Technological Improvements in High Performance Compact Range Test Facilities

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Abstract

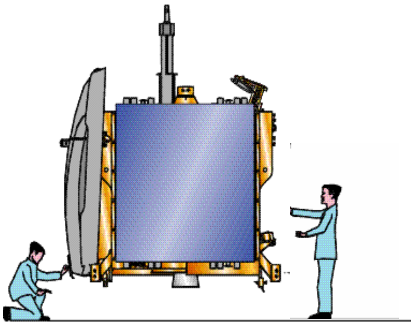
The possibility of launching satellites with increasing volume and weight leads to a higher economy and cost-efficiency for the service of future communication satellites, which are equipped with platforms up to 12 m in width for a variety of different antennas.
For testing the radiation characteristics of the antennas of such large antenna farms, new test facilities are required to be designed and built up. Besides near-field test facilities, compact ranges exist, which provide additionally short test campaigns according to its real time measurement capability. Usually, for communication satellite testing, the highly accurate CCR 75/60 of Astrium GmbH, Germany, was used until now. For the future large satellites, 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, the design criteria, the range geometry and first simulation results of the CCR 120/100 are shown.

1 Introduction

Compensated compact ranges and planar nearfield systems 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].
Future communication satellites are equipped with antenna platforms with dimensions up to at least 12 m in width for different reflector and horn antennas in different frequency bands. The large dimensions of the antenna platforms by launching of satellite busses as e.g. the European Spacebus 4000 were enabled according to the high load capacity of space rockets as the 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 8.5 m in diameter and 12 m in depth. The quiet zone diameter was adapted to the minimum required size of testing future satellite antenna systems. With an additionally optimized design of the sub- and main reflector serrations, the quality of the test facility could be improved regarding the conventional CCR design.
Within the paper, the quiet zone performance within an 8.5 m quiet zone will be presented according to calculation results. The operation frequency range of the CCR 120/100 will be ranging between 1 and 100 GHz.

2 Requirements

Previous communication satellites, launched with e.g. ARIANE IV, were equipped with reflector antennas with a maximum dimension of approximately 2 m in diameter and an equivalent focal length 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 15 m (theoretically) 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



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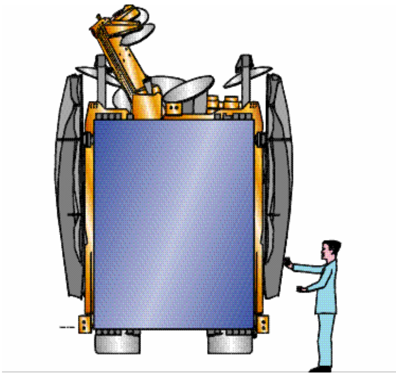

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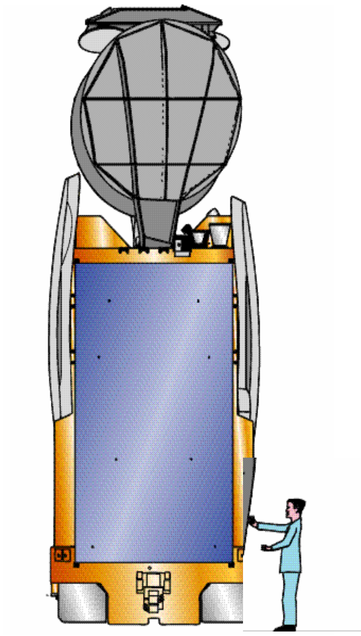


(c)

Figure 1 Different Types of Communication Satellite Busses of Astrium:

(a) Eurostar 2000 Bus (e.g.NILESAT)
(b) Eurostar 2000+ Bus (e.g. Astra 2-B)
(c) Eurostar 3000/+ Bus (e.g. INTELSAT X)

busses of Astrium, Europe. Figure 3 shows the graphical overview with estimated percentage of launched satellite categories (bus types) for the next 3 years in Europe.

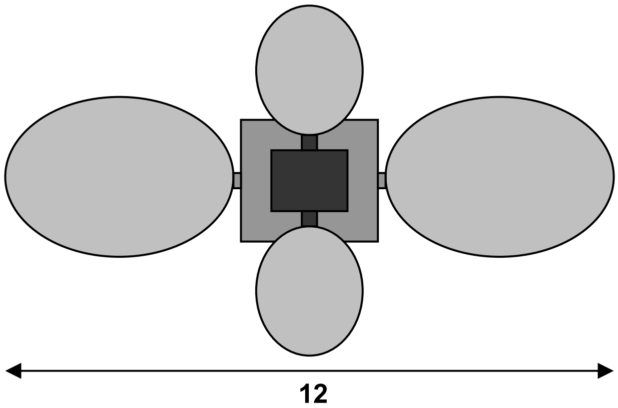


Figure 2 Principle Top View of Large Antenna Platform

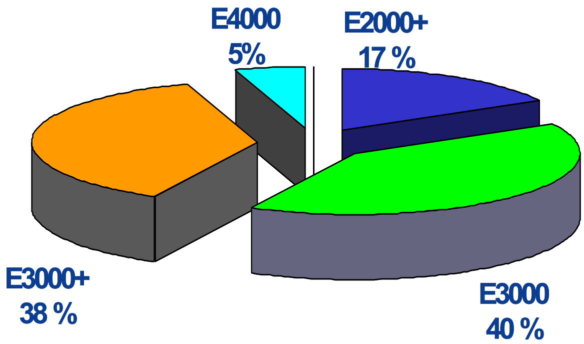


Figure 3 Estimated Percentage of Applied Satellite Busses of Astrium for the next 3 Years:

Small **(S)**	=	< 3 KW*	E2000
Medium **(M)**	=	< 6 KW*	E2000+
Large **(L)**	=	6 - 12 KW*	E3000
Large+ **(L+)**	=	12 - 16 KW*	E3000+
XLarge **(XL)**	=	> 16 KW*	E4000

* Payload power

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. This large type of satellite bus is also used by the GE1i, 2i, 3i, 4i and GE 2E communication satellites. The dimensions of the applied antenna platforms reach values up to 12 m in width and 8 m in height.

For testing of the large satellites on antenna as well as payload level, new test facilities are required, which provide a test zone in the order of at least 8 m in diameter.

3 Range Design

Based on the design of the well known CCR 75/60 (shown in Figure 4), the newly developed CCR 120/100 has to be realized as a compensated system with two double curved hyperbolic and parabolic reflectors. 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 CCR 20/17 at the Munich University of Applied Sciences [3].

Figure 4 CCR 75/60 with INTELSAT VIII Multi-Feed, Reflector and Mockup Structure

For achieving a quiet zone up to at least 8.5 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. The design of one reflector segment is shown in Figure 5. 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 surface was analyzed and surface distortions up to maximum values of 5 to 10 µm were calculated.
The quiet zone performance with applied reflector surface distortions was analyzed and the highest frequency of operation for the test facility with maintaining a 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 applied operation frequency of 100 GHz, maximum distortions of the plane wave field in the quiet zone of the test facility are in the order of 0.1 to 0.2 dB for the amplitude, 2 to 4 degree for the phase and - 85 dB for the cross-polarization contribution of both reflectors.

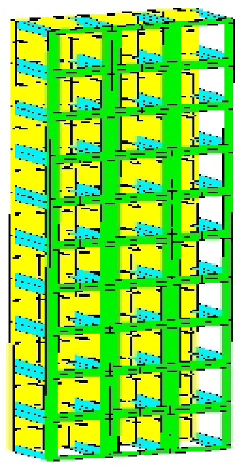


Figure 5 Backing Structure of one Reflector Segment of the CCR 120/100 Reflectors

After freezing the design process for the range type the manufacturing process for the range reflectors, the final range geometry could be analyzed and developed.

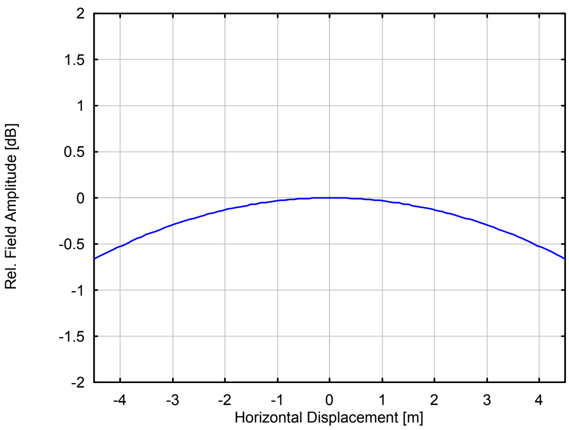
4 Range Geometry

As already applied for the CCR 75/60 this type of test facility exhibits a good scanning performance by lateral movement of the feed. With this option, pattern measurements can be performed without movement of the DUT. The newly designed 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 mentioned in Chapter 3, a SERAP structure will be used instead of the formerly applied Billboard. For the SERAP, an equivalent design can be used as already realized for the Baffle. The position of the SERAP can be optimized via ray-trace analyses.

5 Simulation Results

The quiet zone performance of the CCR 120/100 was analyzed by simulation with e.g. an in-house range design and analysis tool 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, as shown in Figure 7.



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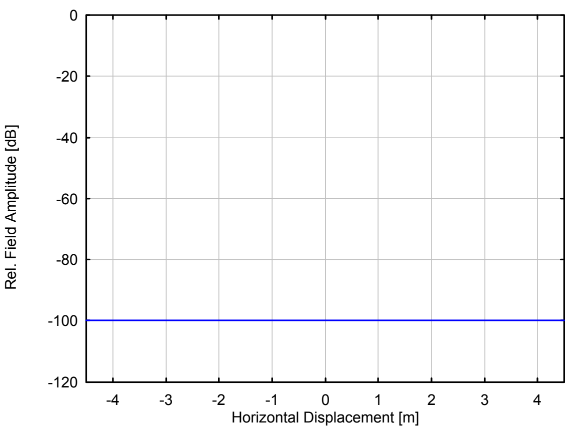

(b)

Figure 6 Co- (a) and Cross- (b) Polar Plane Wave Field in the Quiet Zone resulting only from the Feed and Reflectors (without Distortions of the Reflector Rims applied); Minimum Signal Level set to - 100 dB

6 Conclusions

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. The related antenna platform width for that satellite size is up to 12 m.
For that aim, a new compensated compact range, the CCR 120/100 was designed and developed by 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 8.5 m in diameter an 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 and will be applied by starting the manufacturing of the large reflectors and subsequent installation in the near future.

7 References

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