Application of Double Reflector Compact Ranges for Time Domain RCS Measurements

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Abstract

RF test setups of antenna test facilities are designed and optimized for antenna pattern and gain measurements. However, the operation of test facilities, especially the here considered 'Double Reflector Compact Ranges', can be extended, so that they can also be used for RCS testing.
A simple and very practical expansion of the RF antenna test setup - while maintaining the real-time measurement capability - can be achieved with the aid of a hardware gating system. With this type of setup, RCS measurements have successfully been performed in Compensated Compact Ranges. The applied gating system was the high resolution Hardgating System HG2000 of EADS Astrium, developed together with the Munich Univ. of App. Sciences.
Within this paper, the applied facility and gating system will be described. Further, the modified test setup and the test results of calibration measurements will be shown. They will give an indication of the achievable resolution for the extended test system w.r.t. object size detection and resulting amplitude dynamic range.

1. Introduction

Nowadays, compact range test facilities represent a standard in fast real time and high precision antenna and RCS measurements within a frequency range from 1 to 500 GHz and beyond. With the development of the Compensated Compact Ranges (CCR), a fundamental improvement by suppressing the system inherent cross-polarization was achieved.
For Radar Cross Section (RCS) measurements, a high resolution in time domain as well as in Signal-to-Interference-Ratio (SIR) is necessary. RF pulses with an amplitude dynamic range between 70 to 100 dB are required to achieve such a good amplitude resolution.
The Hardgating System, which originally was developed to suppress undesired distorting fields in antenna test facilities [1,2] can also be applied for RCS measurements. The system isolation between the on-to-off switching status of the PIN-switches can be extended up to 120 ... 140 dB. The spatial resolution of 1.2 m corresponds to the minimum system pulse width, which can be adjusted down to 4 ns. This flexible and adjustable switching capability is preferably applicable for antenna as well as RCS testing.
In the following, investigation results, concerning the application of the proposed Hardgating System for RCS measurements in CCR's designed by EADS Astrium will be presented. The System was already installed and implemented in the CCR 20/17 at the Munich Univ. of App. Sciences, in the CCR 75/60 at EADS Astrium as well as the Compact Payload Test Range (CPTR) of ESA/ESTEC. The achieved RCS results rely on measurements with calibration standards like spheres with different diameters or plane, circular and rectangular reflectors.

2. Test Facility

Compensated Compact Ranges provides the highest standard of compact antenna RF testing mainly for satellite antennas requiring different sizes of test zones. The CCR's main advantage in antenna - and especially in satellite antenna - testing is the high cross-polar purity up to at least - 40 dB. The remaining cross-polar component of the facility below this value is produced from secondary effects as reflector distortions, rim design and feed performance, only. The CCR 20/17 applied for the measurements described within this paper is shown in Figure 1.

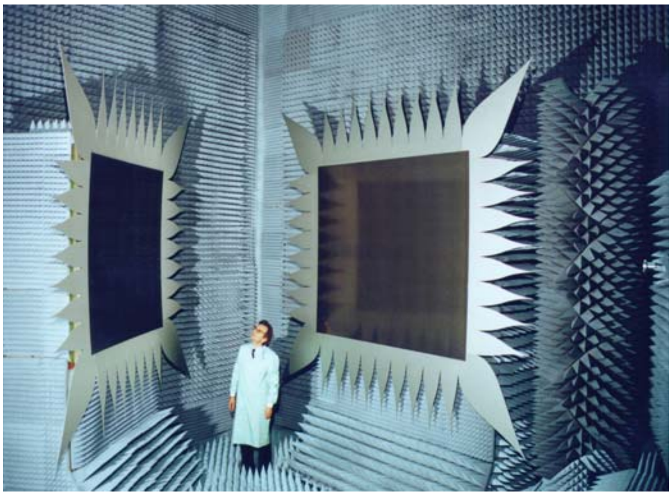
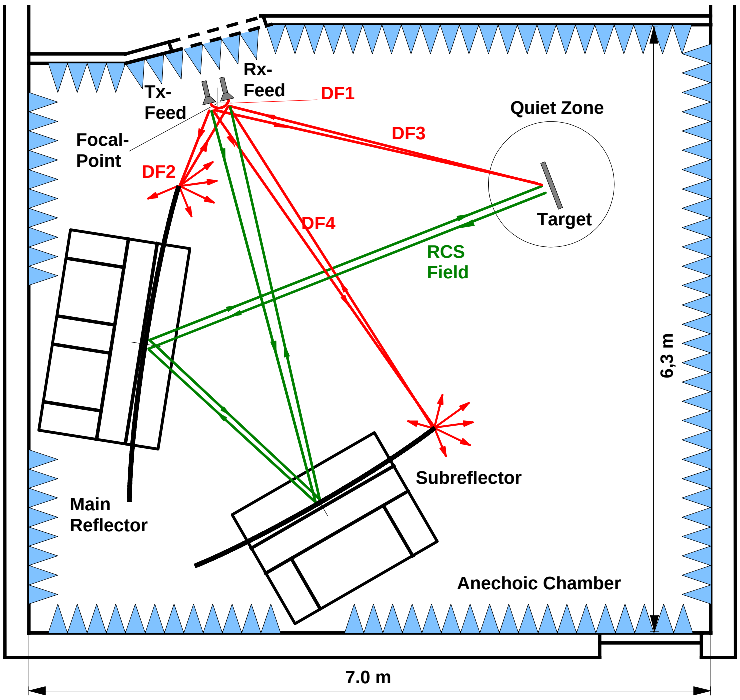


Figure 1 CCR 20/17 at Munich University of Applied Sciences for Research and Development Activities

For mono-static RCS testing, the required single feed is nominally positioned with its phase centre in the focal point of the reflector system. In case of bi-static RCS testing, a boresight deviation w.r.t. the nominal situation occurs, depending on the relationship of the lateral feed position to the resulting boresight angle. Up to now, RCS measurements with the aid of hardware gating have already been performed in the CCR 75/60 and in the CCR 20/17. A top view of the CCR 20/17 visualizing the distorting fields (DF) is shown in Figure 2.



DF1 = Aperture Coupled Field between Tx and Rx Feeds

DF2 = Scattered Fields from Serrations (Main Reflector)

DF3 = Coupling Field from Target

DF4 = Scattered Fields from Serrations (Subreflector)

Figure 2 Ground Plane of CCR 20/17 with Significant Ray Paths

3. Hardgating System

The applied gating hardware is the Hardgating System HG2000 of EADS Astrium GmbH. Hardgating was selected in comparison to software gating as it is a real-time measurement method, which does not require a high number of time consuming measurements. By that, a time saving factor of 10 to 100 can be achieved [3].

Selective measurements of the plane wave field and the different interfering fields or their suppression, respectively, can be performed by insertion of a second fast RF switch at the receiver side between the test antenna and receiver. This switch generates a 'window' in the time domain in which the detected field of the test antenna is forwarded to the receiver. With the system, pulses with a minimum width down to 4 ns - corresponding to a spatial resolution of 1.2 m - can be generated.

4. RCS Test Setup

The principle RF test setup for antenna and RCS measurements is typically based on the distributed mixer concept. In order to achieve higher measurement accuracies, a gating technique can additionally be applied for antenna pattern and RCS measurements to suppress unwanted reflecting or distorting fields in the test facility. The principle test setup for e.g. bi-static measurements with a Hardgating System implemented is shown in Figure 3.
In the setups, one switch unit is inserted in the Tx signal path and one in the Rx signal path. Both switch units are synchronized, controlled and powered by the centrally placed control unit of the system and connected via the coaxial synchronization cables. The mechanical test setup is shown in Figure 4.

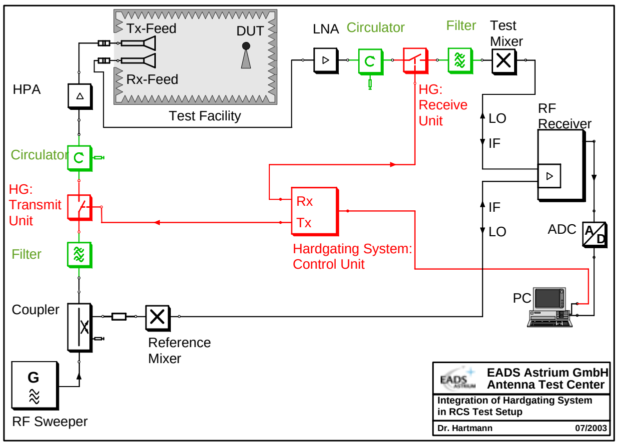


Figure 3 Principle RF Test Setup for Bi-Static RCS Testing with a Hardgating System

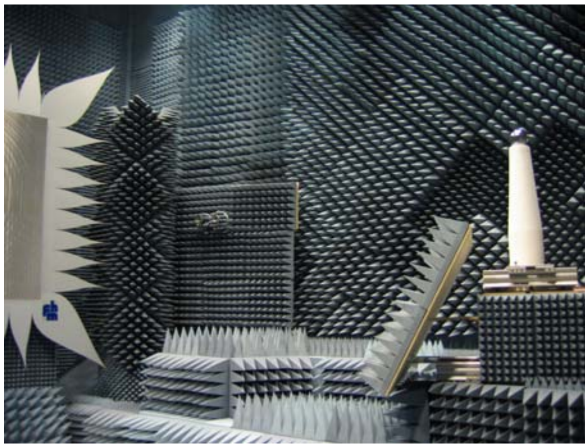


Figure 4 Mechanical Test Setup with Sphere and Pylon in Quiet Zone of CCR

5. Facility Analysis

Before starting the RCS measurements, detailed analyses of the test facility have to be performed in order to determine the incidence of target and disturbing signals at the Rx feed in the time domain. The timing diagram valid for the CCR 20/17 is shown in Figure 5. The diagram is related only to the time delay of the pulses in the facility (see Figure 2) without regarding delays caused by RF cables and RF components. This constant delay values are already subtracted and do not influence the relative positions of the field contribution to each other.

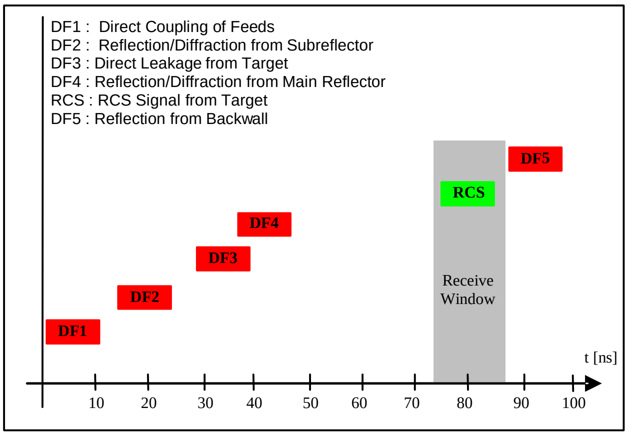


Figure 5 Timing Diagram with Different Distorting Fields (DF1..5) and RCS Target Signal (RCS)

For the CCR 20/17 detailed error analyses were performed for the antenna pattern and gain measurement accuracy. Main disturbers as the diffracted fields from the sub- and main reflector serrations as well as the direct leakage from the feed could clearly be identified. For RCS testing, additional disturbers are the feed coupled field - in case of bi-static setup - and the disturbing fields from the surrounding of the target and from the backwall. With an optimum setting of the Hardgating System the feed coupled field, the field from the backwall and partly the diffracted fields from the serrations can significantly be suppressed.

6. Measurement Results

Prior to performing RCS measurements on unknown targets, calibration data have to be generated in order to verify the test setup and to perform the necessary amplitude normalization of the test data itself. In the RCS test campaigns, described within this paper, the calibration was performed with a sphere, a rectangular plate and a corner reflector.

σ_{Sphere}	=	- 22.99 dBsm		Diameter of Sphere:	0.08 m
σ_{Plate}	=	3.39 dBsm	@ 12.5 GHz	Dimension of Plate:	0.1 m x 0.1 m
$\sigma_{CornerRefl.}$	=	6.40 dBsm	@ 12.5 GHz	Dimension of Corner Refl.:	0.1 m x 0.1 m, H = 0.1 m

The comparative RCS measurement results of the sphere, the plate and the corner reflector as well as a comparison between mono- and bi-static results are shown in Figure 6 for a test frequency of 12.5 GHz and for co-polarization.

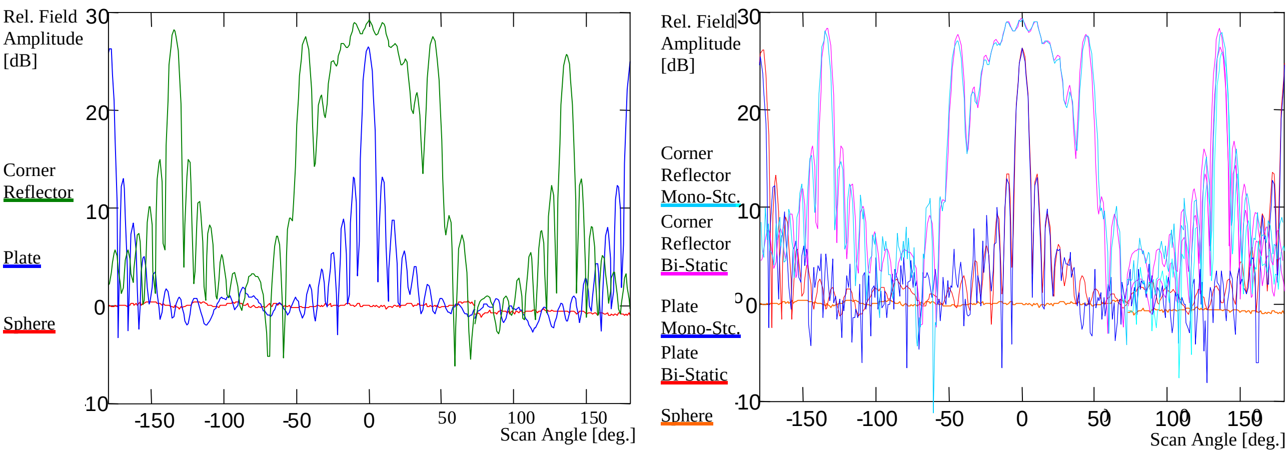


Figure 6 RCS Test Results of Sphere, Plate and Corner Reflector for Bi-static Measurement, VV-Polarization Adjusted and Comparison between Mono- and Bi-Static Results

The measurement results of the calibration targets exhibit a good agreement of the amplitude differences between the applied sphere to the rectangular plate and also to the corner reflector as well as between the rectangular plate to the corner reflector.

7. Conclusions

The standard RF test setup of antenna test facilities can be extended to a RCS setup by applying hardware gating. For two different high performance compact test ranges as the CCR 20/17 at the Munich Univ. of Appl. Sci. and the CCR 75/60 of EADS Astrium in Ottobrunn, Germany, related RCS tests with a Hardgating System were performed. The Hardgating System HG 2000, which originally was designed for improvement of the antenna measurement accuracy, was now adapted to the requirements of RCS testing [4].
Validation measurement results, shown within this paper, exhibit a close agreement of relative measurement values compared to absolute theoretical values of the applied calibration standards like a sphere, a rectangular plate and a corner reflector. A measurement accuracy of better than $\pm$ 0.5 dB could be achieved with the verification measurements. The value was predicted from the measurement accuracy of the calibration standards. The dynamic range or signal-to-interference (SIR) value was determined to a figure up to 70 dB.

8. References

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