defined. After the completion of the electromagnetic compatibility anechoic chamber, it has put forward clear requirements and reference standards for its electrical performance indicators. Finally, this article briefly introduces the use of the anechoic chamber, as shown in Table 2 below. The completed EMC anechoic chamber can meet the standard test items in the table.

| Standard number   | Standard name                                                                 |
|-------------------|-------------------------------------------------------------------------------|
| GJB151A-1997      | Military equipment and subsystems electromagnetic emission and sensitivity requirements |
| GJB 152A-1997     | Electromagnetic emission and sensitivity measurement of military equipment and subsystems |
| GJB151B-2013      | Military equipment and subsystems electromagnetic emission and sensitivity requirements and measurements |
| MIL-STD-461D/E/F  | Requirements for the Control of Electromagnetic Interference Characteristics of Systems and Equipment |
| ANSIC63.4         | Method for measuring radio noise emission of low-voltage electronic and electrical equipment |
| EN/IEC61000-4-3   | Electromagnetic compatibility test and measurement technology Radio frequency electromagnetic field radiation immunity test (GB/T17626.3) |
| CISPR16-1-4(2008) | Radio interference and immunity test equipment and method specifications-part 1-4: Radio interference and immunity test equipment-auxiliary equipment-radiated interference |
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