3D-Printed Filters in Substrate Integrated Waveguide Technology

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***Abstract*—One of the emerging topics in electronic engineering in the last few years is the Internet of Things (IoTs). The IoT enhances the traditional Internet: while internet is used to connect people, IoT will create intelligent connections between inanimate objects, as well as between objects and persons, anywhere and anytime. The deployment of the large number of wireless systems expected for IoT applications requires a suitable manufacturing process and an efficient integration technology. The use of 3D printing opens new perspective in emerging applications under the umbrella of the IoT.**

In this project, the implementation of SIW filters by 3D printing is reported, and the advantages of a reduction in the infill percentage are considered.

***Index Terms*—3D-Printed Filters, Internet of Things, Fused Deposition Modeling, Substrate Integrated Waveguide.**

I. Introduction

We are going toward a fully connected world, a world where a lot of wireless devices are connected among them and with people to provide advanced information. We are going to have a large number of sensors, to provide an enormous quantity of information, that can be used in different services and that will have as first purpose improving the quality of life. Of course, this increasing need of wireless sensors and their future integration with every-day life, which is called Internet of Things (IoT) [1], requires the development of wireless systems to be integrated with sensors. These wireless systems have to be low cost and easy to fabricate.

In order to follow these requirements and to implement the next generation of wireless systems for the IoT, we need a good integration technology, able to efficiently combine active elements, passive components and antennas, and suitable materials. The integration technology that we use is the Substrate Integrated Waveguide Technology and we have a large number of 3-D printing materials that can be suitable for the development of these devices.

For the realization of components in the microwave field by using 3D printing, we concentrate more on FDM (Fused Deposition Modeling), which is only one of the different ways in which we can exploit additive manufacturing to print plastic dielectric layers.

We have a large flexibility in the selection of the material, because one can use standard plastic material like PLA or ABS, materials like NinjaFlex, flexible materials or stiff materials and so on [2].

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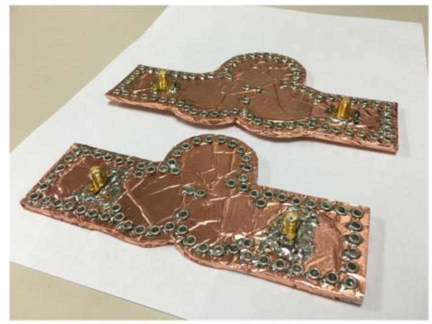


Fig. 1. 3D printed SIW Filters: structure with the low-infill percentage (top) and 100%-infill percentage (bottom) (from [3]).

FDM allows local modification of the printed material properties by acting on the infill factor. The variation of the density affects the effective dielectric permittivity of the printed material as well as its electric loss tangent. With 3D printing, it is so possible to “tune” the permittivity of a material and its loss tangent by acting on the infill factor.

Moreover, if the permittivity changes, losses also change. This is very interesting, because if one prints a filter with a certain material and is not satisfied about the obtained quality factor, it is possible to decrease the infill percentage, increasing in this way the quality factor.

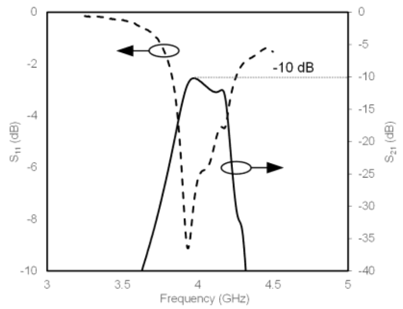
II. 3D Printed Filters

This solution has been adopted in a recent work [3], where two 3-cavities filters (Fig. 1) were 3D-printed using ABS filament.

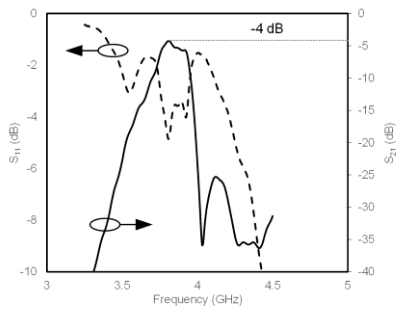
A. Filter with 100% infill factor

The first filter was designed by using a dielectric substrate with 100% infill, corresponding to a permittivity $\varepsilon_r = 2.7$. In this filter, the dielectric permittivity is homogeneous in the whole structure. This filter has been realized in SIW technology, and the optimization has been performed by using Ansys HFSS. The model was then exported as STEP files, which are then re-imported into Solidworks and re-exported into .STL files, which are standard for 3D printing.

Once fabricated, the experimental scattering parameters have been found out and, as we see in Fig. 2a, an insertion loss of about 10 dB is obtained for this structure.

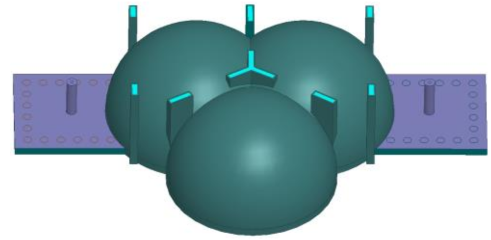


(a)

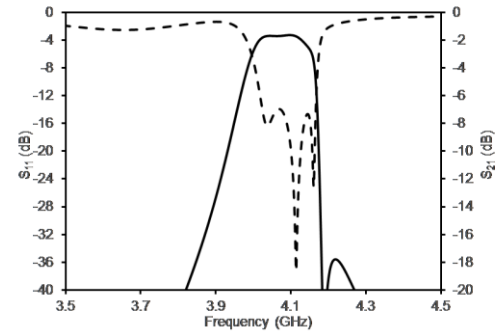


(b)

Fig. 2. Scattering parameters plots: (a) First filter, with 100% infill; (b) Second filter, with 40% infill.



(a)



(b)

Fig. 3. Filter with three hemispherical cavities: (a) Structure of the filter; (b) Scattering parameters plot: the solid black line represents $|S_{21}|$, while the dashed one is relative to $|S_{11}|$.

B. Filter with 40% infill factor

In the second filter, the infill of the cavity resonators was decreased to 40%, corresponding to a permittivity $\varepsilon_r = 1.6$, while the permittivity was kept to $\varepsilon_r = 2.7$ in the input/output waveguides. Since both filters have been designed to have the same frequency response (centered around 4 GHz), the cavities of this second filter are larger than those of the first filter (with higher permittivity). As we see in Fig. 2*b*, this filter had significant lower measured losses (approximately 4 dB insertion loss compared to 10 dB of the first filter).

Therefore, by reducing the infill factor, it is possible to increase the quality factor of the filter, even if at the cost of a slightly increased footprint size.

C. Filter with hemispherical resonators

Since 3D printing has the advantage of allowing the construction of structures with arbitrary shape, a filter with three hemispherical cavities has been realized (Fig. 3*a*). This filter was designed with HFSS by using ABS with 100% infill, both for the resonators and for the input/output lines. Since the hemispherical resonators are empty inside, we expect to obtain very high quality factor with respect to the previous solutions and, consequently, a lower insertion loss. While in the previous filter all the irises were made up by copper cylinders, here they are made up by eight boxes constituted by an external layer of ABS with vacuum inside.

As we can see from Fig. 3*b*, the scattering parameters plot perfectly followed our expectations: the losses are significantly reduced with respect to the cylindrical-cavities filter, and the filter presents an insertion loss of about 1.6 dB.

III. CONCLUSIONS

The research activity proposed in this work deals with the development of filters based on SIW technology and 3D printing. The purpose of this study is to pave the road to low cost and rapid prototyping of novel 3-D printable filters and, in general, components with easily tunable and optimized electrical and mechanical characteristics.

ACKNOWLEDGMENTS AND FUTURE PLANS

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