Study of Spacecraft Low Frequency Cable Installation Technology Oriented to CSB Bus

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Abstract. In response to the needs of spacecraft cable three-dimensional crossover layout, research on cable installation methods based on CSB bus has been carried out. Aiming at the status of using CSB bus cable in the satellite communication cabin of DFH-4 platform for the first time, on the basis of detailed analysis of the performance of CSB bus, the laying and binding methods are analyzed and tested, and the cable installation method on the carbon fiber bracket is proposed. Technical solutions. It has been proved through practice that this method meets the actual needs of satellites, solves the problems of laying and tying the bus cables of the communication cabin, and effectively meets the needs of the spacecraft cable three-dimensional crossover layout, and greatly improves the spacecraft assembly efficiency.

1. Introduction
Communication satellites are developing in the direction of large capacity, high power, and high heat consumption, which will inevitably bring about the continuous increase in the number and weight of the low-frequency cable network of the entire satellite.

How to effectively use the layout space and reduce the weight increase and reliability decrease of the whole satellite caused by the limitation of the low-frequency cable network has become a problem that has attracted more and more attention. A spacecraft used CSB bus cable for the first time in the load bay layout. The CSB bus cable is connected to 56 devices in the communication cabin. The cable direction is complicated and the plugs are widely distributed so that the entire bundle of cables shuttles between the north and south boards and the north-south partitions of the communication cabin[1].

Because the bus cable is very fragile, the requirements for laying and binding are very strict. And when laying the CSB bus cable, the satellite low-frequency cable has been laid and bound in place. The equipment has passed the installation test, and the low-frequency cable plug has basically been inserted in place, and it is very difficult to lay the cable.

Compared with the platform's 1553B bus cable, the CSB cable has a longer length and more plugs, which brings great challenges to operations such as laying and binding.
2. CSB Bus Cable

2.1 Brief introduction
According to the results of the communication cabin equipment layout and cable network layout, the communication cabin is equipped with two independent CSB (C-serial Bus) bus cables, one of which is arranged on the north instrument board of the communication cabin, and the other is arranged on the south instrument board of the communication cabin. Each bus connects 28 TWTA components and 1 PLISU control port. The CSB bus cable shuttles through the entire communication cabin and needs to connect 56 devices in the communication cabin. The length of a single cable is greater than 20 meters, and the equipment and plugs on the satellite have been checked in place when laying, which brings great difficulties to the laying of the cable. There are many branches and plug terminals of the CSB bus cable, which need to be worn when laying, or between high and low frequency cables. The operation space is narrow, and the laying and binding are very difficult. The SPLICE (splicer) on the bus cable is unevenly distributed, and there are at least two splitters at the location of the cable branch, and there are special binding requirements for the splitters. In order to facilitate the binding and fixing, the binding position of the splitter should be determined when laying the cable[2].

The total number of plugs is large. When laying the cable branches and plugs, measures should be taken in advance to prevent the cable branches from being bent under force or the plug tails from being damaged. The plug type is mainly divided into PLISU plug model is D-sub25 core connector, LCAMP plug model is MDM37P.

2.2 Installation conditions
Due to the long length of the CSB bus cable, 56 devices in the communication cabin are involved, and the plugs are all over the communication cabin. When laying, the equipment in the communication cabin has been installed, the low-frequency cable has been laid and bound in place, the semi-rigid high-frequency cable has been installed and connected in place, some plugs have been inserted, the operating space is very limited, and the CSB cable needs to be shuttled between the high and low frequency cables. At the same time, the cabin needs to be worn, which brings huge difficulties to the installation work.

2.3 Cable splitter
Compared with the 1553B bus cable, the coupler on the 1553B bus cable is a key point that requires special attention in binding[3]. There are 3 types of SPLICE (splicer, similar to 1553B coupler) of CSB bus cable, namely "L" type, "R" type and "T" type. Therefore, the lashing must be targeted, as shown in Figure 1.

![Splice types](image)

Figure 1. Three forms of SPLICE branch

3. Carbon fiber bracket
The composite cable bracket can be glued to the carbon fiber panel honeycomb panel, aluminum panel honeycomb panel, equipment housing with an identification temperature of not more than 40°C, and tied between multiple cable bundles. Supports of different heights can be flexibly selected to bind and
fix the transmission line according to requirements, thereby optimizing the cable layout, reducing the
dependence of the cable installation on the satellite cabin wall panels and the fixed installation holes
of the equipment, and greatly increasing the flexibility of the final assembly design. The composite bracket
is a thin-walled structure and needs to bear a certain mechanical load. The application temperature range
is \(-10^\circ C \sim 50^\circ C\). The composite stent molding process must not only ensure the structural size, but also
ensure the performance of the product\(^\text{4}\).

According to the load-bearing conditions and dimensions of the support, the order of the plying
angles and the thickness of the single layer are designed, and the mechanical simulation analysis of the
support structure is carried out to ensure the best mechanical performance. To ensure that the composite
cable support has a high bearing capacity, the compactness and fiber volume content of the product must
be ensured, and there must be no defects such as large pores and delamination. The preparation of
prepreg must ensure the glue content. In order to ensure that the glue content is within a reasonable
range, the fabric prepreg controls the glue density and brushing amount, and the weftless fabric prepreg
controls the winding tension, winding speed, glue density and other process parameters. The prepreg
layer should ensure that the layers are dense, without porosity, and fibers without buckling. On the one
hand, determine the best layup pot life according to the viscosity characteristics of the resin system, and
on the other hand, increase the pre-compaction process appropriately during the layering process. Pre-
compaction should be based on the curing characteristics of the resin, not only to ensure that the product
is pre-compact and compact, but also to ensure that the resin cannot be completely cured.

The surface layer of the carbon fiber composite cable support rod is T300-1k carbon cloth, and the
inner layer is laminated with no weft cloth. Therefore, the carbon fiber composite bracket adopts manual
latitude-free cloth layering and press curing molding process. The carbon cloth prepreg adopts manual
brushing process, and the latitudeless cloth prepreg adopts wet roller molding. The prepreg strictly
controls the surface density of the fiber and the amount of glue. During the laying process, vacuum pre-
compaction is performed after every 3 to 4 layers are laid. After laying, press and cure according to the
curing curve of epoxy resin. After the support rod is demolded, it is processed by cutting equipment
according to the external dimensions to form the final product.

The surface density of the carbon cloth of the cable support is 120g/m2, and the number of layers is
3; the surface density of the weftless cloth is 106 g/m2, and the number of layers is 8 layers. The amount
of carbon fiber is as follows.

$$W_f = 120 \times 0.08 \times 0.013 \times 3 + 106 \times 0.08 \times 0.013 \times 8 = 1.26g$$

The calculated fiber weight content is 1.26g/1.9g=66.3%. The fiber density is 1.76g/cm3 and the
resin density is 1.26g/cm3. The fiber volume content is as follows.

$$V_f = \frac{0.663 / 1.76}{0.663 / 1.76 + (1 - 0.663) / 1.26} = 58.5\%$$
4. Test verification

4.1 Static test
The static test uses two different bonding installation datum planes of aluminum alloy and carbon fiber composite materials for static test. According to the static test results, a kind of bonding surface is determined for dynamic test. The static test includes the body static test and the glued static test\(^5\).

The static test is carried out on the electronic universal testing machine. The static test of the main body tests the static compressive resistance of the cable bracket body in the X and Y directions, and the static test of the glue joint tests the failure load of the glue connection in 3 directions. Gluing load test The cable bracket is glued to the L-shaped mounting board with normal temperature curing adhesive, the mounting board is fastened to the beam of the testing machine with screws, one side of the cable bracket is glued to the mounting surface, and the other side is used for processing the mounting holes Load tooling for installation.

It can be seen that the lowest destructive load of the carbon fiber composite cable support (1) is 727N, the lowest destructive load of the cable support (3) in the X direction is 979N, and the lowest destructive load of the cable support (3) in the Y direction is 1990N.

4.2 Bonding load test
The composite cable bracket adopts 420 room temperature curing adhesive with high viscosity and not easy to flow. Before bonding, the bonding surface of the carbon fiber composite bracket is polished and cleaned, and the aluminum alloy bonding surface is phosphoric acid anodized. The test results of carbon fiber composite cable bracket 1 and cable bracket 3 on the aluminum bonding surface and the carbon bonding surface are basically the same. The minimum load of the aluminum bonding surface is 61N, and the minimum load of the carbon bonding surface is 60N.

4.3 Kinetic test
The dynamic test focuses on verifying the dynamic load-bearing capacity of the composite cable bracket, and adopts the same installation form as the static test. Since the X-direction (perpendicular to the bonding surface) of the cable bracket is much stronger than the Y-direction and Z-direction (parallel to the bonding surface), the dynamic test only performs the Y-direction and Z-direction tests. According to the cable bundling suitable spacing and cable bending requirements provided by the Ministry of Communications, the cable bracket spacing is determined to be 300mm. The vibration tooling is designed according to the Y-direction and Z-direction simultaneous testing of the cable support, and it is L-shaped when installing the cable.

![Figure 3. Bonding test of carbon fiber composite scaffold](image-url)
After the partial vibration test, the maximum response frequency became 66.5 Hz. After the test, it was confirmed that after the mechanical vibration test, the cable support body and the adhesive surface were not damaged, the cable was installed firmly and there was no slipping phenomenon, and the test results met the requirements of technical indicators.

![Figure 4. Full-scale random vibration test for weighted cable identification](image)

### 5. CSB bus installation method

#### 5.1 Preparation before laying

First, spread the CSB bus cable flat, and at the same time, ensure that the cable is in a natural state, and the plug and splitter are not stressed. Determine the start and end of the CSB cable laying according to the process documents. Temporarily fix the plug with the same direction and the main beam cable with 3M. Slowly turn into a circle from the laying end of the cable to make the cable slack and fasten it with temporary straps so that when laying on the satellite, the cable is too long to cause compression and pulling to cause damage to the cable.

#### 5.2 Laying and binding method

When laying the CSB cable, the satellite should be in a state where the low-frequency cable is laid and bound in place, so the laying of the CSB cable should shuttle between the T-shaped brackets that bind the low-frequency cable. When laying from the beginning of the cable, make sure that the cable that turns into a circle is not bent, scratched, or stressed during the shuttle. Use anti-static bubble film to do the necessary protection when in the cabin. When laying, make sure that the plug number is consistent with the socket end of the device and fix it with a temporary cable tie, and then continue laying. This not only ensures the correctness of the laying, but also determines the length of the cable laying. After all the laying is completed in accordance with the process requirements, the laying direction, turning angle and insertion position of the cable need to be checked. The inspector determines that the fixing conditions are met before lashing. Before binding, wrap 3-4 layers of nylon tape on the T-shaped bracket where it needs to be fixed, and at the same time wrap 3-4 layers of nylon tape on the position where the CSB cable needs to be fixed. Teflon cable ties are the preferred choice for fixing, which can be fixed in a crisscross buckle mode, which can be tightened by hand. Tighten the cable tie on the bracket first when binding, and then tighten the cable tie on the fixed cable. In actual operation, you can choose a bracket that can be bound and fixed according to the cable direction and cable length[6].
5.3 CSB bus cable binding technology
The surface layer of the carbon fiber composite cable support rod is T300-1k carbon cloth, and the inner layer is laminated with no weft cloth. Therefore, the carbon fiber composite bracket adopts manual latitude-free cloth layering and press curing molding process. The carbon cloth prepreg adopts manual brushing process, and the latitudeless cloth prepreg adopts wet roller molding. The prepreg strictly controls the surface density of the fiber and the amount of glue. During the laying process, vacuum pre-compaction is performed after every 3 to 4 layers are laid. After laying, press and cure according to the curing curve of epoxy resin.

According to the requirements of the CSB bus assembly, the main cable bundles need to be fixed 10mm before and after the splitter. Therefore, a carbon fiber bracket is attached to the upper surface of each multi-function module to fix the CSB cable. The strength of the bonding surface of each carbon fiber bracket can bear a weight of not less than 1.22kg in the direction perpendicular to the mounting surface, and it can weigh not less than 0.96kg in parallel to the mounting surface.

When binding, pay attention to whether there are sharp-edged devices or high-frequency brackets around the cables. In this case, you need to protect the cables after binding and fixing them. You can choose to wrap 3 to 4 layers of nylon tape where the cable is in contact or where it is likely to be contacted, and tie it with a Teflon cable tie (3.4mm is preferred).

In the position where the CSB bus cable passes through the cabin, a low-frequency cable can be used as a binding point for attachment. Before lashing, you also need to wrap nylon tape and use a cable tie to make a crisscross buckle. Special attention should be paid to the cabin position, and the cables in the cabin position should be protected. It can be wound with heat-shrinkable film, the number of winding layers is more than 5, and the heat-shrinkable film at both ends of the cabin should exceed the cabin plate by 20mm to 25mm. In the absence of T-shaped brackets and other lashing points, nylon bases can be pasted on the deck for fixing with the approval of design and workmanship. Pay attention to the secondary insulation. It is important to note that the CSB bus cable is a signal cable, and it is not allowed to directly use GD414 to paste and fix it on the cabin board.

6. Conclusion
Spacecraft cables should avoid metal components such as spacecraft equipment, grounding stakes, pipelines, heat pipes, etc., and a safety distance of 20mm should be left between them. Low-frequency cables cannot be bent, and the inner bending radius should not be less than 4 times the cable diameter. Low-frequency cables should not touch sharp, rough, and hard edges and corners. Cables near sharp edges and corners and at the hole should be protected by 5-6 layers of heat shrinkable film, and the protective parts should grow at least 20mm from the protected part. At the same time, the sharp edges and corners should be passivated by insulating coating by pasting polyimide single-sided pressure-sensitive tape.

In response to the needs of the spacecraft cable three-dimensional crossover layout, the CSB bus cable installation plan was designed, which can adapt to the complex cable routing conditions. Various experimental results prove that the method is practical and effective. This is the first time that the CSB bus cable has been applied in the development of a positive sample satellite, achieving a three-dimensional, spatial network installation mode, greatly improving the overall assembly efficiency, ensuring product quality, and having a good promotion and application prospect.

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