Design and Measurements of a Double Ridged Guide Horn Feed for P-Band Direct Path Measurements

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***Abstract*— This paper presents the design and realization of a compact Double Ridged Guide Horn (DRGH), developed to perform direct path measurements at low frequency in a compact test range.**

***Index Terms*— Double Ridged Guide Horn; DRGH; direct path measurements; P-Band; Advanced Antenna Pattern Comparison; APCC**

I. Introduction

The Compact Test Range (CTR) facility of the Microwaves and Radar Institute at the German Aerospace Center in Oberpfaffenhofen is equipped with a dual reflector system, whose operational frequency ranges from 1GHz up to 100GHz [1]. The resulting quiet zone dimension varies from a minimum of 2.1 meters at L-Band to a maximum of 3.8 meters at the highest frequency. An alternative measurement method was researched in order to extend the operating frequency range down to 300MHz (P-Band). Antenna patterns at such low frequencies are now characterized with a direct path measurement, bypassing the dual reflector system in the chamber. The feed is mounted on an extendible beam and can be elevated directly facing the model tower carrying the Antenna Under Test (AUT). A laser alignment system has been implemented to ensure a perfect alignment of the two facing antennas. Fig. 12 shows a picture of the described installation.

The chamber is big enough to implement an Advanced Antenna Pattern Comparison (APCC) technique [2-3]. By means of multiple measurements taken varying the antennas distance, any effect due to the chamber environment surrounding the AUT (i.e. multipath reflections) can be eliminated in post process.

In this context, the design of a proper antenna feed is critical. The feed is required to be with broad bandwidth, constant gain over the bandwidth, low cross-polarization level and it should be as much lightweight and compact as possible.

II. Antenna design

The chosen design is a Double Ridged Guide Horn (DRGH) antenna [4-7]. Although horn antennas are not commonly considered for use at frequencies as low as 300MHz, the proposed short axial length design allows the development of a very reasonable sized antenna, maintaining all the advantages of a horn antenna, while overcoming at the same time the main limitation of them, i.e. a long axial dimension is required to maximize the gain for a given aperture size. Fig. 1 shows the design model of the feed.

A fully parametric model of the antenna was created in Ansys HFSS and simulated. Critical design elements like the ridge tapering and the stub cavity dimension were further optimized.

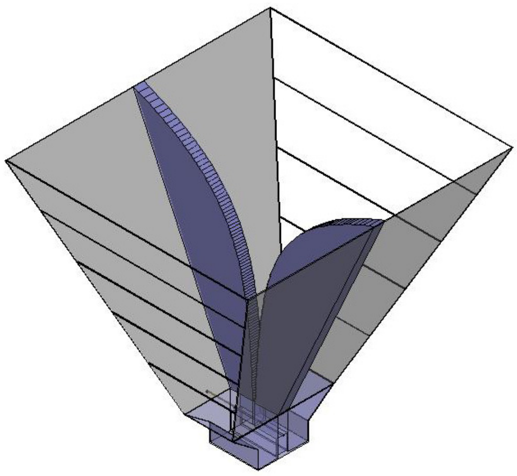

Figure 1. P-Band double ridged guide horn design model.

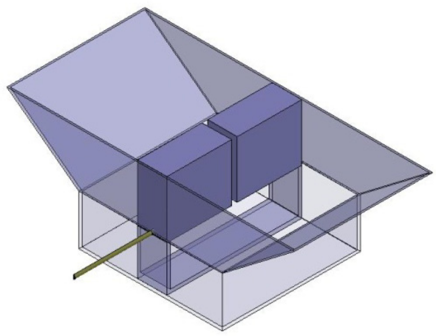

Figure 2. Launching section of the antenna. Particular care was taken shaping the cavity.

The launching section of the antenna can be observed in Fig. 2; this part was carefully designed as it is critical for a good matching and for the radiation performances.

In the Fig. 3, 4 and 5 some simulation results are presented. In particular, Fig. 3 shows the matching of the antenna at the input port: the bandwidth extends from 200MHz to more than 1GHz. Fig. 4 and Fig. 5 show the radiation pattern in the azimuth and elevation plane respectively. Both co-polar and cross-polar components are represented.

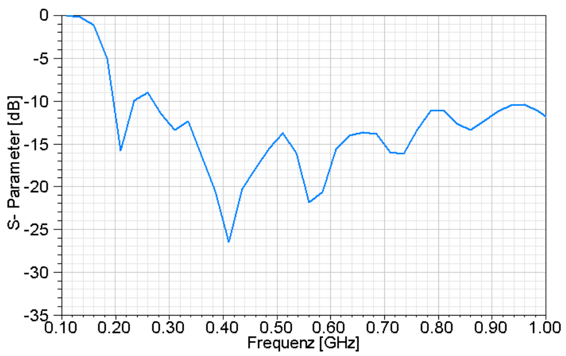

Figure 3. Matching, simulated, of the designed antenna, the bandwidth extends from 200MHz to more than 1GHz.

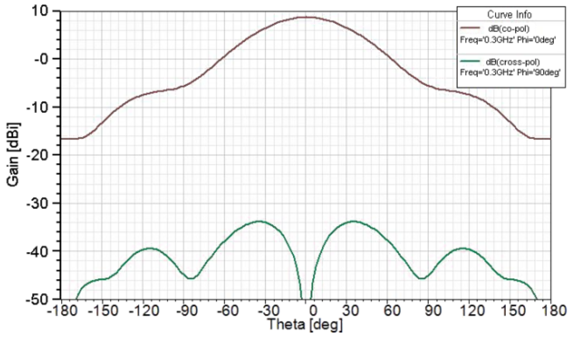

Figure 4. Antenna radiation pattern in the azimuth plane simulated at 300MHz. The purple line is the co-polar component, whereas the green line is the cross-polar component.

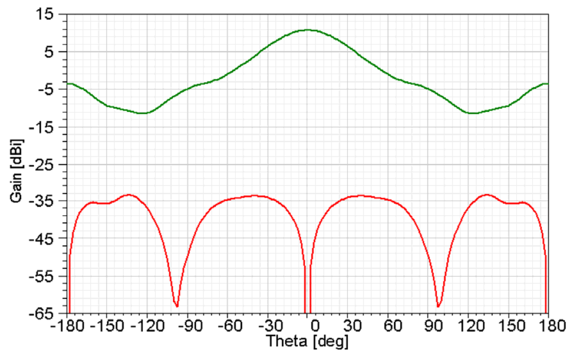

Figure 5. Antenna radiation pattern in the elevation plane simulated at 300MHz. The green line is the co-polar component, whereas the red line is the cross-polar component

III. Antenna Measurements

A prototype of the antenna was completely assembled in the Microwaves and Radar Institute in DLR and Fig. 6 shows a picture of that. The antenna dimensions are 949×691×933mm (width × height × depth), it has been built in aluminum and its weight is as low as 15kg. Its performances were measured in the same Compact Test Range Facility where it will serve as feed [6].

The designed DRGH feed shows a VSWR<2 from 250MHz up to more than 1GHz (see Fig. 7). Nevertheless the usability has been intentionally restricted to 1GHz in order to avoid some degradation in the radiation pattern that typically appear at higher frequencies and that won't be acceptable for the intended application. This beam distortion was further investigated in order to understand the cause.

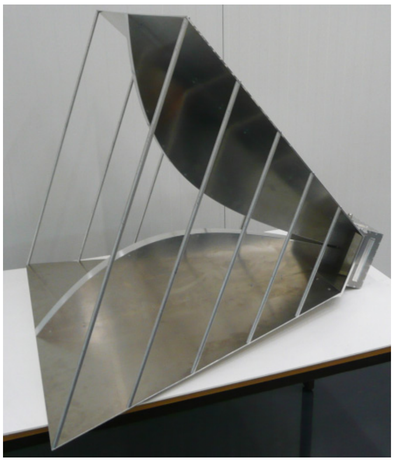

Figure 6. Assembled P-Band DRGH antenna prototype. Dimensions are 949×691×933mm (width × height × depth), the material is aluminum and its weight is 15kg.

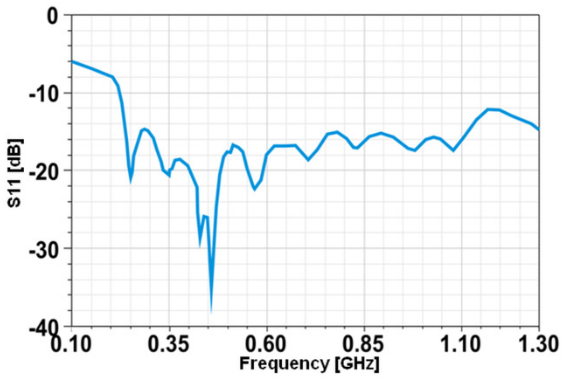

Figure 7. Measured matching at the input port of the assembled DRGH antenna.

Fig. 8 shows how this phenomenon appears: the pattern at 0.9GHz is still acceptable, though not optimal, but at 1.1GHz the side lobes are too high for this application. High side lobes mean high power measured due a multipath in the chamber, making too difficult to isolate the direct path radiation we are interested in. At higher frequencies $(f > 1.2GHz)$ ripples in the main beam become also evident. It is worth to be noted that the antenna matching remains very good above 1GHz, and the absolute gain does not change significantly, just the beam shape is affected. The electric field over the horn aperture was simulated and the results are presented in Fig 9. The left half image shows the electric field calculated at 0.9GHz and the right half image the field at 1.1GHz. It can be noted that superior modes are excited at higher frequencies and those are the cause of the disrupted radiated field.

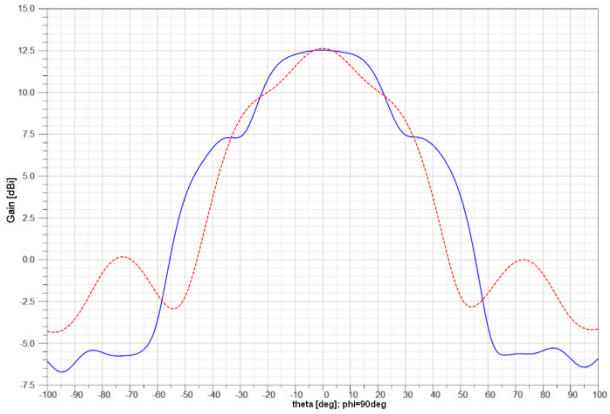

Figure 8. Measured radiation pattern in elevation plane at 0.9GHz (red, dashed line) and at 1.1GHz (blue, solid line). This comparison highlight the distortion of the main beam at higher frequencies, although the antenna matching is still good.

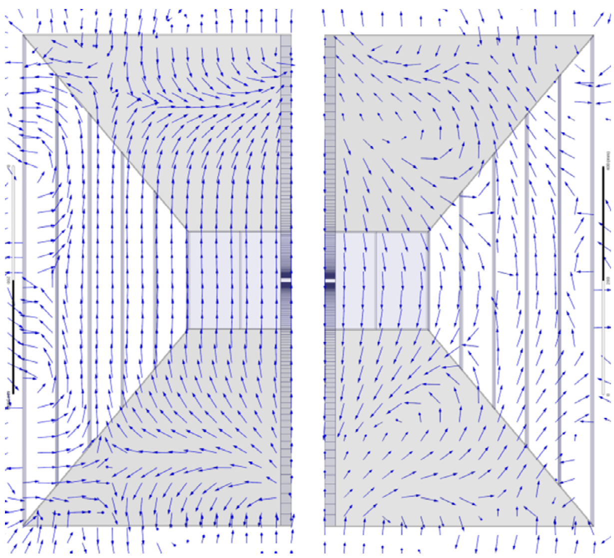

Figure 9. Simulated electric field distribution over the aperture. The left half image shows the field calculated at 0.9GHz; the right half image at 1.1GHz. Superior modes can be noted in the latter.

Fig. 10 and Fig. 11 illustrate other two measurement results. The first plot presents the radiated field in the azimuth cut plane measured at 300MHz; the diagram is normalized. The second one is a plot of the antenna gain over the frequency; in the region of interest the variation does not exceed 4dB. From all these results, we can conclude that the antenna fulfill the requirements.

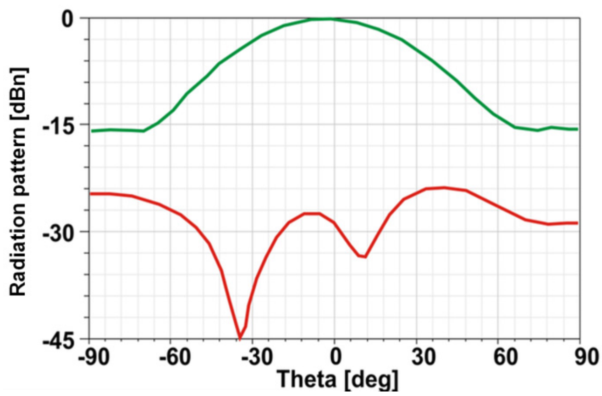

Figure 10. Radiation pattern of the DRGH antenna on the azimuth plane measured at 300MHz. The green line is the co-polar component and the red line is cross-polar compontent of the radiated field.

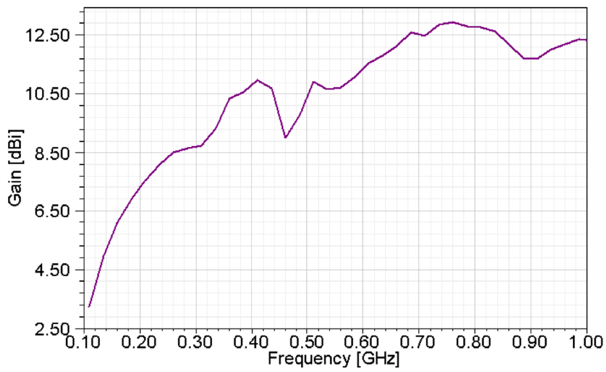

Figure 11. Measured gain over frequency of the DRGH antenna.

IV. Antenna Installation

A final exemplar, practically identical to the prototype except for a better suited mounting flange, was build and installed in the compact test range chamber as can be seen in Fig. 12. The boom over which the DRGH feed is mounted can be extended, so that the antenna come out from the floor and reach the same height as the antenna under test (this alignment is laser controlled). At this point the feed position is fixed, and the AUT is rotated to acquire a complete 3D scan. In order to perform the Advanced Antenna Pattern Comparison technique the AUT is slid backwards and the measurement is repeated. The propagation delay caused by this translation is known and can be removed from the measures. Now the only difference between the two acquisitions is the propagation delay due to the multipath that can be consequently estimated. It is possible to repeat the whole process in order to get a better accuracy.

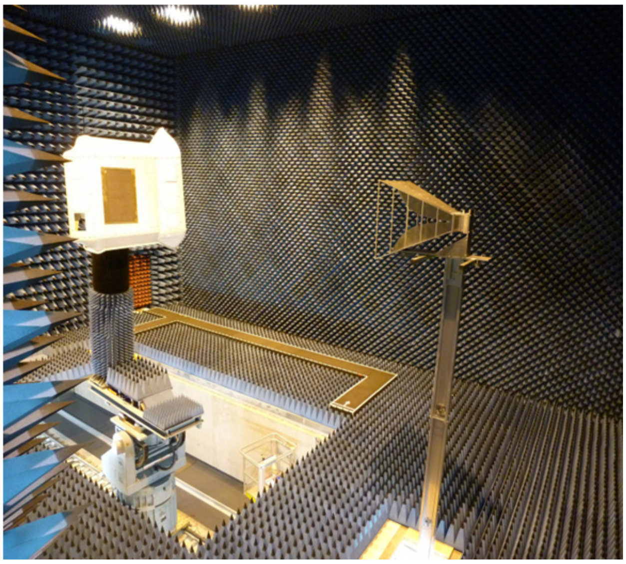

Figure 12. Measurement setup for direct path measurements. The antenna object of this paper is on the right side of the picture and is mounted on an extendible boom that come out from the floor when necessary. The AUT (the white antenna carrier with 5 antennas mounted on it) is mounted on a 6 axis tower and can be observed on the left side.

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