In-Orbit Test Strategy and Results for GX Multibeam Antenna

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Abstract— **This paper presents the multibeam antenna architecture and the in-orbit antenna performance of Inmarsat 5-F4, the latest addition to the I5 satellite constellation that form the Global Xpress network. The first part of the paper presents the advantages of the design choices made and the second part illustrates the in-orbit antenna test strategy and results obtained, that allowed to confirm the actual performance of the antenna in space.**

Keywords— antenna, multibeam antenna, in orbit tests, Global Xpress.

I. INTRODUCTION

The market for telecommunications satellites is seeing a continuous expansion towards broadband Ka services [3]. The demand for increased transmission capacity with the limited available bandwidth has shown technology development trends towards multi beam antenna configurations. This offers increased in-orbit flexibility via the multiple re-use of the allocated frequency spectrum, increasing the spectral efficiency. For generating a multiple spot beams scenario with overlapping spots, the antenna system is a key component. More than one basic principle is possible, but the Single feed per beam (SFPB) design, utilizing one feed horn for each separate beam has the advantage of hardware simplicity and superior RF performance [1].

In this paper, the antenna system based on the SFPB technology, used on board the I5-F4 satellite is presented. Comparison between on ground and in orbit measured performance will be presented to demonstrate the high degree of reliability of Inmarsat's satellites antenna performance.

II. GLOBAL XPRESS SATELLITE CONSTELLATION

Inmarsat 5-F4 is the fourth and last launched member of the Global Xpress system operated by Inmarsat, a seamless global satellite communications system that delivers flexible high-speed mobile broadband communications to maritime, aeronautical, enterprise and government customers worldwide.

I5-F4 satellite, as its predecessors, is based on a Boeing's BSS-702HP platform and embarks a Global Payload that provide a multibeam coverage of all visible Earth, supporting high user download speeds of at least 50Mbps and uplink of 5Mbps (with standard terminals). It also embarks six steerable spot beams (the High Capacity Payload) that deliver a high degree of flexibility to respond to changing demands and allow to place additional capacity where needed. This second system will not be discussed in this paper.

III. I5-F4 ANTENNA SYSTEM FOR GLOBAL PAYLOAD

Inmarsat 5-F4 Global Payload coverage is generated by a SFPB design comprising of two transmit and four receive deployable antennas. As can be seen in fig 2, three Single Offset deployable reflectors are accommodated on each side of the spacecraft (one Tx, two Rx), and each reflector is fed by an array of feeds, generating in total 89 2° wide contiguous beams that cover the full visible surface of Earth.

Fig. 1. The Inmarsta 5F4 satellite antenna farm (artist impression)

The two Tx antennas use an oversized reflector with a long focal length and 89 identical feeds split in two bundles to reduce packaging complexity. The Rx 89-beams coverage is split over four reflectors to allow larger horn size and improved performance. All reflectors are shaped for optimum gain and beam-to-beam isolation performance, but all Tx reflectors and all Rx reflectors have the same identical shaping to simplify manufacturing. The six presented Global Payload antennas, guarantee a Tx gain of at least 35.8dBi and an Rx gain of at least 36.8dBi over more than 98% of the coverage, as measured on ground. All reflectors are equipped with a trimming mechanism that provides in-orbit capability to finely adjust the pointing, which is key to ensure the in-orbit performance of the antennas.

IV. IN-ORBIT TESTS

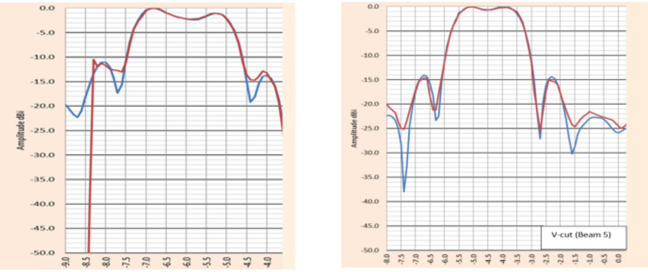
After the successful launch of the I5-F4 satellite on board of the SpaceX launcher Falcon 9 in May 2017, Inmarsat, together with Boeing, successfully completed the In-Orbit Test (IOT) of the satellite from the Inmarsat Ground Station located near Nemea, Greece. A key part of the satellite IOT operations is represented by the antenna IOT, which is important to guarantee the consistency of the performance once the satellite is in operation: this included a number of single plane radiation pattern cut measurements, obtained by pointing the antenna under test to the ground station and then slewing the satellite across it, to obtain a pattern cut. This slews have to be performed in a very time efficient way to ensure meteorological environment doesn't change in the timeframe of a single cut, but also with a great accuracy to ensure the collected data are suitable to be used for fine alignment. The main objectives of an antenna IOT are the following [2]:

- To check that no mechanical damage have occurred to the satellite antenna systems due to harsh launch environment and LEOP operation, and that the antenna pattern shape integrity is not compromised and RF performance not degraded.
- To check the correct alignment of the antennas and to recommend if pointing adjustment is needed to ensure optimal performance in orbit.
- To check the diurnal stability of the antenna, subjected to TEDs (Thermo-elastic Distortions) during a 24 hours cycle and to recommend if fine pointing adjustment is needed to compensate periodical deformations

An in-house developed software was used to compare each cut collected by the satellite telemetry with the ground base antenna measurements. This software is based on the visual matching of the two cuts (the In-orbit and the on-ground tested) to verify the beam shape integrity, and it is able to calculate the misalignment of the beam with respect to the theoretical optimal pointing with a simple adjustable level matching technique. The technique was demonstrated to be accurate enough to calculate the mispointing at a level of accuracy comparable with that obtained by more complex automatic IOT systems. IOT test results collected by Inmarsat are summarized in the following subsections.

A. *Antenna pattern shape integrity*

In Figures 2a and 2b normalized vertical and horizontal cut plots for beam 5 are shown. The patterns are plotted relative to the expected pattern (blue trace): this is the pre-launch pattern measured by the antenna vendor in their antenna range.



(a) (b)

Fig. 2. (a) I5-F4 horizontal pattern cut comparison for beam 5 (b) I5-F4 vertical pattern cut comparison for beam 5. For both plots, red trace is the IOT measured cut and blue trace is the pre-launch pattern data.

The calculated mispointing is arithmetically compensated in the plots to demonstrate a good agreement between the IOT measured antenna cut profiles and the pre-launch patterns. The two presented plots show a very good agreement between in-orbit and on-ground data, demonstrating that the antenna has successfully survived the launch and is operational. Please note that more than one beam has been checked for each reflector obtaining consistent results, but it is not shown for brevity.

B. *Antenna pointing adjustments*

The IOT data analysis predicted an average mispointing of only 0.1° in azimuth and elevation for the Tx antennas, while the Rx antennas were characterized by a more ample range of mispointing: the East side Rx reflectors were experiencing up to 1° of mispointing, while the West side Rx reflectors were presenting up to 0.5° of mispointing. Following the test, the antenna pointing was adjusted using the trimming mechanism stepping motors, in order to recover the expected beam peak positions, keeping in mind that the accuracy of repointing is in the order of the motor step angle.

C. *Antenna diurnal stability and fine adjustments*

For diurnal stability analysis, the behaviour of each antenna was observed during a 24 hours period by periodically performing cuts and comparing their pointing against the nominal value measured on the ground. In 24 hours, each antenna on the spacecraft was sampled seven times on both axes. The diurnal data analysis predicted an average offset in the order of the repointing accuracy for Tx antennas. Some Rx reflectors showed a bigger offset with East Rx1 showing and elevation mispointing of 0.09°. Following the diurnal variation tests, the antenna pointing was adjusted to pre-compensate the thermo-elastic distortions to ensure the best average possible performance in orbit. The correct pointing of the antennas after the repointing operations was confirmed by the following payload In-Orbit Tests.

V. CONCLUSIONS

This paper presented the performance of the antennas on board of the I5-F4 GX satellite, demonstrated via in orbit tests results. The in-orbit test analysis demonstrated that there has not been any mechanical or RF damage of the antenna due to the launch environment, that antenna performance are not degraded and the re-pointing operations performed on the antennas ensured the best possible in orbit performance

ACKNOWLEDGMENT

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