RF Assessment of the Mechanical Design of the Compact Antenna Test Range for HERTZ 2.0

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***Abstract*—The Compact Antenna Test Range (CATR) for the HERTZ 2.0 measurement facility at the European Space Agency was electrically designed to meet the geometrical and RF requirements set by the Agency. The CATR is constituted by a 18.5 m x 16.1 m serrated parabolic main reflector and a 15.2 m x 14.4 m serrated hyperbolic sub reflector achieving a quiet zone (QZ) of 5 m in L band. The reflectors have then undergone a detailed mechanical design to ensure their practical fabrication and installation. In this paper we present the electrical effect in the QZ of the chosen mechanical implementation.**

***Index Terms*—CATR, compact antenna test range, reflector design, quiet zone.**

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 designed CATR is a compensated dual reflector system with serrated edges, providing a quiet zone (QZ) field at 1 GHz with an overall peak-to-peak amplitude ripple of maximum 0.5 dB over a 5 m X 5 m area. The designed main reflector has a total size of 18.5 m x 16.1 m with 32 serrations. The sub reflector has a total size of 15.2 m x 14.4 m with 40 serrations. The structural design is provided by Media Lario, who will also manufacture the reflectors and will be responsible for the installation, integration and the complete optical alignment. The reflectors will be realized by panels of 1.5 m X 1.7 m made in sandwich structure with aluminum honeycomb and 0.6 mm thick stainless-steel foils, making the structures extremely lightweight. A gap of 0.5 mm will exist between the panels and a conductive filler will ensure the continuity of the induced currents over the panels. It is of paramount importance to ensure that the mechanically designed CATR still meets the electrical QZ requirements set during the design phase. In particular, an electrical analysis of the impact of the inter-panel gap and of the proposed filler material is necessary. The very large size of the reflectors combined with the very small gap size and large bandwidth of the CATR do not allow a direct RF analysis of the proposed reflector structures due to computational RF challenges. To get a good physical understanding of the radiation phenomena and to assess whether the proposed filler can be used at all frequencies without impacting the QZ, representative RF models are needed. The purpose of this paper is to describe the representative RF models which were developed and the conclusions achieved at L band, 20 GHz and for frequencies above 100 GHz. Section II summarizes the electrical design of the CATR, while Section III describes the approach proposed for the mechanical realization of the reflectors. The effect on the QZ of the flush and not flush filler is explained in Section IV and conclusions are finally drawn in Section V.

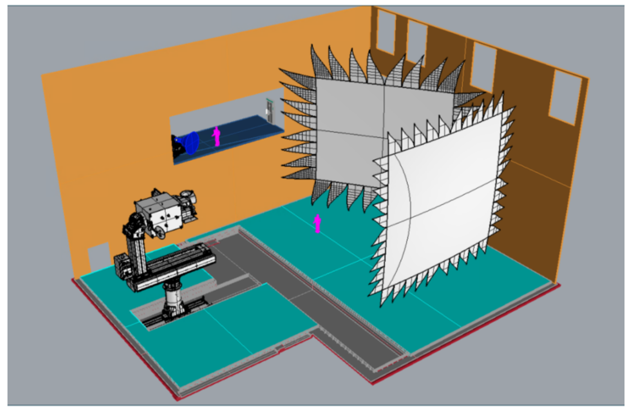

Figure 1: HERTZ 2.0 chamber, showing the designed CATR and the AUT positioner.

II. Electrical Design of The CATR

The CATR designed for the HERTZ 2.0 facility is seen in Figure 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, which is indicated by the grey area on the floor. 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 diffractions of the reflector edge, 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 at L band. 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 electrical design was made with a two-step approach. First, ray tracing from the GRASP software [3] was used to find an optics that could fit within the room geometrical constraints and for which the unwanted triply reflected ray (from feed, to main, then to sub and finally to main) was out of the quiet zone. This also allowed to achieve a negligible direct illumination of the main reflector from the feed, avoiding the need of a SERAP (Serration Radiation Protection) between the feed and the main reflector [4]. After that, the profile and length of the serrations were optimized at L band with goals on the quiet zone amplitude and phase ripple. This was done using a full wave model of the reflectors, in particular the higher-order MoM/MLFMM solver of the commercially available ESTEAM SW product within the TICRA Tools suite, see [3], was used. With this approach, it was possible to account for the coupling between neighboring serrations, for the coupling between main and sub reflectors, and for the direct illumination of the main reflector by the feed at all stages of the optimization. The designed main reflector is seen in Figure 2. It has a total size of 18.5 m x 16.1 m with 32 serrations with length of around 3 m and width of 1.5 m. The sub reflector has a total size of 15.2 m x 14.4 m with 40 serrations with length of around 1.5 m. During the electrical design the CATR was illuminated by the feed pattern seen in Figure 3, showing a flat region around the boresight direction and a high taper, which provided an almost constant illumination of the sub reflector and a low illumination of the subreflector serrations. This ensured an optimal illumination of the main reflector and thus a flat quiet zone field with low ripples.

The quiet zone performance at L band of the designed CATR was presented in [2] and is repeated in I. The percentages are computed with the higher-order MoM/MLFMM full wave solver of the ESTEAM software [3], 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 a baffle will shadow the direct illumination of the feed to the quiet zone. The full wave analysis accounts for the coupling between main and sub reflector and for the coupling between the serrations.

III. Mechanical Realization of the CATR

The main and subreflector will be constituted by several lightweight panels of 1.5 m x 1.7 m made by honeycomb covered by stainless steel foils: 49 panels will be needed to realize the main reflector. Custom-made panels will be needed for each serration, see the drawing in Figure 4. A

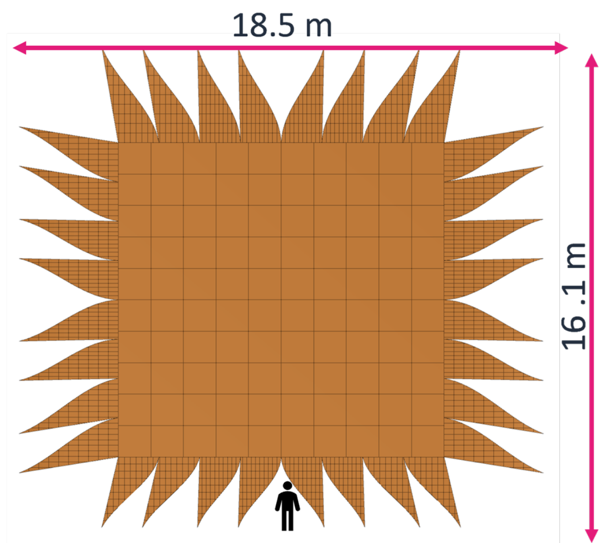

Figure 2: CATR main reflector.

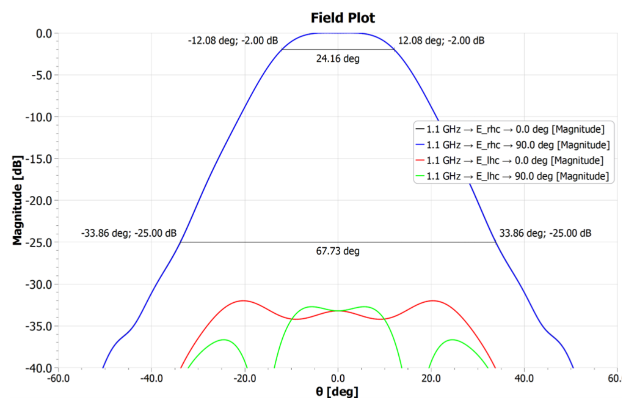

Figure 3: Feed radiation pattern used to illuminate the CATR during the design phase.

Table I: Percentage of points within the ripple requirements at 6 m from the end wall, without direct contribution of the feed to the quiet zone

Freq. (GHz)	Amp 0.5dB PtP. (%)	Phase 4 deg PtP (%)
1.5	96.6	86.6

gap of 0.5 mm will exist between all panels, to allow the installation and the alignment, as depicted in Figure 5. The gaps of 0.5 mm will be filled by a conductive filler. Panels and filler will have different finite conductivities: the value will be 7.2E-05 ohm/cm for the panels and 0.01 ohm/cm for the filler. Moreover, the filler will not be flush to the panels, but a depth of around 50 µm will exist. To assess if the proposed mechanical implementation was suitable for the CATR, it was necessary to evaluate the frequency from which the gap between panels started deteriorating the QZ performance, and if the filler could restore the QZ performance over the large frequency band. It became soon clear that

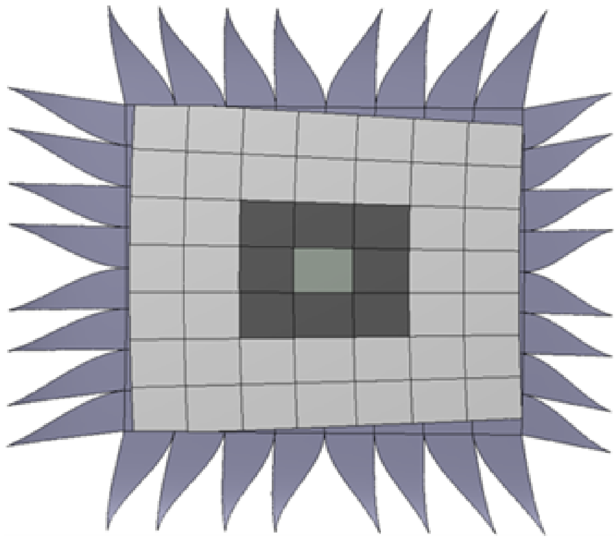

Figure 4: Mechanical realization of the main reflector with panels of 1.5 m x 1.7 m.

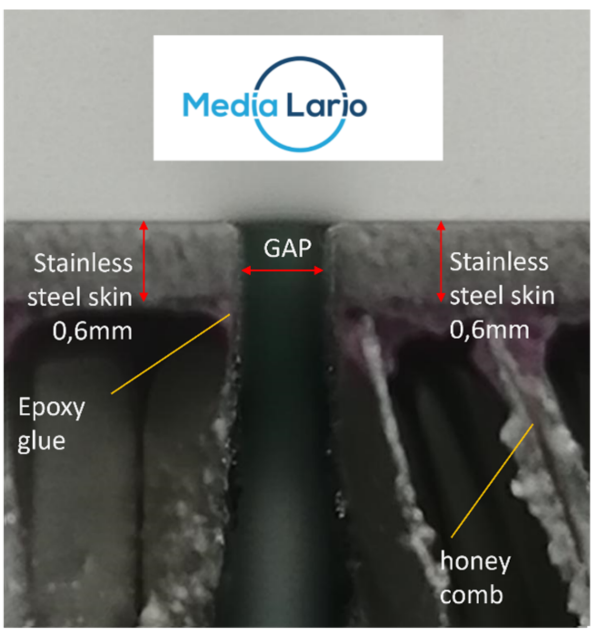

Figure 5: Details about the 0.5 mm gap between panels.

such an assessment needed the development of advanced and equivalent RF models, in order to handle at the same time, the geometrically small filler and the extremely large sizes of the reflectors and obtain an understanding of the physics behind the problem.

IV. Electrical Effects of The Filler

A. Filler effect at L-band

To begin with, it was needed to know at which frequency the air gap between the panels affected the QZ and if a conductive flush filler could recover the loss in the QZ performance. A full wave analysis with the ESTEAM software within TICRA Tools was thus performed in L band on the sub and main

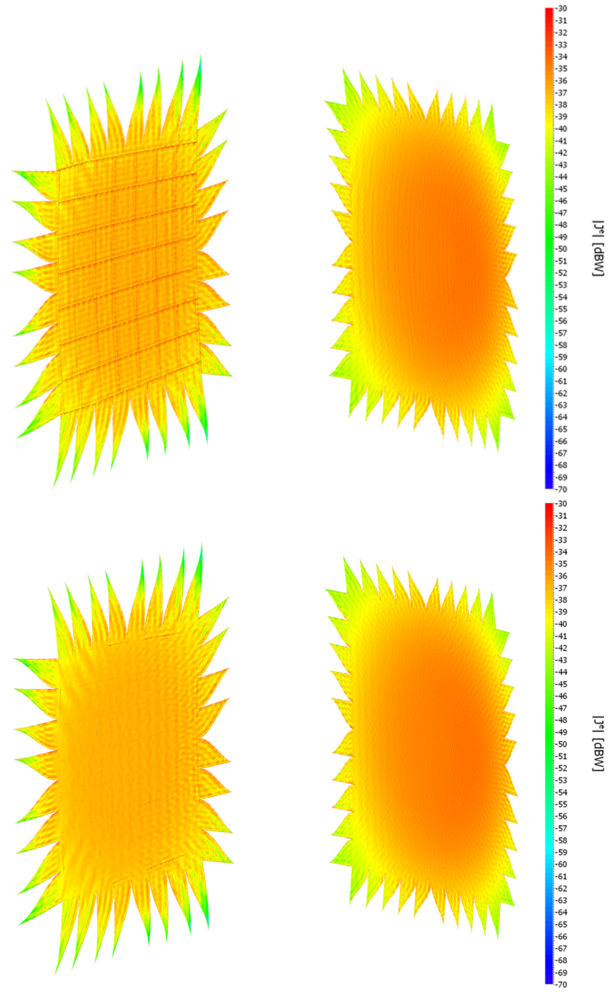

Figure 6: Amplitude of the induced currents on the reflectors computed with MoM/MLFMM at 1.5 GHz: top picture, when air gap exists between the main and sub reflector panels, bottom picture, when a flush filler exists between the main and sub reflector panels.

reflectors with finite conductivity, for the case where no filler existed between the panels and for the case where a flush conductive filler existed between all panels. The results are shown in Table II for the frequency of 1.5 GHz and compared with the nominal case of Table I. A current plot of the induced currents on the reflectors is shown in Figure 6. It is seen that the air gap deteriorates the performance already at L band, since currents cannot flow from one panel to the other and diffract from each panel edge introducing ripples in the QZ. A flush filler with finite conductivity can recover the performances of the full solid reflectors case. It is also observed that the difference in the finite conductivities does not introduce any deterioration in the PtP performance of the QZ. Further full wave analysis indicated that a not flush filler with a depth of around 50 µm relative to the panels did not impact the L band performances relative to the case of the flush filler.

Table II: Percentage of points within the ripple requirements at 6 m from the end wall, without direct contribution of the feed to the quiet zone

Amp 0.5dB PtP. (%)	**Phase 4 deg PtP (%)**	**Note**
96.6	86.6	Nominal case, solid PEC reflectors
60.5	68.5	Panels with finite conductivity and air gap without filler
96.7	85	Panels with finite conductivity and flush filler with finite conductivity

B. Filler effect at frequencies larger than 20 GHz

Method of Moments was a feasible analysis method of the CATR until 10 GHz, but above that frequency the memory needed was a major drawback. Physical Optics (PO) on the main and sub reflector were used in the design phase until 50 GHz, see [2], for the case of the ideal reflector surfaces, while Geometrical Optics (GO) on the subreflector and Physical Optics on the main reflector were used for frequencies above 50 GHz. The question now was if these methods could be used also to model the panels with the not flush filler of 0.5 mm width and 50 µm depth. To investigate this, we first considered six panels of height as in the real CATR and seven vertical gaps with not flush fillers, as shown in Figure 7. We illuminated these by a certain feed and compared the results obtained by MoM/MLFMM and PO, obtaining that PO and MoM/MLFMM results coincided at 20 GHz. We thus concluded that PO was accurate for the analysis of the CATR with panels and non-flush filler for frequencies higher than 20 GHz. A representative model of the HERTZ2.0 system was then used, see Figure 8, to study the effect of the non flush filler in the real CATR. In the representative model, the sub reflector is a perfect hyperboloid without panels and without any serrations. The main reflector has continuous serrations with the same bending used in the real case and is constituted by 49 panels, which are similar in terms of size to the ones of the real case. The filler between the main reflector panels is non flush, with a depth of 50 micron and a width of 0.5 mm. Regarding the analysis methods, Geometrical Optics (GO) is used for the sub reflector and Physical Optics (PO) is used for the main reflector panels, filler and serrations in the GRASP software [3]. The QZ is calculated taking into account the direct ray only (Feed $\rightarrow$ Sub $\rightarrow$ Main $\rightarrow$ QZ). It was found that the impact of the non-flush filler on the main reflector is negligible in terms of variation of the percentage of points in the 0.4 dB PtP amplitude range and 4 deg PtP phase range in the QZ at 20 GHz, as reported in Table 4. The same RF model and approach was used at 50 GHz, 100 GHz and 400 GHz. In all cases it was seen that the non-flush filler on the main reflector had a negligible impact on the QZ ripples, concluding that the proposed mechanical realization of the reflectors was a viable solution for the CATR.

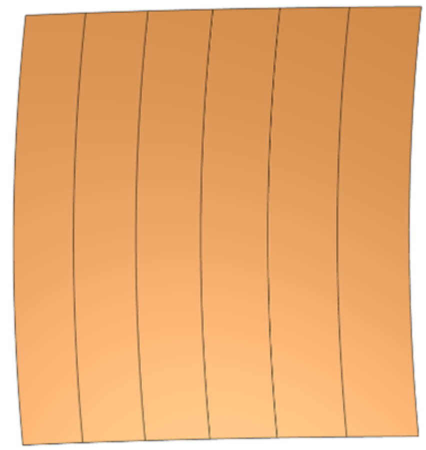

Figure 7: Six panels with seven vertical gaps with not flush filler, for the MoM/MLFMM and PO analysis at 20 GHz.

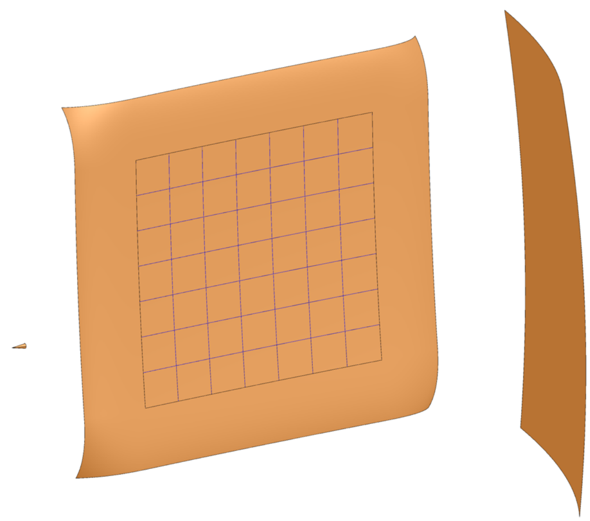

Figure 8: Geometrical model used for the assessment of the non-flush filler for frequencies starting from 20 GHz.

Table III: Percentage of points within the ripple requirements at 6 m from the end wall, for the direct ray at 20 GHz

Amp 0.5dB PtP. (%)	**Phase 4 deg PtP (%)**	**Note**
99.8	94.5	Nominal case, solid PEC reflectors
99.5	92.6	Solid PEC sub reflector, panelized PEC main reflector with non-flush filler

V. Conclusions

In this paper we have reported the results of the RF analyses carried out for the HERTZ 2.0 CATR to assess the feasibility of the mechanical design proposed for the reflectors. It was found that reflectors can be constituted by 1.5 m x 1.7 conducting panels with a 0.5 mm gap. The gap between panels shall be filled by a conducting filler to avoid edge scattering from the panels, which impacts the QZ performance already at L band. The finite conductivities of the panels and filler do not need to coincide and do not impact the QZ performance in terms of ripple. A non-flush filler of 0.5 mm width and depth of 50 micron on the main and sub reflector does not impact the QZ performance from L band to 400 GHz. The approach proposed by Media Lario for the conductive filling of gaps, is adequate and therefore guarantees performances in line with expectations.

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