Compensated Compact Test Ranges for Space Applications

ATMS 2012
Mumbai

Astrium GmbH – 2012
Contents

1. Introduction
    Background
    RF Testing of Communication Satellites

2. Range Trade Off
    Range Comparison
    Compact Range Principles

3. Description of the Astrium CCR’s
    Facility Heritage
    Illumination System

4. Facility Performance
    Plane Wave Probing Data
    Reference Antenna Measurement

5. Conclusion
1 Introduction
Background

⇒ Load Capacity of Launcher:  Ø 3.7 m → Ø 4.5 m  (Ariane IV → V)
  H 8.6 m → H 15 m

⇒ Large Antennas and Antenna Platforms of
  Present and Future Communication Satellites
  → W 12 m

- Eurostar 2000 Bus
  e.g. NILESAT

- Eurostar 2000+ Bus
  e.g. ASTRA 2-B

- Eurostar 3000/+ Bus
  e.g. INTELSAT X
Background

Alpha Bus Scenario
Background

Satellite Busses

- **E3000+** 38%
- **E3000** 40%
- **E2000+** 17%
- **E4000** 5%

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 (AlphaBus)

* Payload power
RF Testing of Communication Satellites

Antenna Tests in the Past and Today:

- Multi-Beam, Multi-Feed or Shaped Reflector Antennas
- Time Efficient Measurement Required

Examples for Measurement Time of Antenna Subsystems:

- **1984 German TV-SAT:**
  - 5 Frequencies per Beam
  - 2 Reflectors (1 East & 1 West)
  - 1 Beam each (Tx & Rx)
  - 6 Weeks Test time

- **2011 Astra Family:**
  - up to 38 Frequencies per Beam
  - 4 Reflectors (2 East & 2 West)
  - 14 Beams
  - 3 Weeks Test time
RF Testing of Communication Satellites

- **Measurement Parameter**
  - **Pattern**
    - Accuracy Requirement co-polar ±0.75 dB @ -30 dB
    - Accuracy Requirement cross-polar ±0.75 dB @ -30 dB
  - **Gain**
    - Accuracy Requirement ±0.25 dB
    - Swept Frequency Measurements with 1 MHz Steps
- **Payload Parameters**
  - EIRP
  - IPFD
  - G/T
  - PIM
RF Testing of Communication Satellites
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RF Testing of Communication Satellites
2 Range Trade Off
Range Trade Off

Scenario for Communication Satellite Antennas
Range Trade Off: Range Comparison

Far-Field Range

<table>
<thead>
<tr>
<th>Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No data transformation required</td>
</tr>
<tr>
<td>• Easy operation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Large measurement distance required!</td>
</tr>
<tr>
<td>• Cleanroom requires Radom!</td>
</tr>
<tr>
<td>• Gravity Compensation for DUT</td>
</tr>
<tr>
<td>• Weather dependence!</td>
</tr>
<tr>
<td>• Ground reflections / interference!</td>
</tr>
<tr>
<td>• Cleanroom requires Radom!</td>
</tr>
<tr>
<td>• Gravity Compensation for DUT</td>
</tr>
</tbody>
</table>

Dynamic Range? Measurement Accuracy?
Range Trade Off: Range Comparison

Near-Field Range

**Limitation / Disadvantage**
- Near field measurements:
- Fourier transformation required for calculation of far field pattern
  - No real-time measurements
  - Coupling between probe and DUT
- High Calibration Effort for Payload Measurements
- Usable frequency range:
  - Typically < 40 GHz limited by probe positioning accuracy (limits phase measurement accuracy)

**Advantage**
- Accurate measurements (0.1 - 40 GHz)
- Short measurement distance < 5 m:
  - Low free space losses
  - Low reflection sensitivity
- Indoor measurement range:
  - Cleanroom conditions
  - 24 hours / day operations
  - Low reflectivity
- Easy Gravity Compensation for DUT
Range Trade Off: Compact Range

**Limitation / Disadvantage**
- Usable frequency range:
  - Typical < 500 MHz limited by diffraction
  - Typical > 200 GHz limited by reflector surface accuracy
- Feed / test-object direct coupling
- Gravity Compensation for DUT

**Advantage**
- Direct far field measurement:
  - No data transformation required
  - Real-time measurements
  - Easy operation
- Short measurement distance < 20m:
  - Low free space losses
  - Accurate measurements (1.5-200 GHz)
- Indoor measurement range:
  - Cleanroom conditions
  - 24 hours / day operations
  - Low reflectivity
Range Trade Off: Compact Range Principles

Goal:
- Test zone with constant amplitude and phase behavior (plane wave)

Starting Point:
- Source feed generating spherical wave

Parabolic Reflector:
- transforms phase front, spherical wave => plane wave
  (equal distances between source feed and test-zone results in constant phase-front)
- Amplitude remains almost unchanged

Requirement:
- Source generates uniform amplitude
Range Trade Off: Compact Range Principles

- **Single Reflector** (Parabola)
- **Double Reflector** (2 Cylinder Parabolas)
- **Double Reflector** (Hyperbola + Parabola)

**Comparison of Complexity:**
- 1 Reflector: Double Curvature
- 2 Reflectors: Single Curvature
- 2 Reflectors: Double Curvature
Range Trade Off: Compact Range Principles

Transforming Geometries of different Compact Range Concepts

Comparison of Compression Factors for comparable Test Zones:

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Plane Wave Uniformity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 : 1</td>
<td>Phase ++ Amplitude -- / Asymm.</td>
</tr>
<tr>
<td>1 : 2</td>
<td>Phase + Amplitude - / Asymm.</td>
</tr>
<tr>
<td>1 : 4</td>
<td>Phase + Amplitude ++ / Symm.</td>
</tr>
</tbody>
</table>
Range Trade Off: Compact Range Principles

Single Reflector

Dual Reflector (Single Curved) Co-Polar

Dual Reflector (Double Curved)

Co-Polar

Cross-Polar

No Cross-Polarization from the Reflector System
**Range Trade Off: Compact Range Principles**

**Conclusions:**
1) Diffraction reduces **Quiet Zone Size** to approx. 80% of Main Reflector Dimensions
2) Good Performance at 1.5 GHz requires at least 1.5m Serration Length
3 Description of the Astrium CCR’s
Since 1985 Supplier of Antenna Test Facilities with 16 Facility in Operation Worldwide

- Global Market Leader in Compensated Compact Ranges
- Maintenance and System Upgrades
- Extremely High Measurement Accuracies at High Reliability
- Preferred Supplier for Leading Satellite Manufactures

Unprecedented High Level of Customer Satisfaction

> 20 Years of Antenna Test Facility Experience
Description of the Astrium CCRs: CCR 75/60

State of the Art Test Facility

- Highly Accurate Satellite Antenna Testing

Astrium CCR 75/60

Main Characteristics

- Dual Reflector System (Top Fed Cassegrain System)
  - Double Curved Hyperbolic Sub Reflector
  - Double Curved Parabolic Main Reflector
- High Surface Accuracy
- Large equivalent Focal-Length
- Fully Cross-Polar Compensated System
Description of the Astrium CCRs
CCR 75/60 at Astrium in Munich
Description of the Astrium CCRs: CCR 75/60

Principal Top View of CCR 75/60

Scale

0 1 2 3 4 5 m

Center: Focussed Quiet Zone
(0.0, 0.0, 0.0)

NPA

Focal Point
(-10.500 m, 6.915 m, 0.0)

Subreflector

Main
Reflector

All the space you need
### Description of the Astrium CCRs: CCR 75/60

#### Geometrical Data CCR 75/60

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sub</th>
<th>Main</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (W x H) exclusive Serrations</td>
<td>5.75 m x 5.60 m</td>
<td>7.60 m x 6.20 m</td>
</tr>
<tr>
<td>Surface Accuracy per Reflector</td>
<td>≤ 20 µm RMS</td>
<td>≤ 20 µm RMS</td>
</tr>
<tr>
<td>Serrations Length</td>
<td>1.70 m</td>
<td>1.70 m</td>
</tr>
<tr>
<td>Number of Segments</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Back Structure Depth</td>
<td>1.2 m</td>
<td>1.2 m</td>
</tr>
<tr>
<td>Mass of Reflector</td>
<td>32400 kg</td>
<td>48600 kg</td>
</tr>
<tr>
<td>Mass of Base Plates</td>
<td>2000 kg</td>
<td>3000 kg</td>
</tr>
</tbody>
</table>
## Technical Data CCR 75/60

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency Range</strong></td>
<td>1.5 – 200 GHz</td>
</tr>
<tr>
<td><strong>Quiet Zone Size (W x H x D)</strong></td>
<td>5.8 x 5.3 x 8.0 m</td>
</tr>
<tr>
<td><strong>Quiet Zone Performance</strong></td>
<td></td>
</tr>
<tr>
<td>Amlitude Ripple</td>
<td>± 0.5 dB</td>
</tr>
<tr>
<td>Phase Ripple</td>
<td>± 6 deg</td>
</tr>
<tr>
<td>Cross-Polar Level</td>
<td>&lt; - 40 dB</td>
</tr>
<tr>
<td><strong>Measurement Errors</strong></td>
<td></td>
</tr>
<tr>
<td>Sidelobes</td>
<td>± 1 dB @ 35 dB</td>
</tr>
<tr>
<td>Gain</td>
<td>± 0.25 dB</td>
</tr>
<tr>
<td>Bore-Sight Accuracy</td>
<td>± 0.014 deg</td>
</tr>
<tr>
<td><strong>Scanning Capability</strong></td>
<td>10 deg</td>
</tr>
<tr>
<td><strong>Scan Angle Accuracy</strong></td>
<td>± 0.0003 deg</td>
</tr>
</tbody>
</table>
Description of the Astrium CCRs: CCR 120/100

Newest Generation Test Facility

- Highly Accurate Satellite Antenna Testing

Astrium CCR 120/100

Main Characteristics

- Dual Reflector System (Top Fed Cassegrain System)
  - Double Curved Hyperbolic Sub Reflector
  - Double Curved Parabolic Main Reflector
- High Surface Accuracy
- Quiet Zone Size 8.5 m
- Large equivalent Focal-Length
- Fully Cross-Polar Compensated System
Description of the Astrium CCRs
CCR 120/100 at CAST in Beijing
Description of the Astrium CCRs:  CCR 120/100

Principal Top View of CCR120/100
# Description of the Astrium CCRs: CCR 120/100

## Geometrical Data CCR 120/100

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sub</th>
<th>Main</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (W x H) exclusive Serrations</td>
<td>9.0 m x 8.6 m</td>
<td>12.0 m x 10.0 m</td>
</tr>
<tr>
<td>Surface Accuracy per Reflector</td>
<td>≤ 35 µm RMS</td>
<td>≤ 35 µm RMS</td>
</tr>
<tr>
<td>Serrations Length</td>
<td>1.75 m</td>
<td>1.75 m</td>
</tr>
<tr>
<td>Number of Segments</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Back Structure Depth</td>
<td>1.2 m</td>
<td>1.2 m</td>
</tr>
<tr>
<td>Mass of Reflector</td>
<td>90000 kg</td>
<td>12000 kg</td>
</tr>
<tr>
<td>Mass of Base Plates</td>
<td>4500 kg</td>
<td>6000 kg</td>
</tr>
</tbody>
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## Description of the Astrium CCRs: CCR 120/100

### Technical Data CCR 120/100

<table>
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<td><strong>Frequency Range</strong></td>
<td>1.0 – 200 GHz</td>
</tr>
<tr>
<td><strong>Quiet Zone Size (W x H x D)</strong></td>
<td>8.5 x 8.0 x 12.0 m</td>
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Description of the Astrium CCRs

▷ Reflector Technology

▷ Special Cast Iron Elements

▷ Milled by a 5-Axes Laser Controlled Milling Machine

▷ highly Stiffened Supporting Structure at the Rear

▷ Long Term Mechanical Stability.
Facility Installation and Integration
Facility Installation and Integration
Facility Installation and Integration
Facility Installation and Integration

Final Surface Contour Deviations of 25 µm (R.M.S.)
4 Facility Performance
Facility Performance: Acceptance Testing

Plane Wave Probing:

- Linear Scanner
- 5.75 m Scanning Range
- 50 µm Planarity
- Frequency Ranges
  - 1 .. 1.5 GHz
  - 4.2 .. 5.5 GHz
  - 12.2 .. 18 GHz
  - 26.7 .. 40 GHz
  - 100 GHz
- Probing Plane: 11 m Ø
- Probing Antennas: 18 dB Standard Gain Horns
Facility Performance: Acceptance Testing

Antenna Testing:
- Calibrated Reference Antenna
- Shaped Beam Antenna (SBA)
- Golden Standard
- Frequency = 12 GHz
Facility Performance: CCR 120/100

Plane Wave Probing Data at 15 GHz in CQZ
Facility Performance: CCR 120/100

Plane Wave Probing Data at 15 GHz in CQZ

Amplitude, Cross-Polar

Rel. Field Amplitude [dB]

Scanning Range [m]
Facility Performance: CCR 120/100

Amplitude, Co-Polar

Phase, Co-Polar

Plane Wave Probing Data at 15 GHz

5 m Scanned Quiet Zone
Facility Performance: CCR 120/100

Plane Wave Probing Data at 15 GHz
5 m Scanned Quiet Zone
Facility Performance: CCR 120/100

Pattern Comparison of Reference Antenna Data at 12 GHz
Conclusion

- **Standard Test Facility CCR 75/60**
  - Fast Real-Time Measurements
  - High Precision Antenna Measurement
  - Large Frequency Range from 1.5 … 200 GHz
  - Large Range of Measurement Applications for Complex Satellite Antennas

- **Newest Generation of Test Facility CCR 120/100**
  - Large Frequency Range from 1.0 … 200 GHz
  - Quiet Zone Size 8.5 m for Centre Quiet Zone
  - Measurement Applications for today's and future Satellite Systems

- **Acceptance Test Results**
  - Reflector Contour Accuracy: Overall < 25 µm RMS
  - Pattern Accuracy: ± 0.75 dB @ -30dB SLL
  - Amplitude & Phase Ripple: ± 0.3 dB ± 3 deg.
  - Amplitude & Phase Taper: ≤ 0.5 dB ≤ 3.5 deg.
  - Cross-Polar Level: ≤ -42 dB
Questions

Thank You for Your Attention

Any Questions?