Compact Antenna Test Range with New Shorter Focal Length for Heavy Duty Antenna Measurements

A. Jernberg[1], M. Pinkasy[2], G. Pinchuk[2], T. Haze[2], R. Konevky[2], L. Shmidov[2], R. Braun[2], A. Giacomini[3], L.J. Foged[3], G. Baran[4], M. Boumans[5]

[1] MVG Sweden, Alingsås, Sweden, anders.jernberg@mvg-world.com

[2] Orbit/FR Engineering Ltd, Emek Hefer, Israel, roni.braun@mvg-world.com

[3] Microwave Vision Italy SRL, Pomezia, Italy, andrea.giacomini@mvg-world.com

[4] PIT-RADWAR S.A., Kobylka, Poland, grzegorz.baran@pitradwar.com

[5] Antenna Measurement Experts GmbH, Ottobrunn, Germany, marcel.boumans@amxprts.de

***Abstract*—In this paper a new shorter focal length design of a Compact Antenna Test Range (CATR) is presented. The new geometry allows the chamber size to be kept about 50% smaller than the geometry of the traditional CATR design. The range we present here has a cubic quiet zone (QZ) of 4.8 x 4.8 x 4.8 m, operating from 0.9 to 18 GHz within a chamber measuring 22 m x 14.5 m x 14.5 m. The design is based on a novel, diagonally fed, short focal length reflector.**

***Index Terms*—antenna, measurement, CATR, new shorter focal length.**

I. INTRODUCTION

The goal of the CATR presented here was to provide a cost-effective measurement system primarily for radar antennas, with excellent co-polarization antenna performance, and reasonably cross-polarization performance. The reflector is a rolled edge design with a shaped skirt to minimize overall size and maintain good low frequency performance. The construction consists of multiple panels, see Fig. 2, manufactured with high accuracy machining. Each panel is positioned in its exact place with individual control from the back structure. The CATR is equipped with a six axes positioner consisting of a roll over upper azimuth, elevation, upper slide, lower azimuth over lower slide. The feed system is fully automatic and covers the frequencies 0.9-18 GHz using a set of newly developed dual polarized full octave feeds that has a gain optimized for the reflector's short focal length. We will here present design considerations and the QZ field probing results.

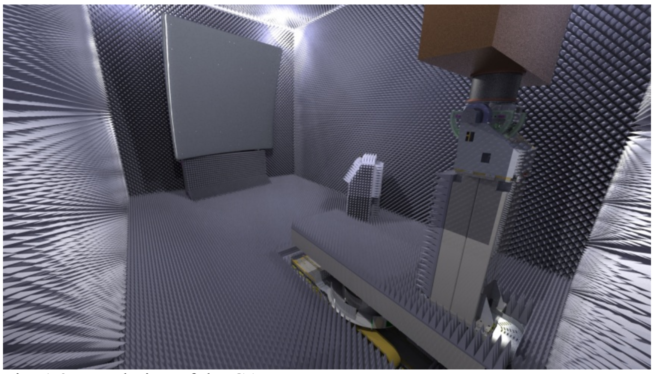

Fig. 1 3D rendering of the CATR.

Fig. 2. Photo from the laser tracker alignment of the reflector segments.

II. DESIGN CONSIDERATIONS

The QZ should be a cylinder of 4.8 m diameter and 4.8 m depth, it should also have an extended cubic quiet zone of 4.8 m with a lower specification. The requirements, in particular the cross-polarization, make a short focal length reflector suitable, which leads to a more compact chamber [1]. The diagonal offset fed system also reduces the chamber length, since the feed can be placed closer to the QZ in down range direction, compared to a floor fed system that must have the antenna positioner system behind the feed system where the positioner floor slide must be placed further away from the reflector. A larger offset angle moves the feed system away from the plane wave and reduces reflections and diffractions. The feed system is also further away from the antenna positioner and thus has less potential for mechanical conflicts. Further the corner fed system minimizes direct feed leakage in both Az & El main cuts, which was relevant for the use of the El/Az and Az/El measurements allowed by the antenna positioner.

With the lowest frequency 0.9 GHz, which is higher than normal for this QZ size, the rolled edge could be kept much smaller than the typical rolled edge reflector design, where the rolled edge size is half the QZ size [2]. Thus, the rolled edge was taken 1.5 m wide instead of 2.4 m, reducing the total reflector size to 7.8 m x 7.8 m instead of 9.6 m x 9.6 m, see Fig. 3. This keeps the reflector cost low and the cross-section of the chamber small.

All of these design considerations resulted in a chamber size of 22 m x 14.5 m x 14.5 m, which is very compact considering the quiet zone size, see Fig. 1.

With low cross-polar feeds, the QZ cross-polarization is driven by the reflector geometry. Due to compact dimensions of the reflector, the cross-polar is higher than traditional CATR designs. The optimized performance nevertheless better than -30 dB in the central 40% of the QZ with worst case -21 dB at the outer edge of the cylindrical QZ and -18 dB at the outer edge of the extended cubic QZ.

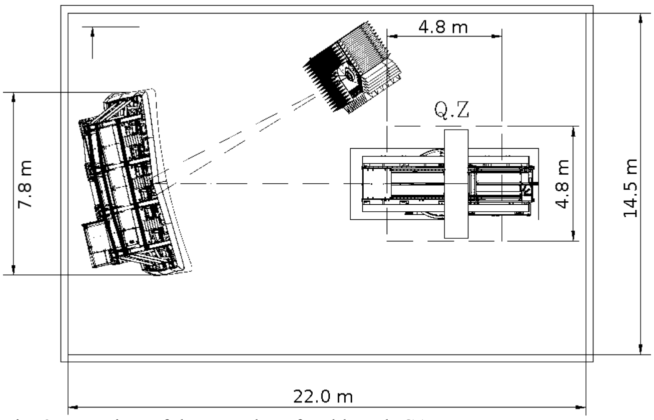

Fig. 3. Top view of the new short focal length CATR.

III. FEED SYSTEM

A. Feed station changer

The feed system has five stations, each one with a polarization positioner. The revolver movement can automatically change to cover the full frequency band 0.9-18 GHz, the feed changer is hidden within the baffle house that can be seen in Fig. 8.

B. Dual polarized octave band feeds

The short focal length design of the CATR described in this paper requires feeds with low gain characteristics. A new series of low-gain dual-polarized corrugated horns have been specifically conceived to ensure quiet zone (QZ) performance over the full frequency range of the measurement system, from L- up to Ka-band. These feeds, referenced as LGF-11 series, exhibit a stable rotationally symmetric radiation pattern, matching the reflector illumination requirements and ensuring an amplitude taper in the quiet zone (QZ) below 1dB. The corresponding directivity levels at primary pattern level are between 10-12dBi, with very low cross-polarization within the reflector field-of-view.

These feeds, one shown in Fig. 4, are typically composed of the ortho-mode-junction (OMJ) feeding two orthogonal polarizations to the common waveguide, the radiating aperture, and the absorber provisions minimizing the scattering from the mounting fixture and the positioner. In addition, all feeds are equipped with highly accurate mechanical interfaces, containing an integrated spirit level as a polarization reference.

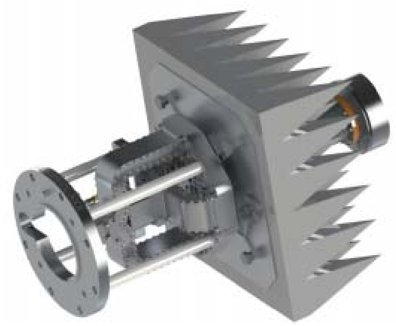
Fig. 4 Octave band dual pollarized CATR feed.

Dual polarization high-precision performance is obtained over a wide operational bandwidth by two different OMJ design approaches, both taking advantage of a balanced feeding scheme.

Below 4 GHz, feeding of the OMJ is done by precision 3dB/180° hybrid couplers based on a coaxial technology [4] and [3]. The couplers are connected to the OMJ with the semi-rigid phase equalized RF cables.

Above 4 GHz, a proprietary OMJ design in ridge waveguide has been used [3]. The OMJ contains two independent polarization channels (H and V). Each channel connects the input RF connector to the radiating aperture with a cascade of ridge waveguide blocks: a connectorized waveguide launcher, an E-plane splitter, two equalized side arms and a balanced turnstile orthomode-transducer (OMT). The waveguide launcher is a transition from a coaxial interface to a double ridge waveguide with a custom designed cross-section. The transition design ensures pure mono-mode excitation over the whole operational bandwidth and enhanced matching. The transition is connected to the E-plane splitter which divides the double ridge waveguide into two single ridge waveguides with identical cross-section. The split signals are then routed by two equalized side arms connecting the E-plane splitter and the OMT. Finally, the OMT guides the signal from the single ridge waveguides to the common waveguide in form of an oversized coaxial structure. Coaxial structure is used to control the modal conversion and impedance matching by tuning the parameters of the inner conductor.

The main advantage of the presented feeds is the frequency coverage of each individual feed exceeding the full-octave bandwidth. Measurement time efficiency can also be further improved using pin diode RF switches [5]. This allows the measurement of both complex components (H and V) radiated by the antenna under test (AUT) within the same acquisition scan.

As a summary, electrical characteristics of the feed series covering the system frequency range is reported in TABLE I. The measurement system bandwidth can be covered according to the standard radar frequency bands (L, S, C, …)

or considering the interleaved frequency bands, providing an extended degree of freedom for the end-user in the coverage of RF spectrum with the most appropriate feed selection. It should be also pointed out that these feeds allow to reach extreme performance in terms of cross polar discrimination in the QZ when used in their initial half octave frequency band.

TABLE I. FEEDS FOR FULL COVERAGE FROM 0. 9 TO 18 GHZ

Part number	Freq. [GHz]	Polarization	Directivity [dBi]
LGF-11-090-WB-DL	0.9 – 1.7	Dual linear	11
LGF-11-170-DL	1.7 – 2.6	Dual linear	11
LGF-11-260-SL-HP	2.6 – 4.0	Single linear high power	11
LGF-11-400-WB-DL	4.00 – 8.20	Dual linear	11
LGF-11-820-WB-DL	8.20 – 18.0	Dual linear	11

IV. HEAVY DUTY POSITIONING SYSTEM

This CATR is designed to handle a large variety of antennas and the positioning system can be setup in three different measurement configurations.

A. *Bottom mounted DUT using lower azimuth*

Elevation over azimuth configuration for large DUT that is mounted on top of the upper azimuth turntable, see picture A in Fig. 5. The Upper Slide is used for alignment of the DUT phase center with the lower azimuth axis of rotation.

B. *Bottom mounted DUT using upper azimuth*

Azimuth over elevation configuration for large DUT to be mounted on top of the upper azimuth rotator, see picture B in Fig. 5. Main operational axes in this case are: Upper Azimuth and Elevation.

C. *Back mounted using an additional upper roll turntable*

Roll over azimuth using additional roll axis and lower azimuth, this setup is for smaller DUT mounted with its backside to the upper roll, see configuration C in Fig. 5. The roll turntable is mounted to the upper azimuth on top of a base riser.

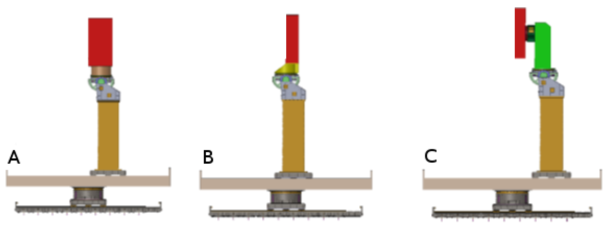

Fig. 5. Device under test positioner showing three configurations.

V. QUIET ZONE SIMULATION AND MEASUREMENTS

A. *Simulations*

The reflector design, in particular the design of the blended rolled edge, was performed using Physical Optics (PO): the far field feed pattern is projected on the reflector, from which surface currents are derived. From these currents the fields in the quiet zone are calculated using the Maxwell equations through numerical integration.

One clearly sees that the shape of the quiet zone has a near-square cross-section at 1 GHz, see Fig. 6. There is a steep roll-off of the amplitude at the corners, due to the fact that at this low frequency one is not in the quasi-optical operation of this CR (strong divergence of the energy). This effect disappears at high frequencies.

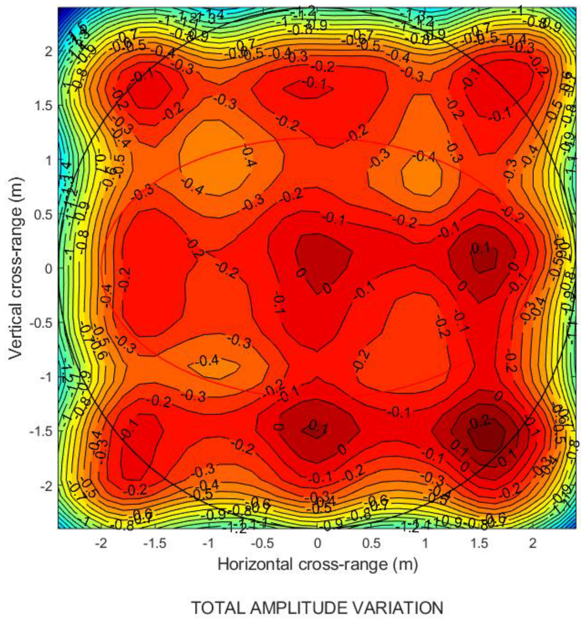

Fig. 6. Co-polarization PO simulation at 1 GHz.

The cross-polarization is not as good as in classical compact range geometries, but more than sufficient for the application, see Fig. 7. In those cases where better cross-polarization is required, this is always possible with the use of a CXR feed [7].

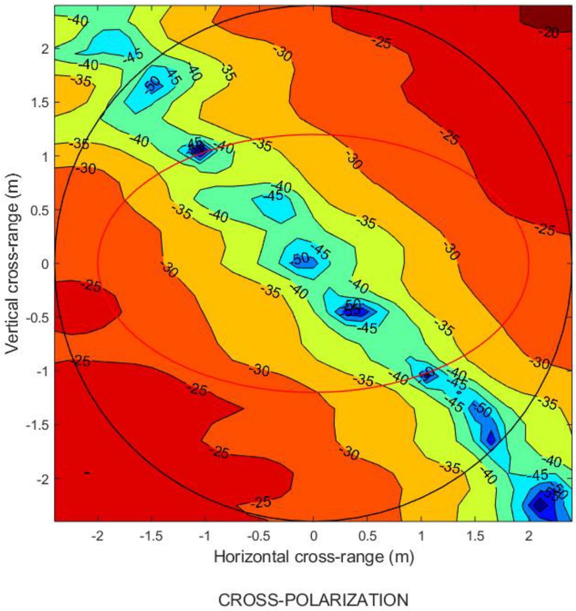

Fig. 7. Cross-polarization PO simulation 1 GHz.

Fig. 8. Field probe scanner mounted on the DUT positioner at diagonal -45 degree.

B. *Field probe scanner*

A field probe scanner [8] with 7 m travel was mounted on the upper azimuth aligned to the boresight of the CATR, see Fig. 8. The QZ has been tested in front, center and back down range positions. In each of these planes the horizontal, vertical and +/- 45 degree diagonal cuts have been measured with amplitude and phase for all four combinations of two orthogonal polarizations between the feed and the SGH that was used as the probe.

C. *Measurment results*

We are here presenting the two diagonal cuts at the central down range position for 1 GHz in Fig. 9 and Fig. 10, 18 GHz in Fig. 11 and Fig. 12.

All results are similar to our predictions.

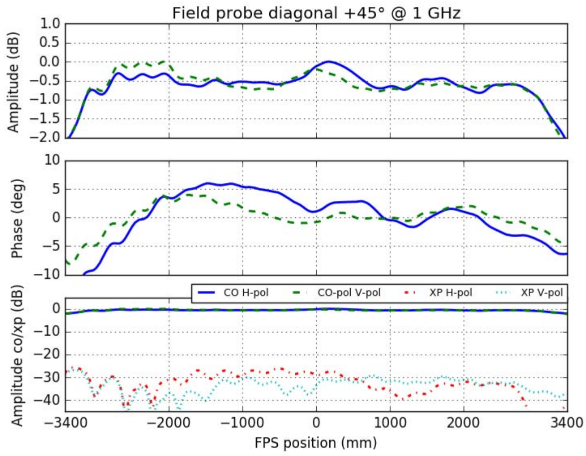

Fig. 9. Diagonal cut +45 degrees at 1 GHz.

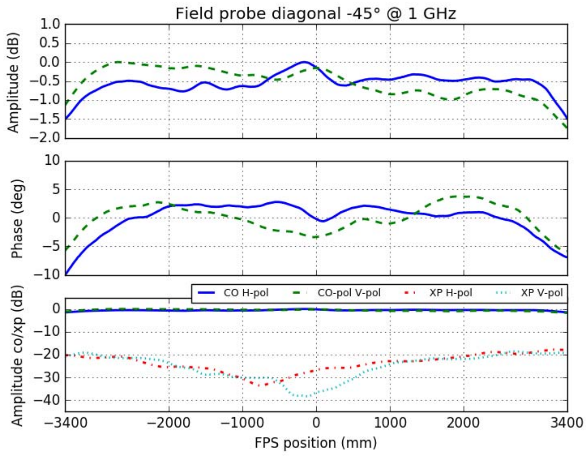

Fig. 10. Diagonal cut -45 degrees at 1 GHz.

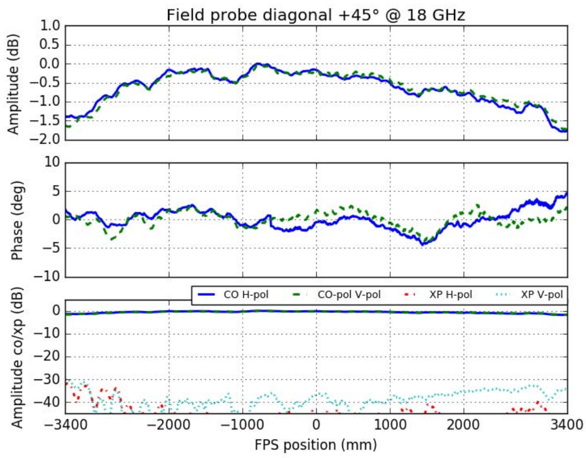

Fig. 11. Diagonal cut +45° at 18 GHz.

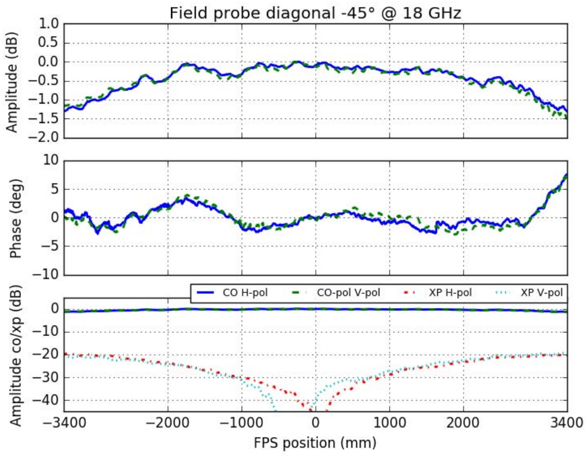

Fig. 12. Diagonal cut -45° at 18 GHz.

VI. CONCLUSIONS

A new Compact Antenna Test Range (CATR) with a cubic quiet zone (QZ) of 4.8m x 4.8m x 4.8m in the frequency range of 0.9-18 GHz has been presented. The system has been built and delivered by MVG as a turnkey facility. The rolled edge reflector with custom shaped skirt, diagonal feeding and shorter focal length allows the system dimensions to be reduced to half the volume within a building. The final system fit the chamber dimensions of 22m x 14.5m x 14.5m. The experimental results, measured by field probing of the QZ have been reported, showing a good correlation with predictions and full compliance to requirements.

ACKNOWLEDGMENT

The authors of this paper would like to thank the PIT-RADWAR team for the excellent cooperation in this project.

REFERENCES

[1] M.Boumans, "Influence of Range Geometry and Feed Characteristics on Compact Range System Level Performance", AMTA 2004, pp.221-226.

[2] Inder J. Gupta, Kurt P. Ericksen, Walter D. Burnside, "A method to Design Blended Rolled Edges for Compact Range Reflectors", IEEE Transactions on A&P, Vol 38, No. 6, June 1990.

[3] L. J. Foged, L. Duchesne, L. Roux, Ph. Garreau, "Wide-band dual polarized probes for high precision near-field measurements", AMTA 2002, Cleveland, OH;

[4] L.J. Foged, A. Giacomini, R. Morbidini, "Dual-Polarized corrugated horns for advanced measurement applications", Antennas & Propagation Magazine, Vol 52, No 6, December 2010.

[5] L. J. Foged, A. Giacomini, R. Morbidini, V. Schirosi, "Dual Polarized Near Field Probe Based on OMJ in Waveguide Technology Achieving More Than Octave Bandwidth", AMTA 2014, Tucson, AZ;

[6] L. J. Foged, A. Giacomini, H. Garcia, S. Navasackd, C. Bouvin, L. Duchesne, "Wide-band dual polarized probe for accurate and time efficient satellite EIRP/IPFD measurements" AMTA 2005, Oct. 30-Nov. 4, Newport, RI.

[7] A. Giacomini, L. J. Foged, A. Riccardi, J. Pamp, R. Cornelius, D. Heberling, "Improving the Cross-Polar Discrimination of Compact Antenna Test Range using the CXR Feed", 38th Annual Meeting and Symposium of the Antenna Measurement Techniques Association, AMTA, Oct 30th-Nov 4th, 2016, Austin, Texas, USA

[8] IEEE Standard. Test Procedures for Antennas, ANSI/IEEE Std. 149-1979, Aug.1980