Optimization of Assembly Process Design about Cable based on MBD in Spacecraft Field

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Abstract: An important part of the low-frequency cable network spacecraft, in order to improve the efficiency of the spacecraft's low-frequency cable network assembly process, according to the characteristics of the spacecraft cable network, based on the three-dimensional digital design of the spacecraft cable network, the spacecraft based on the three-dimensional model. The design and optimization of the cable network final assembly, a digital cable network final assembly was proposed to achieve the purpose of improving the efficiency and reliability of the cable network final assembly.

1. INTRODUCTION
The low-frequency cable network is an important part of the spacecraft. The entire set of low-frequency cable assemblies that connect all electronic equipment and components of the spacecraft is collectively referred to as the spacecraft low-frequency cable network. The cable network is composed of cable assembly connections, and the cable assembly is composed of cables or cable bundles, electrical connectors, and connection terminals. The cable network is widely used in the field of spacecraft assembly. Its main function is to realize the power supply and signal transmission of the spacecraft through the electrical connectors, connection terminals and electronic equipment and components at both ends of the cable network. The key role of bonds and bridges. The cable network is responsible for the spacecraft's safe and reliable transmission of electrical energy to the various sub-systems during different phases of flight. The main functions of the spacecraft cable network: 1) complete the transmission and exchange of electrical signals between the spacecraft sub-systems and equipment; 2) provide the electrical path of the spacecraft through the separated electrical connector to the disconnected electrical connector to achieve ground testing electrical connection of equipment; 3) provide electrical interface between spacecraft and launch vehicle; 4) Provide reliable and safe electrical interface socket for on-orbit flight and ground test through star table socket; 5) programmable switch separated by star and arrow provide star and arrow separation signals for attitude orbit control sub-system and digital tube sub-system; 6) provide a good grounding design to improve the electromagnetic environment of the spacecraft.

The design and assembly of the cable network is a complex system project, which requires not only accurate cable branch connections, correct contact signal allocation, reasonable length binding design, but also more importantly requires that the cable network design be started from the source, with
reliability and safety. Design and electromagnetic compatibility design are for the purpose of designing a set of spacecraft cable network with good application prospects and application space that can operate reliably, safely and stably in orbit. As the spacecraft capacity increases, the number of corresponding low-frequency cables is also increasing. Therefore, using computer three-dimensional modeling technology, the digital prototype design of the cable can be realized at the product design stage, focusing on the cable's reasonable layout and wiring, processing and assembly process, and other issues to ensure the smooth production process of the product [1].

2. CURRENT STATUS OF CABLE NETWORKS

Most foreign spacecraft use T-shaped cylindrical cable supports in their layouts, which can be used to fix cables in layers to make more reasonable use of space. The low-frequency cable is directly fixed with a bracket installed on the surface of the deck to reduce the cable length. For high-frequency cables, a large number of elbow connectors are used to reduce the cable turning radius and more effectively fix the cables. Most foreign aerospace cable networks adopt open platform design and production methods, which is also one of the technical approaches to lightweight cable networks. One is to design and produce the cable network on the formwork, and the other is to design and produce the cable network on the actual platform. Its main advantage is that the direction and laying of the cable network can be reasonably arranged according to the actual layout of the instrument on the template or platform. If necessary, the instrument and cable layout on the platform can be reasonably adjusted, which can not only effectively save the length of the wiring harness, but also make the direction of the cable is more reasonable, which greatly reduces the probability of external force on the root of the cable network, and improves the reliability of the cable network. Figure 1 is a photo of the assembly status of the SPOT6 satellite [2].

![Fig.1 SPOT 6 final assembly status](image)

3. NECESSITY ANALYSIS

The three-dimensional design of the spacecraft cable network is a very important work in the satellite development process. Throughout the entire design process, the entire star cable network is developed and produced by manual or semi-manual design methods. In repeated iterative design coordination, complicated design links and test methods of the entire star cable network, if the previous design thinking mode is still used, it cannot meet the urgent requirements of the aerospace model mission. With the rapid growth of spacecraft model missions and the shortening of development cycles, it is imperative to innovate, expand and optimize 3D design methods and final assembly methods for cable networks. The goal of design optimization lies in optimizing the cable layout first, reducing the weight of the cable, and shortening the assembly period of the cable network.
4. OPTIMIZED DESIGN

4.1 Design Features of Traditional Cable Network

When designing the cable network, the cable bundle diameter should be fully considered, and the cables that need to be pre-formed will be explained. They can also be used as a reference when laying. When designing the cable network, factors such as cable bundle diameter, turning radius, cable plug insertion and removal margin, plug tail cover length, and laying timing should be fully considered during cable laying. The design of the cable network includes the design of the electrical interface of the cable network and various equipment, the design of the distribution of the cable transmission channel, and the reliability and safety design of the cable network, as well as reliability and safety related content such as EMC design.

During the development of traditional spacecraft models, the design, processing, and manufacturing of cables were carried out in the form of two-dimensional drawings for data transmission. The design, according to the cable connection relationship diagram in the equipment two-dimensional layout diagram, the plane of the cable, the approximate length of the cable is estimated based on the two-dimensional routing results, and then drawing the cable branch length diagram according to the cable length, during the design process. In large amounts, it is not easy to find the interference involved in the wiring process. In order to ensure that the cable meets the requirements after the production and processing of the cable, the estimated margin of the cable length is generally large, which increases the weight of the cable and takes up a large space. The layout and direction of the cable in the two-dimensional drawing is only a rough indication. It is different from the actual direction of the cable in the product. There are differences between the drawing and the final assembly, which is not convenient for real-time grasp and quality management of the state of cable installation.

The traditional wiring method mainly has the following problems: traditional cable design is not intuitive, it is not easy to check whether the design wiring is reasonable, interference, etc., especially the interference with pipelines is difficult to check. In the traditional cable design, the length of the cable cannot be accurately obtained. In order not to affect the cable connection, a large margin is usually set, which not only causes excess cables to occupy the space in the cabin, but also increases the weight of the cable, resulting in less overall space, and wasted weight. In the traditional cable design process, the workload is large and the work efficiency is low, so it is easy to cause human error. After the cable design is completed, the verification workload is large, and it is not easy to find hidden problems.

4.2 3D design features

Proe is a large-scale three-dimensional parametric design software developed by American Parametric Technology Corporation (PTC). It contains a variety of design modules. The Pro / cabling module is a cable routing module, which is a separate cable three-dimensional design module. After the three-dimensional wiring with the PRO / CABLING module, a complete digital prototype can be generated. This digital prototype includes not only the arrangement of structural parts and electrical components, but also the way of entering and exiting the cable, the layout of the cable in the model, the cable and connection, plug-in selection, cable tying, etc. After the model design is completed, the designer reviews the digital prototype, exchanges design ideas, and points out problems in the design in a timely manner. The digital prototype after designing with PRO/CABLING is shown in the figure below.
4.3 Optimize design content
The objectives of the three-dimensional design and final assembly of the cable network include improving the cable network design mode, promoting parallel design processes, and achieving rapid iteration of branch design and layout design. By means of information technology, the collaborative work of the cable network designer and the layout designer are realized. The optimization of the branch network design, and the trend design of the cable network start at the layout stage. Establishing a quantitative evaluation method for cable network weight and branch complexity, and combining channel allocation during the design of cable network to optimize the allocation of platform service resources, effectively reduce cable length and branch complexity, and effectively support optimization of cable network direction. Promoting the application of new space-borne buses or data buses represented by space wire, time-triggered Ethernet, etc., and reduce the technical threshold by establishing common protocols and common interfaces; reduce the development cost by developing special integrated circuits and effectively increase the data nodes on the satellite reduce the proportion of discrete telemetry and instructions. The application of new temperature sensing technology and thermal control technology, effectively reduce the number of heating fins and thermistors on the satellite, and reduce the proportion of thermal control cables in the cable network.

This paper proposes a method for 3D design and process coordination of cable networks for rapid final assembly, which mainly includes cable network contact meter design, spacecraft hole opening clamp setting and identification settings, spacecraft cable 3D trend design, cable towards the design, cable branch and length diagram output cable production and delivery, spacecraft final assembly cable laying and other steps.

4.4 Optimization of 3D Via Marking
The identification of the cable network should be confirmed during the design phase of the cable network, and all identification should be reflected on the model. In the three-dimensional design of the cable network, a mark for automatically marking the hole of the deck when a through hole is added, and a mark is generated when the cable network branch and the length map are generated, and the cable manufacturer fixes the mark on the cable when the cable production is implemented on. In the digital three-dimensional cable model, the design of the cable network logo is designed at the design stage, and the logo is produced during the production of the cable. After the final assembly, the cable star installation is completed according to the cable logo and the three-dimensional model of the cable network. The cable is laid, and it is not necessary to lay the cable while looking at the three-
dimensional model, which greatly improves the efficiency and accuracy of cable assembly and shortens the assembly time.

4.5 Channel design optimization
According to the three-dimensional model of the cable network, the overall planning of cables, path optimization, and electromagnetic compatibility considerations can be performed intuitively based on the model. On the outer surface of the cable network, further color differentiation and sub-channel design are carried out when designing various types of cables. According to the type of signal transmitted by the cable, the type of interference and the sensitivity of the circuit to the interference, the cable is classified. The main bundle cable channels, bundling positions, routing directions, etc. are determined in advance during the assembly modeling process. Each main bundle channel is in the same horizontal plane. Each main bundle channel is subdivided into power cables, high-frequency cables and LVDS cables, and other 3 types of subdivided channels such as ordinary cables. During the layout of the equipment, all the connectors are oriented as far as possible to the main beam channel, and the entire star forms a backbone and branched "fishbone" cable network. When designing the layout, it is necessary to determine the layout orientation of the single machine according to the schematic diagram of each sub-system to avoid the phenomenon of long cable links and staggered cable connections.

4.6 Weight optimization
The existing cable 3D factory only contains cable length information, and there is no model library and weight information of the plugs at both ends of the cable. It is difficult to match the model cable weight information with the real cable weight information. In the satellite design where there is a need for light weight, the cable cannot be accurate Lightweight requirements. At present, after the spacecraft cable is produced by the manufacturer, the whole star is delivered in batches. There is no single weight record for the cable weight. The cable has only the batch weight. The total star cable weight is the sum of all batch cable weights. Designers cannot quickly and easily ground weight check and optimization of a single cable.

Based on the three-dimensional model, the quality of the cable network is considered through simulation to make the cable optimal and shortest, and the purpose of reducing the weight of the cable network is achieved. Research on three-dimensional cable network based on information technology can realize fast wiring of cables, generate real cable models, and obtain real cable weight and type information. It is an effective way to quickly calculate cable weight and optimize cable network.

In the cable network design software, open the interface with the weight data recording software of the cable network production department to achieve the comparison of the overall design cable weight with the actual production weight. The designable threshold is X%. X% is marked, the designer can adjust the weight of the design cable model according to the error, and optimize the weight calculation of the cable network model.

4.7 Optimization of installation method
During digital cable installation, a model including complete information including cable supports, decks, equipment, and nylon bases, should be provided to the site, and the cable network on the satellite should be laid according to the model. Some auxiliary cable supports, such as T-brackets, can be used on the cable channel to maximize the distance between various types of cables and improve the star electromagnetic compatibility, power supply safety, and reliability.

T-type bracket, also known as the new type transmission line bracket, is made of "2A12 T4" aluminum alloy with chemical oxidation treatment on the surface. The basic structure of the bracket is T-shaped, and it is machined integrally. The bottom surface of the installation has a long waist, and 2 light round holes are designed for mounting the bracket by screws. The bracket body is an elongated circular ring-shaped straight rod that is penetrated through a through hole. The straight rod can be used to bind and fix low-frequency cables to achieve multilayer layout.
Advantages of the T-shaped bracket: At the same height, the weight of the T-shaped bracket is lighter than the original high-frequency cable bracket. The communication cabin high and low frequency cable paths can be set at different heights and different orientations of the same bracket, which improves the space utilization of the communication cabin, reduces the area of the communication cabin board occupied by the cable, and is more flexible. The power and signal lines of the low-frequency cable can be bundled separately to meet EMC requirements [4].

When using T support to bind low-frequency cable, we should first use P213LW chinlon tape which is 25mm in width at cable and support separately and then tied cross with tapes of same specification.

5. BENEFIT ANALYSIS
In the digital mode, the three-dimensional process digital prototype is sorted out by combining the design requirements as a unified data source for process design. It inherits from the beginning and the beginning, takes the three-dimensional design model and the file as the input, is the source of information for process design and material preparation, and also the basic framework for connecting satellite assembly data packages. At the same time, the three-dimensional process digital prototype includes a product structure tree, a three-dimensional model, and product attributes. The product attributes refer to common attributes such as name, code, quantity, and specifications, and special attributes that different types of products need to include.

Cable installation based on the three-dimensional model can intuitively show the spatial direction of the cable network. Compared with the traditional two-dimensional mode, the method of pasting marks and identifying marks requires low operator skills, high installation efficiency, and is not prone to errors. The cable net assembly method based on the three-dimensional model can greatly shorten the cable network installation time.

6. CONCLUSION
To meet the needs of spacecraft cable cross-layout, a 3D model-based spacecraft low-frequency cable network assembly process design and optimization technology was proposed. Based on the 3D digital design of the spacecraft cable network, the 3D design of the spacecraft cable network for assembly optimized and designed the cable installation on the T-bracket, which can adapt to the complex cable routing conditions, and solve the problems of long total installation period, low quality and high labor cost during the laying of the spacecraft cable network in three dimensions. To achieve the goal of improving the efficiency and reliability of cable network manufacturing and overall assembly, and to meet the mission requirements of spacecraft for cable networks.
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