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IMPROVEMENT OF COMPACT RANGES BY DESIGN OF OPTIMIZED SERRATIONS

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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 the characteristics of an optimized feed 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 [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 (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 asymtotic method, mainly depends on the considered diffraction effects and its asymptotic solutions. 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].

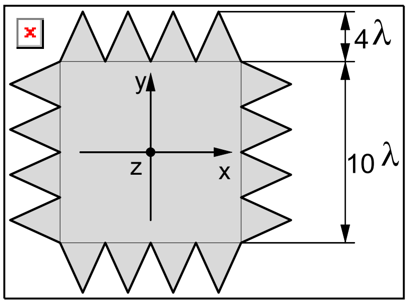
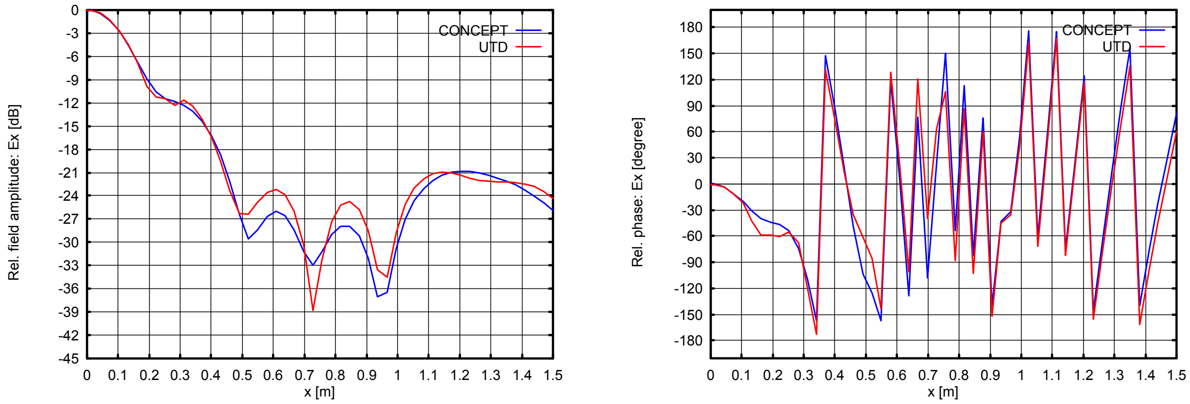


Fig. 1 Example of a test reflector for comparative analyses between GO/UTD and EFIE

For verification of the GO/UTD analysis tool, a comparison with the programm 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 reflector structures with serrated edges but smaller dimensions in order to allow calculations with the EFIE program within reasonable time limits. One example of a test reflector is shown in Fig. 1. The comparative analysis results exhibit a close agreement, as shown in Fig. 2. 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.



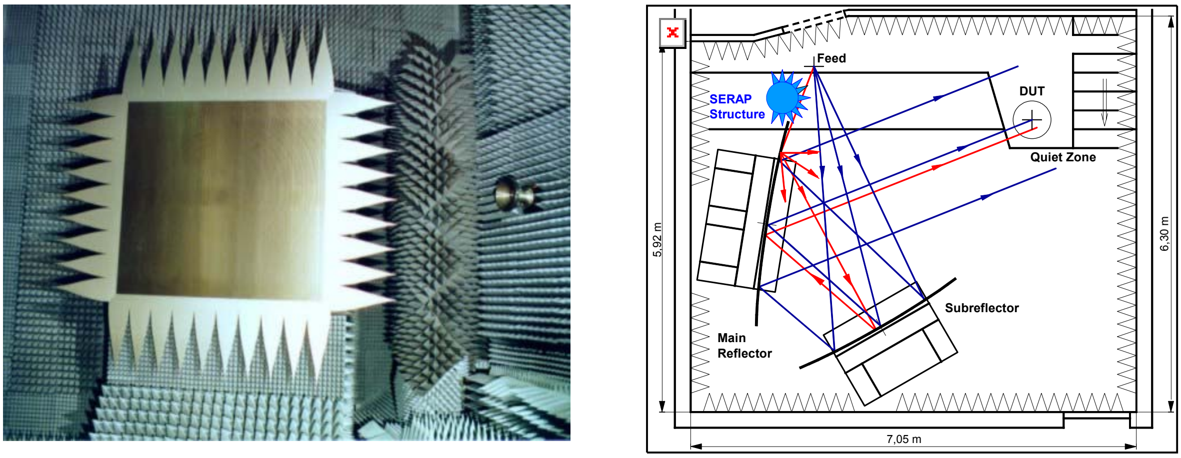
(a)

Fig. 2 Comparison of amplitude (a) and phase (b) pattern: x-cut, x-polarization, z-distance = 100 λ
CONCEPT analysis results ▬ GO/UTD analysis results ▬

3. COMPACT RANGE IMPROVEMENTS

Distorting fields, which degrade the plane wave field in the quiet zone of compact range test facilities, are mainly caused by the direct leakage of the feed and by diffraction effects at the reflector rim. The direct leakage of the feed can be eliminated to a great extent by a well designed baffle or by hardgating [7], while maintaining the realtime measurement capability. The diffracted fields from the reflector rim can be reduced by serrated or rolled edges, whereas rolled edges can not be applied in a double reflector compact range. This type of facility, when designed as a 'Compensated Compact Range (CCR)', exhibits no system inherent cross-polarization and has therefore an excellent cross-polar performance [1]. For that reasons, further investigations are referred to the CCR.

Multipath propagation of the diffracted fields from the serrations into the quiet zone can additionally be eliminated by hardgating if the difference of the propagation time between the main field and the distorting fields is ≥ 4 ns [8]. The triple diffraction/reflection effect, caused by the right edge of the main reflector, can be suppressed by implementation of a billboard [2] or the new developed SERAP (Serration Radiation Protection) structure [9]. The SERAP structure is shown in Fig. 3.

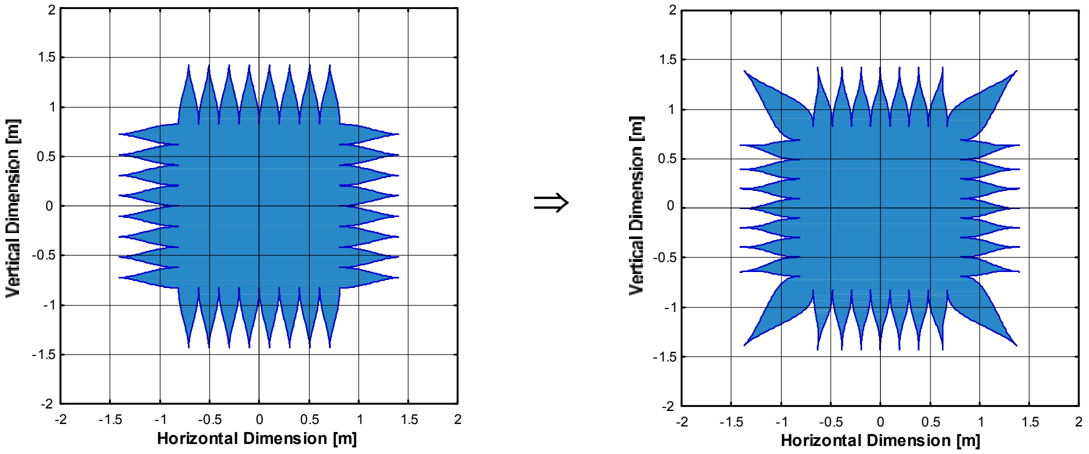


(a) (b)

Fig. 3 SERAP structure in CCR 20/17 at the Fachhochschule München:
(a): Photo of front view of SERAP, installed between main reflector and feed
(b): Top view of test facility with ray path of suppressed triple diffraction/reflection effect

The distorting fields which emanate from the serrations and propagate along the same ray path as the main field via both reflectors were 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. 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 the cross-polar field for horizontal and vertical polarization of the feed within a frequency range from 3 GHz 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. The optimized serration design of the subreflector is shown in Fig. 4.



(a) (b)

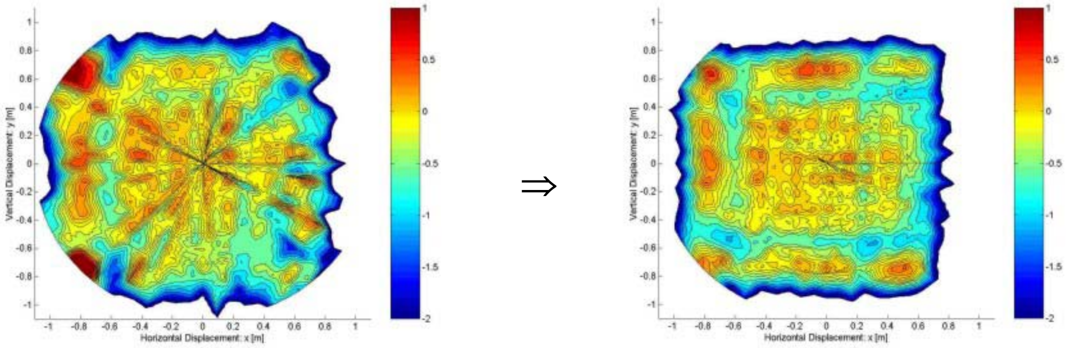
Fig. 4 Improvement of subreflector serrations: previous (a) and optimized (b) serrations

The improvements were verified with plane wave probing in the quiet zone of the investigated CCR (DASA Model CCR 20/17), which is installed in the laboratory for satellite communications at the Fachhochschule München.

4. MEASUREMENT RESULTS

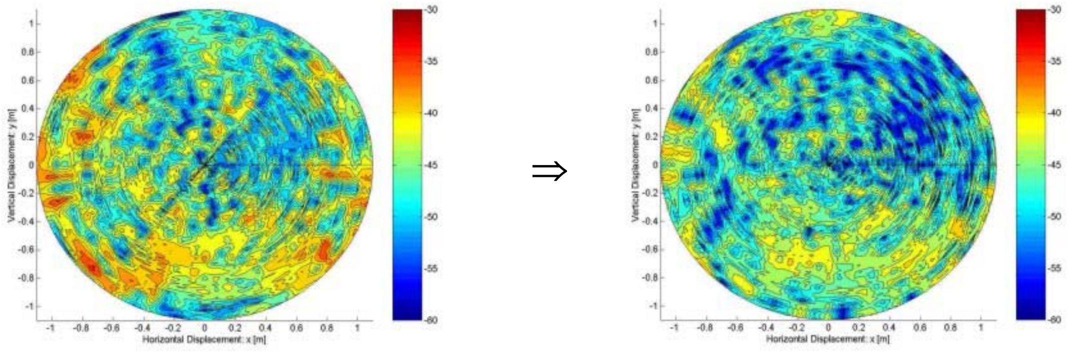
Comparative measurements were performed before and after installation of the optimized serrations at the sub- and main reflector. They were carried out in the quiet zone (circular, 1,3 m diameter) with a high precision polar plane wave scanner of appr. 2,2 m diameter and a positioning accuracy of appr. 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 vertical polarization are shown in Figs. 5 and 6.



(a)

Fig. 5 Measured co-polar field in the quiet zone: before (a) and after (b) optimization of the serrations, 12 GHz



(a)

Fig. 6 Measured cross-polar field in the quiet zone: before (a) and after (b) optimization of the serrations, 12 GHz

The improvements 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, a special designed compact range feed (DASA CCR-Feed) with a cross-polarization of - 50 dB max. was used.

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 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 compensated compact range at the Fachhochschule München. A new set of serrations for the sub- and main reflector of the test facility were manufactured and installed. Comparative measurement results, achieved with a 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.

6. REFERENCES

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