Proposal Research Topic: 3D-Printed Reconfigurable Components in Substrate Integrated Waveguide Technology

Student: Giulia Maria Rocco

Faculty mentor: Maurizio Bozzi, *Senior Member, IEEE*

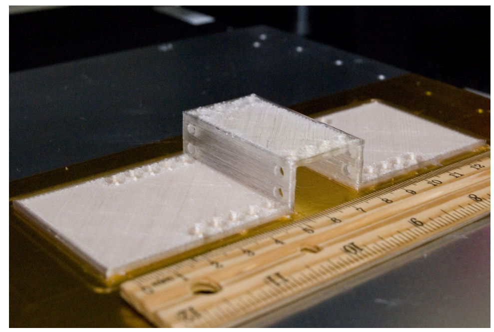
***Abstract*—Additive manufacturing is becoming a very popular fabrication technique for the rapid prototyping of low-cost and flexible microwave components and systems with arbitrary geometry. The use of 3D printing opens new perspectives in emerging applications under the umbrella of the Internet of Things (IoT). Substrate integrated waveguide (SIW) structures based on 3D printing have been recently proposed and demonstrated.**

This research activity aims to study and design low-loss and reconfigurable microwave components in SIW technology, manufactured by 3D printing. The loss reduction will be pursued by modifying the material density, in order to achieve resonant cavities with higher quality factor. A commercially available liquid metal alloy named Galinstan will be adopted for the implementation of the reconfigurable components. The geometry of SIW filters based on 3D printing and Galinstan is briefly outlined in this proposal.

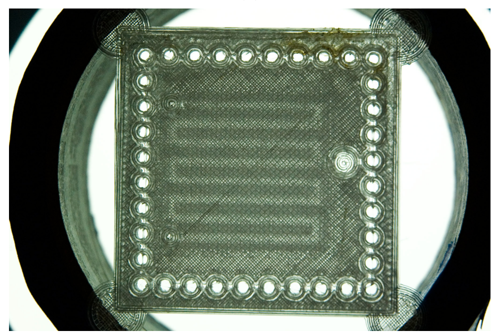
I. Introduction

The development of the next generation of Wireless Sensor Networks (WSN) toward the Internet of Things (IoT) paradigm [1] demands for RF and microwave components with special features in terms of flexibility, light weight, compact size, and easy fabrication. The deployment of the large number of wireless systems expected for IoT applications requires a suitable manufacturing process and an efficient integration technology. Among the emerging manufacturing technologies, 3D printing [2,3] is becoming very popular, as it allows for fast prototyping, high resolution, and the implementation of fully 3D complex shapes and geometries that are impossible for subtractive techniques. Among the integration technologies, the substrate integrated waveguide (SIW) has been widely adopted in the last decade for the implementation of active and passive components and antennas, as well as for the integration of complete systems at microwave and mm-wave frequencies [4]. A variety of SIW components and antennas have been already implemented on non-standard materials for wearable and eco-friendly applications, including paper, textile, and plastic.

The combination of SIW technology and 3D printing has been recently proposed [5]: an SIW interconnect with four 90-degree E-plane bends has been developed and manufactured (Fig. 1*a*): the substrate was printed by fused deposition modeling and the metallizations were based on copper tape and metal rivets. In the case of SIW components, 3D printing allows to overcome the limit of the planar components fabricated by standard printed circuit board (PCB) process. Moreover, 3D printing permits to realize dielectric materials with different density, thus allowing to control the dielectric permittivity [6]. 3D printing has also been adopted for the implementation of an SIW-based microfluidic sensor [7]. It consists of a square SIW cavity with a pattern of thin pipes directly embedded in the substrate, with two vertical exits on the top of the substrate (Fig. 1*b*). The two vertical exits are designed in order to guarantee a continuous flow of fluid within the pipe. The presence and characteristics of the liquid determined a frequency shift of the cavity resonant modes.



(*a*)



(*b*)

Fig. 1. Example of 3D printed substrate integrated waveguide components: (*a*) SIW interconnect with four bends in the E-plane (from [5]); (*b*) SIW-based microfluidic sensor (from [7]).

In this project, the focus will be mainly on the development and the implementation by 3D printing of innovative SIW components, which exhibit low losses and feature reconfigurability of their frequency response. The work will require, on the one hand, the investigation and design of suitable circuit topologies, and, on the other hand, the improvement and full control of the manufacturing process. In particular, the use of a commercially available liquid metal alloy named Galinstan [8] will be investigated for the implementation of the reconfigurable components.

II. Project Description

The first aim of the project is the development of innovative SIW components based on additive manufacturing that exhibit low losses. In fact, most of the printable materials are not developed specifically for microwave applications and their loss tangent is quite high, representing the major contribution of loss in SIW components. In the case of filters, the large dielectric loss limits the selectivity of the frequency response.

3D printing offers a powerful solution to mitigate the loss problem: a smaller filling factor can be adopted to reduce the material density, thus lowering the dielectric permittivity and the loss tangent, according to the Bruggeman's model.

This concept will be applied to the design of SIW filters, where lower density material will be used to fill the resonant cavities (Fig. 2*a*). This solution will improve the quality factor of the cavities, at the price of a slightly larger circuit size.

Besides the design of the filter, the implementation of this idea will require a significant effort in the fine-tuning of the printing technology, including the choice of the most suitable material and the optimization of the printing process.

The second major aim of this project is the development of reconfigurable SIW components, based on the combined use of 3D printing and Galinstan. To this aim, a micro-pipe will be printed directly in the substrate, and the Galinstan is injected inside the pipe to modify the effective size of the SIW component.

An SIW filter based on this concept will be designed (Fig. 2*b*). In the first implementation, a single pipe with Galinstan will be used to modify only the size of the resonant cavities, with the aim to shift the pass band of the filter. To achieve better performance, the pipe with Galinstan can also be used to modify the coupling between the cavities.

The open points of this work will be the analysis of the material compatibility, in particular to avoid any critical interaction between the Galinstan and the printed substrate. Moreover, the electrical contact between the Galinstan and the top/bottom ground planes of the SIW structure will need a special care.

Definitely, this project will require a good balance between theoretical and experimental activities, to achieve the implementation and full verification of the prototypes.

III. Conference to Attend and Scholarship Usage

If Giulia receives the Undergraduate/Pre-Graduate MTT-S scholarship, she plans to attend the IMS2016 conference in San Francisco, CA. After listening to the previous experience of other students in Pavia, Giulia believes that IMS represents a great opportunity to get in touch with the world of microwaves, and she is looking forward to attending the most relevant microwave event worldwide. Moreover, during the IMS2016, she intends to participate in the Graduate Student Challenge and also help as a Student Volunteer.

Giulia will pursue her graduate studies in the field of microwaves and wireless technologies. If her application is successful, she intends to invest the funds to attend a couple of Summer Schools in the field of wireless technologies.

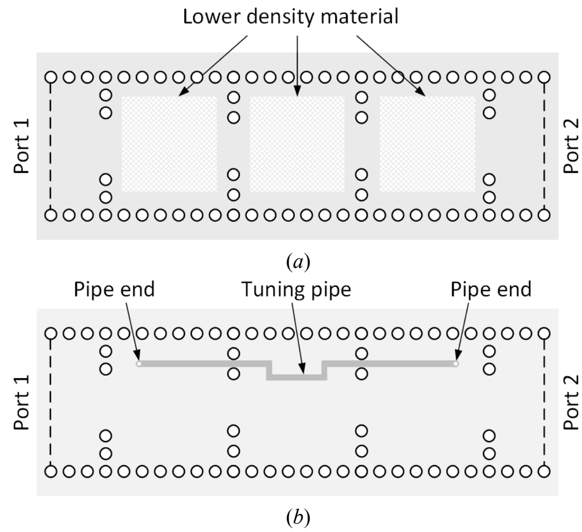


Fig. 2. Schematics of low-loss and reconfigurable 3D printed SIW components to be designed: (*a*) low-loss SIW filter, showing low-density regions in the resonant cavities to improve the quality factor; (*b*) reconfigurable SIW filter, based on the injection of Galinstan in the pipe.

IV. Conclusion

The research activity proposed in this document aims to develop innovative microwave components, based on SIW technology and additive manufacturing, which exhibit superior performance in terms of loss and feature reconfigurable frequency response.

An SIW filter with variable-density substrate material will be designed and manufactured. The use of a liquid metal named Galinstan will be investigated for the implementation of a reconfigurable SIW filter: a micro-pipe for the Galinstan will be 3D-printed directly inside the substrate.

These devices will open new perspectives in the field of wireless sensor networks and the Internet of Things, thanks to their compact size, flexibility, easy fabrication, and low cost.

References

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