Additive Manufacturing Techniques Applied Towards the Fabrication of Millimeter-Wave Components

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***Abstract*— Additive manufacturing technology has made significant advances in terms of materials, resolution, and surface finishes. The technique is becoming more and more common in science and industry. Since it has proven effective in constructing small parts with fine features, 3D printing is well suited for improving upon the manufacturing processes of microwave components. This paper explores the approach specifically applied to waveguide components produced via electroforming. Several 3D printed mandrels have been used in the manufacturing of a number of different types of microwave components. Initial testing of the components' electrical performance at microwave frequencies is encouraging.**

I. Introduction

Millimeter wave components with complex geometries often require specialized microfabrication techniques. Some of these techniques include electron discharge machining (EDM), photolithography, and laser ablation [1]. Such manufacturing processes can be limiting in terms of cost, labor, and schedule.

For components designed to perform in the 100-200 GHz frequency range, copper electroforming is often used. Electroforming is a metal plating process that deposits layers of copper onto a mandrel, which is the base form of the inner surface of the part. Mandrels are usually precision machined out of metal, typically stainless steel or aluminum. After the electroforming deposition process, the mandrel is chemically dissolved leaving the outer copper shell, which is then the basis for the desired component.

Electroforming has been used successfully for a variety of microwave components at General Atomics (GA). However, producing a finished part with this approach tends to be time-consuming since it requires several steps: machining the mandrel, electroforming, dissolving the mandrel, and attachment of mating flanges. It may be possible to reduce the production time by fabricating the mandrel using additive manufacturing techniques such as 3D printing, a process step which takes less than one day. Eventually, it may even be possible to print metal parts using a process called Direct Metal Laser Sintering (DMLS), avoiding the need for electroforming altogether [2].

II. Results

Two separate previously-designed microwave components at GA were selected for manufacturing using 3D printed mandrels. The first was rectangular-to-circular waveguide transitions designed for operating from 90-150 GHz (Fig. 1). Such parts are small, so plastic mandrels were easily reproduced using additive manufacturing. The overall tolerances of the mandrels were ±0.001/1 in. of printed material [3]. No post-printing surface finishing was performed. Two waveguide transitions were built and tested in the laboratory.

The other components were a pair of rectangular to square tapers designed to operate from 100-180 GHz. They had similar-sized features as the other mandrels, but were larger and therefore more challenging for the 3D printer. The mandrels are long and thin; initial printed units were significantly warped. An outer support frame was added to provide rigidity. The same set of printing parameters was used as in the previous case.

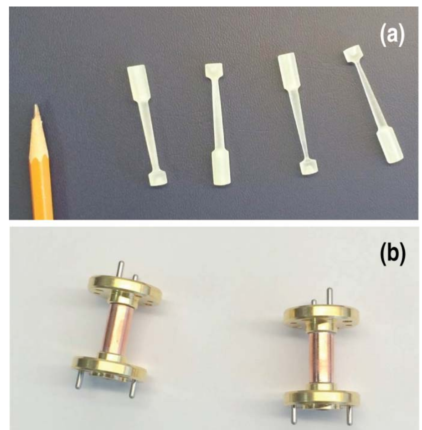

Fig. 1. 3D printed mandrels (a) used in the elctroforming of rectangular-to-circular waveguide transitions (b).

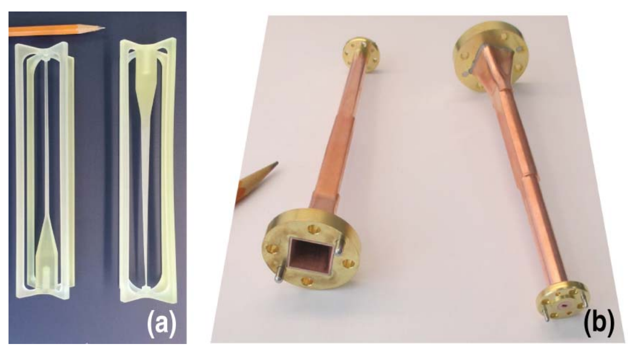

Fig. 2. Mandrels with extra support for rigidity (a) used in the manufacturing of rectangular-to-square tapers (b).

Although there is some added roughness to the inner surfaces of the components using the 3D printed mandrels, initial RF measurements demonstrated low loss. Future measurements are planned to determine mode purity.

Ackknowledgement

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References

[1]. J.H. Booske et al, "Vacuum electronic high power terahertz sources," *IEEE Trans. THz Sci. and Tech., vol. 1*, pp. 54-75, Sept. 2011.
[2] J.P. Anderson, R. Ouedraogo, and D. Gordon, "Fabrication of a 35 GHz Folded Waveguide TWT Circuit Using Rapid Prototype Techniques," in *Proc. 39th Int'l Conf on IMMW-THz Waves*, Tucson, AZ, 2014.
[3] Solid Concepts website, www.solidconcepts.com/technologies/polyjet.