3D printing of X band waveguide resonators and filters

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Abstract

We present a novel approach to fabricate microwave passive components using very cheap SLA 3D printing technology associated with copper electroplating of the resulting 3D plastic structures. Some test structures are presented showing the excellent performance of the process.

1. Introduction

Novel material processing technologies open important innovative opportunities for the manufacturing of microwave and radiofrequency components. Particular interest is being devoted to the manufacturing of passive components using Additive Manufacturing (AM) technologies, such as stereolithographic (SLA), selective laser sintering (SLS), direct metal laser sintering (DMLS), fused deposition modeling (FDM)[1, 2, 3, 4, 5]. The key feature of such technologies is the ability to build an entire component from its digital design without or with great reduction of the part assembly process in a very short time. This new technology can lead to an automatic production of prototypes from the CAD files once they have been designed and optimized by numerical simulation tools.

As far as waveguide components are concerned, unless expensive SLS or DMLS technology are employed, the printing process produces a plastic model that needs to be plated by a conductive layer. The most common approach is based on painting the surface of the plastic model with silver based ink.

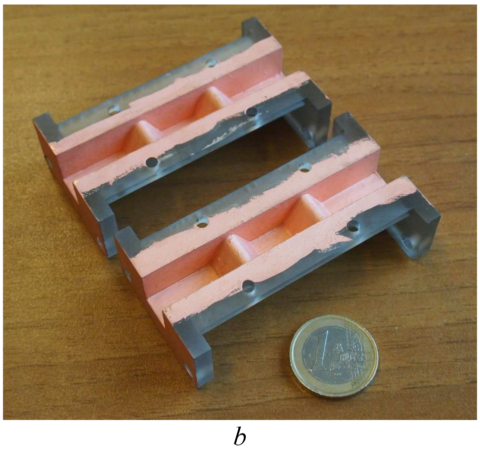
Unfortunately, conductive ink does not perform as a real metal layer so that it is not a good solution for components that have to show very low loss, such as filters. We have therefore developed a somewhat different approach using electrolytic copper deposition to create high quality conductive layers on SLA-made plastic structures. Several examples of microwave components requiring a high quality conductive layer, such as resonators and filters, are presented in this paper to demonstrate the accuracy of the SLA 3D printing and the excellent conductivity of the layers laid on the surface of the component.

2. The test structures

We have performed a preliminary test on an X-band waveguide resonator in order to set the process parameters. The electrolytic copper deposition is performed after the deposition of an initial conductive layer deposited by silver ink. The adhesion of copper to the plastic of the structure is a key issue that requires a proper choice of the initial layer.

Figure 1 shows two different prototypes, a single piece suitable for dip coating and a split one suitable for the inspection of the deposition onto the internal surface.

a



b

Figure 1. a) X band waveguide resonator before metallization, b) split version with copper deposition on the internal surface.

The copper layer has been deposited by electrolytic reaction. Once assembled, the split resonator has been measured.The comparison between the experimental and the theoretical responses is shown in figure 2. It is apparent the accuracy of the manufacturing process that has led to a resonance frequency very close to the theoretical one. Moreover the Q factor of about 3700 confirms the excellent performance of the copper electroplating.

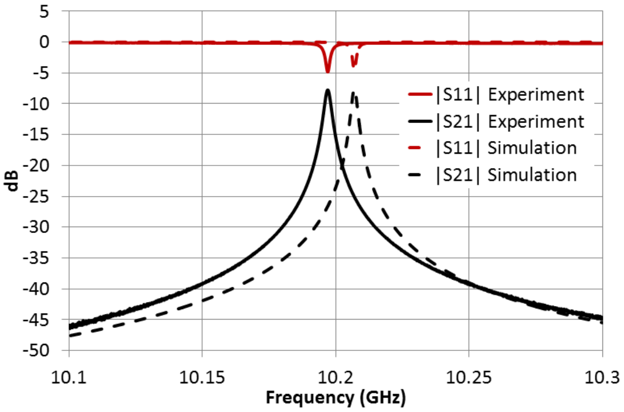
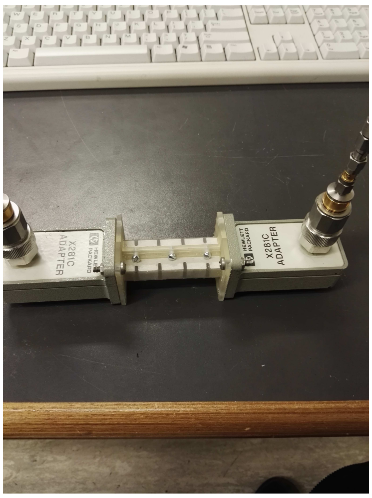


Figure 2. Measured and simulated X band resonator (split version) with copper deposition on the internal surface.



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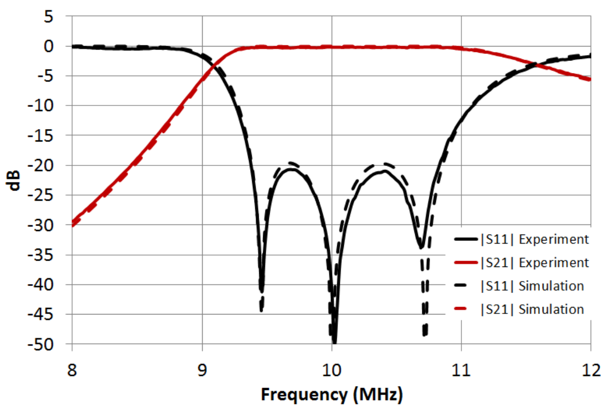

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Figure 3. X band filter, a) finished structure, b) measured scattering parameters

The inspection of the surface of the deposition has shown little roughness and a metal thickness greater than 10 um. The metal thickness can be optimized depending on both the electroplating current and the deposition time.
In order to test the feasibility of the technology for the manufacturing of filters in the X-band, a third order iris-filter has been designed and manufactured.
The filter structure and the measured scattering parameters are shown in figure 3. The insertion loss at 10 GHz is of the order of 0.2 dB, demonstrating the good dimensional accuracy achieved by the SLA printing process and the excellent conductivity of the electroplated copper layer.

3. Conclusions

A novel approach has been set up to fabricate microwave passive components using very cheap SLA 3D printing technology associated with copper electroplating of the resulting 3D plastic structures. Various microwave components involving resonant structures, such as resonators and filters, have been fabricated and measured. An excellent conductivity of the copper electroplating and good mechanical tolerances have been demonstrated on two X-band filters, whose electromagnetic performances are very close to those obtained by the conventional fabrication methods. Fast protoping and good electromagnetic performance make the technology presented a very promising one.

4. References

1. O. A. Peverini; M. Lumia; F. Calignano; G. Addamo; M. Lorusso; E. P. Ambrosio; D. Manfredi; G. Virone, "Selective Laser Melting Manufacturing of Microwave Waveguide Devices," in *Proceedings of the IEEE*, vol.PP, no.99, pp.1-12

2. F. Calignano; D. Manfredi; E. P. Ambrosio; S. Biamino; M. Lombardi; E. Atzeni; A. Salmi; P. Minetola; L. Iuliano; P. Fino, "Overview on Additive Manufacturing Technologies," in *Proceedings of the IEEE*, vol.PP, no.99, pp.1-20.

3. H. Xin; M. Liang, "3D Printed Microwave and THz Devices Using Polymer Jetting Techniques," in *Proceedings of the IEEE* , vol.PP, no.99, pp.1-19

4. J. Maas; B. Liu; S. Hajela; Y. Huang; X. Gong; W. J. Chappell, "Laser-Based Layer-by-Layer Polymer Stereolithography for High-Frequency Applications," in *Proceedings of the IEEE* , vol.PP, no.99, pp.1-10

5. U. Beaskoetxea, S. Maci, M. Navarro-Cía and M. Beruete, "3-D-Printed 96 GHz Bull's-Eye Antenna With Off-Axis Beaming," in *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 1, pp. 17-25, Jan. 2017.