High-Performance Smooth-Walled Antennas for THz Frequency Range: Design and Evaluation

D. Montofré, R. Molina, A. Khudchenko, R. Hesper, A. Baryshev, N. Reyes and F.P. Mena

***Abstract*—Traditionally, corrugated conical horn antennas have been the main choice for use in astronomical receivers in the range of millimeter and submillimeter waves. They present low cross-polar level and high coupling efficiency into the fundamental Gaussian mode. However, this type of antenna is difficult to manufacture, inevitably increasing its price and extending the production process. In this work, we present two kinds of feed horn antennas, aimed for use in the ALMA Band-6 frequency range (211-275 GHz), which can be fabricated in a much simpler way with conventional machining tools. Specifically, we present the design and performance comparison of smooth-walled spline-profile horns in two geometries, diagonal and conical. Optimization of the designs has been made by means of an algorithm that allowed us to obtain models whose electrical and mechanical characteristics make them competitive when compared with corrugated horns. Our simulations have shown a good cross-polar performance with levels below −20dB and gaussicity above 96%. These properties make this type of horns an option at the time of choosing a feed system for cutting-edge astronomical applications**

***Index Terms*—spline-profile, diagonal, conical horn, millimeter/submillimeter wave.**

I. Introduction

Corrugated conical horn antennas have been, traditionally, the main choice when it comes to developing instruments for astronomy applications in the range of millimeter and submillimeter waves (including part of the THz frequency spectrum) [1]. They have been selected due to their excellent characteristics. In particular, their coupling to the fundamental Gaussian mode (in short *Gaussicity*) is around 98% and cross-polar level lower than -30 dB [2]. Nonetheless, this sort of antennas is difficult to manufacture, inevitably extending the production process and, therefore, increasing their price. There are other options to corrugated horns, e.g., conical and pyramidal horns. However, they lack symmetry in the radiation pattern and, additionally, pyramidal horns present astigmatism [3].

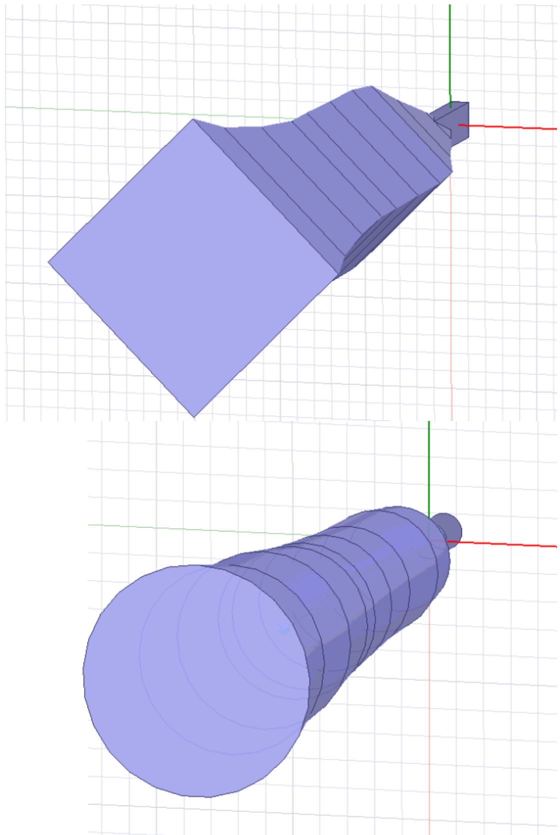

Fig. 1. The two horns under study. (Top) Diagonal-spline horn connected to a rectangular waveguide. (Bottom) Conical horn connected to a circular waveguide. Both designs were optimized in order to reach the goals described in table 1.

In this work, we present the comparison of two types of smooth-walled spline-profile horn antennas, diagonal and circular (figure 1). This work has been focused on the frequency range of ALMA Band 6 (211-275 GHz), currently one of the most interesting observation bands for astronomers, with the image of HL-Tau [4] and the first image ever taken of a Black Hole

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Event Horizon [5] as examples of its major achievements. Simulations and measurements have shown cross-polar levels lower than -20 dB, sidelobes below -25 dB in the E and H cardinal planes, and a Gaussicity around 96%, in agreement with previous reports [6].

II. HORN DESIGNS

The starting point to design both horn antennas is the profile of the walls, which defines the features of the radiation pattern. We have followed a similar methodology as described in [7]. In order to simplify the machining even further, we have used straight lines to connect nodes instead of a cubic spline curve Once the initial wall shape is defined, the next step is creating the volume. On the one hand, the diagonal-spline horn is created by rotating the 1-D wall profile in 90°, then the both profiles are linked using a straight line. The result is profiles connected by segmented flat rectangular surfaces. Then, the final volume is obtained just mirroring the resulting surface, by means of selecting the proper symmetry axis. On the other hand, the conical-spline is created by applying a 360° rotational sweep to the initial 1-D wall profile. Both horn geometries are shown in figure 1. Diagonal-spline and conical-spline horn designs are fed using a rectangular (0.5-mm×1.0-mm) and a circular (diameter = 1.30-mm) waveguide, respectively. This election was made to facilitate the subsequent machining process.

III. PERFORMANCE EVALUATION OF DESIGNS

Figure 2 shows the simulated radiation pattern of the diagonal and conical spline horns at their three key analysis frequencies. Both horns show a very good symmetry between E, D and H planes for levels above -20 dB. This means that both horns will produce a beam with good circular shape or, equivalently, they present low beam ellipticity. The cross-polar levels are lower than -20 dB for both designs over the entire bandwidth. However, the conical-spline design shows a better performance at all frequencies, reaching levels close to -30 dB. This better cross-polar performance correlates with lower levels of sidelobes in D plane. For the diagonal-spline geometry, sidelobe level is below -40 dB in the E and H-plane. D plane shows higher level of sidelobes with values above -30 dB for 211 and 243 GHz, and a level slightly below -20 dB for 275 GHz. For the conical-spline geometry, on the other hand, sidelobe level is around 30 dB in the E, D and H plane for 211 and 243 GHz. A difference is observed at 275 GHz, where sidelobe level is slightly below -20 dB in the H-plane. This difference in sidelobes level at different cardinal planes results in the diagonal-spline design having a more symmetrical beam shape, but at expenses of having higher levels of cross-polar component.

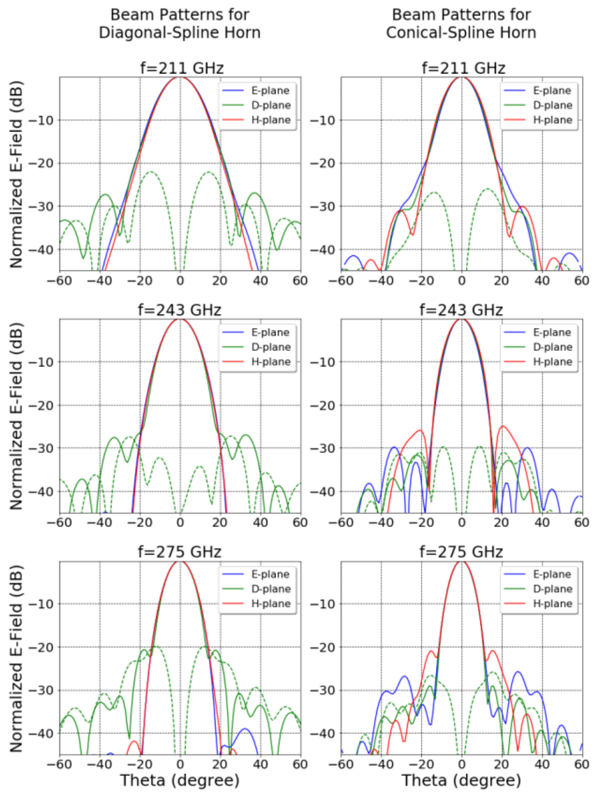

Fig. 2. Comparison of radiation pattern for diagonal-spline (left column) and conical-spline horns for their key analysis frequencies. Co-polar curves are shown in solid line, and cross-polar curves for D plane are shown in dashed line. Diagonal-spline horn it has lower level of sidelobes in E and H planes and a wider beam width. On the other hand, conical-spline horn exhibits lower sidelobes in D-plane, which correlates with lower levels of cross-polar for all the frequencies.

IV. CONCLUSION

We have designed and analyzed two smooth-walled spline-profile horns. The simulated radiation patterns have shown a very good performance with a Gaussicity over 96%, cross-polar lower than -20 dB over the entire frequency range. We deem that the simulated performance for both antennas meets the requirements to be used in astronomical applications.

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