Modelling and Impact of 3D Print Inaccuracies on the Performance of Circular Waveguide Hybrid Coupler

Amrita Bal [1] and Gregory H. Huff [2]

[1] Department of Electrical and Computer Engineering, Texas A&M University, College station, TX-77843, USA
abal@tamu.edu

[2] Department of Electrical Engineering, The Pennsylvania State University, State College, PA-16801, USA
ghuff@psu.edu

Abstract **─** Circular waveguide hybrid coupler operating over a frequency range of ISM 57-64 GHz, additively printed and metal plated using electroless technique is introduced. Effects of orientation of print and thickness of intricate structures on the performance of circular waveguide hybrid coupler are presented. The structure is printed using commercially available stereolithographic (SLA) printer. Circulatory system operated by a peristaltic pump is used for selective silver deposition of the hybrid coupler.

Index Terms **─** 3D printing, circular waveguide hybrid coupler and electroless silver deposition.

I. INTRODUCTION

Different 3D printing processes are used for fabrication of microwave and millimeter-wave components in lesser time and cost. These techniques are stereolithography (SLA), polyjet, digital light processing (DLP), selective laser melting (SLM) and various others. Various structures fabricated using these additive manufacturing techniques are discussed in [1]. Print inaccuracies can lead to degraded performance. Inaccuracies introduced during printing and their impact on the performance of the structure is analyzed in [2]. Waveguide components are often modified for ease of fabrication and metal deposition [3]. Metal deposition is an important step that follows 3D printing. Metal deposition using electroless methods is discussed in [4].

This article aims to draw attention on the 3D printing inaccuracies and their effects on the performance of the structure. Simulation results of hybrid coupler are compared with measured structure with print inaccuracies. Figure 1 shows the CAD model and the fabricated model of the circular waveguide hybrid coupler. Figure 2 focusses on the intricate structures of the coupler. The group of ridges at the center of the structure and the vertical posts are prone to inaccurate prints. The authors aim to focus on the deviation between measured and simulated results due to print inaccuracies. High-frequency Structure Simulator (HFSS) is used for carrying out simulations of the hybrid assuming perfectly conducting electric walls).

Fig. 1. Fabricated model (top) and CAD model (bottom) of coupler.

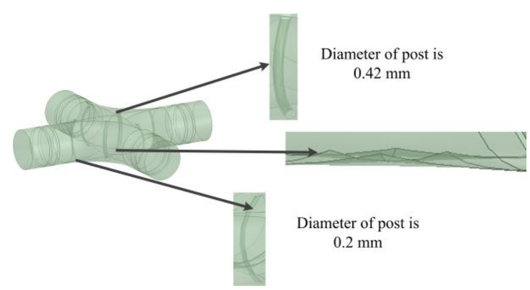

Fig. 2. Delicate structures inside the circular waveguide hybrid coupler.

II. 3D PRINTING OF THE HYBRID COUPLER

The hybrid coupler is printed in different orientations along x- and y-axis on the build plate for accurate prints of the group of ridges. On printing the hybrid horizontally on the build plate, two among the four ridges supported by the internal post in the structure are printed accurately while, the other two unsupported ridges get deformed. In the next iteration the

Submitted On: September 9, 2020
Accepted On: September 9, 2020

https://doi.org/10.47037/2020.ACES.J.351111

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structure is printed at incremental angles from 10 to 30 degrees with respect to x- and y-axis. Figure 3 compares the printed ridges at the center of the structure for angle of print 10 and 30 degrees respectively. Clearly the ridges are printed accurately at higher elevation.

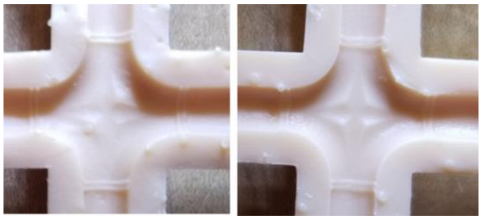

Fig. 3. Printed structure at 10 degree (left) and 30 degree (right) elevation along x- and y-axis.

A comparison of the printed posts of diameter 0.2 mm and 0.42 mm for similar curvature are shown in Fig. 4. Clearly, the 0.42 mm diameter post is printed accurately than the 0.2 mm diameter post.

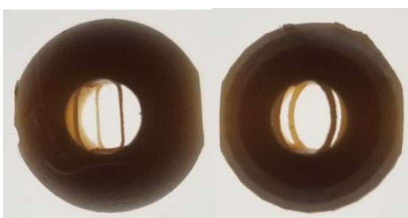

Fig. 4. Printed post of diameter 0.2 mm (left) and 0.42 mm (right).

III. MEASURED RESULTS

A. Equation formatting

This section discusses the effects of printing inaccuracies on the performance of the structure. The measured structure has inductive post of diameter 0.2 mm, printed at an elevation of 10 degrees to x- and y-axis. The hybrid coupler is metal plated using electroless silver deposition technique discussed in [4]. Figures 5 and 6 show the measured and simulated results. Figure 6 shows the unequal power division at the output ports. Figure 7 shows the error encountered in path length between input and output due to fabrication inaccuracies.

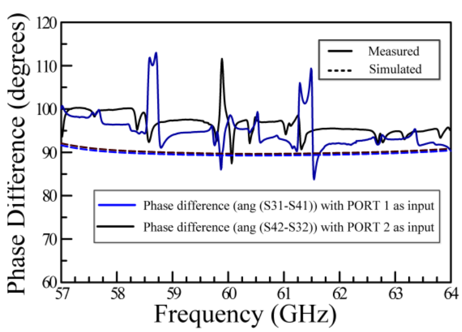

Fig. 5. Measured and simulated phase difference between output ports.

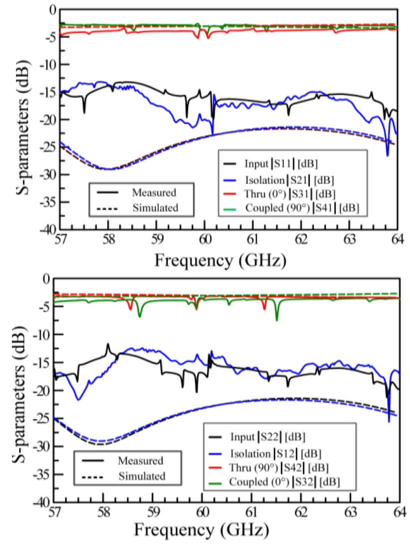

Fig. 6. Measured and simulated magnitude distribution at output ports when PORT 1 (top) and PORT 2 (bottom) are excited.

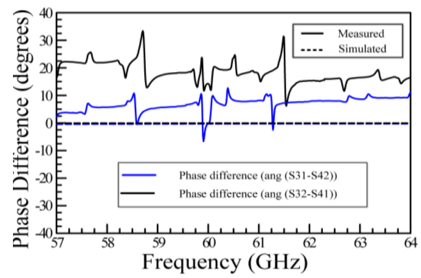

Fig. 7. Difference in path length between input and output ports.

VI. CONCLUSION

This paper summarizes the performance variations observed in a hybrid coupler due to print inaccuracies. Unequal power distribution at output and significantly different path lengths are some of the effects of print inaccuracies. These results can be leveraged to understand similar 3D printed microwave components with delicate structures.

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