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Innovations in Satellite Antennas and Payloads Measurement

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Abstract

This paper describes various innovations conceived and successfully implemented in URSC's Comapct Antenna Test Facility (CATF) on various communication and navigation satellites of ISRO's satellite program. URSC-CATF has rich experience of characterizing successfully 35 spacecrafts and more than 250 device under tests over the frequency band of 200 MHz to 40 GHz. It is to be noted that nominal range of frequency of operation of the facility is from 1 GHz to 40 GHz. Some of the Innovative methods developed at ISAC-CATF are presented here viz. (i) Characterization of Large Antenna and associated payloads in small Quiet zone (ii) Payload Characterization of High Throughput Satellite. All these innovative measurement techniques are discussed in this paper.

1. Introduction

The prime objective of the integrated satellite level tests [1] [2] AT URSC-CATF is to confirm by RF means the (i) correct alignment of all on-board antennas on the S/C;(ii) to observe the impact of satellite body on the subsystem level measured radiation patterns;(iii) to ensure that there is no degrading impact on the antenna performance as well as payload performance, subjecting the satellite to various environmental tests. Performance of various onboard satellite antennas are critical for overall mission requirements. Measurement of various onboard antenna parameters before launch is mandatory to verify the conformance of design specifications.

URSC-CATF has rich experience in successful testing of 35 spacecrafts and more than 250 device under test. Each of these spacecrafts were unique in their own sense and demanded innovative measurement techniques to be developed to meet individual spacecraft requirements. Based on the test requirements innovations in antenna and payload measurements have been proposed and implemented successfully at satellite level with in the ambit of available resources and with cost effective manner. Two of the most innovative methods are discussed in this paper.

In some of the spacecrafts there was a requirement to test antennas having size bigger than Quiet zone size of the URSC-CATF. An innovative method has been proposed and successfully demonstrated for pattern and payload characterization for spacecraft level testing. The detailed measurement method and results are discussed. Generally, integrated spacecraft level payload characterization at URSC-CATF will be done by pointing onboard antennas at In Orbit Testing geo-location. Satellite having single coverage beams can be characterized without any problem using above method. However, in the case of High Throughput satellites having multiple narrow beams spatially separated over coverage polygon this method has multiple limitations. To circumvent these limitations an innovative method was used and successfully implemented in more than **than 3 spacecrafts.**

2. Innovations

a. Characterization of Large Antenna and associated payloads in small Quiet zone

Satellites having antenna size (6m in this case) bigger than Quiet Zone size of URSC-CATF (5.5mx5.0mx8.0m) on-board can't be tested in URSC-CATF due to the constraint on size of QZ and deployment therefore a novel way was proposed to characterize the Large Antenna and Associated payload with Scale down (2m in this case) Mesh antenna in radiation mode at CATF. The construction of 2M antenna is similar to 6 M antenna having different optics to accommodate the feed illumination pattern.

As mentioned in previous sections, there was limitation of testing 6m Flight antenna along with the spacecraft due to constraints on size of Quite Zone, zero-G support after deployment. In light of this, the possibility of characterizing S band payload along with scaled down version (2m Antenna) of the flight antenna is proposed. Satellite along with large antenna being first-of-its-own kind for ISRO, needs to be tested in CATF for:

a. Overall RF System performance in Radiation mode
b. Integrity of Waveguide Joints
c. Feed Alignment & Antenna Alignment
d. Polarization verification & Radiation pattern measurement of onboard payload and TTC Antennae
e. Payload performance
f. PIM and Auto Compatibility Tests

There were 2 options proposed for satellite level test:

(i) Satellite level Test using S-Band feed; (ii) Satellite level Test using S-band 2m Antenna (Maintaining 6M antenna Optics)

(i) S/C testing using S-band feed alone:

It is observed that due to different bore sight (look angle) of S-band feed (AEV side) and C-Band antenna (EV-Side), as shown in Fig. 1, it is not feasible to perform C and S band payload transponders characterization in radiation mode.

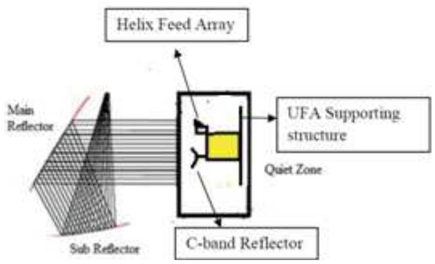

Figure 1: Satellite Configuration at URSC-CATF (Option-1)

In this configuration, C-band antenna pattern measurements can be carried out and payload characterization can be performed in cable mode (as S-Band Antenna is not available) and to Rx S-Band feed illumination a dedicated setup may be required. Location of this setup has to be adjusted in-situ during the measurement to align the respective feeds. Further, proper analysis needs to be carried out to estimate the power density at back wall absorber walls due to safety reasons. Additionally, Integrity of waveguide joints after coupler, S-band feed alignment & auto-compatibility tests are also not possible.

(ii) S/C testing using 2m Scale down Antenna:

It was proposed to use 2m scale down antenna during CATF testing by maintain the optics of 6m antenna. This option does not have the limitations of 1st option and thus preferred choice due to following observations:
(i) Feed Alignment can be verified by integrating 2M scale down antennas; (ii) All payload measurement can be performed in Radiation mode. With this, all the main objectives of the CATF test (a-f) can be achieved. The following figure shows satellite configuration in URSC-CATF with 2m Scale down antenna.

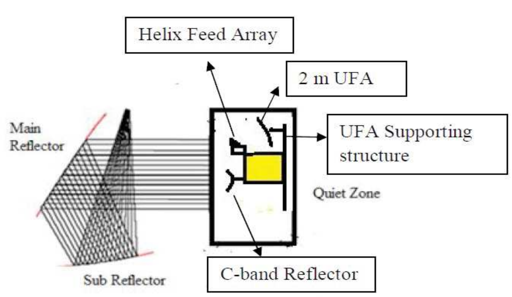

Figure 2: S/C Configuration at CATF (Option-2)

Since, all the objectives are met it was decided to do CATF test along with 2 M UFA.

Pattern measurement of all channels were performed at channel center frequencies and measured data was analyzed using Satsoft. Since the diameter of large antenna became 1/3rd, accordingly beam width of each beam will become 3 times more than 6m large antenna's beam width. For analyzing the results earth map was scaled accordingly and then results are compared with subsystem measured data. The following plot shows the comparison of 2m scale down antenna measured at sub-system level and S/C level.

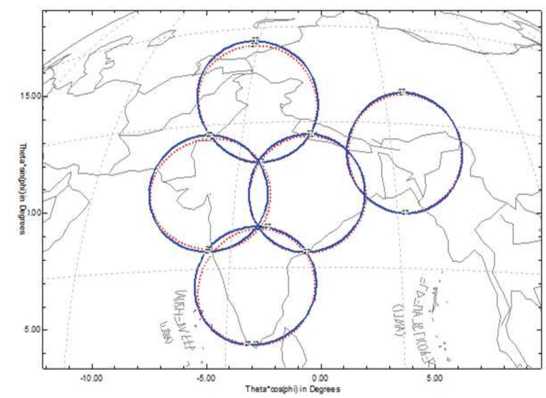

Figure 3: Measured antenna results (Dotted: Sub-system, Solid: Satellite level)

b. Payload Characterization of High Throughput Satellite

It is to be noted that payload characterization of all the transponder channels will be carried out in URSC-CATF by making In Orbit Test geo location (in this case, Hassan) parallel to Nominal Plane wave Axis.

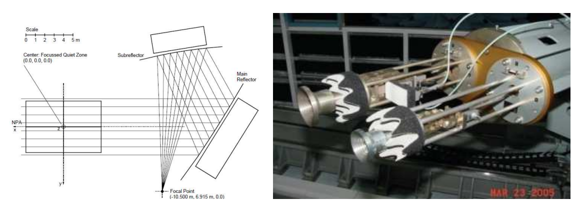

Figure 4: Top view of CATF, Uplink and Downlink feeds are mounted twin feed plate

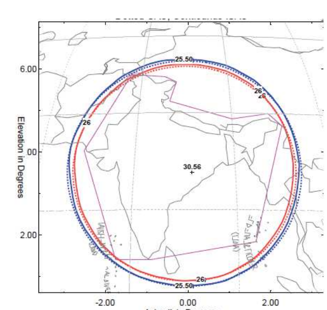

Figure 5: Typical Single Beam gain contours of communication S/C

Uplink (U/L) and downlink (D/L) feeds are mounted on twin feed plate on feed positioner as shown in figure 2. During characterization of uplink (or downlink) parameters uplink (or downlink) feed will be in focus and downlink (or uplink) feed will be away from the focus. Based on the measured U/L, D/L parameters and radiation patterns measurements edge of coverage contours are evaluated and will be compared w.r.t specifications.

For efficient utilization of transponder band width and to increase data rate capacity, multi beam antennas (frequency, polarization re-use) are widely used in advanced communication spacecrafts. Typical foot print of multi-beam satellite antenna is shown in figure 6. In multiple narrow beam scenario, it may not be possible to perform transponder characterization in radiated mode similar to single beam method. In the case of Multi beam payload if one beam will be made parallel to NPA and other beam (either U/L or D/L) will be away from NPA. Further, due to roll off of the respective beams it may so happen that saturation of that particular beam channel may not be possible, which is essential condition for most of the payload characterization. Hence, payload characterization is required to be carried out at each beam peak location.

Another challenge in multi-beam payload characterization is increase test time and each individual beam will act as an antenna. Hence, in case of multi-beam antenna test time is multiplied by as many no. of beams w.r.t. single beam antenna.

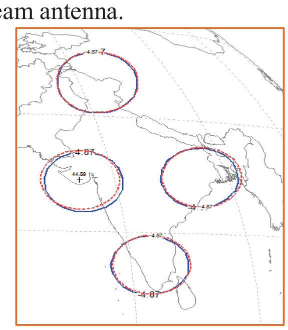

Figure 6: Typical foot print of multi-beam spacecraft

To derive Individual beam locations for U/L and D/L beams, ray tracing and geometrical analysis were used. By mounting all the feeds at respective derived beam peak locations, in a single test setup both U/L and D/L parameters can be measured and test time can be reduced upto the extent of 70%. The 2 twin feed plate concept was replaced with multi-feed plate concept and all the measurements were performed successfully.

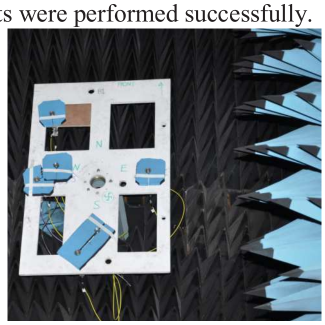

Figure 4: Mapping of Multiple Beams on Feed plate

3. Conclusion

In this paper two most important innovations of URSC-CATF is discussed and presented. Methods to perform large antenna measurement in smaller quiet zone and high throughput satellite payload measurement is discussed and presented. With these innovations test time is reduced significantly and precise measurements meeting all the test objectives were performed.

4. Acknowledgements

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5. References

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