EXTENSION OF THE EADS ASTRIUM COMPACT RANGE FAMILY WITH THE LARGE CCR 120/100

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Abstract

The possibility of launching satellites with increased volume and weight leads to a higher economy and cost-efficiency for the service of future communication satellites, which are equipped with platforms up to 12 m in width for a variety of different antennas.
For testing the radiation characteristics of the antennas of such large antenna farms, new test facilities are required to be designed and built up. Usually, for communication satellite testing, besides near-field systems the highly accurate CCR 75/60 of Astrium GmbH, Germany, is used worldwide. For satellites with large antenna platform, Astrium newly designed the CCR 120/100, which provides a test zone of more than 8 m in diameter.
The paper shows the requirements for testing of the large satellite antennas. Further, design criteria and range geometry of the CCR 120/100 will be presented.

1. Introduction

Compensated compact ranges and certain types of near-field ranges nowadays represent the standard for highest accurate measurement of space applications as e.g. communication satellite antennas. For highly efficient testing of multi-feed and multi-beam satellite antennas, compact ranges exhibit a high measurement accuracy [1]. Further, for applications in the mm-wave frequency range compact ranges represent already the required highly accurate measurement state [2].
Large communication satellites are equipped with antenna platforms with dimensions up to at least 12 m in width. The large dimensions are enabled by launching of extra large satellite busses according to the high load capacity of space rockets as e.g. the European Ariane 5.
The large antenna platforms now require large test facilities for an efficient testing of the antennas of communication satellites. For that aim the CCR 120/100 of Astrium GmbH was developed in order to ensure a quiet zone up to 8 m in diameter and 12 m in depth.

2. Requirements

Communication satellites, launched with e.g. ARIANE IV, were equipped with reflector antennas up to maximum dimensions of approximately 2 m in diameter and equivalent focal lengths in the same order. The maximum size of the carried satellites is up to 3.7 m in diameter and 8.6 m in height. The applied satellite busses for European space applications were the small, medium and large Eurostar 2000, 2000+ and 3000 satellite bus.

For larger applications, which e.g. ARIANE V can launch, the extra large busses Eurostar 3000+ and 4000 were developed. The maximum dimensions of the satellites, which can be carried with ARIANE V are up to 4.5 m in diameter and theoretically 15 m in height. The maximum dimensions of the reflector antennas for this category of communication satellites are appr. 2 to 3 m. The maximum focal lengths are up to 3.5 m. The related dimensions of the satellite busses of EADS Astrium, Europe, with typical applications are given in Figure 1.

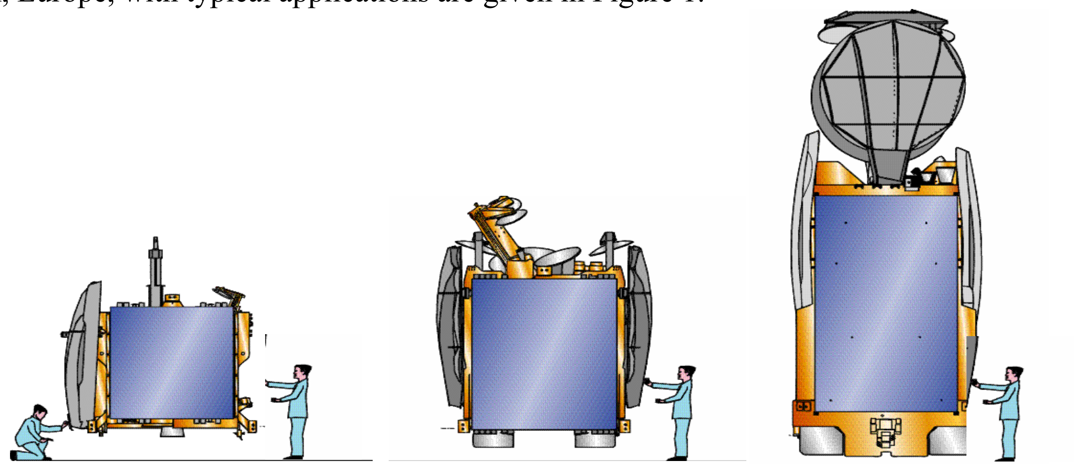

Figure 1 Communication Satellite Busses: (a) Eurostar 2000 Bus (e.g. NILESAT), (b) Eurostar 2000+ Bus (e.g. Astra 2-B), (c) Eurostar 3000/+ Bus (e.g. INTELSAT X)

The largest European communication satellite ASTRA 1K, built by ALCATEL Space Industries, France, uses the Spacebus 4000 satellite bus which can be compared to the Astrium's Eurostar 4000. The height of this satellite is 7.6 m and the payload mass is 680 kg. The applied communication antennas have dimensions in the order of 2.2 m and 3.5 m in diameter and are working in different frequency bands.

3. Range Design

Based on the design of the well known and very accurately working CCR 75/60, the newly developed CCR 120/100 was again realized as a compensated system with two double curved hyperbolic and parabolic reflectors. The design goal for the CCR 120/100 was the achievement of at least the same high performance as for many years present for the CCR 75/60. According to the experience in reflector surface accuracy, a milled, cast iron process was foreseen for the manufacturing of the reflectors of the new test range. According to the required large dimensions of the reflectors, analyses were performed for reduction of weight and for rising of stiffness and long-term stability. Further, the risk of earth quakes was regarded within the design process. The analyses resulted in a reduction of wall thickness and structural optimization of the reflector segments.
For optimization of the RF performance, a huge number of range configurations were analyzed and the related quiet zone performances were calculated for each case. At last, the new design results in the application of a SERAP structure nearby the right side of the main reflector and equipment of the right main reflector edge with serrations instead of the previous used billboard. This design was already applied for the small CCR 20/17 at the Munich University of Applied Sciences [3] and qualified within a study for INTELSAT for investigation of highly accurate satellite antenna test facilities.

Figure 2 CCR 120/100 of EADS Astrium GmbH

For achieving a quiet zone up to at least 8 m in diameter with a double reflector and compensated design, dimensions up to 12 m in horizontal and 10 m in vertical direction for the main reflector were identified to be necessary. The dimensions of the belonging sub-reflector are 9 m x 8.6 m. Both reflectors of the CCR 120/100 consist out of different segments, 6 for the sub- and 8 for the main reflector. According to the large height of the reflectors, an additionally segmentation in height by two was herewith firstly applied. According to weight reduction measures up to 65 %, the large CCR 120/100 reflectors have the same weight as the CCR 75/60 reflectors.
The reflector surfaces were analyzed and expected surface distortions were calculated. After manufacturing the contour accuracy was measured with a mechanical sampling system in lying position and with a laser tracker in upright position of the reflectors. At the end the contour accuracy could be verified with 35 µm for the upright position over a total reflector area of 12 m x 10 m.
The quiet zone performance with applied reflector surface distortions was analyzed and the highest frequency of operation for the test facility with maintaining certain plane wave accuracy can be derived. The mentioned maximum distortion values occur at the bottom of the reflector and were already minimized by the design of the segments via reduction of weight, mainly. For a highest requested operation frequency of 100 GHz, maximum distortions of the plane wave field in the quiet zone are in the order of 0.3 for the amplitude, 5 degree for the phase and - 45 dB for the cross-polarization contribution of both reflectors including rim zone effects and feed contribution.
After freezing the design process for the range type the manufacturing process for the range reflectors, the final range geometry was analyzed and developed.

4. Range Geometry

As already applied for the CCR 75/60 this type of test facility exhibits a good scanning performance by lateral movement of the feed so that a total silent volume cross-range area of 14 m could be achieved for the extreme feed positions. With this option, pattern measurements can be performed without movement of the DUT. The CCR 120/100 provides a scanning relationship of 2 degree of AoA (Angle of Arrival in the Quiet Zone) per 1 m lateral feed displacement. Therefore, complete payload transponder measurements can be performed with the application of two feeds at a distance of e.g. 5 m for two resulting quiet zones with a maximum angular difference of 10 degree for the AoA. One of the feeds is used for the up-link case in combination with the Rx-Antenna of the DUT and the other feed is used for the down-link case in combination with the Tx-Antenna of the measured satellite. As already mentioned a SERAP structure will be used instead of the formerly applied Billboard.

5. Results and Conclusion

The quiet zone performance of the CCR 120/100 was analyzed by simulation with e.g. an in-house range design and analysis tool based on UTD as well as with the analysis tool GRASP, in order to get comparative results w.r.t. the CCR 75/60. When only regarding the reflector system without any distortions from edge effects of the applied serrations, the amplitude and phase of the co-polar field reproduces only the feed taper without any ripple and without any cross-polarization contribution. The field distortions in the quiet zone according to the previous mentions surface distortions are in the order of 5 µm at the outer rim of the reflector (bottom side) for a Frequency of 100 GHz.

According to the possibility of launching larger payloads, the dimensions of communication satellites as well as its antennas are more and more increasing. For testing of reflector antennas with apertures up to 3 m in diameter and focal lengths up 3.5 m, larger test facilities are necessary to verify the performance characteristics of such systems.

For that aim, a new compensated compact range, the CCR 120/100 was designed and developed by EADS Astrium GmbH, Germany. The concept of the system is based on the well known CCR 75/60 whereas detailed range analyses were performed in the last years and possible improvement steps for the new facility were implemented. The CCR 120/100 provides a quiet zone of more than 8 m in diameter and 12 m in depth.

Within the paper, the design of the test facility as well as the range geometry is described. Analysis results of the quiet zone field, resulting from the reflector geometry is presented. The results exhibit, that the new CCR provides an equivalent high accuracy of the plane wave field in the quiet zone as the previous developed and applied CCR’s.

The new test facility is now under construction whereas the reflectors were already installed and aligned in a 42 m x 28 m x 18 m (L x W x H) absorber chamber so that the operation can start in the first half of 2005.

6. References

[1] J. Habersack, H. Kress, W. Lindemer, H.-J. Steiner, "Satellite Payload Parameter Measurements in a Compensated Compact Antenna Test Range", *Proc. 21st AMTA 1999*, Oct. 1999, Monterey, USA

[2] J. Habersack, J. Hartmann, J. Lemanczyk, P. de Maagt, H.-J. Steiner, "Facility Trade-Off for Measurements up to 500 GHz", *Proc. 22. AMTA 2000*, Oct. 2000, Philadelphia, USA

[3] J. Hartmann, D. Fasold, "Improvement of Compact Ranges by Design of Optimized Serrations", AP2000, Davos, Switzerland, 2000

[4] J. Hartmann, F. Hartmann, J. Habersack, H.-J. Steiner "Technological Improvements in High Performance Compact Range Test Facilities", INICA 2003, Berlin, Germany, 2003