DLR-HR Compact Test Range Facility

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***Abstract*— A Compact Test Range (CTR) facility shall extend the measurement capabilities at the Microwaves and Radar Institute of the German Aerospace Center (DLR) in Oberpfaffenhofen. Today's accuracy requirements in the RF-component characterization are decisive factors for the specification of a new measurement facility. Parts of a Compact Antenna Test Range (CATR) model 8074B, manufactured by March Microwave Systems B.V., have been purchased by the Institute in 2006. On the basis of these components, a compact test range in a new building named 'HF-TechLab' is currently under construction. It is planned to be operational at the end of 2009. An overview of the entire CTR facility is the objective of this paper.**

I. Introduction

Antenna measurements have been performed by the Microwaves and Radar Institute on the site in Oberpfaffenhofen from 1937 on. The activities included 'in-flight' measurements of airborne antennas for reconnaissance and flight navigation systems. Additionally developed measurement methods were based on stationary facilities and ground mobile equipment as well as captive balloons.

After years of improvements in antenna and RCS measurement methods, several outdoor antenna ranges have been established. 'AMA' ('Antennen-Mess-Anlage'), the latest system is operating until now. The AMA is an elevated antenna range with a rail-mounted model tower carrying the transmitting antenna under test 8.5 meters (28 ft) above ground. With the down range movable model tower, measurement distances can be up to 180 meters. Especially for frequencies down to the VHF band, the test range is well suited. Measurement accuracy for antenna and RCS measurements are in the range of ± 1 dB. Besides the known limitations of outdoor free-space ranges, the AMA operation is more and more impeded by growing building activities on the Oberpfaffenhofen site and frequency interferences due to the very close airport.

Present accuracy requirements in the RF-component characterization ask for a reliable but very versatile highly accurate measurement system working under controlled environmental conditions. A facility of shielded anechoic chambers was designed to include the new compact test range as well as the already existing bi-static W-band system and a multi-purpose chamber. With the purchase of pre-owned key components of a CATR, the Microwaves and Radar Institute of the German Aerospace Center was in the position to build-up an own CTR facility in Oberpfaffenhofen for research and development purposes as well as for third-party funded measurements. This CATR system was originally manufactured by March Microwave Systems B.V. [1] and operated in Germany from 1993 on.

II. CTR Facility

The Compact Test Range facility (CTR) will combine three measurement systems in one complex. A common control room will be used for the large CTR and the smaller W-band bi-static measurement system, see Fig. 1. W-band chamber, control room and CTR feed system are arranged on the first floor level. An additional room for reflection measurements is located underneath the W-band chamber.

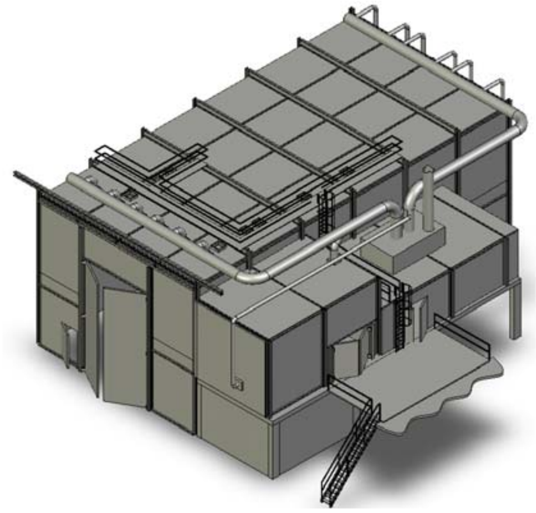

Fig. 1: Perspective view of the CTR facility.

U-frames of steel girders, filled-out with lightweight sandwich panels, form the construction principle of the facility. The spacing in the framework is 4 meters. The panels are made of expanded polystyrene (EPS) that are covered on both sides with steel plates of 0.8 mm thickness. The steel plates on the inner side are hot-dip galvanised. To ensure the required shielding property of the structure, the panels have overlapping joints that are additionally sealed with a metallic adhesive tape. The inner surface appears plane and smooth to install the absorbing material. The technical installations are routed outside the chambers. For service and maintenance, the lamps and fire detection units can be accessed from the roof tops. A separate air conditioning unit is located on top of the control room. It is used to regulate the environmental parameters inside the chambers.

A balcony is connecting the CTR facility to the corridor of the HF-TechLab building on the first floor, see Fig. 1. A staircase to the ground floor provides easy access to the CTR chamber.

This complex of shielded chambers is setup in the hall of the new 'HF-TechLab' building that is currently under construction. An adjacent wing provides adequate space for the Institute's laboratories. The workflow will benefit from the close neighbourhood of these twelve different laboratories and the measurement facility. HF-TechLab will be operational from the end of 2009 on.

In the following chapters the components of the CTR facility will be described in more detail including mechanical dimensions and electrical specifications.

A. CTR Chamber

The CTR chamber is a shielded anechoic room of inner (clear) dimensions 24 x 11.7 x 9.7 meters (l x w x h). A large gate, 7.5 meters in height and 5.3 meters in width is located in the receiving wall of the CTR chamber. Two supplementary doors enable personal access. Outside the chamber a gantry crane is located to handle the DUT.

The CTR chamber will be used for the characterisation of antennas, active and passive RCS targets and further on, for the calibration of pulsed radar systems. Operational frequency range of the chamber will start at 300 MHz and it is specified up to 100 GHz. A dual reflector system is used from 1 GHz upwards. At lower frequencies the reflectors appear too small for properly focusing. Anyhow, direct illumination of the target / DUT or near field scanning shall be feasible. Cylindrical as well as spherical near field scanning methods will be implemented.

Shielding requirements are specified to be not too stringent. The defined shielding capability from 300 MHz up to 40 GHz is shown in Fig. 2. Above 40 GHz the absorber material will have sufficient absorbing capability to avoid interferences with the ambient electrical environment.

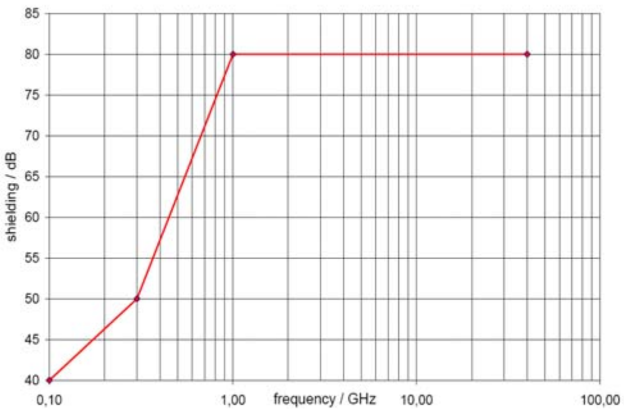

Fig. 2: shielding requirements on CTR chamber.

The absorber layout is designed to meet all above mentioned applications. Emerson & Cuming Microwave Products [2] from Belgium will supply and install the absorbing materials. They calculated an optimum layout for the CTR chamber by involving the manufacturer of the dual reflector system as well as the Microwaves and Radar Institute. Different types of ECCOSORB pyramidal foam absorber are provided:

- VHP-36-NRL on the receiving end wall (91.4cm),
- VHP-18-NRL manly on the side walls, the ceiling and on the floor (45.7cm),
- VHP-26-NRL in corners and in other dedicated areas (66.0cm),
- HFX-18-HC honeycomb hollow, pyramidally-shaped, high power absorbers in the feed area.

Side walls will be lined in a diamond shape (at 45° angle) to enhance the backscatter behaviour of the pyramids for RCS measurements. To be prepared for a variety of measurement tasks, it is decided to use no wedge absorbers. Hence, the CTR chamber is well equipped for measuring targets of medium radar cross section. Complementary to that, the W-band chamber is designed to cover measurements on the very low RCS targets.

A 6-axis Orbit/FR [3] model tower is available to manipulate the device under test inside the chamber. The parameters of the Orbit/FR model tower are:

- 6 axis – two linear slides, elevation over azimuth, roll over azimuth,
- maximum DUT load 300 kg,
- 1 pick-up elevation axis with 200 kg maximum load,
- all axis' accuracy better ±0.03 degree.

The first axis of the model tower is a linear travel of 19 meter in length, in a pit, that allows this unit to exit the chamber completely via the large gate. The linear travel gives room for a second slide that can then be used to mount an RCS target on a specially designed tower. The size of the pit is 20 by 4 by 2.5 meters (l x w x d) that allows the concurrent operation of both towers inside the chamber for near filed measurements (cylindrical readings, about 5 m vertical scanning range). Moreover, it is designed to mask out the major bulky parts of the model tower. Additionally, it gives room to hide a target access elevator. Cover panels on the pit are lined with microwave absorbing materials.

The core component of the CTR chamber is the dual reflector system by March Microwaves Systems. The shape of the both reflectors describes a section of a parabolic cylinder. The dimensions of the main reflector without serrations are 4.8 (width) by 3.8 meters, the subreflector is 2.89 by 3.8 meters. Cosine-shaped serrations are applied to both reflectors. The length of the serrations is 1.6 (horizontal) and 1.8 meter (vertical), see Fig. 3. This dual reflector system is a model 8074B in the March nomenclature.

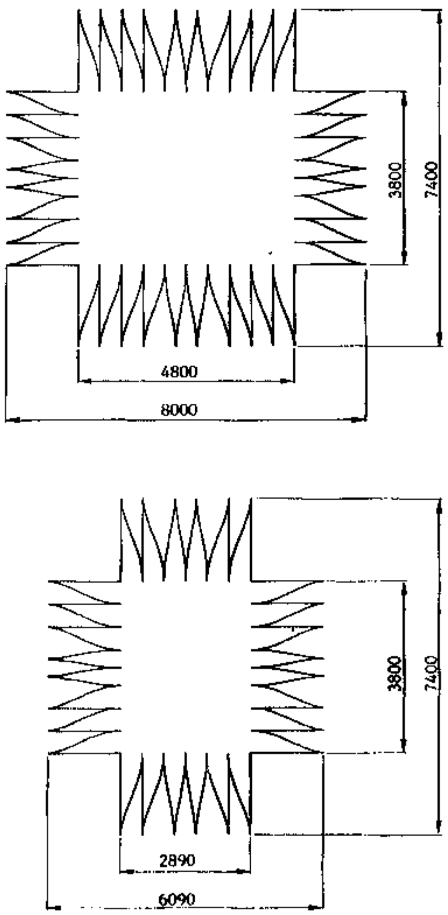

Fig. 3: Reflector dimensions in mm. Top: main reflector; bottom: subreflector.

The focal length of the main reflector is about 10.5 meters whereas the focal length for the subreflector is approximately 9 meters. The quiet zone diameter at 5° phase variation is 3 to 3.6 meters in the general specification of model 8074B. Verification measurements of the quiet zone with this reflector arrangement result in a quiet zone diameter of up to 3.8 meters, depending on the frequency. The maximum tolerable phase deviation for the quiet zone there is 5.2°.

Measurements that were carried out prior to the disassembly of the CATR showed good results. The performance for antenna measurements in the specified frequency ranges was entirely satisfactory. With the new absorber layout, a proper reflector alignment and a new set of feed antennas, the performance can be enhanced in the future.

The feed system is mounted on a combination of two linear slides to allow easy exchange of the feed antenna and to adjust them to their phase center. There are several options for the configuration of the feed system:

- the original configuration with 'impedance walls',
- an enhanced feed antenna without impedance walls,
- slewing the feed from the dual reflector system to the DUT for direct illumination.

In either case the feed antenna is mounted on an Orbit/FR polarisation turn table.

B. W-Band Chamber

The second shielded anechoic chamber is designed for W-band measurements (70 – 110 GHz). The inner dimensions are 8.5 x 5.2 x 5.0 meters (l x w x h). A double leaf door is used as entrance into the chamber. Two hatches at the connecting wall to the control room increase the flexibility of the facility. With the measurement chamber located on the first floor, the quality of the chamber floor slab was carefully examined. This results in a concrete slab that is separated from the rest of the facility. Consequently, the measurement system is protected from interference with vibrations in the building.

Shielding requirements are the same as shown in Fig. 2 for the CTR chamber. A well established measurement system of the Microwaves and Radar Institute will be moved into the new W-band chamber.

The specification of the absorber material allows measurements down to X-band, as well. No application specific absorber layout is used, because no dedicated path or direction of microwave energy is given. Only one type of ECCOSORB VHP-4-NRL (10.1 cm) pyramidal absorbers is applied inside the entire chamber.

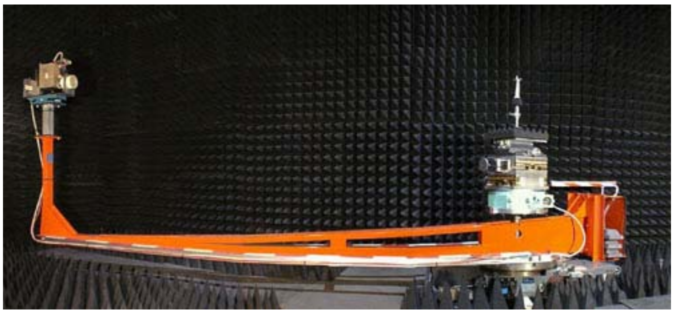

Fig. 4: Mono-static and bi-static RCS measurement facility with a test object on the rotator in the centre, the transmitting antenna on the arm (left) and the receiver (right).

The W-band chamber is mainly used for bi-static reflection measurements on canonical targets and on scaled models, for example, tactical aircrafts. This system is based on a balanced, rotating arm, where the DUT is mounted in the center of rotation, see Fig. 4. Furthermore, it is well suitable for a variety of measurement applications like feed antenna characterisation.

C. Control-/ Feed Room

The control room of the CTR facility is used to operate both shielded anechoic chambers. There, a shielding is not required. Consequently, the doors and windows, the air-conditioning system and the electrical installations are much easier and less expensive.

1) *Control room*: The control room houses the electrical installation and sub distribution for the complete CTR facility. Its base area is 11 x 5 meters. Our experience shows that the W-band chamber is not constantly in use, therefore, the space for the operators and customers inside the control room is considered to be sufficient. A short balcony or walkway

connects the control room with the laboratories and the offices of the HF-TechLab. There, customers will find a well equipped working environment and it provides additional storage area for the feed system equipment.

For a versatile operation of the CTR, two hatches are installed in the connecting wall of the control room and the CTR chamber. Both hatches measure about 1.2 by 1.65 meters in size. One of them is assigned to the feed system; the second one is for supplemental measurement methods like radar system characterisation. There, the chamber is used as a termination for the antennas including a pulse delay unit to simulate the propagation effects, range delay and target's RCS properties.

The control room has an individual air conditioning system which is connected to the buildings ac-system. Thus, the working conditions can be adjusted independently to the conditions inside the chambers. The system ensures a constant temperature and low humidity to ensure long lifetime of the absorber material and all other devices installed inside the chambers.

2) *CTR Feed System:* The feed system of the CTR chamber is integrated into the control room. That gives easy access to the polarisation turn table and the feed antenna, mounted on the slide system. Moreover, an antenna can be mounted perpendicular to the standard orientation on that slide system, for direct measurements. For proper shielding capability, the feed system closes the chamber with a matched plate when it is pushed forward into the operating position.

D. Bi-Static-Reflection Measurement System

Underneath the W-band chamber and the control room, a chamber for an additional reflection measurement system is available. This system measures the forward reflection under different angles of a rotating probe. Two mechanically connected arms ensure that both of them have the same angle in respect to the probes surface normal.

The mechanical construction of this room is identical to the whole CTR facility but no special requirements on shielding are defined. The room will be covered with pyramid absorbers for operations in X-band. Additionally, there will be sufficient room for a separate control area.

III. Conclusions

The combination of the CTR facility within the HF-TechLab will bring the Microwave and Radar Institute in an advantageous position for its work in research and development. An optimum working environment will be available with the established microwave measurement systems together with the new CTR chamber and the nearby laboratories.

The goal is to develop new innovative measurement methods besides performing standard measurements of antennas, signatures and RCS. An important working field of the Microwaves and Radar Institute is Synthetic Aperture Radar (SAR) covering technology, hardware development, algorithms, data takes on radar missions and processing of images. The whole process chain is handled within the Institute. From that experience, we believe that SAR processing techniques like SAR tomography can give a significant impulse to indoor RCS measurements.

Certification of the CTR facility is a goal in the near future, to ensure a constant quality level for internal and external customers. This is a first step in the accreditation process that qualifies the facility for test and certification measurements of new antennas and / or radar systems for the third party market.

References

[1] "CATR 8074B", March Microwave Systemes B.V., Nuenen, Netherlands

[2] "Absorber Data sheets", Emerson & Cuming, Westerlo , Belgium

[3] "Data sheets", Orbit/FR - Telemeter Elektronic GmbH, Donauwörth, Germany