Procedure and Process Optimization for Reduction of Measurement Uncertainties in RF Test Facilities

ATMS 2012

Mumbai

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Content

1 Introduction

Introduction

Nowadays Satellite Antenna Testing requires State of the Art Test Facilities like Near-Field or Compact Ranges. In both Types

Highly Accurate Satellite Antenna Testing

is possible.

However each Type of Test Facility with its own Environment and Equipment is characterized by dedicated Accuracy Budgets.

2 Motivation for Establishing Procedure

Motivation for Establishing Procedures

Input:

Test Specification

Human Error

DUT Positioning System

Physical Limits of Test Facility

Alignment of AUT

RF Measurement System

Environmental Influence

Data Acquisition Computational

Output:

Test Results

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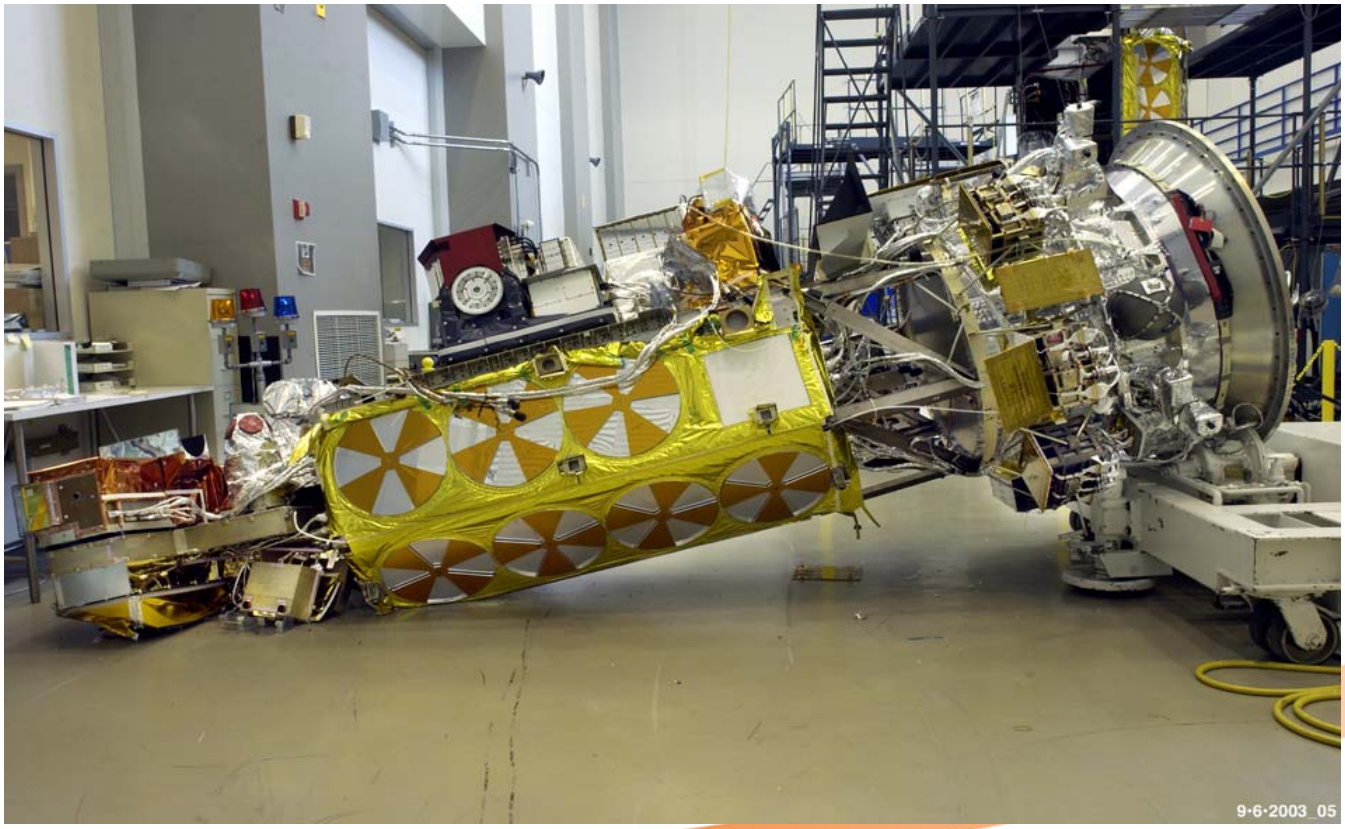
Motivation for Establishing Procedures

⇨Caused by Human Error



3 ISO 9000 Standard Definition

ISO 9000 Standard Definition

The main Objectives of the ISO 9001 Standard are:

- Securing of the Product Quality
- Customers' Satisfaction
- Continuously Improvement of Processes

and additionally with ISO 9001-2000

- Quality Metrics Catalogue
  - ➢ Questionnaire to the Customer

ISO 9000 Standard Definition

To reach and maintain these Goals, a Quality Management System has to be developed and implemented, to cover the following Issues:

- Management
- Configuration Control
- Maintenance
- Operation

ISO 9000 Standard Definition

The applicable Documents are divided into four Levels:

Level 0: Company Policy

Level 1: Quality Manual

Level 2: Procedures and Standards

Level 3: Work Instructions (Internal Standards)

For Antenna Testing Activities Level 2 and 3 Documents are valid.

ISO 9000 Standard Definition

Level 2 Documents shall cover at minimum:

- Product Identification and Traceability
- Process Control
- Inspection and Test Status
- Control of Nonconforming Records
- Control of Measuring and Test Equipment
- Handling, Storage and Transport
- Control of Test Records and Test Data
- Training of the Employees
- Test Procedures

ISO 9000 Standard Definition

Level 3 Documents are working Instructions and can be written in the national Language, which cover the dedicated Company Know How of the Basic Design and/or Operation Processes.

- **Design and Development Process**
- **Manufacturing, Assembly & Integration Process**
- **Calibration of Test-Equipment**
- **Range Management Procedures**

These Documents have not to be delivered to the Customer.

4 Range Procedures for Compact Ranges

Range Procedures for Compact Ranges

An Antenna Test Facility can only be used if the Test Range is fully qualified.

To avoid a new Qualification before starting a new Measurement Program, two different Procedures have to be used:

- **Range Management Procedure**
  valid through the Live-time of the Test Facility
- **Test Procedure**
  valid for each individual Measurement Program

Range Measurement Procedure

- Maintenance Activities and Recording of the Range Condition have to be performed through the Live-Time of the Test Facility.
- A Maintenance Plan should define the Maintenance Activities as a Function of Time Intervals.
- The Maintenance Activities are depending on the particular Test Range, but at a minimum the following Activities have to be done:

Range Measurement Procedure

- Visual Inspection of all Mechanical Parts of the Test Range (Reflector, Positioner, Feedscanner)
- Inspection of all Electrical Parts of the Test Range (Motors, Air-Conditioning)
- Cleaning and Protection of Reflectors
- Greasing / Oil-Change at movable Parts like Turntable Gears
- Functional Test of Emergency Break and Limit Switches

Range Measurement Procedure

- Visual Inspection and Cleaning / Changing of Air Filters (Air-Conditioning, RF-Equipment)
- Visual Inspection of RF-Equipment Fans
- Visual Inspection of RF-Cables and Connectors
- Calibration of Range and Test Equipment
- Range Alignment

Range Measurement Procedure

The Maintenance Activities have to be recorded on a Log Book which covers the following records added by Date and Signature:

- Range Calibration Status
- Range Alignment Status
- Equipment Calibration Status
- Maintenance Status
- Environmental Conditions such as Temperature, Humidity and Cleanliness
- Equipment Faults / Changes
- Software Faults / Changes
- Other Anomalies

Test Procedure

Each Compact Range Test consists as Minimum of four Main Steps:

1. Preparation for Compact Range Measurement
2. Compact Range Data Acquisition
3. Post Processing of Measurement Data
4. Evaluation of Far-Field Data

The individual Steps have to be defined in a Test Procedure, which will be valid for the actual Measurement Program.

Test Procedure

1. Preparation for CCR Measurement

- Unpacking and Inspection of Test Antenna
- Mechanical Installation of Test Antenna
- Electrical Installation of Test Antenna
- Electrical Installation of RF Test Set-Up
- Alignment of CCR Feed
- Optical Alignment of Test Antenna
- Optical Alignment of Test Facility
- Description of Test Set-Up
- Test Requirements
- Error Budgets for RF and Alignment
- Step by Step Test Procedure

Test Procedure

2. CCR Data Acquisition

Performing of Pre-tests:
Saturation, Linearity, Noise Level, Dynamic, Stability over Time

Determination of Test Parameter	**Determination of Average Parameter**		
Antenna Pattern Measurement (Set of Data Recordings)		**Measurement of Feed Channel Difference**	**Measurement of Gain**
Set of Data Files (horizontal and vertical Polarized)		**1 Amplitude- 1 Phase-Value per Frequency**	**Power Relation P_r / P_t**

Test Procedure

3. Post Processing of Measurement Data

- Amplitude and Phase Correction
- Linear to Circular Transformation (if required)
- AAPC Calculation (if required)
- 2 Data-Files: Co- and Cross-Polar (per Frequency)

Test Procedure

4. Evaluation of Far-Field Data

- Optical Alignment Values
- Gain Values
- Coordinate Transformation
- Numerical Evaluation
- Contour Plots
- Comparison against Specification

5 Measurement Errors for Compact Ranges

Measurement Errors for Compact Ranges

All Major Components of the Compact Range Measurement System that effect the Measurement Accuracy can be grouped into nine Categories:

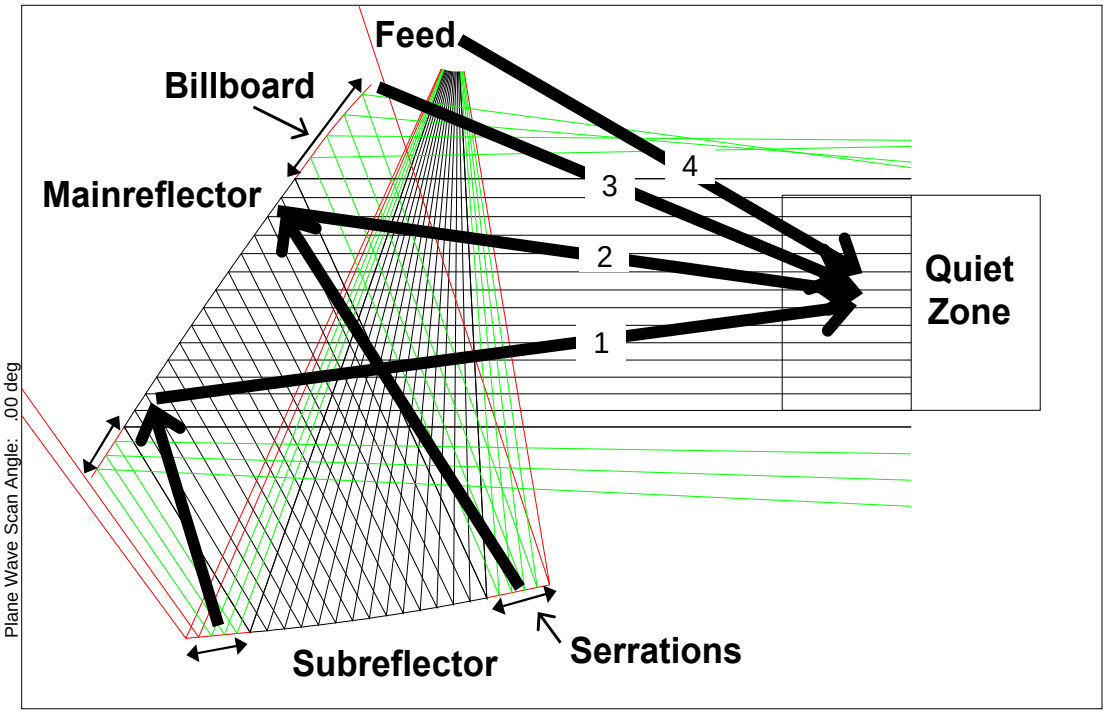
1. RF Measurement System
2. Feed System
3. Reflector System including Serrations and Billboard
4. Direct Leakage Suppression by Baffle
5. DUT Positioning System
6. Antenna Under Test
7. Environmental
8. Measurement Procedure
9. Computational

Measurement Errors for Compact Ranges

The Most Critical Errors in the Compact Range are generated by:

1. The Reflector System including Serrations
2. The Billboard Edge
3. The Direct Leakage from the Feed into the Quiet Zone.

Measurement Errors for Compact Ranges



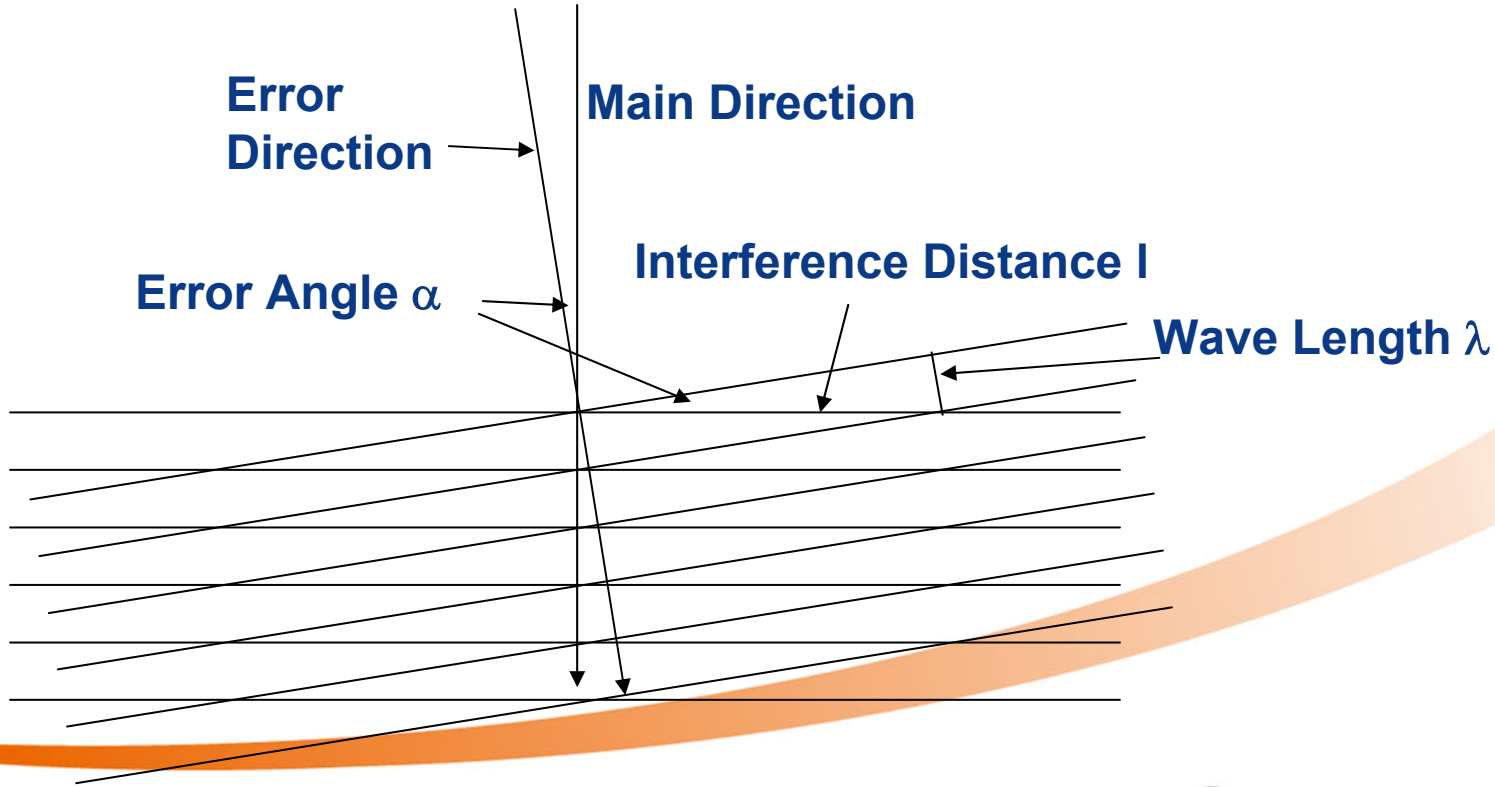
1: appr. -8 degrees
2: appr. +8 degrees
3: appr. +25 degrees
4: appr. +30 degrees

regarding to
Main Direction

Measurement Errors for Compact Ranges

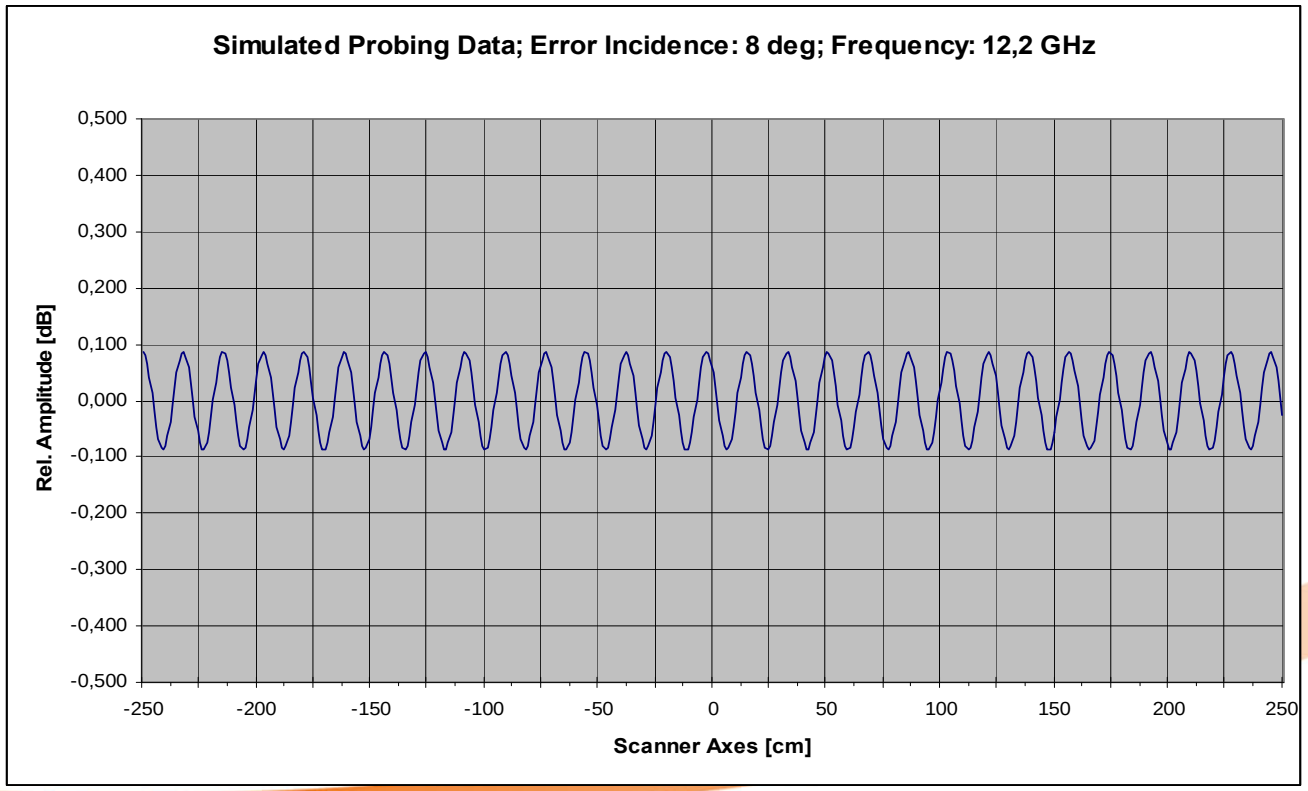
Interference of 2 Plane Waves generates an Interference Wavelength

$$l = \lambda / \sin(\alpha)$$



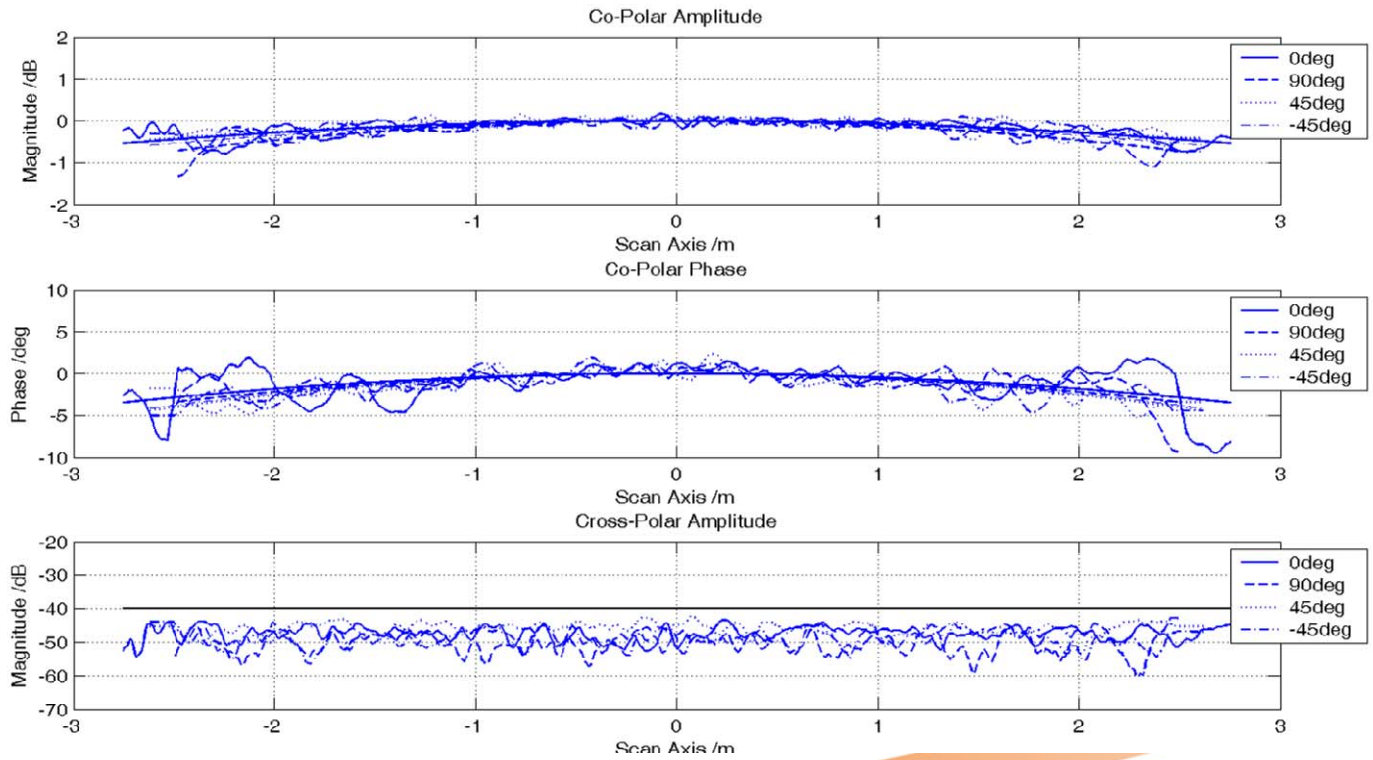
Measurement Errors for Compact Ranges

Simulated Probing Data with Interference Period
l = 17.67 cm, α = 8 deg, f = 12.2 GHz



Measurement Errors for Compact Ranges

Realistic Probing Data f = 12.2 GHz



Measurement Errors for Compact Ranges

For High Gain Antennas, these Errors could not be combined in RSS-Method, because they interfere with the Plane Wave at different Pattern Angles.

- **5 Error Budgets for Pattern Measurement Accuracy are established**

6 Detailed Error Budgets

Detailed Error Budgets for Pattern Measurements

Basic Error Budget for Pattern Measurements in CCR 75/60
High Gain Antennas (> 25 dBi), C-Band and higher
AAPC Algorithm assumed, 3σ values
Angular Range outside the Reflector Area

	Disturber	Pattern Level	Error Level	Error	Error^2
	[dB]	[dB]	[dB]	[lin]	[lin]
Feed x-polarization isolation	-75	-35	0,09	0,0002	0,0000
Feed alignment	-200	-35	0,00	0,0000	0,0000
Feed mismatch	-80	-35	0,05	0,0001	0,0000
Reflector system including serration and billboard copol	-85	-35	0,03	0,0001	0,0000
Reflector system including serration and billboard x-pol	-88	-35	0,02	0,0000	0,0000
Direct leakage suppression	-86	-35	0,02	0,0001	0,0000
Quiet zone taper	-65	-35	0,28	0,0006	0,0000
AUT positioning system	-83	-35	0,03	0,0001	0,0000
AUT mismatch	-80	-35	0,05	0,0001	0,0000
Receiver amplitude nonlinearity	-76	-35	0,08	0,0002	0,0000
Receiver dynamic range	-70	-35	0,16	0,0003	0,0000
Multiple reflections	-70	-35	0,16	0,0003	0,0000
Room scattering	-70	-35	0,16	0,0003	0,0000
Leakage and crosstalk	-75	-35	0,09	0,0002	0,0000
Other errors	-75	-35	0,09	0,0002	0,0000
X-pol error	-85	-35	0,03	0,0001	0,0000
X-pol error at copolar mainbeam	-55	-35	0,92	0,0018	0,0000
RSS Value copol	**-61,15**				0,0009
RSS Value x-pol	**-61,33**				0,0009
RSS Value x-pol	**-54,09**				0,0020

Error Budget copol:	**-0,42**	**0,44**
Error Budget x-pol:	**-0,41**	**0,43**
Error Budget x-pol at copolar mainbeam:	**-0,91**	**1,02**

Detailed Error Budgets for Pattern Measurements

Basic Error Budget for Pattern Measurements in CCR 75/60
High Gain Antennas (> 25 dBi), C-Band and higher
AAPC Algorithm assumed, 3σ values
Angular Range appr. at -8 degrees

	Disturber	Pattern Level	Error Level	Error	Error^2
	[dB]	[dB]	[dB]	[lin]	[lin]
Feed x-polarization isolation	-75	-35	0,09	0,0002	0,0000
Feed alignment	-200	-35	0,00	0,0000	0,0000
Feed mismatch	-80	-35	0,05	0,0001	0,0000
Reflector system including serration and billboard copol	-55	-35	0,92	0,0018	0,0000
Reflector system including serration and billboard x-pol	-61	-35	0,45	0,0009	0,0000
Direct leakage suppression	-86	-35	0,02	0,0001	0,0000
Quiet zone taper	-65	-35	0,28	0,0006	0,0000
AUT positioning system	-83	-35	0,03	0,0001	0,0000
AUT mismatch	-80	-35	0,05	0,0001	0,0000
Receiver amplitude nonlinearity	-76	-35	0,08	0,0002	0,0000
Receiver dynamic range	-70	-35	0,16	0,0003	0,0000
Multiple reflections	-70	-35	0,16	0,0003	0,0000
Room scattering	-70	-35	0,16	0,0003	0,0000
Leakage and crosstalk	-75	-35	0,09	0,0002	0,0000
Other errors	-75	-35	0,09	0,0002	0,0000
X-pol error	-85	-35	0,03	0,0001	0,0000
RSS Value copol	**-54,06**				0,0020
RSS Value x-pol	**-58,15**				0,0012

Error Budget copol:	**-0,92**	**1,03**
Error Budget x-pol:	**-0,58**	**0,63**

Detailed Error Budgets for Pattern Measurements

Basic Error Budget for Pattern Measurements in CCR 75/60
High Gain Antennas (> 25 dBi), C-Band and higher
AAPC Algorithm assumed, 3σ values
Angular Range appr. at +8 degrees

	Disturber	Pattern Level	Error Level	Error	Error^2
	[dB]	[dB]	[dB]	[lin]	[lin]
Feed x-polarization isolation	-75	-35	0,09	0,0002	0,0000
Feed alignment	-200	-35	0,00	0,0000	0,0000
Feed mismatch	-80	-35	0,05	0,0001	0,0000
Reflector system including serration and billboard copol	-58	-35	0,64	0,0013	0,0000
Reflector system including serration and billboard x-pol	-61	-35	0,45	0,0009	0,0000
Direct leakage suppression	-86	-35	0,02	0,0001	0,0000
Quiet zone taper	-65	-35	0,28	0,0006	0,0000
AUT positioning system	-83	-35	0,03	0,0001	0,0000
AUT mismatch	-80	-35	0,05	0,0001	0,0000
Receiver amplitude nonlinearity	-76	-35	0,08	0,0002	0,0000
Receiver dynamic range	-70	-35	0,16	0,0003	0,0000
Multiple reflections	-70	-35	0,16	0,0003	0,0000
Room scattering	-70	-35	0,16	0,0003	0,0000
Leakage and crosstalk	-75	-35	0,09	0,0002	0,0000
Other errors	-75	-35	0,09	0,0002	0,0000
X-pol error	-85	-35	0,03	0,0001	0,0000
RSS Value copol	**-56,29**				0,0015
RSS Value x-pol	**-58,15**				0,0012

Error Budget copol:	**-0,72**	**0,78**
Error Budget x-pol:	**-0,58**	**0,63**

Detailed Error Budgets for Pattern Measurements

Basic Error Budget for Pattern Measurements in CCR 75/60
High Gain Antennas (> 25 dBi), C-Band and higher
AAPC Algorithm assumed, 3σ values
Angular Range appr. at +25 degrees

	Disturber	Pattern Level	Error Level	Error	Error^2
	[dB]	[dB]	[dB]	[lin]	[lin]
Feed x-polarization isolation	-75	-35	0,09	0,0002	0,0000
Feed alignment	-200	-35	0,00	0,0000	0,0000
Feed mismatch	-80	-35	0,05	0,0001	0,0000
Reflector system including serration and billboard copol	-58	-35	0,64	0,0013	0,0000
Reflector system including serration and billboard x-pol	-61	-35	0,45	0,0009	0,0000
Direct leakage suppression	-86	-35	0,02	0,0001	0,0000
Quiet zone taper	-65	-35	0,28	0,0006	0,0000
AUT positioning system	-83	-35	0,03	0,0001	0,0000
AUT mismatch	-80	-35	0,05	0,0001	0,0000
Receiver amplitude nonlinearity	-76	-35	0,08	0,0002	0,0000
Receiver dynamic range	-70	-35	0,16	0,0003	0,0000
Multiple reflections	-70	-35	0,16	0,0003	0,0000
Room scattering	-70	-35	0,16	0,0003	0,0000
Leakage and crosstalk	-75	-35	0,09	0,0002	0,0000
Other errors	-75	-35	0,09	0,0002	0,0000
X-pol error	-85	-35	0,03	0,0001	0,0000
RSS Value copol	**-56,29**				0,0015
RSS Value x-pol	**-58,15**				0,0012

Error Budget copol:	**-0,72**	**0,78**
Error Budget x-pol:	**-0,58**	**0,63**

Detailed Error Budgets for Pattern Measurements

Basic Error Budget for Pattern Measurements in CCR 75/60
High Gain Antennas (> 25 dBi), C-Band and higher
AAPC Algorithm assumed, 3σ values
Angular Range appr. at +30 degrees

	Disturber	Pattern Level	Error Level	Error	Error^2
	[dB]	[dB]	[dB]	[lin]	[lin]
Feed x-polarization isolation	-75	-35	0,09	0,0002	0,0000
Feed alignment	-200	-35	0,00	0,0000	0,0000
Feed mismatch	-80	-35	0,05	0,0001	0,0000
Reflector system including serration and billboard copol	-85	-35	0,03	0,0001	0,0000
Reflector system including serration and billboard x-pol	-88	-35	0,02	0,0000	0,0000
Direct leakage suppression	-56	-35	0,81	0,0016	0,0000
Quiet zone taper	-65	-35	0,28	0,0006	0,0000
AUT positioning system	-83	-35	0,03	0,0001	0,0000
AUT mismatch	-80	-35	0,05	0,0001	0,0000
Receiver amplitude nonlinearity	-76	-35	0,08	0,0002	0,0000
Receiver dynamic range	-70	-35	0,16	0,0003	0,0000
Multiple reflections	-70	-35	0,16	0,0003	0,0000
Room scattering	-70	-35	0,16	0,0003	0,0000
Leakage and crosstalk	-75	-35	0,09	0,0002	0,0000
Other errors	-75	-35	0,09	0,0002	0,0000
X-pol error	-85	-35	0,03	0,0001	0,0000
RSS Value copol	**-54,85**				0,0018
RSS Value x-pol	**-54,89**				0,0018

Error Budget copol:	**-0,84**	**0,93**
Error Budget x-pol:	**-0,84**	**0,93**

Detailed Error Budgets for Gain Measurements

Two different Types of Gain Measurements are possible to perform in the CCR.

- First the well known Substitution Method using a Gain calibrated SGH (Standard Gain Horn).
- Second the Power Measurement Method (PMM) using a 2 Channel Power Meter.

Detailed Error Budgets for Gain Measurements

The Main Errors for both Methods are the Gain Accuracy of the SGH respectively the CCR Feed and the multiple Reflections between the AUT and the CCR Feed.

The Accuracy Budgets for both Methods are nearly the same, but from the practical Side of View, it's much easier to use the PMM. No additional Test Set-Up and no Quiet Zone Probing is needed.

Detailed Error Budgets for Gain Measurements

Error Budget for Peak Gain Measurements in CCR 75/60
High Gain Antennas (> 25 dBi), C-Band and higher
3σ values
Substitution Method with SGH

	Disturber	Pattern Level	Error Level	Error	Error^2
	[dB]	[dB]	[dB]	[lin]	[lin]
Feed x-polarization isolation	-75	0	0,00	0,0002	0,0000
Feed alignment	-200	0	0,00	0,0000	0,0000
SGH gain accuracy	-36	0	0,15	0,0168	0,0003
Accuracy of receiver measurement at AUT	-50	0	0,03	0,0032	0,0000
Accuracy of receiver measurement at SGH	-50	0	0,03	0,0032	0,0000
Accuracy of attenuator calibration	-40	0	0,09	0,0100	0,0001
Influence of quiet zone ripple on SGH	-45	0	0,05	0,0056	0,0000
Influence of quiet zone taper on AUT	-50	0	0,03	0,0032	0,0000
Mismatch at AUT	-45	0	0,05	0,0056	0,0000
Mismatch at SGH	-45	0	0,05	0,0056	0,0000
Multiple reflections	-40	0	0,09	0,0100	0,0001
Room scattering	-75	0	0,00	0,0002	0,0000
Leakage and crosstalk	-75	0	0,00	0,0002	0,0000
Other errors	-50	0	0,03	0,0032	0,0000
RSS Value	**-32,10**				0,0248
Error Budget:			**-0,21**	**0,22**	

Detailed Error Budgets for Gain Measurements

Error Budget for Peak Gain Measurements in CCR 75/60
High Gain Antennas (> 25 dBi), C-Band and higher
3σ values
Power Measurement Method

	Disturber	Pattern Level	Error Level	Error	Error^2
	[dB]	[dB]	[dB]	[lin]	[lin]
Feed x-polarization isolation	-75	0	0,00	0,0002	0,0000
Feed alignment	-200	0	0,00	0,0000	0,0000
Feed gain accuracy	-36	0	0,15	0,0168	0,0003
Accuracy of power measurement at feed	-53	0	0,02	0,0022	0,0000
Accuracy of receiver measurement at AUT	-53	0	0,02	0,0022	0,0000
Accuracy of free space loss depending on feed position	-50	0	0,03	0,0032	0,0000
Accuracy of attenuator calibration	-40	0	0,09	0,0100	0,0001
Influence of quiet zone taper on AUT	-53	0	0,02	0,0022	0,0000
Mismatch at AUT	-45	0	0,05	0,0056	0,0000
Mismatch at Feed	-45	0	0,05	0,0056	0,0000
Multiple reflections	-40	0	0,09	0,0100	0,0001
Room scattering	-75	0	0,00	0,0002	0,0000
Leakage and crosstalk	-75	0	0,00	0,0002	0,0000
Other errors	-50	0	0,03	0,0032	0,0000
RSS Value	**-32,36**				0,0241
Error Budget:			**-0,21**	**0,21**	

7 Conclusion

Conclusion

With the discussed

- ISO 9000 Standard
- Range Management Procedure
- Test Procedure for Pattern and Gain

The given Accuracy Budgets for this Type of Test Range can be fulfilled and the Human Factor can be minimized.

Questions

Thank You for Your Attention

Any Questions?