Measurement Performance of Basic Compact Test Range Concepts

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Astrium GmbH – 2012

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1 Introduction

Introduction – History

- The first Compact Range – a single reflector range for RCS – was developed 1969 by Richard Johnson from Georgia Tech, USA (with support by Doren Hess from Scientific Atlanta (now MI Technology)
- Basic Developments and improvements at the Ohio State University (Institute of Walter Burnside), USA
- A first dual reflector range (two orthogonal cylinder parabolic reflectors) was introduced by Vaclav Vokurka, Technical University of Endhoven, Netherlands
- New concept for dual reflector ranges by Dietmar Fasold, MBB (now Astrium) by utilizing an side fed Cassegrain System, i.e. dual curved reflector system with hyperbolic and parabolic reflectors (in the eighties)
- Additional works from Walter Burnside using smaller shaped sub-reflectors in dual reflector ranges in the eighties

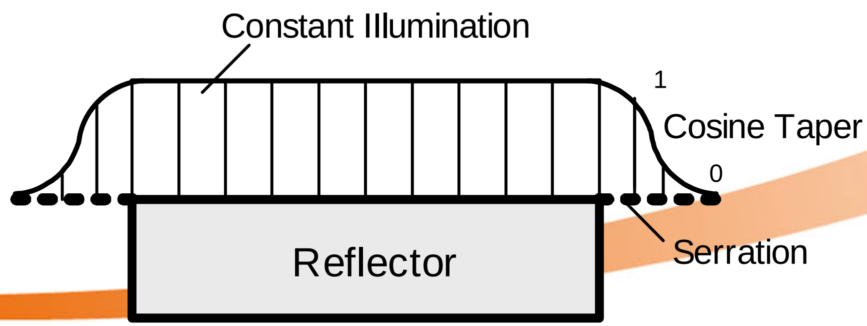
Introduction – Objective of the Analyses

- Nowadays, typically three different types of Compact Ranges are in use
  - **Single Reflector Compact Ranges** (SCR)
    - With short focal length (**SCR-S**)
    - With long focal length (**SCR-L**)
  - **Dual Cylindrical Parabolic** (Compact) **Ranges** (**DCPR**) consisting of two single curved cylinder parabolic reflectors
  - **Compensated** (Double Reflector) **Compact Ranges** (**CCR**) consisting out of two double curved and compensated reflectors
- These types will be analyzed theoretically by means of a software simulation in order to compare it w.r.t.
  - Test Zone Performance
  - Characteristic Data

2 Compact Range Analysis

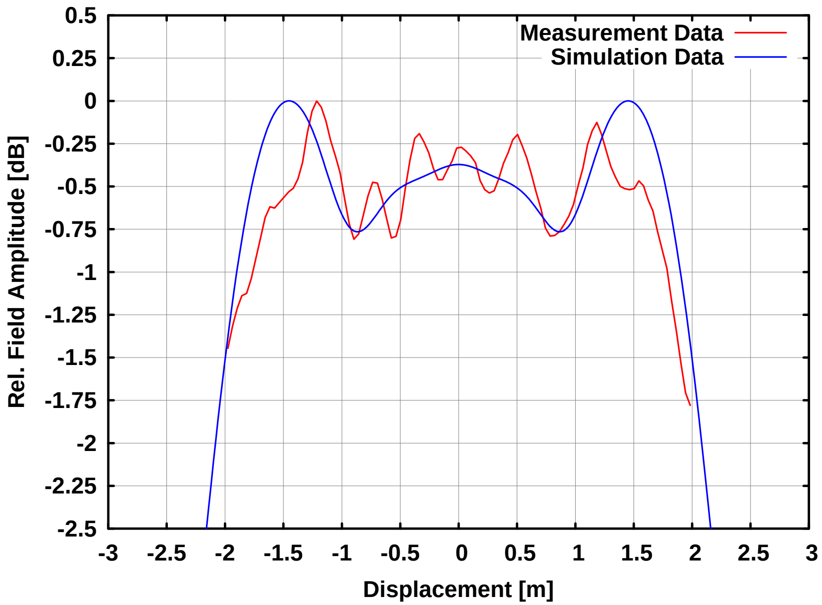
Compact Range Analysis - Simulation Aspects

- Plane Wave test zone performance data of each basic compact range concept required for
  - Comparison of Test Zone Performance
  - Determination of Antenna Measurement Accuracy
- Simulation based on a GRASP (9.2.01) Physical Optics (PO) calculation with
  - Identical Edge Treatment of all models
  - GRASP integrated Serration Model with uniform illumination over the reflector surface and a cosine taper function along the serration length

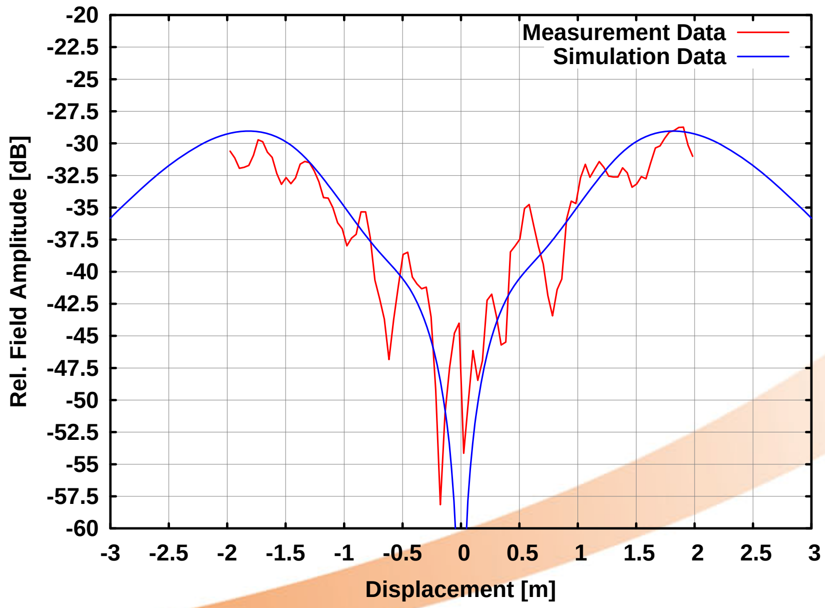


Compact Range Analysis - Simulation Aspects

- Accuracy Assessment of the Simulation Software based on the Comparison of Simulation and Measurement Results of test zone data (SCR)
- Reflector Size 3x3 m, 2.5 GHz, 90 deg (vertical) Cut



Co-Polar



X-Polar

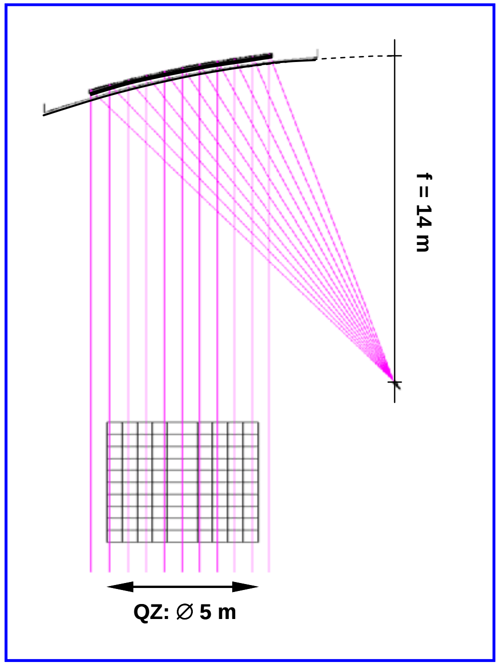
Compact Range Analysis - Facilities Geometries

- Test Zone Size (Quiet Zone) shall be 5 m in diameter (lateral to plane wave incidence) for all four types of considered compact ranges
  - Reflector Size depends on the type of compact range
  - Serration Size is fixed for all types and selected by 1.5 m

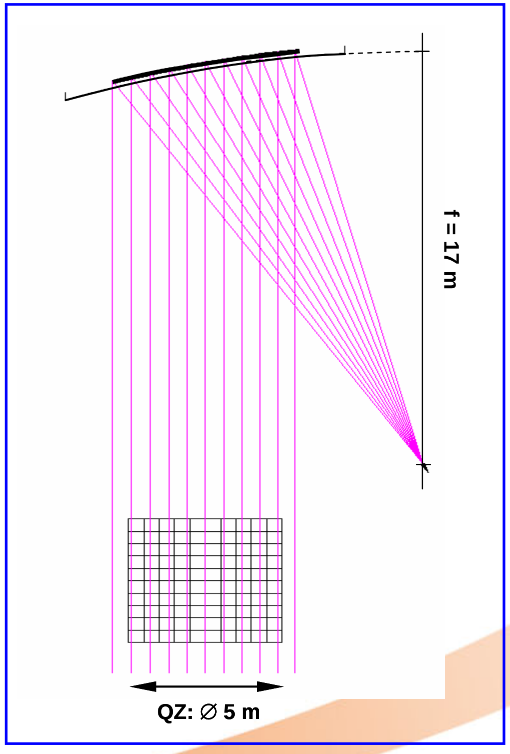
Subject	Focal Length (Equiv. FL)	Dimensions Main Reflector
SCR-S Reflector	11 m (n.a.)	7.0 m x 6.7 m
SCR-L Reflector	14 m (n.a.)	6.9 m x 6.7 m
DCPR Main Reflector	16 m (16 m)	7.5 m x 6.0 m
CCR Main Reflector	40 m (130 m)	7.5 m x 6.0 m
Serration Length	1.5 m	
Quiet Zone Size	∅ 5 m	

Compact Range Analysis - Facilities Geometries

- Single Reflector Types



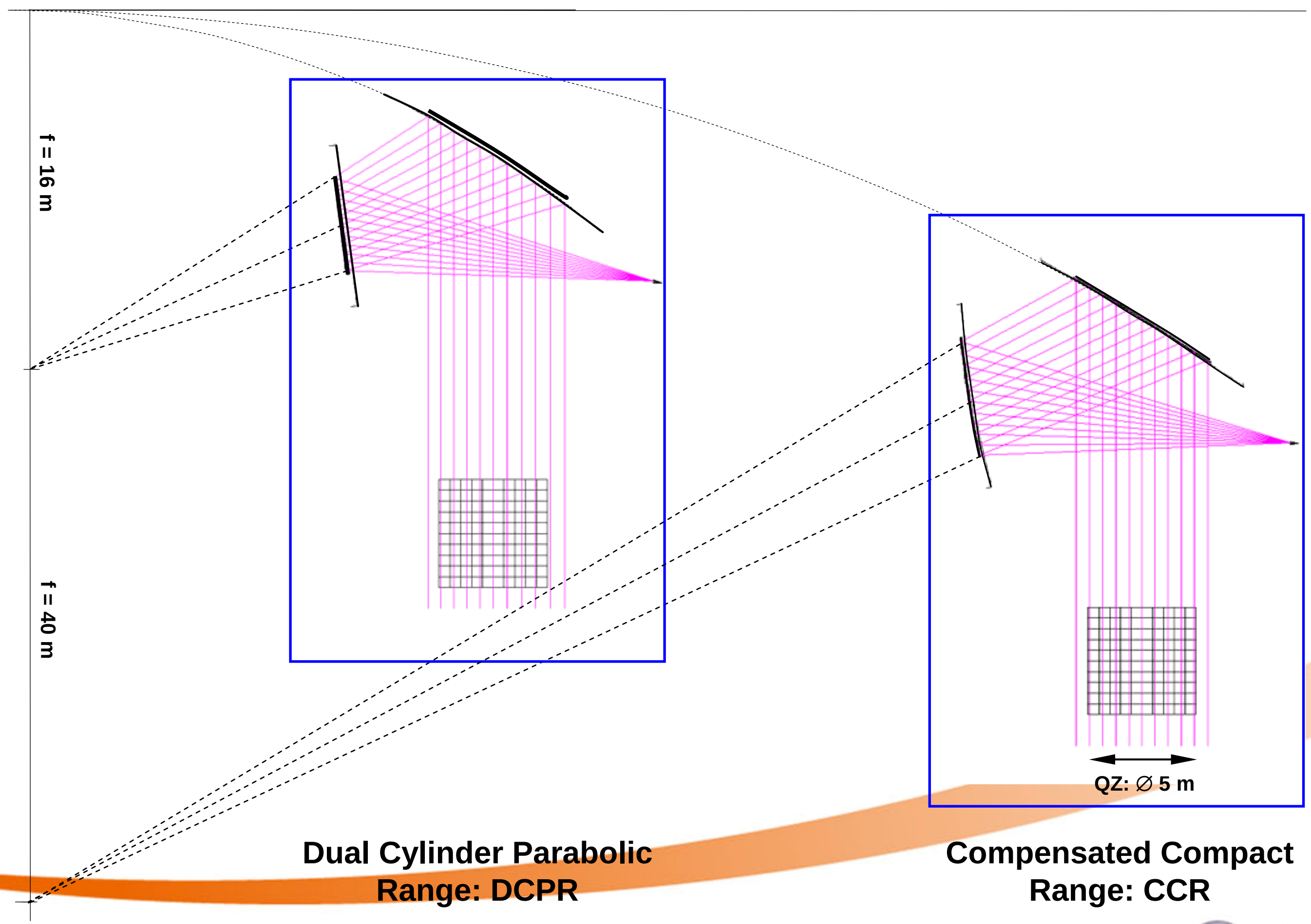
**Single Reflector Compact Range,
Short Focal Length: SCR-S**



**Single Reflector Compact Range,
Long Focal Length: SCR-L**

Compact Range Analysis - Facilities Geometries

- Double Reflector Types



Dual Cylinder Parabolic Range: DCPR

Compensated Compact Range: CCR

3 Analysis Results

Analysis Results - Content

- Analysis Parameter Summary
- Plane Wave Field Performance Data for 4 radial cuts through the test zone (0°, 45°, 90°, 135°)
- Measurement Accuracy Values Derived from Convolution Analyses of One-dimensional Test Antennas with Different Lengths (from 5 cm up to 3 m)
- Characteristic Facility Data

Compact Range Analysis – Analysis Parameter

- Plane Wave analysis parameter are listed below
- Antenna Accuracy calculation utilizing a
  - 1D convolution of the non-ideal plane wave data with a synthetically DUT aperture
  - 1D FFT of the convoluted pattern and comparison with ideal far-field data

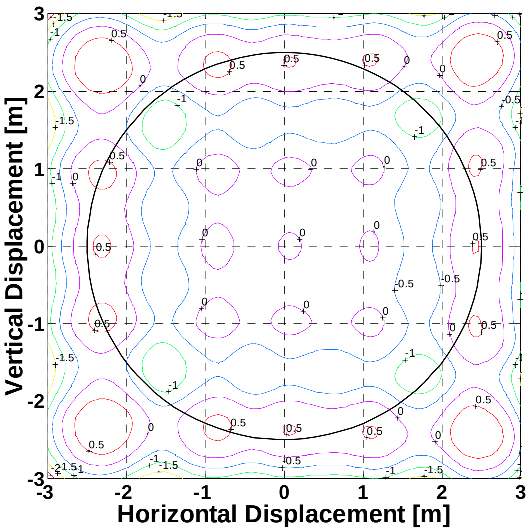
Parameter	Setting
Feed	- Edge Taper 0.5 dB at Reflector Edge - Linear Polarization - No Cross-Polarization
Frequencies	- 1.5 GHz - 12 GHz
Device Under Test, DUT for Pattern Accuracy Analyses (Co-, Cross-Polar)	- Low Gain Antenna: Linear Dimension: 0.05 m (0.4 m for 1.5 GHz), Constant Aperture Illum. - Medium Gain Antenna: Linear Dimension: 1.5 m, Constant Aperture Illum. - High Gain Antenna: Linear Dimension: 3.0 m, Constant Aperture Illum.
DUT Positions for Pattern Accuracy Analyses	- Center of Quiet Zone - 1 m Offset of Center - Cuts at 0°, 45°, 90°, 135°

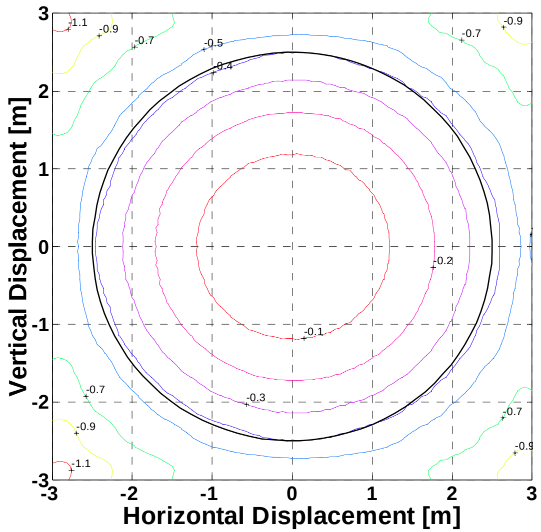
Analysis Results - **SCR-S** Plane Wave Performance

1.5 GHz

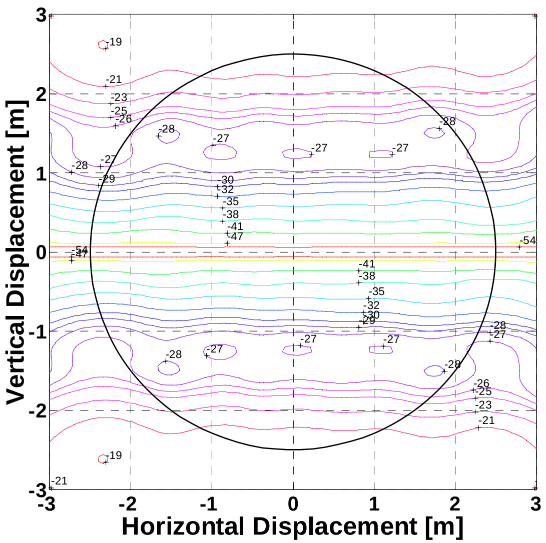
12 GHz

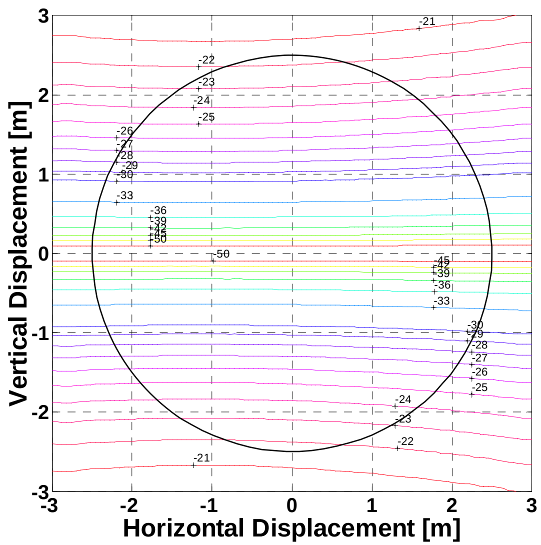
Co-Polar





X-Polar

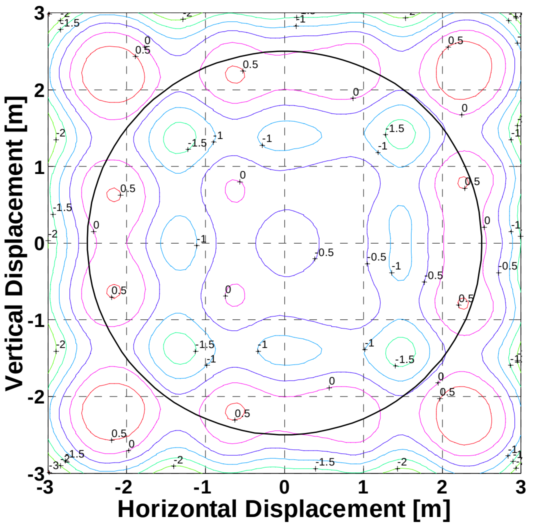


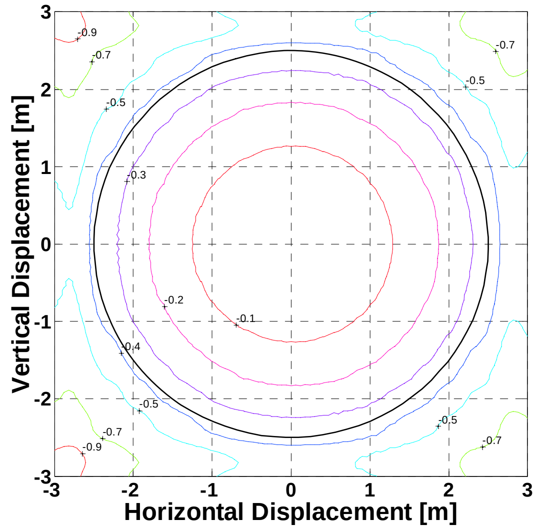


Analysis Results - **SCR-L** Plane Wave Performance

1.5 GHz

12 GHz





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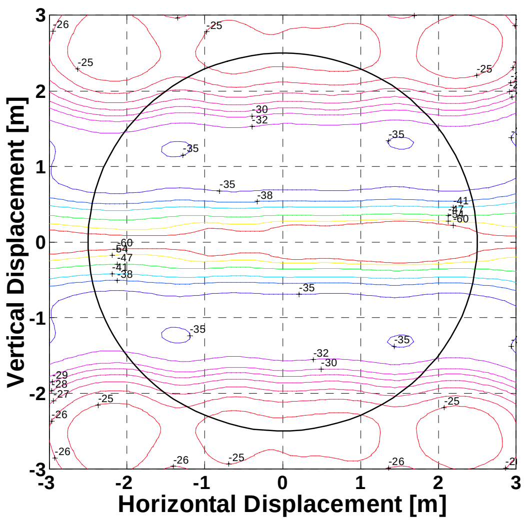
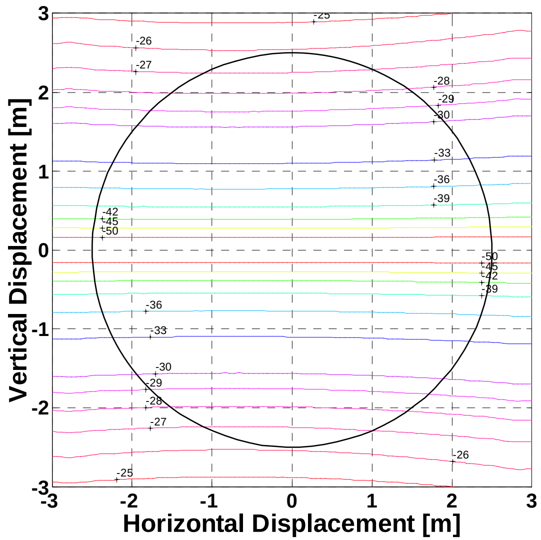




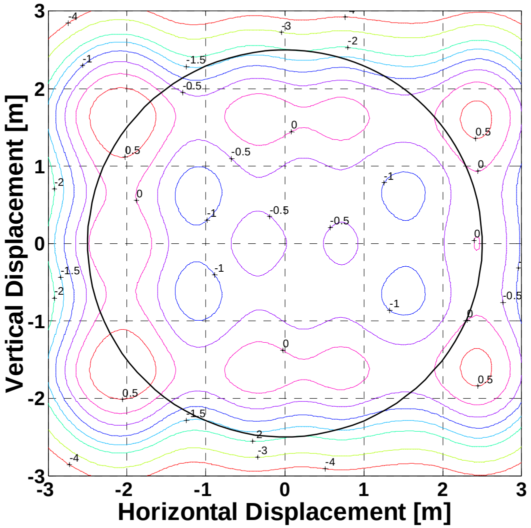
X-Polar

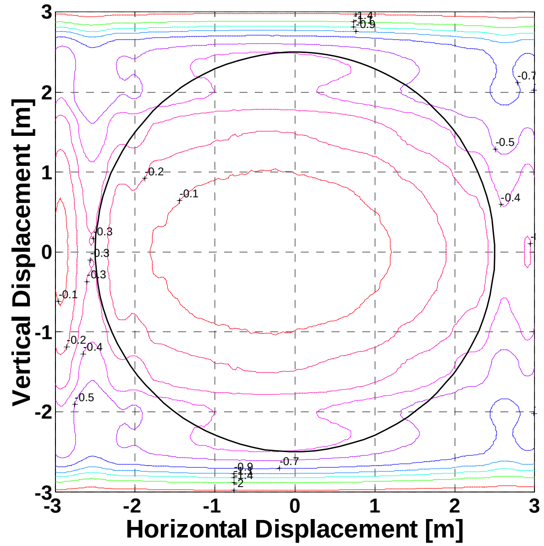
Analysis Results - **DCPR** Plane Wave Performance

1.5 GHz

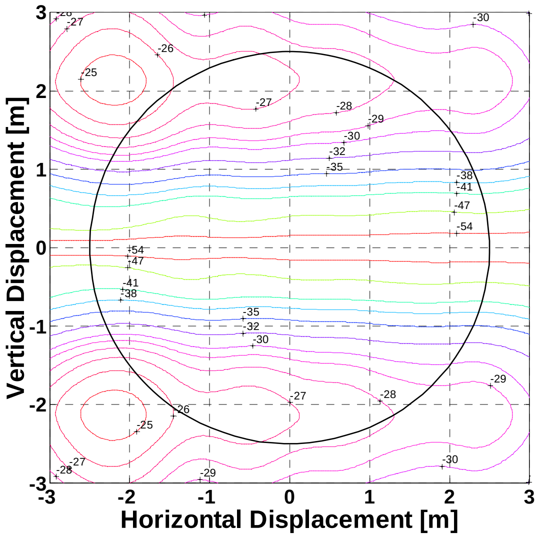
12 GHz

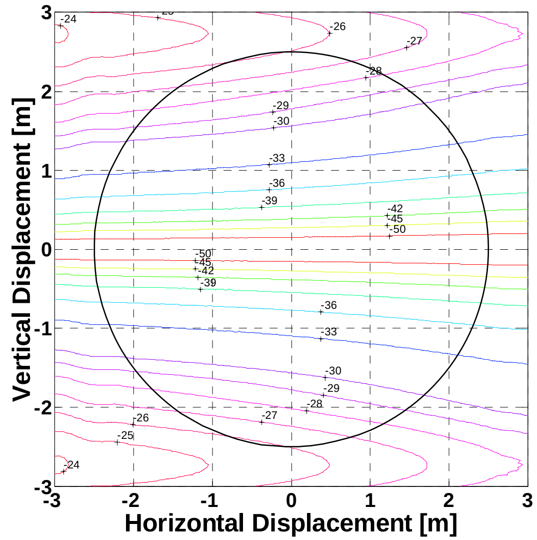
Co-Polar





X-Polar



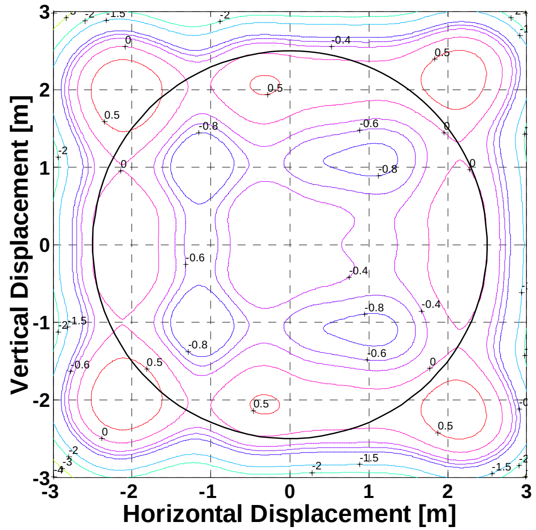


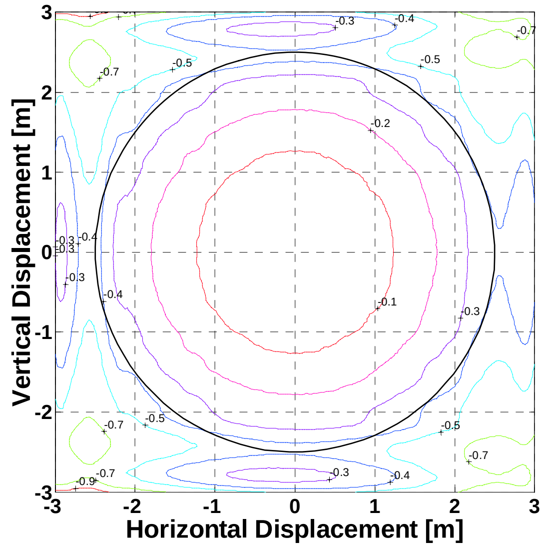
Analysis Results - **CCR** Plane Wave Performance

1.5 GHz

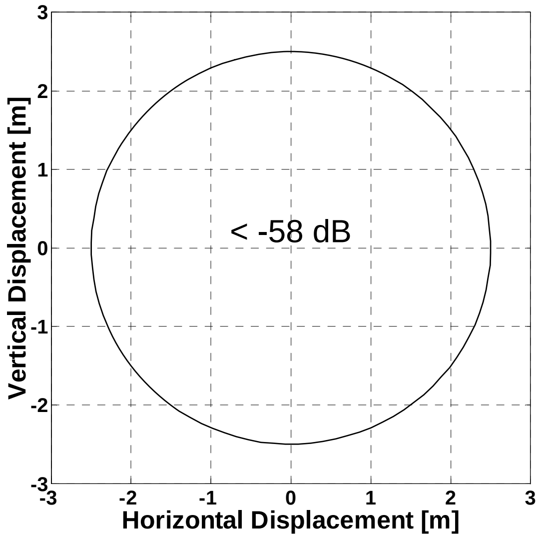
12 GHz

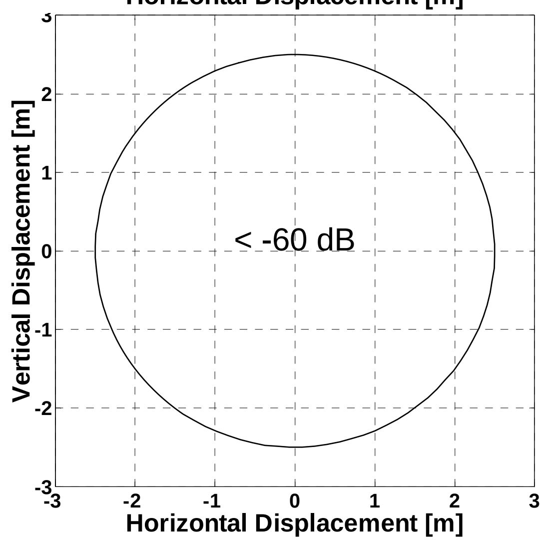
Co-Polar





X-Polar





Analysis Results - Summary Plane Wave

- Some general conclusions can be drawn from the predicted plane wave fields in the QZ:
  - SCR facilities show slightly better co-polar performance compared to dual reflector ranges for low frequencies (1.5 GHz). This effect disappears above 3 GHz.
  - SCR-L and CCR show most symmetric and flat characteristic in co-polar field (related to larger equivalent focal length)
  - CCR shows the best cross-polar performance due to the compensated reflector system.
  - For the other ranges the SCR-L shows the lowest cross-polarization in the QZ, as it has the smallest offset angle.

Analysis Results - Antenna Measurement Accuracy

- Utilized Method to determine the Antenna Measurement Accuracy
  - **Step 1:** Convolution of the calculated plane wave performance data in the test zone with an synthetic antenna aperture (1D case)
  - **Step 2:** FFT of the convoluted data of Step 1 in order to get the plane wave spectrum (Far-Field) of the synthetic antenna aperture
  - **Step 3:** Convolution of an ideal plane wave in the test zone with an synthetic antenna aperture (1D case) (= uniform illuminated DUT aperture)
  - **Step 4:** FFT of the convoluted data of Step 3 in order to get the plane wave spectrum (Far-Field) of the synthetic antenna aperture (= sinc function)
  - **Step 5:** Comparison of the plane wave spectra of Step 2 and Step 4 in order to get the differences in far-field between the ideal plane wave and an " real" plane wave illuminated antenna aperture

Analysis Results - Antenna Measurement Accuracy

- Example with an DUT size of 3 m
- Location: Center of Test Zone
- Frequency: 1.5 GHz
- Evaluated Cut: 0° / 180°
- Range Feed Antenna with no Cross-Polar contribution

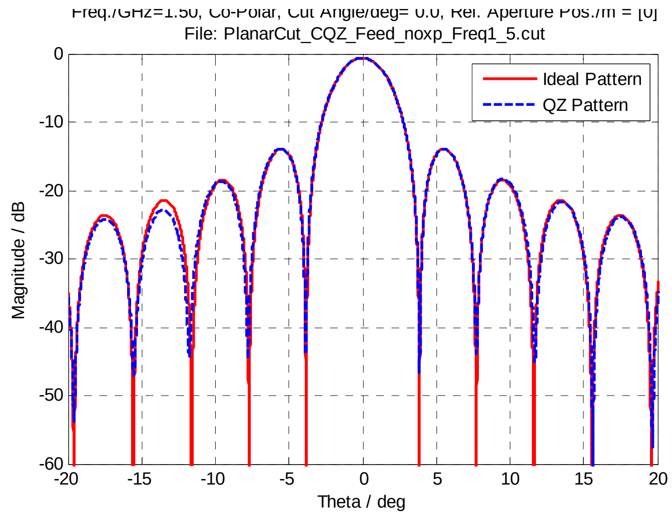
Analysis Results - Antenna Measurement Accuracy

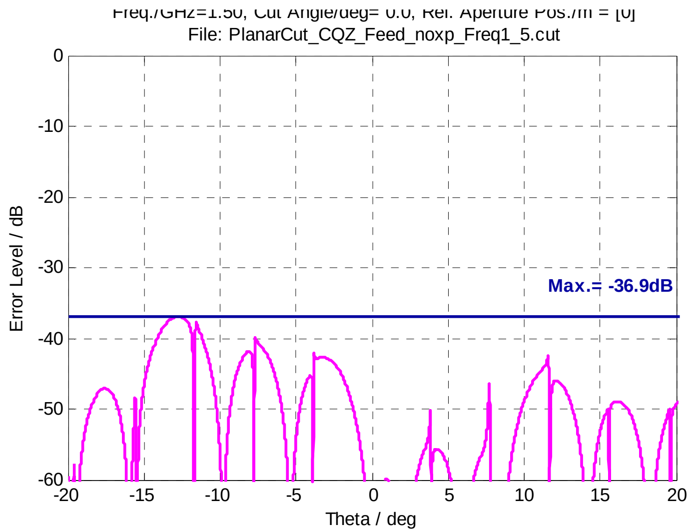
Pattern

1.5 GHz

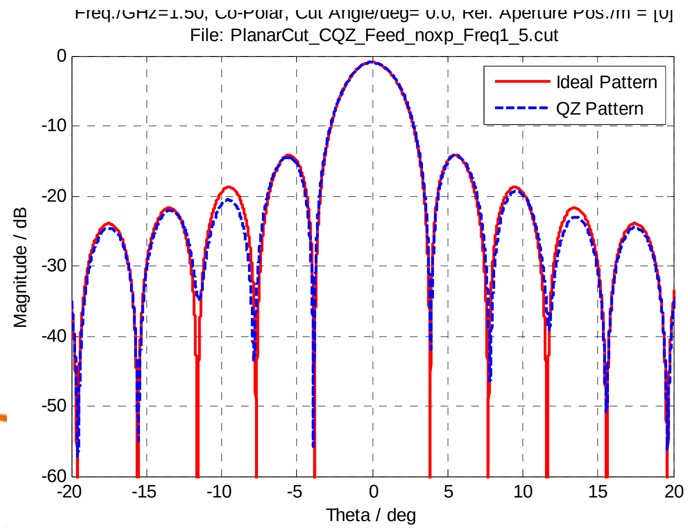
Error

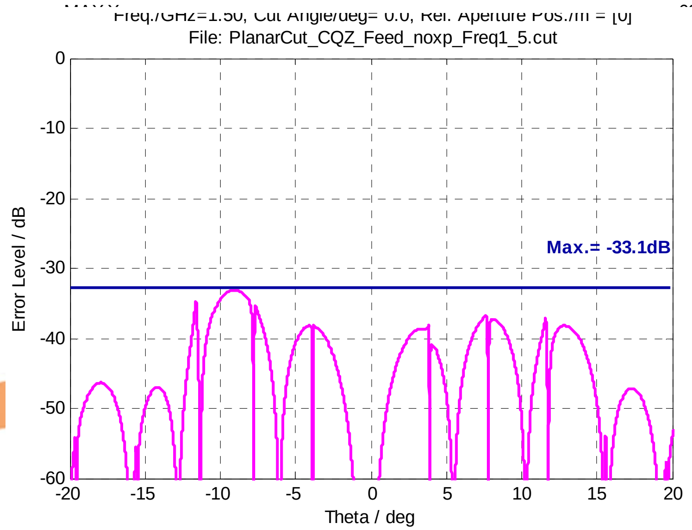
SCR-S





SCR-L





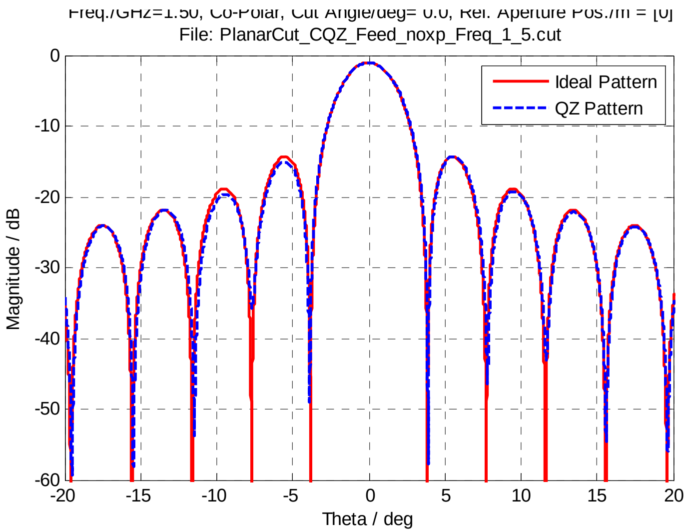
Analysis Results - Antenna Measurement Accuracy

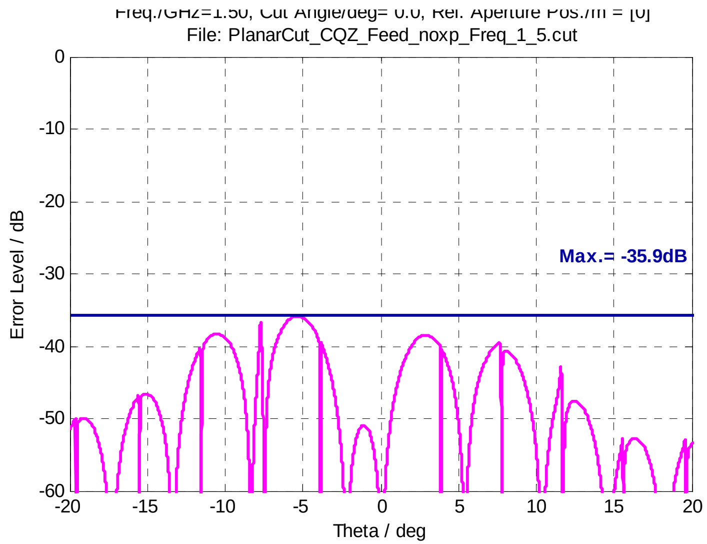
1.5 GHz

Pattern

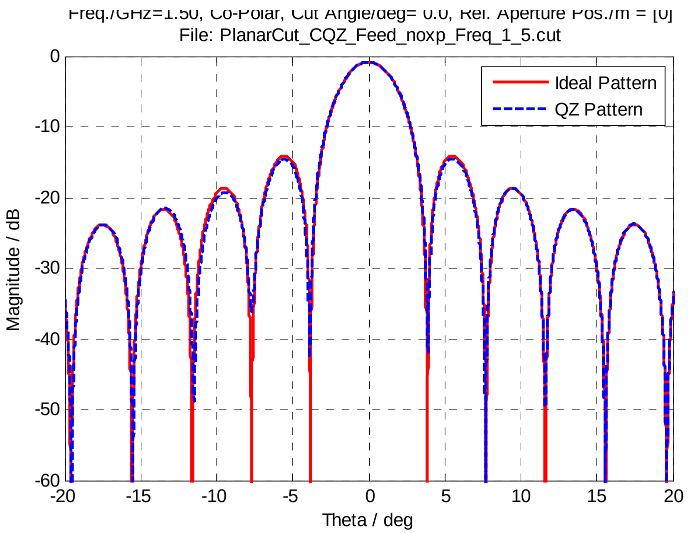
Error

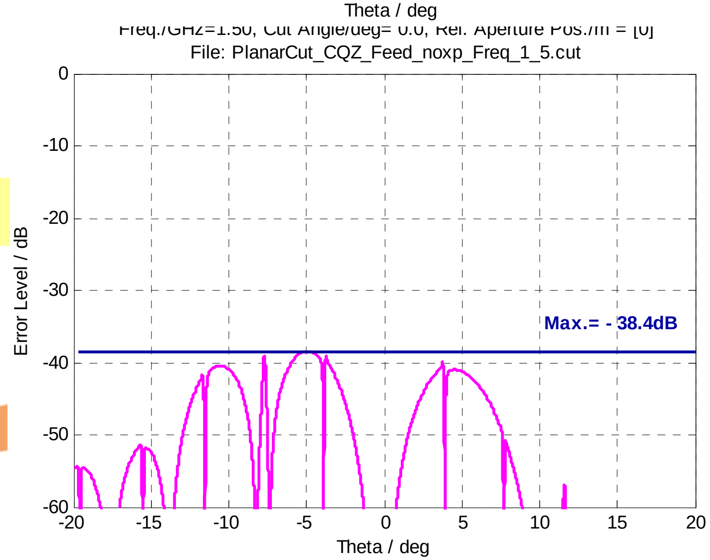
DCPR





CCR





Analysis Results - Antenna Measurement Accuracy

- In order to get more information about the antenna measurement accuracy the following scenario was calculated in the following pages:

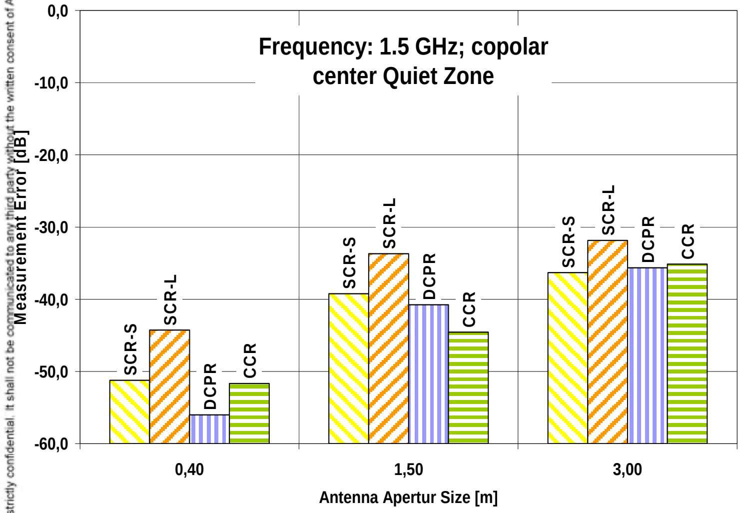
  - All 4 different Compact Range Concepts
  - 3 DUT Aperture Sizes (0.4 m, 1.5 m, 3.0 m)
  - 4 Cuts (0°, 45°, 90°, 135°)
  - 2 Frequencies: 1.5 GHz, 12 GHz
  - Position 1 in Test Zone: Center
  - Position 2 in Test Zone: 1 m lateral offset
  - Cross-Polar Evaluation at worst case cut (90°)
  - Range Feed with no Cross-Polar Contribution

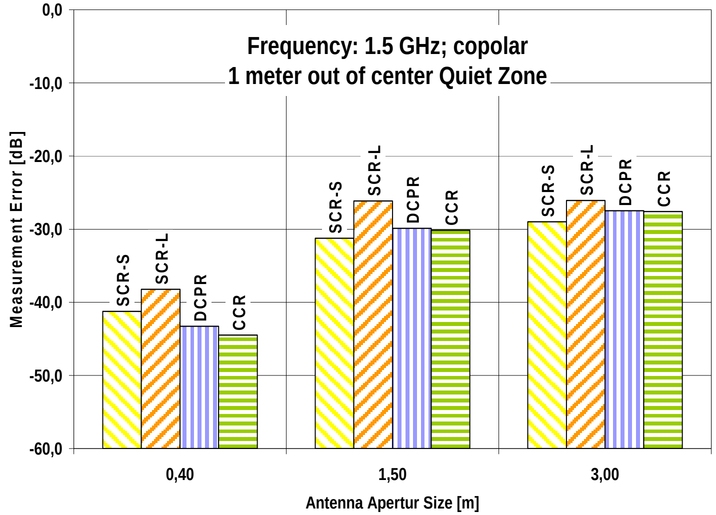
Analysis Results - Antenna Measurement Accuracy

Center

1.5 GHz

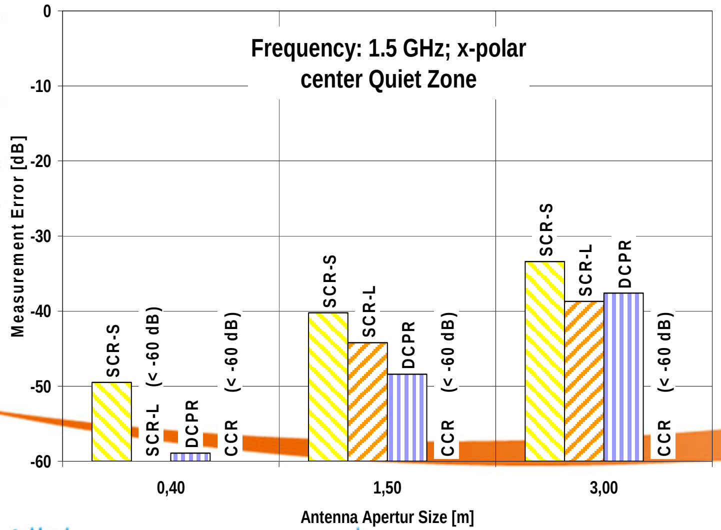
1 m Offset

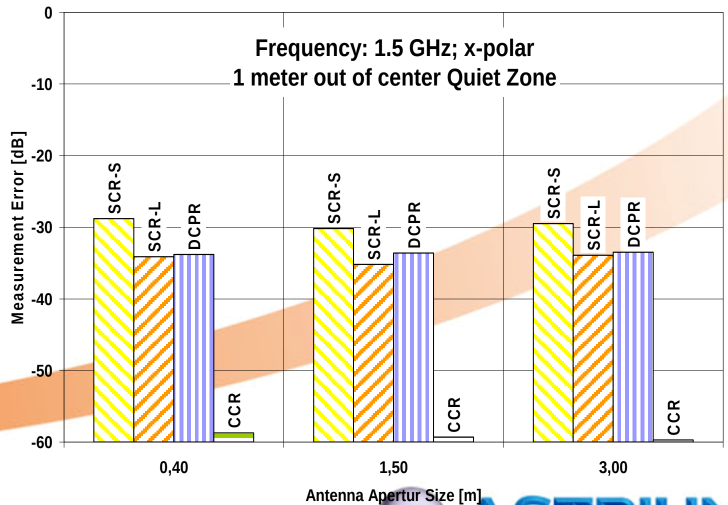




Co-Polar

X-Polar



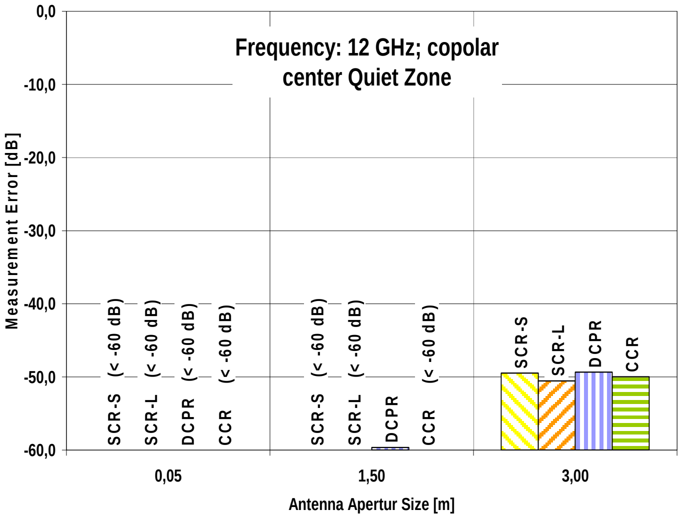


Analysis Results - Antenna Measurement Accuracy

Center

12 GHz

1m Offset



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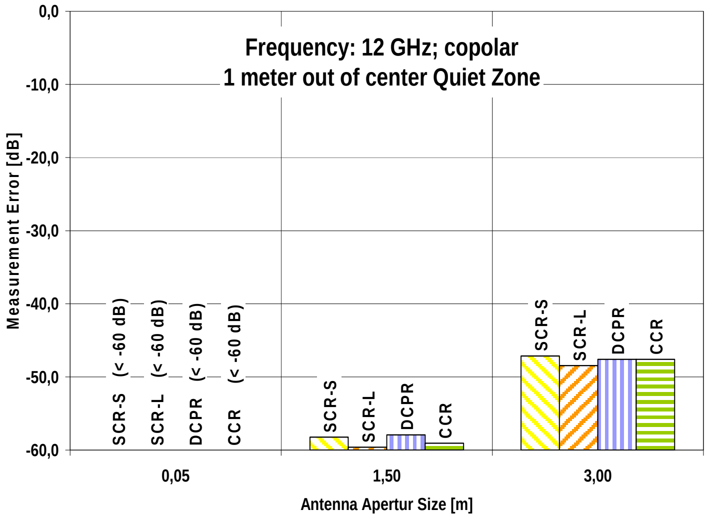
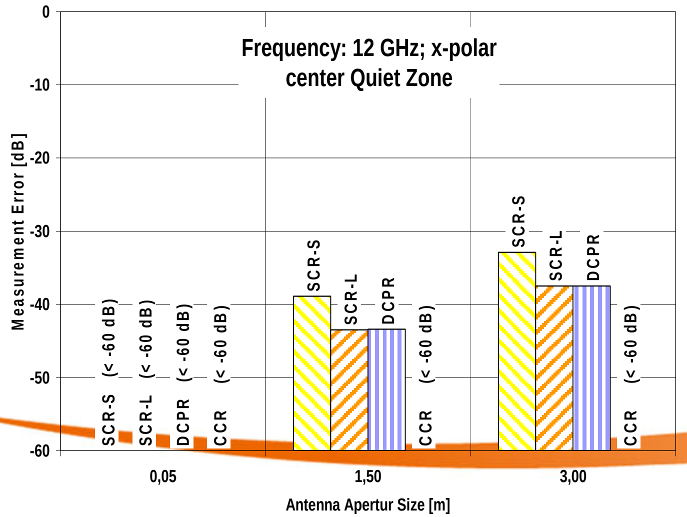
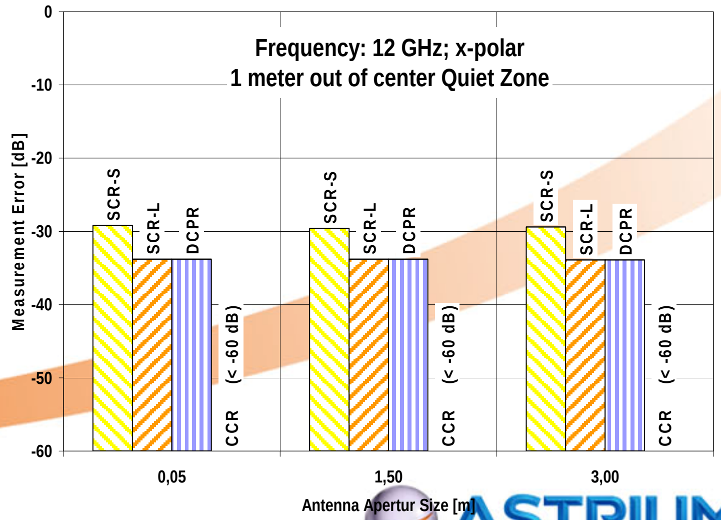




X-Polar



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Analysis Results - Summary Antenna Measurement

- The following general statements can be derived from these predictions:
  - Co-polar performance decreases for all ranges if the test antenna is moved from the center of the QZ to outer positions.
  - A partly similar effect is achieved if the size of the test antenna is increased.
  - Co-polar error figures predicted for high frequencies above 3 GHz are in the same order of magnitude for all considered ranges (variation less +/- 1.5 dB).
  - For the lowest frequency at 1.5 GHz the double reflector compact ranges are slightly superior to the SCR-L. This degradation is mainly related to the too large distance of the QZ of the SCR-L to the main reflector.
  - For the cross-polar far-field pattern the CCR is superior to all other ranges, as in this range type no system inherent cross-polarization occurs.
  - The cross polar pattern errors of the other ranges are significantly higher but all in a rather equal range with a variation of less than +/- 2.5 dB. Especially the SCR-L and DCPR show to a large extent same results.

Analysis Results - Range Characteristic Data

- Room Volume
- Room Efficiency
  - Can be calculated by the relation of quiet zone volume w.r.t. room volume.
  - For the calculations, the **Quiet Zone Volume** of all analyzed facilities was assumed with **100 m^3**.

Facility	Room Volume	Room Efficiency
SCR-S	2940 m^3	3.4 %
SCR-L	3360 m^3	3.0 %
DCPR	4000 m^3	2.5 %
CCR	4000 m^3	2.5 %

4 Conclusion

Conclusion

- The results can be roughly summarized in a short form, that
  - for co-polar measurements at low frequencies (1…2 GHz) all four facilities show similar results,
  - for all measurements requiring high polarization purity the CCR is superior to all of the considered facilities and
  - for other standard measurements all four facility types can be applied with only minor performance differences.

Questions

Thank You for Your Attention

Any Questions?