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Presenter: Senior Expert Team of EADS Astrium, Germany

1. Measurement Performance of Basic Compact Range Concepts

Compact range test facilities represent a high standard for fast real-time and precision measurements. Nowadays, test applications are varying from single antennas to full payload antenna platforms, full-scale RCS and imaging objects to be tested within a frequency range starting from some 100 MHz up to 1000 GHz and beyond.

Different facility types were developed during the last 30 years and for the different applications a variety of facility optimizations were performed. Up to now, mainly three different types of compact test ranges are used and installed worldwide.

This paper gives an overview of the facility types i.e. Single Reflector, Dual Cylindrical Reflector and Compensated Compact Ranges with its advantages for specific applications and also pros and cons when compared to each other. The facilities were analyzed with a proven software tool so that performance data for the plane wave quality, the measurement accuracy and system characteristic data including impact on radiation pattern related to different sizes of test antennas could be extracted for comparative analyses.

2. Compensated Compact Test Ranges for Space Applications

Compensated compact ranges and planar near-field systems represent nowadays the standard for highest accurate measurement of space applications such as satellite antennas and payload systems. For highly efficient testing of multi-feed and multi-beam satellite antennas compact ranges exhibit high measurement accuracy. Further, for applications in the mm-wave frequency range compact ranges represent already the required highly accurate measurement state.

The testing of large antenna platforms requires large test facilities for an efficient testing of the antennas of communication satellites. For that aim the CCR 75/60 and the CCR 120/100 of Astrium was developed in order to ensure a quiet zone from 5.5 m to 8.5 m in diameter and 6 to 12 m in depth. The quiet zone diameter was adapted to the minimum required size of antenna payload testing. With an additionally optimized design of the sub- and main reflector serrations, the quality of the test facility could be significantly improved.

Regarding economic aspects, modern test facilities are no longer used only for testing mainly one type of application as e.g. reflector antennas. Highly accurate test facilities can be extended for measurements of multi-purpose test objects ranging from extremely large antennas and satellite antenna platforms to omni-directional antennas, RCS objects and payload parameter.

Within the paper, acceptance test results of the extremely large and highly accurate Compensated Compact Ranges CCR 75/60 and CCR 120/100 will be shown which demonstrate the excellent RF behaviour of the range comprising a frequency range from at least 1 up to 100 GHz. Further, the measurement capability of different applications will be shown and demonstrated with measurement results.

3. Extended Applications for Existing Compact Ranges by additional Integration of Near-Field Scanners

This topic addresses the applicability of near field scanners in existing compact test ranges. The analysis is motivated by creating multi-purpose test chambers having the advantages of both, near field systems and compact test ranges. The discussion comprises the proper installation position of near field scanners inside a typical compact test range. A ray tracing analysis is presented taking these positions into account in the assessment of near field errors due to multi-path reflections. It is shown how reflections from the absorbers and reflectors have different impact on near field measurements for low, medium and high gain antennas. The impact is quantified in terms of error levels used in common near field error budgets. It is demonstrated that the combined approach is realizable for specific configurations only.

The outcome of this presentation will be a view insight future multi-purpose test facilities able to deal with a variety of antenna measurement tasks. In addition, a way of simulating test facilities is shown to the participants. Limits of current simulation tools are discussed to reveal the strengths and weaknesses of recent computational power for the investigation of extended measurement applications in large test ranges.

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

The measurement accuracy of state-of-the-art RF test facilities like near-field or compact test ranges is influenced due to applied system hardware as well as operational facts which are influenced by human errors. The measurement errors of near-field test facilities were analyzed and published in the past times and are based on the 18-term error model of Newell. For compact test ranges and especially for the cross-polar free compensated compact range a similar error model was established at Astrium GmbH within a study for the satellite service provider INTELSAT in order to define possible facility performance improvements and maximum achievable values for the measurement accuracy. It has to be remarked, that test programs for space applications require very stringent adherence to procedures and documentation of process steps during a test campaign.
In general, for testing the RF performance of space products like satellites or payload modules and its antennas, state-of-the-art test facilities with proven procedures and optimized processes for time efficient testing are required. The procedures have to cover the range maintenance, valid for the facilities lifetime and the test program itself, which is valid for each individual measurement program. All necessary documents are described in the ISO 9000 standard definitions.

Within this paper, a facility trade-off with description of main error contributions in the two mainly applied types of state-of-the-art RF test facilities will firstly be performed. Furthermore, the error budgets for pattern and gain measurements and achievable performance improvements of the Compensated Compact Range (CCR) of Astrium GmbH will be given. At last, recommendations for process optimizations and procedures will be presented to guarantee the adherence to the valid error budgets and to minimize the Human Factor.

5. RF Test Setup up to 500 GHz for Instrument Testing in Compact Ranges

Earth observation and limb sounder instruments are working in a frequency range between 100 GHz and a few 1000 GHz. For high spatial resolution, instruments such as e.g. MASTER or HERSCHEL/PLANCK imply the use of large antenna aperture dimensions in the order of 2.2 m and 3.5 m. The main requirements to the instruments concerning antenna performance are related to pointing accuracy, beam efficiency and dynamic ranges of ACAP. For reaching outstanding values, mainly the antenna reflector, the feed i.e. quasi optical networks (QON) and the internal alignment of the antenna system have to fulfil the design criteria w.r.t. reflector surface accuracy and pattern and gain values of the feed very accurately. According to the high operating frequencies, the required performance data are in the same order or beyond of achievable performance data, mainly when looking to future THz applications.

During the last years, several studies for ESA/ESTEC were performed at Astrium to analyze the accuracies and limits of RF measurements as well as prediction results out of simulations in the mm-wave frequency range. For that aim, a RF test setup was designed and established in order to measure antenna pattern in large test facilities up to at least 500 GHz with required test accuracy, dynamic range and stability. In the mentioned frequency range, related basic Tx- and Rx-modules are available based on GUNN-Oscillators, multipliers for up-conversion and base-band mixers for down-conversion.

The applied test object is a representative test object which was designed and built during the ADMIRALS study for ESA/ESTEC. The RTO consists out of a 1.5 m offset reflector antenna with 3 m focal-length and using quasi-optical networks for its feed. In parallel, simulations of the test object were performed with different software tools in order to generate prediction results.

Comparisons between measurement and prediction results of the antenna pattern as well as the RF test setup will be presented and discussed.

6. Time Efficient Measurements based on new Network Analyzer Generation

A new generation of RF test equipment requires for efficient utilization an ultra-fast and flexible real time controller for state-of-the-art data acquisition and test control. Astrium developed an own Measurement System Controller (MSC3001) taking into account two design goals: (1) Command compatibility and compatibility of the electrical interfaces with the Multiple Channel Controller HP85330A from Agilent for full replacement, (2) additional functionalities and capabilities as support for automated antenna RF measurements.

The controller unit incorporates as a basic module the Antenna Measurement Real Time Controller and optional a Power Sensor Multiplexer and an Rx/Tx Switch, entirely assembled in a single 19"mounting rack 3U module. Due to the modular design concept further extensions and custom specific tailoring are easily possibly. The MSC3001 is controllable via touch screen and remotely by GPIB and Ethernet. System compatibility with standard measurement instrumentation is ensured.

The presentation explains in detail the measurement system concept as well as typical applications e.g. passive antennas, active antenna control, pulsed radar operation and control of multi-port antennas. Additionally the presentation points out the attainable time efficiency for typical spacecraft antenna measurements in compact range test facilities using state-of-the-art equipment.

7. High Performance Broadband Feeds for Economical RF Testing in Compact Ranges

Compact test ranges are worldwide used for real-time measurements of antenna and payload systems. The Compensated Compact Range CCR 75/60 and 120/100 of Astrium represent a standard for measurement of satellite antenna pattern and gain as well as payload parameter due to its extremely outstanding cross-polar behaviour and excellent plane wave field quality in the test zone. The plane wave performance in the test zone of a compact test range is mainly dependent on the facilities reflector system and applied edge treatment as well as on the RF performance of the range feed.

To provide efficient and economic testing and maintaining the needed measurement accuracy the existing standard set of high performance single linear feeds covering the frequency range from 1 - 40 GHz had been extended to operate simultaneously in dual linear polarisation. In addition several customer specific range feeds had been developed and manufactured and validated. For example a dual band dual circularly polarised M/K-band feed covering the frequency bands from 10.7 - 12.8 GHz and 17.2 - 18.4 GHz had been developed to allow RF measurements of satellite antennas in Tx- and Rx frequency band without changing the test setup configuration. Typical design drivers had been the axial ratio (XPD) better 0.25 dB, return loss and port to port isolation.

Other examples for such costumer specific range feeds are a set of dual circularly polarized feeds covering the extended Tx & Rx C-band range from 3.7 GHz – 4.8 GHz and from 5.7 GHz – 7.5 GHz respectively and the Ka-Band. Also for low frequency applications, a dual linear polarised UHF Probe had been designed and manufactured for a Galileo test campaign.
More detailed information and achieved test results for the new high performance range feeds will be presented.

8. Real Time Satellite Payload Testing in Compact Ranges

The performance of modern Satellites Antennas and Payloads is characterized by physical parameters like e.g. Antenna Pattern and Gain; EIRP, Flux Density, G/T and the overall PIM-performance. The available time frame for measurement of these parameters is getting constantly shorter. The Astrium GmbH Compensated Compact Range (CCR) allows a time efficient measurement of all payload parameters with high accuracy under controlled environmental conditions.

In addition to an efficient measurement facility high-performance measurement equipment is required. The economical budgets of most space programs demand the application of well-known measurement techniques in a cost efficient way. Astrium GmbH has developed an easy to handle and therefore cost optimized measurement platform for Satellite Payload Measurements.

This platform consists mainly of a generic switch matrix operating up to 40GHz which can be connected to a wide range of measurement equipment. The matrix allows a highly flexible routing of the RF uplink and downlink signals including reference paths. Integrated and/or external RF components, like amplifiers, attenuators, and hybrids can be added to the paths, depending on the required test configuration. Starting from a minimum configuration the system can be modularly upgraded to satisfy any further test requirements.

The software interface utilizes standard protocols and can be therefore easily addressed by any user specific measurement software. The Astrium GmbH Advanced Antenna Measurement System (AAMS) includes an optional payload toolbox which provides a modular concept expandable for additional test functions.

The presentation explains the theory and measurement relations behind the typical spacecraft payload parameter testing, depicts RF set-ups for radiated measurements at the up- and downlink, shows error budgets and demonstrates the advantage of utilizing a generic switch matrix for payload measurements.