Compact Half-Mode Substrate Integrated Waveguide Filters on Paper Substrate

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***Abstract*— This report presents the study and design of compact Substrate Integrated Waveguide (SIW) filters on traditional and paper substrates. These devices are small, low cost, easy to fabricate and eco-friendly, and thus ideal for Internet of Things (IoT) and Wireless Sensor Network (WSN) applications. SIW technology has been chosen for its ease of implementation and high electromagnetic performance, which helps to lessen paper's inherently high losses. These filters are based on the control of the frequency of the resonant modes of the SIW cavity through perturbations of the metal layer. A modified version of the SIW technology called Half-Mode SIW (HMSIW) has been applied to reduce the component dimensions and suppress some of the higher order resonant modes of the SIW cavity.**

***Index Terms*— Internet of Things, Microwave filters, Passive circuits, Substrate Integrated Waveguide.**

I. Introduction

THE REQUEST for low-cost and eco-compatible components for wireless communication has increased dramatically during the last few years, with the development of the Wireless Sensor Networks (WSN) and the Internet of Things (IoT). In this framework, alternative substrate materials have been subject to intense research. Paper, being completely organic, readily available and very low cost, is one of the most promising materials currently under study; however, due to its high losses, it requires particular care in the design. For this reason, the substrate integrated waveguide (SIW) technology represents the ideal solution for paper-based device implementation.

The SIW is a waveguide-like structure, based on a dielectric substrate with metal layers at both sides (to define the top and bottom walls) and two parallel rows of metal vias (to define the side walls). SIW structures are used for the production of both passive and active components in microwave and mm-wave applications, due to their good electromagnetic features, ease of integration in complete systems and high versatility. In the last years, SIWs have been implemented with a variety of substrates, like textile, plastic, and paper.

This report presents the development of passive band-pass filters substrate using SIW technology with a particularly compact topology.

This work was supported by the IEEE MTT-S Undergraduate/Pre-graduate Scholarship Program.

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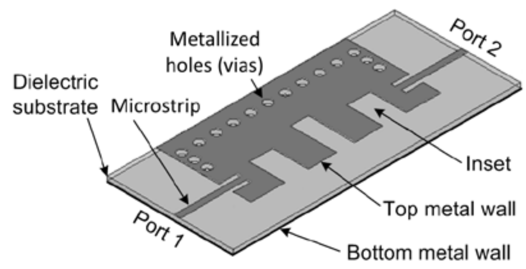


Fig. 1. Topology of the half-mode SIW resonant cavity filter.

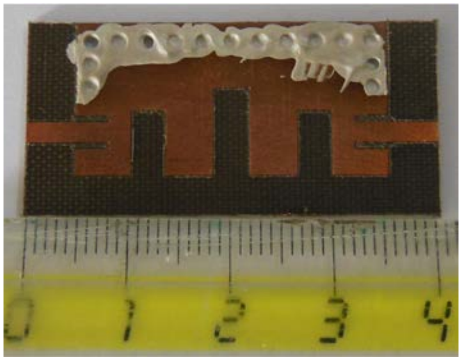
II. Filter Design

This project starts with the design of an SIW resonant cavity filter. Since IoT applications require the circuit components to be as small as possible, a modified version of the normal SIW structure called half-mode SIW (HMSIW) has been used in order to minimize the footprint. An HMSIW is obtained by simply removing half of a normal SIW, along the propagation axis. Due to the presence of a virtual magnetic wall condition on the open side, the electromagnetic fields remain confined in the structure. The result is a component halved in size, with minimal additional loss and the suppression of some of the higher propagation modes.

To obtain the filtering effect, the cavity is then modified by carving some insets in the upper metal layer. This perturbation affects some of the resonant modes of the structure, by shifting them in frequency. By properly choosing the size, shape and position of these insets, it is possible to control the resonant mode spectrum of the cavity and obtain the desired frequency response.

This topology has first been tested by designing filters on standard TLX-9 substrate [1,2]; Fig. 2 shows the prototype and the frequency response of a two-pole filter based on this concept, and Fig. 3 reports an analogous four-pole filter. These two examples show the versatility of this topology: the two devices have almost the same physical dimensions but different bandwidth and number of poles. The wide out-of-band region comes from the suppression of some of the higher order resonant modes by the HMSIW structure.

The two-pole filter was then reproduced on paper substrate [3]. The substrate exhibits $\varepsilon_r = 2.2$ and $\tan\delta = 0.04$. Its prototype and frequency response are shown in Fig. 4. The higher insertion loss and lower selectivity of the component compared to the TLX-9 filter is due to the higher paper loss.



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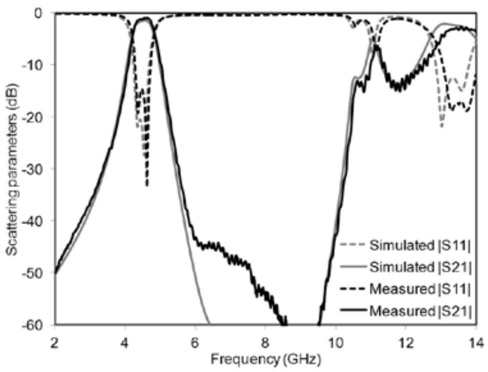

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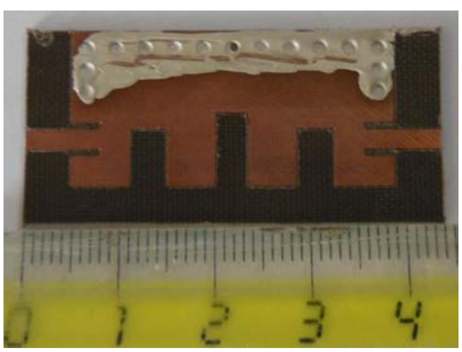
Fig. 2. Two-pole half-mode SIW filter on TLX-9 substrate: (*a*) photograph of the prototype; (*b*) frequency response of the filter (HFSS simulation: gray lines; measurement: black lines) [1,2].



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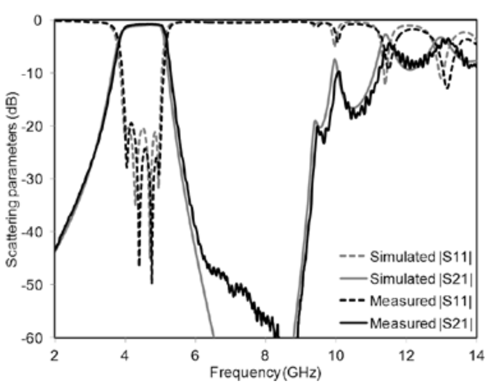

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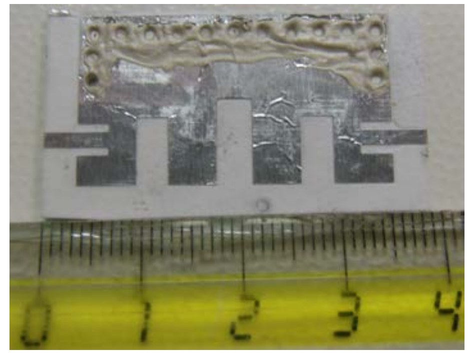
Fig. 3. Four-pole half-mode SIW filter on TLX-9 substrate: (*a*) photograph of the prototype; (*b*) frequency response of the filter (HFSS simulation: gray lines; measurement: black lines) [1].



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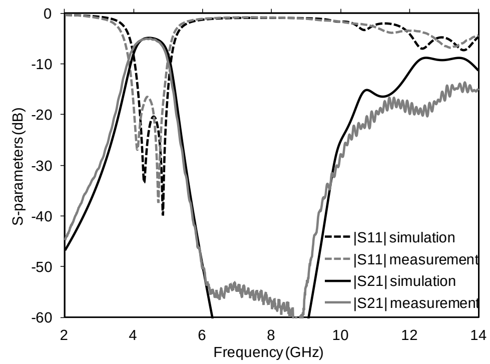

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Fig. 4. Two-pole half-mode SIW filter on paper substrate: (*a*) photograph of the prototype; (*b*) frequency response of the filter (HFSS simulation: black lines; measurement: gray lines) [3].

III. Conclusion

This report has shown the principles of operation of a compact and efficient SIW filter topology. Three filters were designed both on standard and paper substrates. For each of them, a prototype has been realized and measured.

IV. Acknowledgement

The MTT-S Undergraduate/Pre-graduate Scholarship Awards has been a great accomplishment and a source of motivation for me to continue my studies in the telecommunications and microwave fields. The trip to IMS2016 in San Francisco, which I attended as a student volunteer, has been an interesting formative experience and made me realize the relevance of the microwave industry. My next plan after graduating is pursuing a PhD in the microwaves field.

References

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