SMWD 2023, KTH Royal Institute of Technology, Stockholm, $23^{rd} - 25^{th}$May2023

Tolerance Analysis of Horn Antennas for Robust Supra-THz Design

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Summary

This paper presents the design, fabrication, measurement, and split-block misalignment tolerance analysis of three horn antennas operating at 400 GHz. The tolerance analysis is for receiver applications at supra-THz frequencies up to 4.7 THz where split-block misalignment has a more significant effect on a horn antenna's performance.

1 Introduction

The interest in developing technology for terahertz (THz) applications has been increasing over the last decades. The THz spectral region uses submillimeter-wave horn antennas for their applications in radio astronomy, biological sciences, and communication. While horn antennas are used due to their excellent coupling of THz signals in free space to waveguide modes or vice versa, the fabrication of these antennas is quite challenging. The commonly used corrugated horn radiates an almost perfect Gaussian beam but is impractical to produce above frequencies around 1.5 THz due to tolerance limits [1]. Therefore, antennas with simpler designs are preferred since they have fewer manufacturing requirements. Another advantage is that they lend themselves well to the split-block technique, which is commonly used for waveguide-led mixers at sub-millimetre wavelengths. By machining a block in two pieces and milling the waveguide cross-section channel in both halves, this technique avoids losses in the TE_{10} mode since the split is done along the maximum E-field vector in the centre of the waveguide [2].

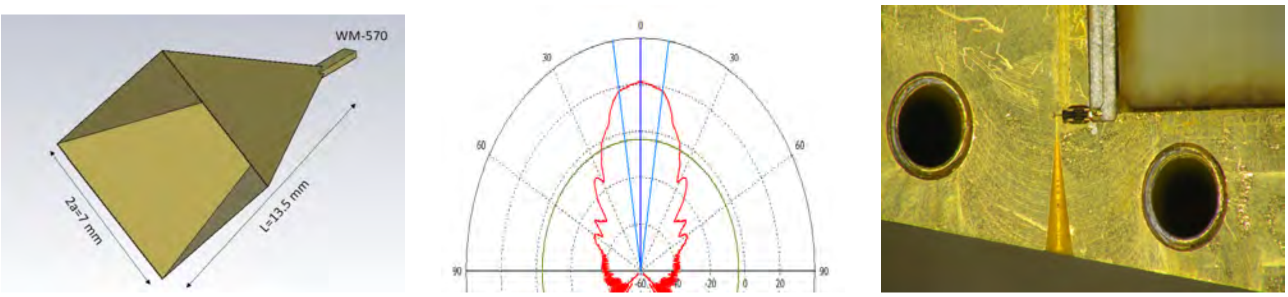

Figure 1. The full 3D-EM model of an aligned diagonal horn antenna with a WM-570 waveguide feed (left), the correspondent simulated E-plane far-field pattern at 400 GHz (middle), and a micrograph of an integrated diagonal feedhorn in a mixer block (right) [3].

Fig. 1 shows the layout of a perfectly aligned diagonal horn antenna used for the 3D-EM model. However, horn antennas made with the split-block technique are susceptible to misalignment when the two block halves are conjoined. The misalignment can affect the polarization and the coupling of power from the LO/RF source, which hinders components connected to the antenna from functioning optimally [3]. While there have been studies of the beam misalignments due to lateral offset and tolerance analysis of the horn antenna's fabrication methods, there has not been a focus on the split-block misalignment. Hammar et al. [4] mention that the split-block misalignment drives up the cross-polarization level and suggest manufacturing the horn in a solid metal block if such high levels are unwanted. Ding et al. [5] have considered the split-block misalignment in their design as it affected the circular polarisation of the septum polarizer, which led them to change the splitting position to reduce the misalignment contribution. However, this paper seeks to study the misalignments for symmetrically split blocks, which makes the approach in [5] unsuited for this case.

Investigating and measuring the misalignment effects on the horn antennas at supra-THz frequencies such as 4.0 THz is very difficult; instead, a ten times scaled-down design operating at 400 GHz is more manageable. The lower frequency design is incorporated with appropriately scaled misalignment to study how they affect the supra-THz horns. Therefore, this study aims to design and characterize three types of horn antennas at 400 GHz. The study will perform tolerance analysis on the antennas and investigate the possibility of scaling the analysis to their respective equivalent antenna operating at 4.7 THz. This would provide sufficient ground to compare the three types' robustness and conclude which is preferable at supra-THz frequencies.

2 Method

The choice of which three types to design and fabricate is based on the following requirements: the ability to manufacture at supra-THz frequencies, high Gaussicity, and low side-lobe level. Table I shows three potential feedhorn types that fulfill the requirements. A full electromagnetic simulation is performed using commercial EM software. The simulated far-field pattern is used to calculate parameters such as the beam waist (w_0), far-field divergence angle (θ_0), phase centre location (PCL), gain, and Gaussicity. Using the calculated parameters as reference values, introduce the split-block misalignments to the EM design until the simulation results are unsatisfactory.

TABLE I. Potential feedhorn types for the tolerance analysis.

Feedhorn Type	Gaussicity (%)
Diagonal	84
Pyramidal	85
Spline	96

The respective split-block CAD mechanical design is done with multiple alignment pin setups that would allow a specified level of misalignment in the horn antenna blocks. The manufacturing is performed in high-precision machining facilities at MC2. The manufactured antennas are measured using near-field measurements since far-field measurements would not offer a sufficiently large dynamic range that would appropriately characterize the antenna radiation pattern. The measurement setup uses an open waveguide as the measuring probe. The probe is mounted on two linear stages, orthogonal to each other, that form a planar near-field measurement. The measuring instrument, a Vector Network Analyzer (VNA), is connected to frequency extenders that enable measurements at the WM-570 band. The linear stages and the VNA are controlled by code sent through LabVIEW to the respective instrument.

The measurement is repeated for all the horn antennas and their misalignment setups. The near-field measurements are transformed into their respective far-field patterns using code based on the modal expansion method for planar systems [6]. This is expected to produce a far-field pattern with a dynamic range of around 65 dB. The calculated far-field patterns are compared to the simulation results to check their validity.

The measurement results and conclusion on the different horn antennas' robustness will be presented at the conference.

3 Acknowledgment

The authors would like to thank Mr. Mats Myremark for the high-precision machining of the horn antenna blocks.

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