Full-Waveguide Band Orthomode Transducer for the 3 mm and 1 mm Bands

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Abstract

The design of a novel, full-waveguide band orthomode transducer (OMT) for the 3 mm (75 - 110 GHz) waveguide band was previously reported [1]. Here, the fabrication details and test results from OMTs made for the 3 mm band are presented. New optimized designs for the 1 mm band are also shown.

1 Introduction

An orthomode transducer (OMT) is a device that separates orthogonal polarizations within the same frequency band. The traditional way of separating orthogonal polarizations, the wire-grid diplexer, is large and bulky. A broadband waveguide-based OMT would be a preferable alternative as it would be much smaller, can be cryogenically cooled, and it would be a good match to available high-performance dual-polarized broadband corrugated feedhorns. The design of a novel waveguide-based OMT was previously presented [1]. In this paper, the measured results of a 3 mm prototype are shown, and new optimized designs for the 1 mm band are presented.

2 Fabrication and Testing of 3 mm Band OMT

With improved fabrication techniques [2], high-quality waveguide blocks can be directly machined to 1 THz and beyond. One of the principal requirements in our design is the scalability of the design to terahertz frequencies. To verify the design, a 3 mm prototype was built using split-block techniques. Figure 1 shows the split-block view of the WR-10 OMT, and a close-up view of the septum. Design details and dimensions are summarized in [1]. The split-block was fabricated in Aluminum using NC machining on a conventional Haas milling machine. The only major challenge is the long ($\sim$ 9.5 mm) oval waveguide for the vertical (main arm) polarization. This latter feature was milled from both sides of the block to meet in the middle. The septum is 0.254 mm (0.010 inches) thick, and was fabricated using the micro-milling technique described in [2] from a 0.010 inch thick Aluminum shimstock. The septum is placed in a 0.127 mm deep pocket on the split-plane, and the two split blocks are tightened together using fasteners. Recessed 0.127 mm deep pockets on either split block outside the waveguide features (see Figure 1a) allows enough pressure to be applied to ensure adequate grounding of the septum to the block.

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The assembly is very simple, and the measurements are quite repeatable when the OMT is disassembled and then reassembled.

Figure 1b shows the results for the fabricated 75–110 GHz band OMT. Measurements were performed using a scalar network analyzer setup. While the OMT was designed originally using a square waveguide at the input, at the time of fabrication, a circular-square transition was built in to the input of the OMT (see Figure 1a). The measurement setup employed a WR-10 rectangular to circular transition at the input. Two back-to-back rectangular to circular transitions were first measured to calibrate the insertion loss (~ 0.1 dB across the band) of the single transition. The losses in the measurement setup have thus been removed in the insertion loss plot shown in Figure 1b. The insertion loss is ~ 0.2 to 0.3 dB across the band.

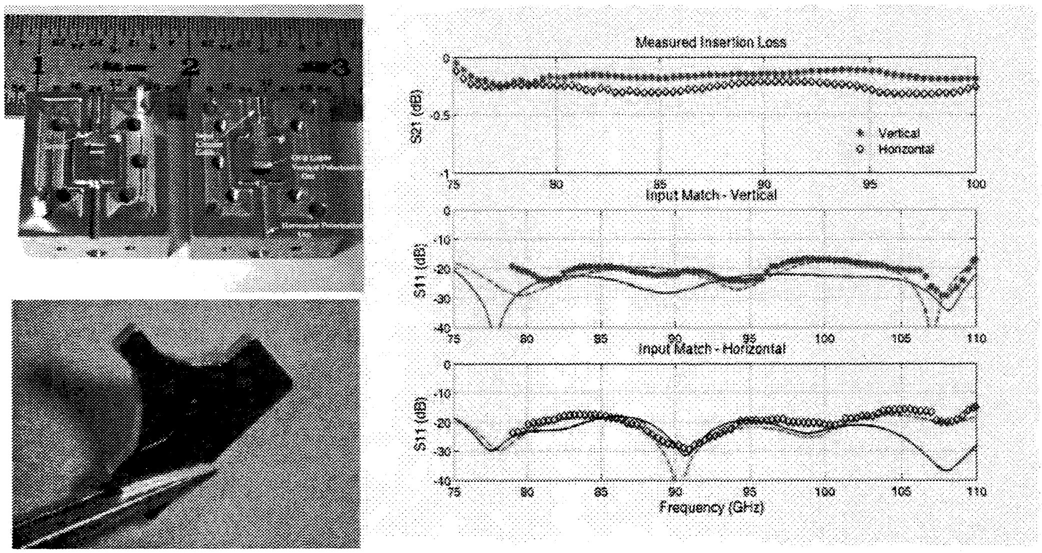

Figure 1: (a) Top. Split-block view of the 3 mm band OMT. Bottom. Zoomed-in photograph of the septum used in the OMT. (b) Scalar network analyzer measurements of the 3 mm OMT. Top panel. Insertion Loss in dB for each polarization. Bottom two panels. The measured input match for both polarizations is shown along with two simulated curves. The measurements points are shown as stars. The solid curves show the simulation for the designed OMT with an input square waveguide. The dashed curves show the effect of simulating the full OMT with the circular-to-rectangular transition that was added in the prototype model to facilitate the measurements.

The bottom two panels of Figure 1b show the measured input match for both polarizations, measured at the input circular waveguide flange. The match looked somewhat worse than that predicted by the original design (shown in solid lines in the bottom two panels). However, in the original design we did not simulate the circular-to-square transition. If we simulate the circular-to-square transition that was added at the input to the fabricated prototype, the agreement is much better. This circular-to-square transition is necessary to test the OMT, and was added at the fabrication stage without fully accounting for its effect on the OMT. Measured S11 points below 79 GHz have been removed from the plot in Figure 1b, as the source used in the scalar measurements did not have enough power to provide adequate dynamic range for the measurements. This same dynamic range problem in the measurement setup is present at other frequencies as well, which probably explains why the measurements are not able to reproduce the deep dips seen in the simulations. Even with a poorly matched circular to square transition, the prototype OMT has good input match ($<$ 17 dB across the band). An optimized transition will yield better performance. The good match with the simulations indicate that there were no major errors in the fabrication.

Compared to the Bϕifot OMT design outlined by Wollack et al. in [3], the OMT reported in this work offers the following advantages: (1) The Wollack NRAO OMT design had very tight mechanical tolerances and difficult assembly, and is not suitable for scaling much above $\sim$ 150 GHz. The new OMT design presented here can be scaled upto 1 THz without posing significant fabrication difficulties. (2) The waveguide pins (0.127 mm for W-band) that was used in the Wollack design has been replaced with simple capacitive steps in waveguide walls, considerably easing assembly and fabrication issues. (3) The new design also has a septum that is over four times thicker than that used in the Wollack design, which is easier to fabricate, provides better stiffness, alleviates mode conversion problems and provides better grounding to the block.

3 1 mm Band OMT Design

The most challenging part of the fabrication of the OMT is the long oval guide (9.5 mm) required for the vertical polarization to exit the block. This length is required to accommodate a normal UG-387 19 mm diameter flange on all three ports of the OMT. For the 3 mm band OMT, the tooling required for this guide is not specialized, but for the corresponding 1 mm band OMT, special tooling is required to mill the oval guide. One way around the problem is to split the block another time at the location of the output oval guide. The two side arm waveguides will then need to be bent by a H-plane bend and then recombined together. Figure 2a (bottom) shows such a "symmetric" configuration, with the two output rectangular output ports located on either side symmetrically from the input square waveguide. This latter structure has two split-planes, one on the YZ-plane as in Figure 2a (top), and one parallel to the XZ-plane and shown with a dark line in Figure 2b (bottom). On this latter split-plane, there is an E-plane bend and a H-plane bend, both of which can be optimized quite well, since we can utilize the entire waveguide height and width respectively for the bends.

Both types of OMT shown in Figure 2a were designed and optimized using CST Microwave Studio (CST MWS)[4], a time-domain finite-element analysis software suite. The predicted input match for both types of OMTs for either polarization are shown in Figure 2b. In a real receiver system, the input to the OMT will be a corrugated feed-

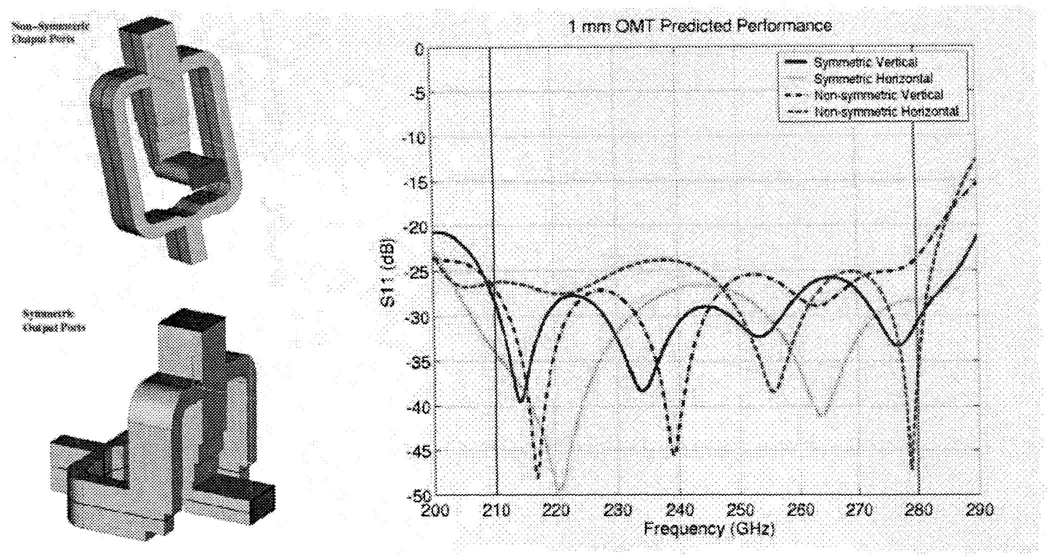

Figure 2: *(a) Left:*Two different designs for the 1 mm band OMT. The top figure shows essentially a scaled version of the 3 mm design with the two output ports orthogonal to each other (dubbed the "Non-Symmetric" type). The split-block plane is shown as a dark line and coincides with the YZ plane. The bottom figure shows the two side-arm guides bend through a H-plane bend and recombined to yield the two rectangular waveguide output ports located symmetrically with respect to the input square waveguide port. In addition to the YZ split-plane, another split plane is used (a plane parallel to the XZ plane, and shown as a dark line). The "symmetric" configuration does not need the oval waveguide. For the vertical (main-arm) polarization, the split-plane occurs where the current flow is at a maximum, so care is required in fabrication and assembly. *(b) Right:* Simulated input return loss for the "symmetric"and "non-symmetric" configurations of the 1 mm band OMTs shown to the left.

horn, so a waveguide flange will not be required at the input. This can ease the task of putting flange patterns on the other two ports, as also the required real-estate on the blocks for fasteners and alignment pins. The two split-plane "symmetric" configuration shows slightly better performance than the single split-plane "non-symmetric" configuration. But the "symmetric" configuration is more complex to fabricate and assemble.

4 Conclusions

A novel full-waveguide band orthomode transducer has been designed, fabricated and tested. The W-band prototype has $>$ 17 dB return loss and $<$ 0.3 dB insertion loss over the full design band of 75 – 110 GHz ($\sim$ 40% bandwidth). This new OMT is simple to fabricate and assemble and is scalable to frequencies of $\sim$ 1 THz. New optimized designs for the 1 mm band were also presented.

5 References

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