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Development of QM Ka-band Feed Assembly for the Satellite Antenna Subsystem

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1. Introduction

The antenna feed assembly for satellite communication system is hampered by electrical and mechanical requirements. Among the important electrical constrains, the low insertion losses, the very low level of PIM (Passive Inter-modulation) and the sufficient multipaction margins have to be considered for its successful development. An accurate computer aided design is necessary to avoid the needs for any additional adjustments, which limit the maximum transmittable power, generate PIM products, and increase the cost of device [1]. In addition, the small size and volume are required from a mechanical point of view.

This paper deals with the Ka-band(20/30 GHz) antenna feed assembly composed of feed horns, diplexers and waveguide runs as shown in Fig. 1. The feed equipment was designed optimally in both the electrical side and the mechanical side and performed the environmental tests. The RF performance specifications of the Ka-band feed assembly were satisfied under the given environmental conditions. The verification about the design method and the performance of the Ka-band feed assembly was achieved from these measurement results.

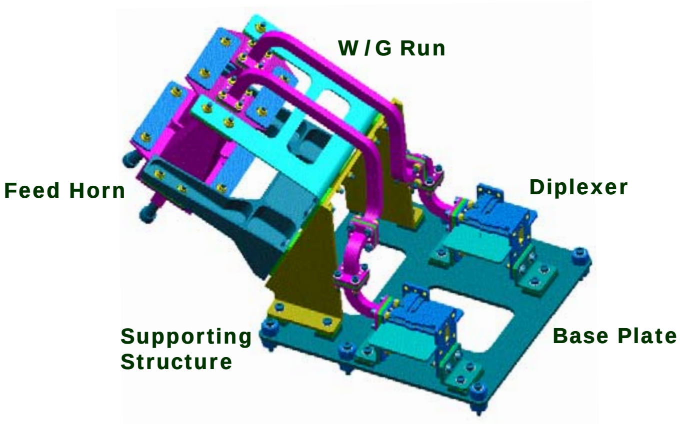

Figure 1: Feed Assembly for Satellite Antenna Subsystem

2. Design and Analysis

The type of pyramidal horns is used for the feed horns to be located in the prime focus area of the reflector. The horns have the proper edge taper at the reflector edge and the suitable aperture size for good performances. The diplexers consist of a corrugated low pass filter [2] for transmit frequency band, an asymmetric inductive iris band pass filter [3] for receive frequency band and a manifold [4] to combine two filters. An E-plane T-junction, not an H-plane, is chosen for manifold because it is appropriate for a device to be manufactured by splitting the broad wall of the filters and manifold to ensure very low electrical current across the interface, which makes reduction of PIM level [5]. Normally, the reason for PIM generation at waveguide contacts is the poor metal contact in combination with native oxidation of the waveguide metals and the lack of precision in

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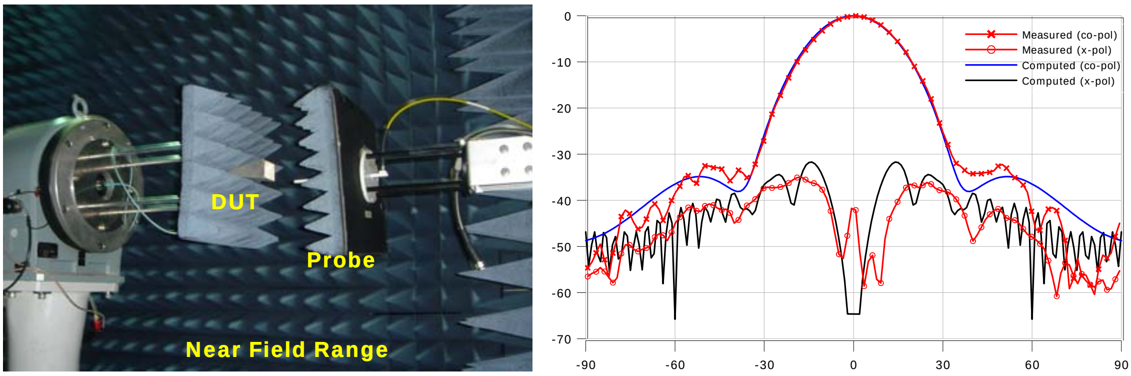
the fabrication process. Therefore, the careful processes at the design and manufacturing phase are required [6]. The PIM order of the feed equipment is very high, 49^{th}, so that the low PIM level is predicted. In the multi-carrier case, the recommended multipaction margins are more than 6 dB [7]. Aluminum has a very high secondary electron emission coefficient primarily, thus silver or gold plate in waveguide is used in vacuum or space applications. Among the antenna feed equipment the highest electric field is found in the diplexer. Consequently, the diplexer determines the peak power capacity of the feed assembly. The predicted maximum handling power of the silver-plated diplexer is 4.4 kW or 12.18 dB multipaction margin above input peak power of 264 W.

The Ka-band feed assembly for QM (Qualification Model) reflector antenna system was assembled from the constituting components, and installed onto the spacecraft bus or an MGSE simulating spacecraft bus. For the safe mount, the modal analysis, sine and random vibration analysis, etc. were performed. The first natural frequency is 87.29 Hz, which exceeds the goal of 50 Hz. The input level of sine vibration is 6 g within frequency range from 5 to 120 Hz with respect to x, y, and z-axis. The notching has been performed in order that the interface loads of the sine vibration do not exceed that of quasi-static. The random vibration of the feed assembly was analyzed under 18.4 grms in z-axis and 12.8 grms in x and y-axis. The input overall frequency range is from 10 to 2000 Hz. The acceleration grms results of the feed assembly in each x, y, and z-axis were 211 grms, 141 grms and 112 grms, respectively. 6-layer MLI for thermal control is aluminized Kapton foil with an ITO coating and surrounding whole the feed assembly structure. In addition, the outer surface of the feed assembly exposed to space was painted white for low solar flux absorption and efficient heat rejection. The predicted minimum and maximum temperatures under on station condition were -116 °C and +124 °C, respectively.

3. Experimental Results

The feed horn performance was measured at the near field test range and the results are presented in Fig. 2. The measured co-polarization and cross-polarization patterns have a good agreement with the analysis results. There is just small discrepancy in sidelobe, but its level is below -30 dB. The respectable cross-polarization level of more than 35 dB was obtained owing to the exquisite alignment between the feed horn and the scanning probe. The return losses for transmit and receive frequency bands exceed 21.3 dB and 29.8 dB, respectively. All performance parameters are satisfied with the specifications.

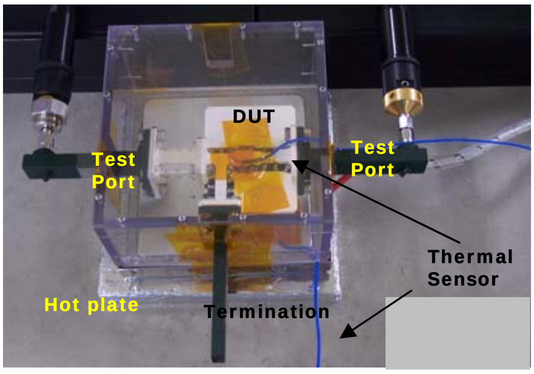


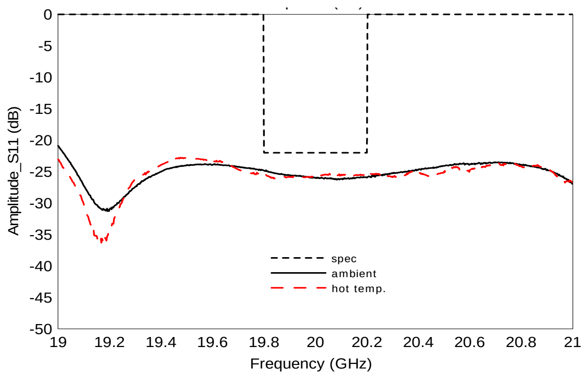
(a) Near Field Test Setup (b) Near Field Test results

Figure 2: Near Filed Test of the Feed Horn

The RF performance of the diplexer was measured at ambient and hot temperature. Fig. 3 shows the hot plate and thermal sensors for the temperature test. The few thermal effects like 70 MHz frequency shift was appeared because the diplexer has broadband characteristic. The performance levels are similar each other as shown in Fig. 3(b). The return loss of about 25 dB and the isolation of 45 dB or more were measured and all performance parameters including group delay were compliant with specifications.

The Ka-band QM feed assembly included to the waveguide runs was appropriately fabricated through the mechanical analysis. The survivability of the fabricated feed assembly would be verified by the environmental tests such as a vibration, a thermal cycling and EMC test. The RF performances would be checked at pre- and post- environmental tests. In this paper, it will describe only the RF test results.

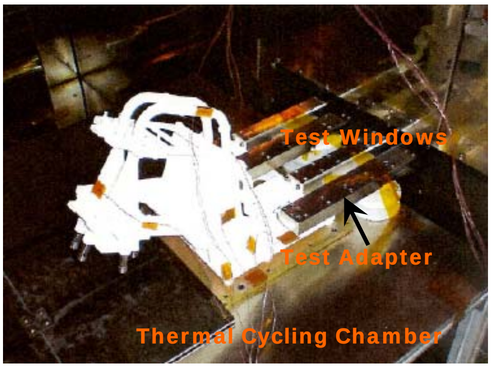


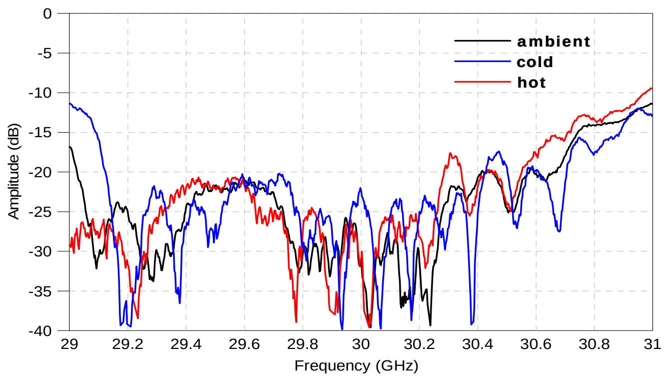


(a) Hot Temperature Test (b) Test results at ambient and hot temperature

Figure 3: RF Performance Test of the Diplexer

Fig. 4(a) shows the feed assembly installed in the thermal cycling test chamber. The feed assembly was applied on the thermal range of -130~+140 °C for the total 6 cycles. The functional performance testing was performed at ambient conditions, prior to and following thermal cycling testing and at cold/hot plateaus on the first and last temperature cycles. The performances under the thermal cycle period were measured as depicted in Fig. 4(b). They have noise and fluctuation in the measurement results due to not the feed assembly itself but the test adapter. Actually, the performance variations by the temperature are small.





(a) Thermal Cycling Test (b) RF Performance test results

Figure 4: Thermal Cycling Test

The leakage test was performed at EMC chamber and measured by injecting 10 mW RF signal into input port. The antenna for receiving the leakage level put in a location from the feed assembly at a distance of 1 meter. The leakage level measured by the receiving antenna with 16 dB gain was 150 dB below in comparison with the input signal and compliant with the specification of 120 dBc.

4. Conclusions

In not only in efficiency which is electrical but also the high power capability and the mechanical side, the Ka-band feed assembly described in this paper was altogether designed with optimization. The tests for the verification of the optimized design and space qualification were achieved. The vibration test, the thermal cycling test and the EMC test were performed for the space-proof. And the Ka-band feed assembly was found to survive in the space environment through the RF performance measurement at both before and after the environmental tests. The Ka-band feed assembly developed in this paper is compatible with the high power system like the satellite as well as the terrestrial system.

Acknowledgement

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