Full Wave Modelling and Design of a Baffle for the HERTZ 2.0 Compact Antenna Test Range

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Abstract— **A baffle has the purpose of preventing the feed of a compact antenna test range to radiate in the quiet zone and it is typically constituted by a cylindrical structure covered by pyramidal absorbers. In this paper we describe the electrical design of a baffle for the new compensated compact antenna test range for the HERTZ 2.0 facility at ESTEC. Two modelling approaches are shown and compared and the updated performance of the quiet zone field at L band is given.**

Index Terms—**RF performances, RF predictions, RF measurements, Compact Antenna Test Range, Serrations, baffle, Physical Optics, Full Wave Analysis**

I. INTRODUCTION

The HERTZ 2.0 facility to be built at the European Space Agency in the Netherlands will be a state-of-the art test centre including a dual compact antenna test range (CATR) for antenna and payload RF measurements of current and future satellite missions from 1 GHz up to 400 GHz [1]. The challenging electrical and geometrical requirements set by the Agency required a custom electrical design of the CATR, which was provided by TICRA and which was described in [2].

The CATR for HERTZ 2.0 is a compensated dual reflector system with serrated edges. The serrations have the same surface of the reflectors and those on the main reflector are slightly tilted. The electrical design was performed with a novel approach making use of an initial trade-off with ray tracing in the GRASP software and a subsequent detailed full wave analysis and optimization of the serrations profile, length and orientation in the ESTEAM software, both commercially available in the TICRA Tools suite [3].

The results presented in [2] showed that the quiet zone field met the demanding requirements of an overall peak-to-peak (PtP) amplitude and phase ripple of maximum 0.5 dB and 4 deg, respectively, at L band over a 5 m X 5 m quiet zone. The performances were achieved using a feed pattern characterized by a flat region around the boresight direction and a high taper, which provided an almost constant illumination of the subreflector and a low illumination of the subreflector serrations. This ensured an optimal illumination of the main reflector and low ripples in the quiet zone. In the last phase of the design it was decided to include the direct contribution of the feed in the quiet zone evaluation to assess its impact. It was found that the quiet zone was affected by that and therefore a baffle able to shadow the direct illumination of the feed to the quiet zone became necessary.

The purpose of the present paper is to describe the electrical design at L band of the baffle for the HERTZ 2.0 CATR. Two modelling approaches will be proposed and compared.

In particular, Section II summarizes the design of the CATR reported in [2], while Section III describes the approach and trade-off used to design the baffle, providing the updated quiet zone performance. Conclusions are finally drawn in Section IV.

II. THE DESIGNED CATR

The CATR of the HERTZ 2.0 facility fits the chamber shown in Fig. 1. The total height of the room is 18 m. Besides the CATR, a planar scanner will create a no-go area with a width of 3 m. The subreflector is contained in the upper 7 m x 20 m section to reduce diffractions into the quiet zone. The green area indicated in the lower left part of the figure is a volume at the floor level with cross section of 2.5 m x 2.5 m, reserved for transportation of equipment to the quiet zone. The positioner is at 6 m from the end wall. Absorbers of 18 inches are placed behind the reflectors, while the remaining walls will be covered by 26 inches absorbers. At L band, the overall peak-to-peak amplitude and phase ripple of the quiet zone field shall be smaller than 0.5 dB and 4 deg, respectively. These requirements include both the effect of the feed taper and the effect of the reflector edge diffractions, which are typically quantified separately. In order to meet the requirements, the feed shall have a very flat pattern and the serrations shall be carefully designed at L band to push the diffractions to a minimum. Finally, the size of the quiet zone shall be at least 5 m x 5 m.

The main and sub reflectors are arranged in a so-called compensated configuration satisfying the Mizuguchi condition, providing low cross polarization and small scan aberrations. The design was made such that the unwanted triply reflected ray (from feed, to main, then to sub and finally to main) was out of the quiet zone, and the direct illumination of the main reflector from the feed was negligible, avoiding the need of a SERAP (Serration Radiation Protection) between the feed and the main reflector [4]. The designed main and sub reflector are shown in Fig. 2 and Fig. 3.

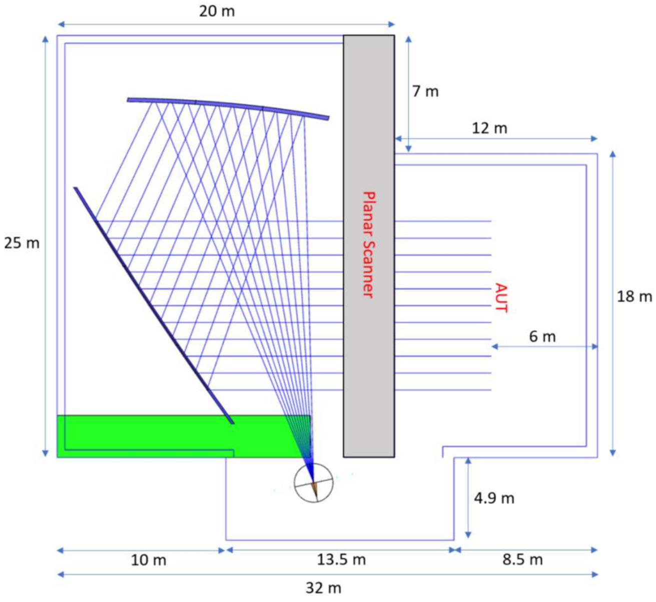

Fig. 1. HERTZ 2.0 chamber dimensions with example of dual CATR. The envelope of the 18 inch and 26 inch absorbers is also indicated.

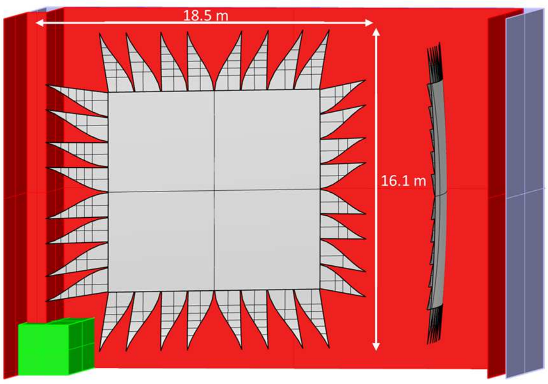

Fig. 2. Main reflector of the final CATR in the HERTZ 2.0 room.

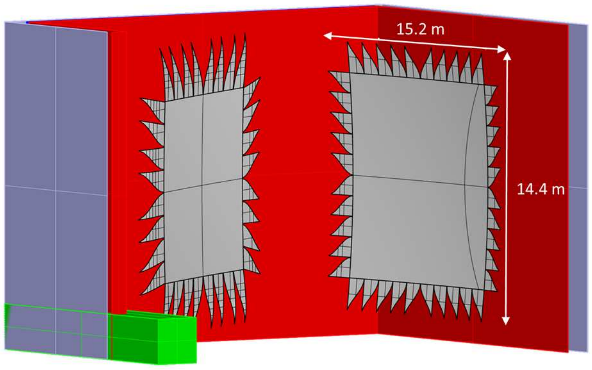

Fig. 3. Subreflector of the final CATR in the HERTZ 2.0 room.

The CATR is illuminated at L band by the feed pattern used during the design and shown in Fig. 4.

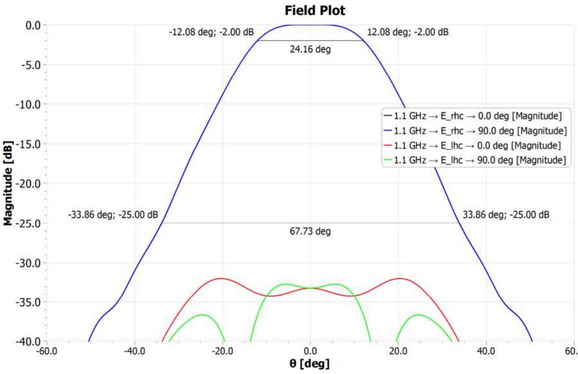

Fig. 4. Feed radiation pattern used to illuminate the CATR during the design phase.

The quiet zone (QZ) performance at L band of the designed CATR was shown in [2] and is repeated in the left column of TABLE I. The percentages are computed with the higher order MoM/MLFMM solver of ESTEAM over the 5 m x 5 m quiet zone with a sampling step of 45.87 mm, considering only the field scattered by the main and sub reflector. In practice the radiation of the subreflector towards the quiet zone will partly be shadowed by the absorbers on the 7 m wall parallel to the quiet zone, and the feed will radiate directly to the quiet zone. When the direct field of the feed is added to the QZ field, the performance become as in the right column of TABLE I. It is shown that the direct field from the feed deteriorates the quiet zone performance by around 3.5% at L band. A field cut on the QZ with and without the direct illumination from the feed at 1.1 GHz shows the slight increase of the amplitude ripple when the direct illumination of the feed is present, see Fig. 5.

TABLE I. PERCENTAGE OF AMPLITUDE POINTS WITHIN THE RIPPLE REQUIREMENTS AT 6 M FROM THE END WALL: WITH/WITHOUT DIRECT CONTRIBUTION OF THE FEED TO THE QUIET ZONE

Freq [GHz]	Reflectors alone 0.5 dB PtP [%]	Reflectors with feed 0.5 dB PtP [%]
1.1	89.9	88.0
1.5	96.7	93.3

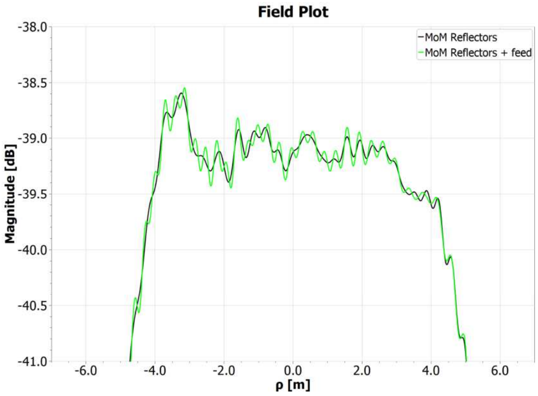

Fig. 5. Quiet Zone field cut with (green curve) and without (black curve) direct feed illumination.

III. BAFFLE ELECTRICAL DESIGN

To avoid the increased ripple in the quiet zone caused by the direct illumination of the feed shown in TABLE I. a baffle shall be added to the CATR between the feed and the quiet zone. The baffle is constituted by a cylinder covered by 18” absorbers.

To design the baffle, the approach described in [5] is initially used, first evaluating the required angular range of the feed pattern to be shadowed. Then, a metal plate with serrations is used as a model of the baffle, to simulate with Physical Optics (PO) in GRASP the shadowing effect of the baffle in the quiet zone. The serrations on the plate have a length equal to the absorber length, i.e. 18”. A series of parameter sweeps of the plate size and position is performed to find the optimal position of the serrated plate.

A drawing of the final baffle setup is shown in Fig. 6 while the baffle size and position are listed in TABLE II. The baffle is placed in such a way to shadow the feed pattern after 30 deg from the boresight direction of the feed.

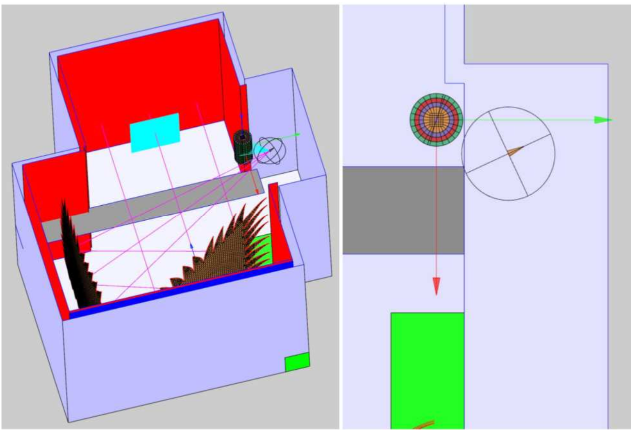

Fig. 6. Designed baffle (shown as lossy cylinder with three layers).

TABLE II. FINAL BAFFLE SIZE AND POSITION

Baffle parameters	
Diameter (including 18” absorbers)	1.8 meters
Height	3.5 meters
Position (with respect to main reflector centre)	z +15.9 m x +8.05 m

As a second, and alternative, modelling approach, the full wave solver from ESTEAM is used to define a lossy cylinder with the same position and diameter given by the plate with serrations found with PO, and with three concentric absorbing layers with increasing loss and total height equal to the absorbers length of 18”. The layers with increasing loss allow one to model the absorbing properties of the material, minimizing the reflections of the incoming signal. The model also allows one to compute a full wave analysis of the baffle, that can be compared with the Physical Optics analysis of the serrated plate. The full wave model of the baffle can also be directly included in the full wave model of the CATR reflectors accounting for the interaction between the baffle and the reflectors, something which is not possible with PO model of the serrated plate. It is noted that the interaction and coupling between the feed and the baffle is always disregarded, since no 3D model of the feed was available.

The losses in the cylinder layers are tuned to produce a shadowing of the feed pattern in the QZ similar to the one given by the metallic serrated plate. Comparing the reflection of a flat lossy three absorbing layers vs data sheets of the actual 18” absorbers shows that the three absorbing layers have 15 dB higher reflection (-25 dB vs -40 dB at 1 GHz normal incidence). This difference leads to small uncertainties when considering the field reflected by the baffle, and thus the coupling between the baffle and the feed or the sub/main reflector, yet has no influence on the field transmitted through the baffle. It was found that increasing the number of layers in the lossy cylinder model did not change the QZ performance. The three layers model was chosen as a compromise between the PO plate model and a full wave pyramid absorber model, which would have required a multi-layer design conformal to the pyramids, to minimize the reflections of the impinging signal. Simulation results of the quiet zone using full wave on the system given by the CATR and baffle (thus including coupling between baffle and reflectors, shown in red) are seen in Fig. 7 and compared to full wave on the reflectors with the addition of the baffle (baffle model only affects field from the feed towards the QZ), modelled either with PO on the serrated plate (shown in black) or MoM on the lossy cylinder (shown in blue). The figure shows excellent agreement between the models and indicates that the two proposed baffle analysis methods are equivalent. Moreover, it shows that the designed baffle does not couple with the reflectors and does not affect the feed pattern and thus the subreflector illumination.

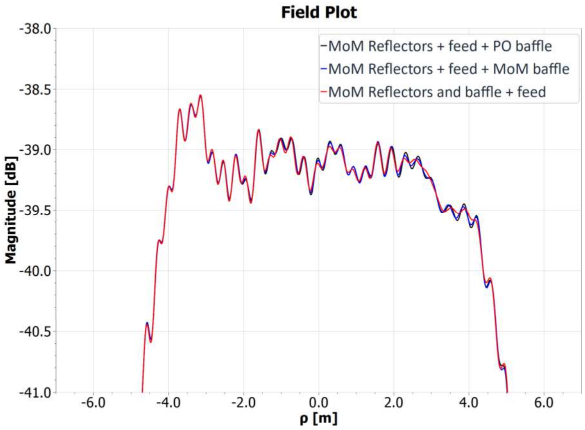

Fig. 7. Quiet Zone at 1.1 GHz field cut comparing the PO and MoM model of the designed 1.8 m baffle, relative to a full wave solution of the system given by CATR and baffle (red curve).

The resulting QZ field quality at 1.1 and 1.5 GHz is summarized in TABLE III. It is shown that the baffle with diameter of 1.8 m allows to recover from 1.4% to 2% of the lost 3.5 % performances at L band.

The advantage of using the full model of the baffle can be seen in Fig. 8, where a baffle of 2 m in diameter able to shadow the feed radiation after 20 deg from its boresight is considered.

The picture again shows that the results with the PO and MoM model of the baffle coincide, but they differ from the pattern obtained with MoM on the system given by reflectors and baffle. This is because the baffle now affects the feed pattern and thus the illumination of the subreflector, which gives higher ripple in the total field. The possibility of including the baffle in the full wave analysis of the full CATR system is therefore of paramount importance.

TABLE III. PERCENTAGE OF AMPLITUDE WITHIN THE RIPPLE REQUIREMENTS AT 6 M FROM THE END WALL: WITH/WITHOUT DIRECT CONTRIBUTION OF THE FEED TO THE QUIET ZONE AND WITH THE DESIGNED BAFFLE OF 1.8 M

	0.5 dB PtP [%]		
Frequency [GHz]	Reflectors alone	Reflectors plus feed	Reflectors plus feed and baffle
1.1	89.9	88.0	89.2
1.5	96.7	93.3	95.4

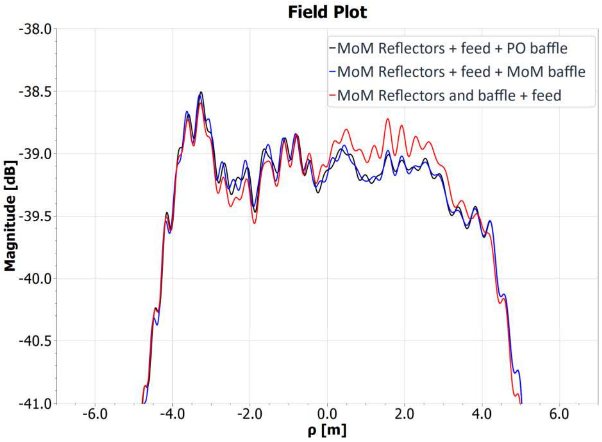

Fig. 8. Quiet Zone at 1.1 GHz field cut comparing the PO and MoM model of a 2 m baffle, relative to a full wave solution of the system given by CATR and baffle (red curve).

IV. CONCLUSIONS

The paper described the electrical design of a baffle for the CATR of the upcoming HERTZ 2.0 facility of the European Space Agency. The baffle is a cylinder covered by pyramidal absorbers with length of 18’’and has the purpose to shadow the direct illumination of the feed in the quiet zone. Two equivalent modelling approaches for the baffle were presented, one modelling the baffle with Physical Optics as a plate with serrations with length equal to the 18” absorbers, and another one modelling the baffle as a three layers lossy cylinder in MoM/MLFMM. The two modelling approaches are general and computationally efficient and can be applied to any CATR once the feed pattern and the room geometry are known. It was found that the two modelling approaches provide identical results. The designed baffle has a total diameter of 1.8 m including the 18” absorbers and a height of 3.5 m.

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