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ADVANCED SERRATION DESIGN FOR COMPACT RANGES WITH UTD

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Abstract

Nowadays, highly accurate antenna pattern and RCS measurements are performed in compensated compact range test facilities, which fulfil the stringent space requirements for measurements up to 500 GHz and more. As the suppression of diffracted fields from the reflectors mainly determine the quiet zone field performance, the reflector edge treatment is an important design parameter for this type of test facilities. Within the present paper a novel serration design will be shown. The analyses as well as measurement results exhibit a clear improvement of the quiet zone field performance when compared to previous solutions.

The new serration design was implemented and proved with the CCR 20/17 of Astrium GmbH at the Munich University of Applied Sciences.

Keywords: Antenna Measurement, Compact Range, Serration Design

1. Introduction

Compact range test facilities represent a standard in fast realtime and high precision antenna and RCS measurements within a frequency range from 1,5 to 200 GHz and beyond [1]. With an optimized feed characteristic and the suppression of multipath propagation, the edge treatment of compact range reflectors mainly determine the performance of the plane wave field in the quiet zone. Existing solutions result either in the application of serrated or blended rolled edges for suppression of the reflector diffracted fields. In double reflector compact ranges, serrated edges are superior to rolled edges, which cause direct reflection effects, degrading the plane wave field in the quiet zone. Additionally, the manufacturing process of serrated edges is less expensive.

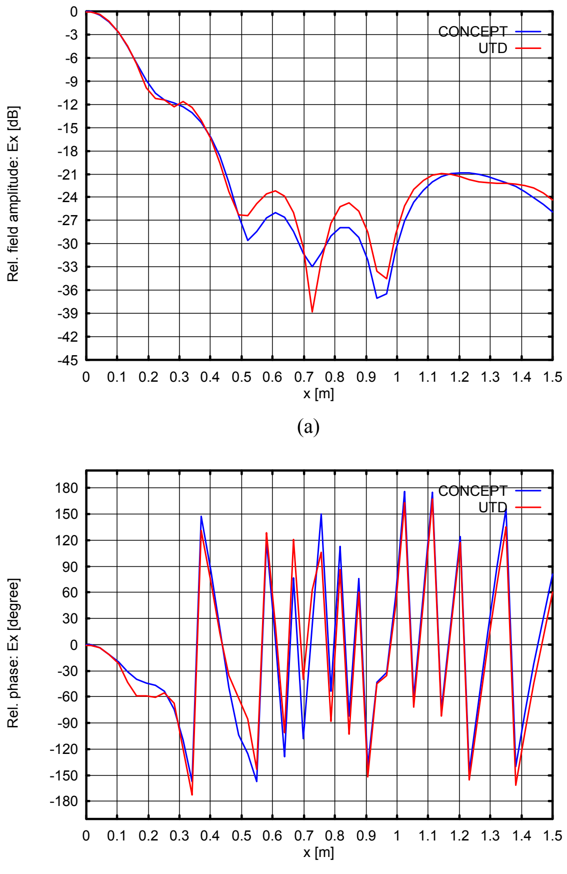
Within this paper, performance improvements for compensated compact ranges with serrated edges will be presented, which exceed the basic requirements of ± 0,5 dB and ± 5 degr. for the co-polar ripple and - 40 dB for the maximum cross-polar field amplitude in the quiet zone [2]. The improvements were obtained by the application of an optimized serration design, based on analytical analyses of the investigated test facility.

2. Quiet Zone Field Analysis

With respect to the electrically large dimensions of compact range reflectors with fine contoured rim structures as e.g. serrations, an analysis tool for the quiet zone field calculation has to combine the properties of acceptable computation time with the required prediction accuracy. Generally, existing methods can be divided in exact and asymptotic methods, as well as hybrid methods, whereas the calculation time of the numerically solved exact methods and the accuracy of the asymptotic methods mainly determine its applicability. Hybrid methods were increasingly developed during the last few years.

For the analyses within this paper, a newly developed analysis tool was applied, based on the combination of Geometrical Optics (GO) and Uniform Geometrical Theory of Diffraction (UTD). The analysis tool provides a very time efficient and accurate calculation of the quiet zone field. For optimization purposes, it allows an easy variation of the geometrical parameters of the serrations.

The accuracy of an analysis tool, based on an asymptotic method, mainly depends on the considered diffraction effects and its solution methods. With the developed GO/UTD analysis tool, the effects of reflection and diffraction by edges, corners and discontinuities in the reflector curvature of arbitrarily curved and contoured reflector structures can be calculated. Single reflector systems as well as simplified double reflector systems can be implemented. The applied and further improved UTD diffraction coefficients are based on the coefficients published by Kouyoumijan and Pathak [3], Sikta and Burnside [4] and James [5].



(a)

(b)

Figure 1: Comparison of amplitude (a) and phase (b) pattern: x-cut, x-polarization, z-dist. = 100 λ

CONCEPT analysis results 🟥

GO/UTD analysis results 🟦

For verification of the GO/UTD analysis tool, a comparison with the software tool CONCEPT was performed, which is based on the exact solution of the electrical field integral equation (EFIE) by the methods of moments (MoM) [6]. The analyses were carried out with adequate serrated reflector structures but smaller dimensions in order to allow calculations with the EFIE program within reasonable time limits. The comparative analysis results exhibit a close agreement, as shown in Figure 1. A comparison of the calculation times resulted in more than 3,5 hours for the program CONCEPT, which is the factor 40 higher than that of the GO/UTD analysis tool. One example of a test reflector is shown in Figure 2.

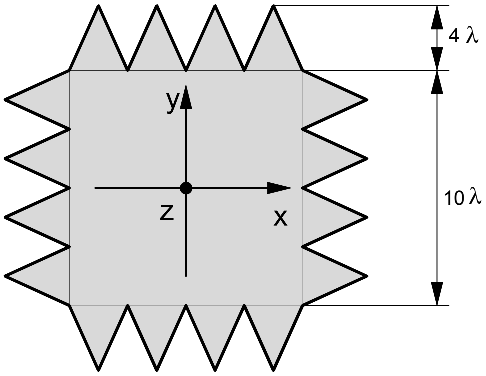


Figure 2: Example of a test reflector for comparative analyses between GO/UTD and EFIE

3. Compact Range Improvements

Distorting fields, which degrade the co- and cross-polar plane wave field in the quiet zone of compact ranges are mainly caused by direct leakage of the feed, multipath propagation via absorber and reflecting objects, diffraction effects at the reflector rims and insufficient feed performance.

The direct leakage of the feed can be eliminated to a great extent by a well designed baffle or by hardgating [7]. Both methods ensure the required realtime measurement capability of compact ranges. Multipath distortions can also be eliminated by hardgating if the difference of the propagation time between the main field and the distorting fields is ≥ 4 ns [8]. Triple diffraction/reflection effects, caused by the right edge of the main reflector, can be suppressed by implementation of the 'Billboard' [9], designed by Astrium or the new developed SERAP (Serration Radiation Protection) structure [10]. The SERAP structure, originally invented and presented by the Munich University of Applied Sciences, is shown in Figure 3.

The diffracted fields from the reflector rims can significantly be reduced by specially designed rim structures, like the well known serrated or rolled edge design. Rolled edges, which are based on lateral GO deflections, were mainly applied to single reflector systems, whereas a complete rolled edge design can not be applied in double reflector compact ranges. According to the combination of quasi continuous transitions with lateral GO deflections, when using a new described 'R-Card' solution [11], also this concept is not fully applicable to double reflector compact ranges.

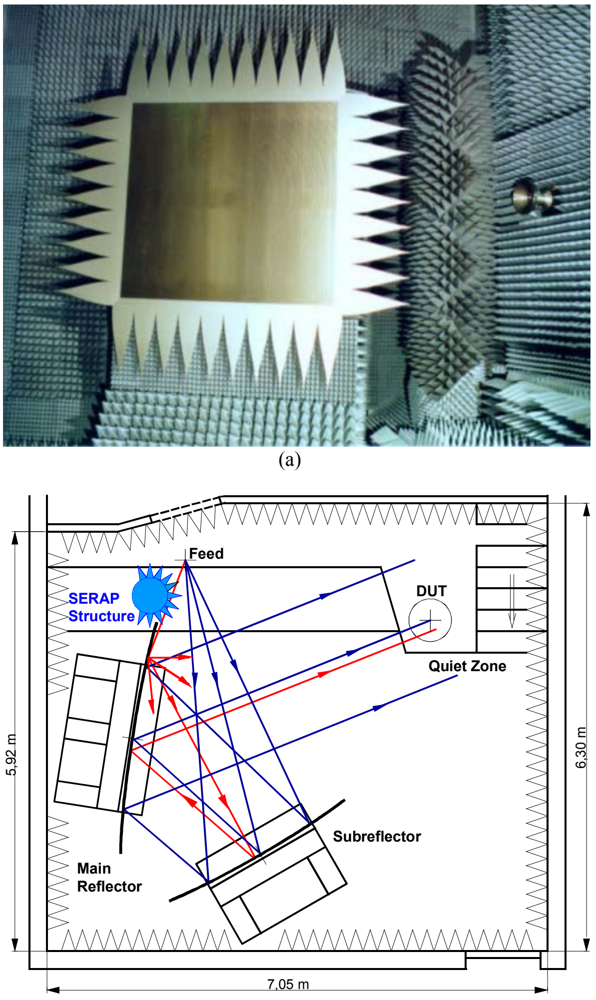


Figure 3: SERAP structure in CCR 20/17 at the Munich University of Applied Sciences:
(a): Front view photo of SERAP structure
(b): Top view of test facility with ray path of suppressed triple diffr./reflection effect

Double reflector compact ranges, when designed as 'Compensated Compact Ranges (CCR)', exhibit no system inherent cross-polarization and have therefore an excellent cross-polar performance [1]. For that reasons, further investigations are only referred to CCRs.

Analyses resulted in cross-polarization levels of - 45 dB or even lower within CCRs. For verification of such results in real antenna test facilities, high performance feeds are necessary. The Astrium CCR feeds, which exhibit a cross-polarization of < - 50 dB and which are provided for a frequency range from 1,5 to 40 GHz were applied within this investigations [2,11]. Typical measurement results, obtained with a X-Band feed, are shown in Figure 4.

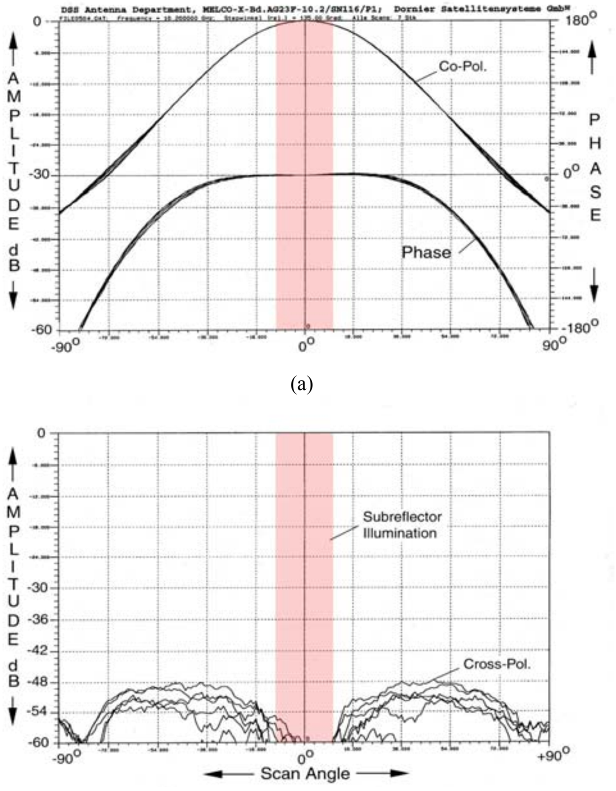
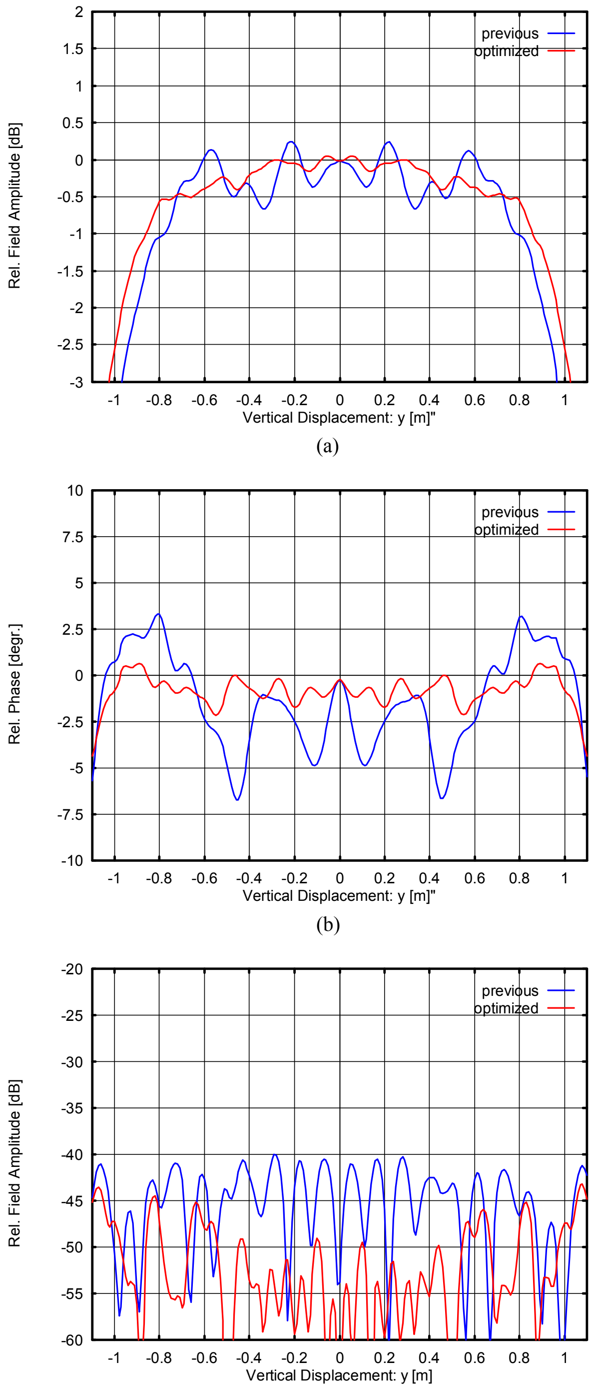


Figure 4: Feed performance data of Astrium CCR X-Band feed at 10 GHz, 7 cuts each:
(a): Measured co-pol. amplitude and phase pattern
(b): Measured cross-pol. amplitude pattern

The distorting fields which emanate from the serrations and propagate along the same ray path as the main field via both reflectors were furtheron reduced with a new serration design.

With the GO/UTD analysis tool, the geometrical serration parameters like rim contour, serration length, position, tilting, etc. were investigated within a large range of variation [12,13]. The quiet zone field was calculated along single cuts and in full planes, transverse to the incident main field. The optimization considered the co-polar as well as cross-polar field for horizontal and vertical polarization of the feed within a frequency range from 3 to 30 GHz. The results exhibited a new arrangement of the serrations and a new serration contour function, which differs from the formerly used cosine shape. Figure 5 shows comparative GO/UTD analysis results with the previous and optimized serrations at the CCR 20/17 subreflector for f = 10 GHz along a vertical cut in the quiet zone. The optimized serration design of the subreflector is shown in Figure 6.

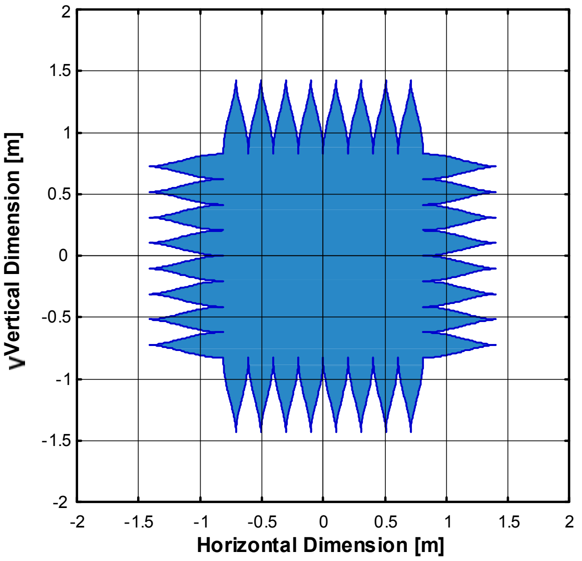


(a)

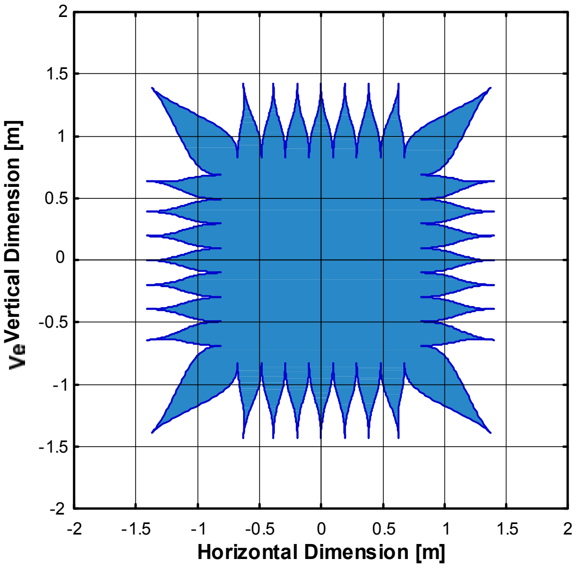
(b)

(c)

Figure 5: UTD analysis results:
Previous and optimized serrations, amplitude (a) and phase (b) of co-polar field and amplitude (c) of cross-polar field in the quiet zone for horizontal feed polarization, vertical cut, f = 10 GHz



(a)



(b)

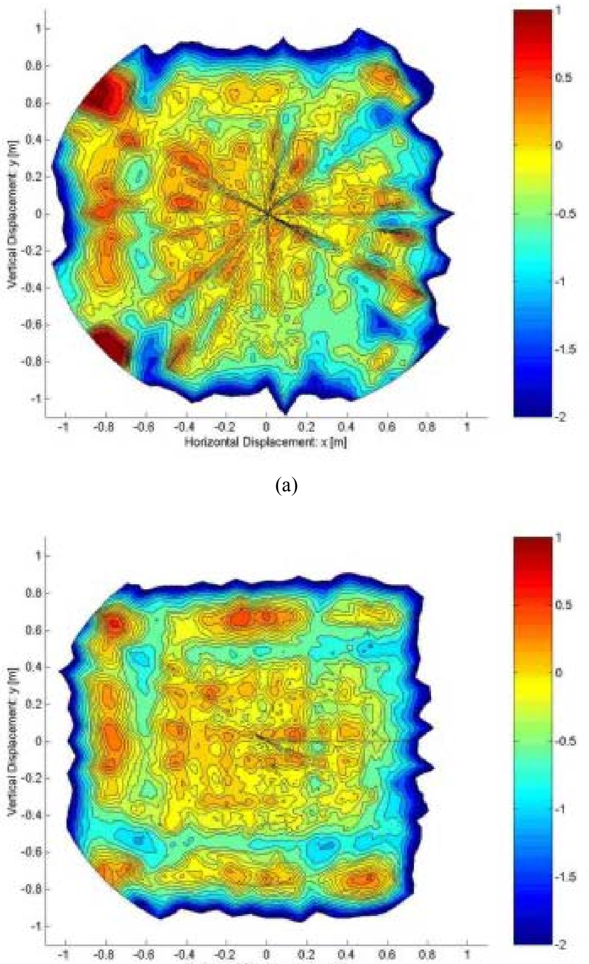
Figure 6: Improvement of subreflector serrations:
Previous (a) and optimized (b) serrations

At the main reflector, a similar serration design was implemented, which differs only in the number of serrations per reflector side according to the different reflector size.
The improvements were verified with plane wave probing in the quiet zone of the investigated CCR (Astrium, Model CCR 20/17), which is installed in the laboratory for satellite communications at the Munich University of Applied Sciences.

4. Measurement Results

Comparative measurements were performed before and after installation of the optimized serrations at the sub- and main reflector. They were carried out in the quiet zone (circular, 1,3 m diameter) with a high precision polar plane wave scanner of appr. 2,2 m diameter and a positioning accuracy of appr. 40 µm. The frequency range for the measurements covered the C- and M-band, whereas at several frequencies in each band the co- and cross-polar fields along single cuts and full planes were detected for horizontal and vertical feed polarization.

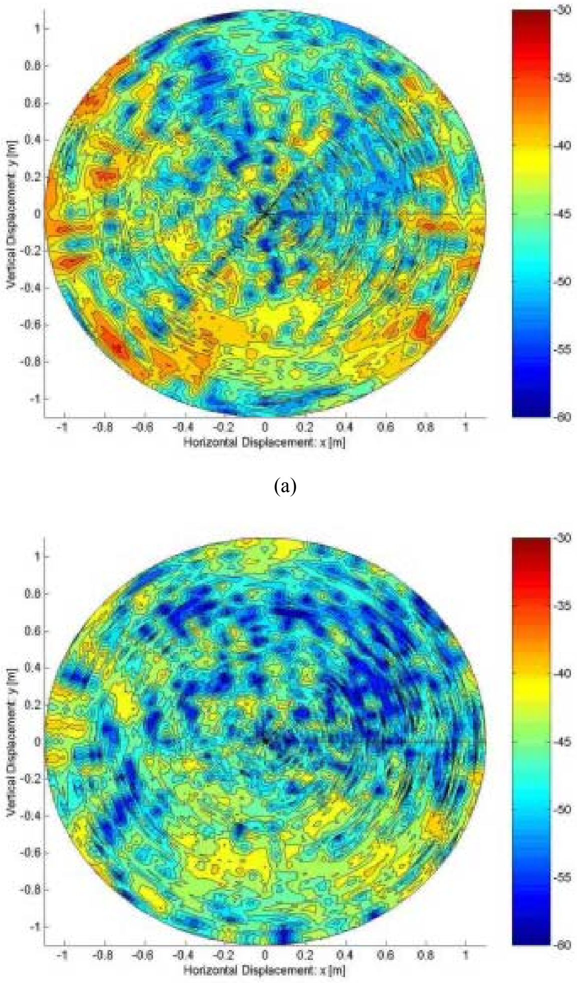
The co- and cross-polar measurement results for a frequency of 12 GHz and e.g. vertical polarization are shown in the Figures 7 and 8.



(a)

(b)

Figure 7: Measured co-polar field in the quiet zone: Before (a) and after (b) optimization of the serration design, 12 GHz



(a)

(b)

Figure 8: Measured cross-polar field in the quiet zone: Before (a) and after (b) optimization of the serration design, 12 GHz

The improvements, mentioned in Section 3, resulted in a reduction of the amplitude and phase ripple from ± 0,5 dB and ± 3 degr. to ± 0,3 dB and ± 2 degr. for the co-polar field and a reduction of the cross-polar field from - 38 dB to - 43 dB within 95 % of the quiet zone. Additionally, a more homogeneous field distribution in the quiet zone could be achieved.

For all measurements, the special designed Astrium compact range feeds, also mentioned in Section 3, were applied. Additionally, the SERAP structure was installed and the hardgating system was activated during all measurement periods in generally.

5. Conclusions

The measurement accuracy of compact range test facilities is mainly dependent on the suppression of distorting fields, emanating from the feed and the serrations of the reflectors. When propagating along different ray paths with respect to the main field, the distorting fields can be suppressed by hardgating and a billboard or new developed SERAP structure. Distorting fields, reaching the quiet zone with the main field, can be reduced by an optimized serration design.

For that aim, a GO/UTD analysis tool was developed and applied to the reflectors of the Astrium compensated compact range CCR 20/17 at the Munich University of Applied Sciences. A new set of serrations for the sub- and main reflector of the exemplary investigated Astrium compact range was manufactured and installed.

Comparative measurement results, achieved with a highly accurate polar plane wave scanner for the previous and optimized serrations, exhibited a performance improvement for the co-polar amplitude and phase ripple as well as for the maximum cross-polar field amplitude in the quiet zone. With all of the mentioned improvements, a significant step towards higher measurement accuracy for future satellite antennas in compact range test facilities could be achieved while maintaining the realtime measurement capability.

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