Electromagnetic Shielding Design of Transfer Orifice for Military Shelter

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Abstract: Modern warfare has put forward higher and higher electromagnetic shielding requirements for the shelters loaded with various types of high-performance electronic equipment. The use of high-performance electromagnetic shielding shelters has become an important means to ensure the combat effectiveness and survivability of weapons and equipment. In view of the design of the transfer aperture of a certain type of military shielded shelter, starting from the electromagnetic shielding principle of the shelter, according to the theoretical calculation method of electromagnetic shielding effectiveness, the structural design elements of the shielded shelter transit orifice are detailed. Finally, according to the national military standard for shielding test verification, the shelter transfer orifice can meet the requirements of the shielding index, which can provide reference for the similar shielded shelter design.

1. Introduction
As the increasing deterioration of the battlefield environment, the demand of the ability to resist various environments of the combat equipment is becoming higher and higher. Undoubtedly, the most directly, economical and effective way is to improve the protective ability against the environment of the shelter[1]. At present, sandwich structure is used in the shelter panels. Considering the manufacturing process, environmental adaptability and electromagnetic shielding of the shelter, inner and outer continuous double shielding structure is adopted, but the double-layer shelter panels should be sectional drilled in cabin door, window and transfer orifice, if electrical continuum can’t be guaranteed, then the Electromagnetic leakage will be induced. Therefore, the Shielded design of transfer orifice is particularly important to the shielded design of the whole shelter.

2. Electromagnetic Shielding Principle
Electromagnetic shielding, on one hand, shields the radiation from the outer electromagnetic energy to the inner equipment, on the other hand, shields the inner electromagnetic leakage in the same shielding quantity, the electromagnetic shielding of the shelter is mainly to control the transmission of the electromagnetic energy[2]. electromagnetic energy is classified into electric shielding, and magnetic shielding and electromagnetic shielding.

Electric Shielding: When the disturbance sources are the voltage form, capacitive electric coupling will be presented between the electric equipment and the disturbance sources, then electric shielding is the most directly and effective anti-disturb way. The electric coupling disturbance degree is correlated with the frequency, the higher frequency, the stronger disturbance. Thus, the higher the frequency, the more necessity of the shielding.

Magnetic Shielding: When the disturbance sources are the current form, the magnetic generated from the current disturbs the neighborhood signal by mutual coupling, then magnetic shielding is the most
directly and effective anti-disturb way. With different frequencies of this kind disturbance, the principle of the shielding is different as well, they are mainly divided into high frequency and low frequency disturbances, which should be treated differently.

Electromagnetic shielding: magnetic field is assigned to high frequency and low frequency magnetic, high frequency magnetic shielding is actually the electromagnetic shielding, the higher frequency of the electromagnetic field, and the easier it can be adsorbed by the metal, the quicker it is attenuated. In the other words, the stronger magnetic conductive and electric conductive ability of the metal, the more efficient absorption of the electromagnetic field[3].

3. The structure and the shielding characteristic of the transfer orifice
The transfer orifice of the shelter is mainly used as the switching of the power and the communication signal from the shelter to the outward foreign, the transfer orifice is assigned to orifice plate, orifice frame/transfer panel support and transfer panel. The outer side of the transfer panel should be tightly riveting pressed on the covering of the shelter panel; meanwhile the inner covering of the shelter panel is clipped by the rivet joint with the internal frame plate, which guarantees the electrical continuum between the frame and the whole cabin. The transfer panel support is installed in the inner side of orifice frame; the transfer panel is installed in the outer side of the frame outside-in, the relative power and the signal transferring connector is fixed on the transfer panel. The structure of the transfer orifice is showed in fig.1.

![Fig.1 the structure diagram of the transfer orifice](image)

The shielding leakage of the transfer orifice is mostly depends on the material and the thickness of the panel covering, the crevice between the transfer panel support and the orifice frame, the crevice between the transfer panel and the transfer panel support, and the electric conductivity between the electric connector on the transfer panel and the transfer panel.

4. The shielding design of the transfer orifice

4.1. the material and thickness design of the inner and outer metal covering of the shelter panel
Generally speaking, the magnetic conductivity of the material will sharply decrease as the increasing frequency; high frequency makes the conductor generate induced voltage, induced voltage makes the conductor generate current flow, while the magnetic field generated by the flowing current can cancel the original incident magnetic field. If the conductor is a certain ideal conductor, then the incident magnetic field can be totally cancelled. The magnetic is attenuated because the conductor resistance absorbs partial electrical energy and transforms it into thermal energy, and the attenuation degree increases as the increasing frequency, therefore the superior conducting material has the higher attenuation ability to the high frequency magnetic field. Meanwhile, due to the skin depth influence of the material, the sicker the material, the bigger the absorption loss, the better the shielding effectiveness. $\delta$ is the skin depth, it is defined by:
In the formula, \( f \) is the frequency of electromagnetic wave; \( \mu \) is the magnetic conductivity of the metal; \( \sigma \) is the electric conductivity of the metal.

When the thickness of the metal sheet is constant, the smaller the \( \delta \) value is, the bigger the absorption attenuation of the metal is, the higher the shielding ability of the metal is. Suppose \( t \) is the transmission distance of the electromagnetic wave in the metal sheet, when \( t = \delta \), the intensity of the electromagnetic field in the metal sheet will be attenuated to \( 1/e \) of the original, that is 36.8%; when \( t = 2.3\delta \), the intensity of the electromagnetic field in the metal sheet will be attenuated to 109% of the original; when \( t = 4.6\delta \), the intensity of the electromagnetic field in the metal sheet will be attenuated to mere 1% of the original. The skin depths of the commonly used metal in the frequency between 150kHz and 10GHz are showed in tab.1.

![Tab.1 The skin depths of the commonly used metal](image)

The overall frequency of the shelter is 150kHz-10GHz, when the frequency is over 150kHz, 1.2mm Aluminum sheet after conductive oxidating should be used in preference.

4.2. the treatments of the joint crevice in the transfer orifice

Crevices presents in the transfer orifice between the outer panel covering and the orifice frame, between the orifice frame and the inner platens, between the inner platens and the inner panel covering, and between platens and transfer panels due to the unevenness of the joint surface, inadequate cleaning, oil contamination and unsatisfying riveting and welding quality. The electromagnetic wave transmission in these crevices induces transmission loss and reflection loss, thus the treatment of these crevices is the key of the whole shelter electromagnetic shielding.

When the electromagnetic wave through the crevices, the mainly attenuations are transmission loss and reflection loss, which can be formulated as follow:

\[
S = A + R
\]

(2)

In the formula, \( S \) is the shielding efficiency of the electric field or the magnetic field, \( A \) is the transmission loss, \( R \) is the reflection loss.

\[
RE = 2\log\left(\frac{4500}{DfZ_s}\right)
\]

(3)

\[
RH = 20\log\left(\frac{2Df}{Z_s}\right)
\]

(4)

In the formula, \( RE \) is the reflection loss of the electric field component of the electromagnetic wave, \( RH \) is the reflection loss of the magnetic field component of the electromagnetic wave, \( f \) is the frequency of the electromagnetic wave, \( D \) is the coefficient of the electromagnetic disturbance sources, \( Z_s \) is the emission resistences[4].
According to the formula 3 and 4, the smaller the wave impedance value of the crevices in the orifice commissure is, the better shielding efficiency it has, thus the key of the improving shielding efficiency in the commissure is the how to deduce the impedance in the commissure. Considering the practical projects, riveting is adopted in the orifice structure between orifice frame and outer covering, between orifice frame and inner platen, and between inner platen and inner covering, while bolting is adopted between orifice frame and transfer panel, and between transfer panel support and transfer panel. When the riveting and bolting are adopted, the length between the rivets and the screws is the key point, the estimation formula of the length is as follow:

\[
\frac{0.01\lambda}{4} \leq \text{reviet (screw length)} \leq \frac{0.1\lambda}{4}
\]  

(5) [5]

When the shielding requirement is 40dB, single-row rivet or screw conjunction can meet the requirement, according to the calculation, when the rivet (screw) length \( \leq 60\text{mm} \), and the crevices in the orifice is between 150kHz~10GHz, the shileding efficiency can be greater than 40dB; When the shielding requirement is 60dB, double-row rivet or screw interleaving conjunction should be adopted, when the rivet (screw) interleaving length \( \leq 30\text{mm} \), and the crevices in the orifice is between 150kH\( \sim \)10GHz, the shileding efficiency can be greater than 60dB.

4.3. material design and processing quality control of the orifice frame and the transfer panel
The surface conductive state and the joint surface planeness of the transfer orifice frame and the transfer panel directly affect the whole electric continuity of the transfer orifice and the shelter and play a vital role in the whole cabin shielding. Aluminum alloy profile is usually used as the orifice frame material, the certain planeness should be satisfied during the frame processing especially the frame joint surface processing, while joint surface oxidation and pollution that can influent the electric conductivity should be avoided. Aluminum sheet is usually used as the orifice transfer panel material, conductive oxidation treatment should be done after the processing, while painting on the joint surface of the transfer panel support should be forbidden to improve the electric conductivity of the orifice transfer panel.

Before the riveting or bolting between transfer orifice frame and inner-outer covering, between transfer panel support and orifice frame and between transfer panel and transfer panel support, the installing surface should be cleaned, elastic conductive gaskets should be installed and painted with conducting solution, while the compression quantity of the conductive gaskets should be controlled between 30%-50% [6].

4.4. installation design of the connector of the orifice transfer panel
If the wire cables cross the inner and outer side of the shielding shelter directly, then massive electromagnetic leakage will be generated from the whole cabin through the wire cable, therefore, the connection of inner and outer wire cables usually implemented by the connectors installed on the transfer panels. The connectors installed on the orifice transfer panels should use electric conductive plugs or sockets, and conductive gaskets should be equipped during the installation. Meanwhile, shielding cable should be used in the rear side of the connector plugs or sockets, wire cable shielding layer and the connector should be compressed to form a complete electric continuum. Under some special cases or high shielding demand, higher shielding efficiency could be implemented by installing anti-disturb filter on the orifice transfer panel or adopting filtering connector directly [7].

5. Electromagnetic Shielding Efficiency Test of the Certain Shelter Transfer Orifice
According to GJB6785-2009, shielding efficiency test is processed under the frequency between 150kHz~10GHz, at least one frequency point should be selected in every frequency ranges [8], the test point is the middle point of the Orifice seam and the Orifice panel surface, and the data should be recorded. Testing system includes receive equipment, signal sources, amplifiers, antennas, testing cables and so on, the testing equipment is showed in fig.2. After the testing, the practical shielding efficiency is greater than 40dB which meets the shielding demand, the scene diagram of the shielding test is showed in fig.2.
6. Conclusion
The shielding design is the important segment of the electromagnetic shielding of the shelter, therefore the electromagnetic shielding design of the whole shelter should be overall considered at the demonstration phase, while shielding transfer orifice is the vital part in the shelter shielding composition. In this paper, starting with the electromagnetic shielding principle, according the efficiency calculation of the electromagnetic shielding, an important thought of the shelter orifice structure design is presented, and through the electromagnetic shielding testing of the orifice in the practical project, the possibility of the design thought is verified, and it could give reference to the electromagnetic shielding design of the military shelter transfer orifice.

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