Study on Design of Novel Function/Structure Integration Mounting Plate for Space borne SAR Antenna for Wireless Communication

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Abstract. A novel lightweight and high-precision synthetic aperture radar (SAR) antenna mounting plate scheme based on functional structure integration technology is proposed. The thermal control function, high and low frequency blind insertion signal transmission function of the system are combined with the antenna structure to greatly reduce the size and weight of SAR antenna. The design verification of a high-density integrated SAR antenna mounting plate breaks through the key process technologies such as accurate splicing of multiple interfaces of the mounting plate, highly reliable cementation of non-uniform honeycomb and large-scale warpage control, and solves the key technical difficulties of high precision, high temperature and high reliability. The results show that the antenna mounting plate (size 649mm × 430mm) the overall flatness is better than 0.28mm, the thickness limit dimension deviation is less than 0.1mm, and the temperature consistency is less than 1.8℃. It can meet the requirements of lightweight, structural stiffness and strength, RF blind plug connection and heat dissipation for space borne SAR antenna.

Keywords: Synthetic aperture radar, Integration of structure and function, lightweight antenna, temperature consistency.

1. Introduction

Spaceborne synthetic aperture radar (SAR) is an active microwave imaging sensor with all-weather working capacity. It is widely used in important livelihood fields such as natural resource survey and disaster monitoring [1-3]. In order to improve the gain and performance of spaceborne SAR Antenna, the amount of equipment and power consumption of antenna are increasing, and the design of high integration and lightweight is urgent.

Antenna mounting plate is the most important basic structural bearing unit of spaceborne SAR antenna. It integrates a large number of radiation units, feed network, and Transmit/receive (T/R) modules, power supply and other electronic equipment. It not only has complex interface, abundant structural stiffness and strength redundancy, good thermal conductivity, but also has strict requirements for weight index. Public information shows that [4-5], the parasitic weight of enclosure, interconnection,
support, packaging and other related antenna equipment accounts for 50%, and the lightweight method of reducing the weight of the structure itself is not desirable. The integrated antenna technology of multifunctional structure (MFS) is an important way to realize large aperture spaceborne SAR Antenna [6-8]. Its remarkable feature is that it has two or more functions, integrating electronic, thermal control, traditional structural support and other functions. In this paper, the integrated design and forming of mounting plate for a satellite antenna are studied.

2. Integrated design of function and structure
As shown in Figure 1, the core idea of MFS design is to break the independent relationship in the form of each single machine subsystem from the overall perspective of antenna structure system, and construct its unimportant repetitive structure and parasitic structure into a complete integrated structure with multiple functions.

The multi-functional structure integration method is to optimize the structure of scattered structural parts, thermal controls and mounting parts through physical structure combination and function combination, and give new functions such as thermal control, electromagnetic shielding, anti-irradiation and grounding, including multi field coupling simulation, efficient thermal control, new advanced manufacturing and molding, etc.

The structure function integrated (SFI) mounting plate is the key bearing component of spaceborne SAR Antenna and the integration basis of integrated antenna module. The typical structure is shown in Figure 2. It is generally equipped with mechanical connection interface, electrical connection interface, thermal control functional elements and other functions. It is a multifunctional structure integrating thermal control and load-bearing.

Figure 1. Design method of MFS in SAR antenna system.

Figure 2. Design scheme of SFI mounting plate.
3. Research on sample design and forming technology of mounting plate
As shown in Figure 2, the SFI mounting plate includes three parts and the integrated phase change material devices are embedded in the sandwich structure. In order to reduce the weight, an electric adapter is hidden in the integrated antenna mounting plate, which greatly saves the volume and reduces the weight of the system.

3.1. Performance requirements of SFI mounting plate
In order to reduce weight, the SFI mounting plate adopts honeycomb sandwich structure, the skin is made of aluminum alloy, and the sandwich is commonly made of aluminum honeycomb. The mechanical properties of its structure can meet the installation and use requirements. Detailed technical requirements are shown in Table 1.

Table 1. Design parameters of the mounting plate.

| No. | Term                  | Value             | Unit   |
|-----|-----------------------|-------------------|--------|
| 1   | Size                  | $649^{0.2}_{-0.2} \times 430^{0}_{-0.2} \times 11^{0.02}_{-0.08}$ | mm     |
| 2   | Overall flatness      | 0.4 (P-P)         | mm     |
| 3   | Local flatness        | 0.1:100×100       | mm     |
| 4   | Cementation dislocation | ≤ 0.05           | mm     |
| 5   | Curing temperature    | ≤ 85℃             | ℃      |
| 6   | Bonding shear strength | ≥ 23             | MPa    |
| 7   | Weight                | ≤ 1.85            | kg     |

3.2. Forming process of light SFI mounting plate
The SFI mounting plate is cemented by molding method. The manufacturing work includes numerical control processing and surface treatment of panel parts, cutting / paving of honeycomb and adhesive film, composite of panel honeycomb / heat materials, and thermal curing molding of active mounting plate. It is divided according to the production process, including preparation before bonding, glue mold / honeycomb paving, heat unit embedding, upper and lower skin composite and curing. The specific production and manufacturing flow chart is shown in Figure 3.

Figure 3. Manufacturing process and equipment curves of SFI mounting plate.
4. Trial production and performance test

4.1. Plane moulding test
In order to verify the parallel processing and deformation of the upper and lower molding surfaces of the upper and lower molding plates of the mold, 10 batches of cementation tests were carried out, and the results are shown in Table 2.

It can be found from the table: a) With the increase of using times, the flatness of the die becomes larger and tends to be stable; b) The flatness of the honeycomb sandwich panel is higher when the pressure temperature is lower than that of the honeycomb sandwich panel with higher pressure temperature; c) The thickness of the test plate is relatively good at about 75 °C, the thickness is thin at 70 °C and thick at 80 °C; D) the first mock exam is two pieces of molding, which can meet the flatness and thickness design requirements of the mounting plate.

| Flatness of mould | Honeycomb sandwich plate | Temperature of mould |
|-------------------|--------------------------|----------------------|
| No.1              | ≤0.05mm                  | ≤0.22mm              | 70°C |
| No.2              | ≤0.05mm                  | ≤0.22mm              | 70°C |
| No.3              | ≤0.08mm                  | ≤0.18mm              | 70°C |
| No.4              | ≤0.08mm                  | ≤0.15mm              | 75°C |
| No.5              | ≤0.10mm                  | ≤0.12mm              | 75°C |
| No.6              | ≤0.10mm                  | ≤0.12mm              | 75°C |
| No.7              | ≤0.10mm                  | ≤0.16mm              | 75°C |
| No.8              | ≤0.10mm                  | ≤0.15mm              | 80°C |
| No.9              | ≤0.10mm                  | ≤0.15mm              | 80°C |
| No.10             | ≤0.10mm                  | ≤0.14mm              | 80°C |

4.2. Thickness consistency moulding test
The design thickness dimension of the mounting plate is 11(-0.08, +0.02) mm, and the adopted adhesive film is 0.2mm. Because the adhesive film will become soft during heating and has certain extrusion fluidity, on the premise of ensuring that the adhesive film thickness is sufficient and effective, the uniformity of the adhesive thickness is jointly guaranteed by the thickness accuracy of the front and rear cover plates, the height accuracy of the contour block and the flatness of the die at the corresponding position. According to the processing limit tolerance requirements of die steel, the matching tolerance is 0.01mm, that is, in order to ensure the uniformity of bonding area, the height dimension of contour block of die is 10.99 ± 0.01.

| Term                        | Value       | Unit |
|-----------------------------|-------------|------|
| Front skin thickness        | 0.40~0.45   | mm   |
| Rear skin thickness         | 0.42~0.45   | mm   |
| Aluminium honeycomb thickness | 9.96~10.04  | mm   |
| Adhesive film thickness     | 0.05~0.10   | mm   |
| Mounting plate thickness    | 10.83~11.04 | mm   |
4.3. **Performance test**

According to the test results of the above forming method, the batch trial production of formal products is carried out. As shown in Figure 4, 57 SFI mounting plates were produced, and the structure size, weight, plane accuracy and temperature consistency were tested.

![Physical drawing of the SFI mounting plate.](image1)

**Figure 4.** Physical drawing of the SFI mounting plate.

4.3.1. **Thickness consistency test results.** The key dimensions of thickness and flatness are measured. The maximum and minimum values of each plate are shown in Figure 5. It can be seen that the thickness meets the design requirement, which is between minimum 10.92 and maximum 11.02, and the average value is 10.978 mm. The overall front flatness and back flatness are less than 0.28 mm, and the local flatness is less than 0.05 mm.

![Thickness and flatness of SFI mounting plates.](image2)

**Figure 5.** Thickness and flatness of SFI mounting plates.
4.3.2. **Isothermal test.** The isothermal performance test was carried out on the single machine mounting surface of the SFI mounting plate. A total of 57 modules and 456 heat units were produced and processed. As shown in Figure 6, the isothermal performance of all mounting plates is better than 1.8 °C, which meets the design requirement ≤ 3 °C, and the weight of SFI mounting plates is between 1.8 kg and 1.87 kg.

![Isothermal property](image)

Figure 6. Flatness and weight of SFI mounting plates.

5. Conclusion
Space borne SAR antenna is developing towards large aperture and high resolution, and antenna integration is facing new major challenges. The integrated antenna design method aiming at multifunction integrates structural mounting plate, antenna thermal control, transmission cable, antenna equipment and its support, shell packaging and other auxiliary components into one. It is a system engineering of mechanical, electrical and thermal integration of electronic equipment.

This paper discusses the design and forming technology of the functional integrated antenna mounting plate in detail. The test results show that the integrated mounting plate has excellent mechanical and thermal functions, can meet the development requirements of SAR antenna technology such as large aperture, lightweight and high integration in the future, and has broad development space and application prospects.

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