Research on Flatness Rapid Measurement Technology of Large Deployable Antenna

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Abstract. The flatness of large deployable antenna needs to be measured several times during the deployment test, the theodolite measurement accuracy was low and the speed was slow, and the laser radar measurement range was limited. By building a flatness rapid measurement system for large deployable antenna, using autonomous navigation mobile technology to plan measuring path, and using digital photogrammetry technology to detect the flatness of antenna. It can realize rapid and automatic measurement for flatness of large antenna. The test results show that the accuracy of digital photogrammetry camera and laser tracker is no more than 0.05mm; the measurement accuracy of the flatness rapid measurement system shall not be more than 0.034mm away from the accuracy of laser radar, it can meet the requirements of flatness rapid measurement of large deployable antenna. This method can improve the efficiency and automation level of flatness measurement of large deployable antenna, and it lays a foundation for the plane measurement of large deployable antenna with larger size and more complex structure.

1. Introduction
The large deployable antenna is an important part of satellite. The planeness and pointing accuracy of the antenna after deployment directly affect the observation accuracy and performance of the satellite. Therefore, it is necessary to measure the planeness and pointing accuracy of the satellite antenna after deployment test [1-3].

At present, the satellite antenna is measured by theodolite or laser radar, the measurement accuracy of theodolite is low and its speed is slow; laser radar measurement range is limited, all of these have certain limitations for large deployment antenna. After the large deployment antenna is assembled, repeated deployment tests are required, the flatness needs to be measured for each deployment, therefore, the accuracy and efficiency of the existing measurement methods are low, which are not suitable for the flatness measurement of large-scale antenna [4-6].

In this paper, a fast measurement method of large deployable antenna plane is proposed, the panel of large antenna deployment system is measured automatically by photogrammetry technology; The autonomous navigation mobile system is used to realize the measuring path planning, improve the plane measurement efficiency and automation technology level of large antenna deployment system, It can meet the technical requirements of flatness rapid measurement of large antenna deployment system, and adapt to the development trend of large antenna in the future.
2. Construction of Flatness Rapid Measurement System for Large Deployable Antenna

The flatness rapid measurement system of large deployable antenna is shown in Figure 1. The system consists of autonomous navigation mobile system and high-precision digital photogrammetry system. In the measurement process of large deployable antenna, autonomous navigation mobile system and digital photogrammetry system can communicate in real time.

![Figure 1. Flatness rapid measurement system of large deployable antenna](image)

Autonomous navigation mobile system has optical automatic guidance function, it can make the digital camera move along the horizontal or vertical direction according to the planned path; the digital photogrammetry system is used to measure the flatness of large deployable antenna. After the autonomous navigation mobile system moves to the designated position according to the planned path, it sends signals to the digital photogrammetry system, the digital photogrammetry system takes pictures and feeds them back to the autonomous navigation mobile system after shooting, the autonomous navigation mobile system continues to move, and arrives to the next designated location for shooting, until the scanning of the whole antenna is completed. The closed-loop control of antenna measurement and autonomous movement is formed, so the automatic measurement of large antenna is realized.

2.1. Autonomous navigation mobile system

The autonomous navigation mobile system can move according to the planned path, and it can realize the movement of digital camera in horizontal or vertical direction, so the measurement efficiency is improved [7-9]. The autonomous navigation mobile system is mainly composed of autonomous navigation mobile device, guide rail, control system (industrial computer, controller, control software), etc. The autonomous navigation mobile device has the functions of omni-directional movement, intelligent obstacle avoidance, automatic positioning, etc. it can move or stop along the horizontal direction according to the specified path. The guide rail can be accurately positioned and can move or stop in the vertical direction. The main function of the control system is to receive the signal of arriving position for autonomous navigation mobile device or guide rail, convert it into control command to control measurement system for measurement, and receive the feedback signal of the measurement system, convert it into control command to control the autonomous navigation mobile device or guide rail to move according to the specified path.
2.2. Digital photogrammetry system
The digital photogrammetry system is composed of high-precision industrial camera, pan-tilt, photogrammetry software, control system, etc. The pan-tilt is a supporting device for installing and fixing cameras, which is suitable for scanning in a wide range, and it can expand the field of view of the camera. The photogrammetry software processes the collected image data, and completes the flatness analysis and other related functions. By using the high-resolution measurement camera, more than two digital images of the measured object are acquired at different positions and directions. After image scanning processing, sign recognition, image matching, spatial triangle intersection and beam adjustment, the three-dimensional coordinates of the object to be measured are obtained. After processing, 3D data of tested object will be entered into the coordinate system, it calculates the planeness and pointing accuracy of large antenna [10-12].

3. Path Planning of Measurement System
In order to have a better measurement network type and the angle of intersection, the measuring method of 45° angle between the main axis of visual line and the normal line of the antenna panel is adopted. During the measurement, first place the camera horizontally for shooting measurement, then rotate the camera 90° along the main axis of visual line to measure the same area. Move the autonomous navigation mobile device to the next location to continue the measurement, until the entire antenna panel area is measured. The measured attitude of the camera is shown in figure 2; the camera is placed horizontally, with the main axis of camera visual line at an angle of 45° from the normal of antenna panel.

The distance between the camera and the antenna panel is 1.4m, and the camera parameter field of view is 72°×51°. When the camera is placed horizontally, the effective observation range of camera is 2.2m in the horizontal direction, and 1.2m in the vertical direction. According to the measurement method of 60% overlap degree in both horizontal and vertical directions, the moving distance in each horizontal direction is 0.85m, and that in the vertical direction is 0.45m after a row of shooting is completed.

When the camera rotates 90° along the main axis of visual line, and is placed vertically for measurement, the effective observation range of camera is 1.9m in the horizontal direction, and 1.6m in the vertical direction. According to the measurement method of 60% overlap degree in both horizontal and vertical directions, the moving distance in each horizontal direction is 0.75m, and that in the vertical direction is 0.55m after the row is finished.

In order to ensure that the overlap of the camera's horizontal and vertical placement can reach 60%, so the camera's moving distance is 0.75m in the horizontal direction and 0.45m in the vertical direction. The measurement range of antenna panel is 10m × 2.5m. The camera needs to move 14 times in the horizontal direction and 6 times in the vertical direction.

![Figure 2. Measurement attitude of camera](image-url)
4. Accuracy verification of measurement system

4.1. Accuracy verification of digital photogrammetry system

The accuracy of digital photogrammetry camera is detected with a laser tracker (as shown in Figure 3). A digital photogrammetric field is established, in which six target balls are placed as measurement points. By comparing the measurement results of laser tracker and digital photogrammetry camera, the accuracy of measurement camera is verified.

![Figure 3. The accuracy verification test of camera](image)

The difference between the digital photogrammetric camera and the laser tracker is shown in Table 1. It can be seen from Table 3 that the accuracy deviation between the digital photogrammetric camera and the laser tracker is not more than 0.05 mm, which meets the accuracy requirements.

| Target ball | Coordinate X (mm) | Coordinate Y (mm) | Coordinate Z (mm) | Mean square deviation (mm) |
|-------------|-------------------|-------------------|-------------------|---------------------------|
| 1           | -0.02             | 0.03              | 0.02              | 0.041                     |
| 2           | 0.02              | -0.01             | 0.01              | 0.025                     |
| 3           | -0.03             | 0.02              | -0.02             | 0.041                     |
| 4           | 0.01              | -0.03             | 0.01              | 0.033                     |
| 5           | 0.02              | 0.02              | -0.01             | 0.03                      |
| 6           | 0.01              | -0.01             | -0.01             | 0.017                     |

4.2. Experimental verification of flatness rapid measurement system

Verify the principle of flatness rapid measurement system (as shown in Figure 4). Paste photogrammetric marks, including coding point marks and single point marks, within 10m × 2.5m of the flat wall, and place the measuring datum ruler. According to the measuring path planning, set the distance between the horizontal movement of autonomous navigation mobile device and the vertical movement of guide rail, run the flatness rapid measurement system to measure, and carry out five times measurements on the measurement area. The measurement results are shown in Table 2. Then the laser radar is used to measure once. Through data comparison, it can be seen that the maximum deviation between the accuracy of the plane measurement system and the laser radar is 0.034 mm, and the minimum deviation is 0.009 mm, which meets the use requirements.
5. Conclusion
The rapid measurement technology of large deployable antenna can realize the flatness measurement of large deployable antenna. The antenna panel is measured by digital photogrammetry technology, the accuracy deviation between digital photogrammetry camera and laser tracker is not more than 0.05\(mm\); the measurement accuracy deviation between the flatness rapid measurement system and the laser radar is not more than 0.034\(mm\), which can meet the requirements of flatness rapid measurement of large deployable antenna. This technology solves the problems of low precision and slow speed of theodolite measurement system, and solves the problem limited measurement range of laser radar measurement system. It improves the measurement efficiency and automation level of large deployable antenna, and lays a foundation for plane measurement of large deployable antenna with larger size and more complex structure.

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