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Microstrip To Surface Mounted Foam-Based Waveguide Transition For Ka-Band Filter Integration

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Abstract

This paper introduces a novel transition structure between a microstrip line and a surface mounted waveguide. The waveguide structure is based on foam material and comprises a flange cavity, the design of which aims both to achieve the impedance matching of the transition and to enable potentially a fully automated assembly onto an RF printed circuit board (PCB), complying so with surface mounted device (SMD) technology. The new concept has been applied to two 30GHz waveguide filter designs, presenting respectively a Chebyshev and a pseudo-elliptic response.

Introduction

With the continuous growing demand for radio communication systems capable of higher data rates, there is a natural trend to use millimeter-wave systems to support this demand. This regards for example 2-way by satellite systems operating at 20/30GHz, 42GHz point-to-multipoint systems and 60GHz WLAN systems. Obviously these equipments, which are dedicated to the consumer market, have to be designed at the lowest cost, despite the high operating frequencies and the requested stringent electrical performances. This target can be achieved only if appropriate system architectures and manufacturing technologies are deployed. Issues such as packaging and interconnection are also central, particularly for millimeter-wave transceivers for which assembly process compatible with surface mounted device technology remains highly demanded.

Nowadays, current low cost technologies such as LTCC or HTCC enable SMD type packaging of active MMIC functions. However, for filtering functions, application of these technologies is more restrictive because of the exhibited dielectric losses that are nearly as high as those of soft low-cost dielectric substrate [1]. The ideal way to achieve high resonator quality factor Q, requested by low insertion loss and high selectivity filters, is to use waveguide structure. To make this technology mass producible various approaches have been presented recently, by using metallized plastic materials [2] or dielectric filled waveguides [3-4].

The approach presented in this paper is based on foam materials that can be machined or milled and that promise innovative designs thanks to their use flexibility, as previously described in [5-6]. The proof-of-concept is performed here in the VSAT 30GHz band with the design of two foam waveguide filters mounted on a currently used low-cost substrate.

Concept of the microstrip-to-waveguide transition

As illustrated in Fig. 1, the concept is based on a foam rectangular waveguide block integrating a flange that can be soldered onto a PCB. In a similar way as a coaxial probe in a waveguide-to-coaxial transition, a printed microstrip line feeds the waveguide by the help of a probe through a small aperture in the wider wall, this waveguide being short-circuited by a cavity milled or molded in the PCB carrier. The flange is designed so as to be compliant with the mechanical and soldering constraints, and to ensure the best coupling between the waveguide TE₁₀ mode and the quasi-TEM mode of the microstrip line. The design aims also to avoid any EM field leakage and parasitic resonance in the useful frequency band.

As the flange is made-up itself by a cavity, potential resonance can appear. This occurrence depends mainly on how is sized the flange on the backside of the waveguide (side A in Fig.2, value d in Fig.3), in the probe axis, because in this side the excited electric field is at maximum level. On the contrary, on the three other sides (B/C/D) the fields are less present, and therefore the flange width (value c in Fig. 3) is just fixed to the minimum value requested for the soldering of the module onto the

board. The flange thickness ($T=1.9\text{mm}$) is also set to the minimum value requested by the mechanical constraints.

The foam waveguide device is fully metallized, excepted a rectangular aperture located at the flange base (Fig.2), and another aperture located on the vertical plane of the microstrip line-to-waveguide interface.

The flange footprint is printed on the board, as depicted in Fig.1&3. This soldering area is linked to the ground by metallized via-holes that serve also to shield the interface between the foam waveguide and the approximate quarter-wavelength deep ($H=1.7\text{mm}$) cavity milled or molded in the PCB carrier. The board layout comprises also a quarterwave transformer that aims to match the transition to a 50Ω impedance microstrip line.

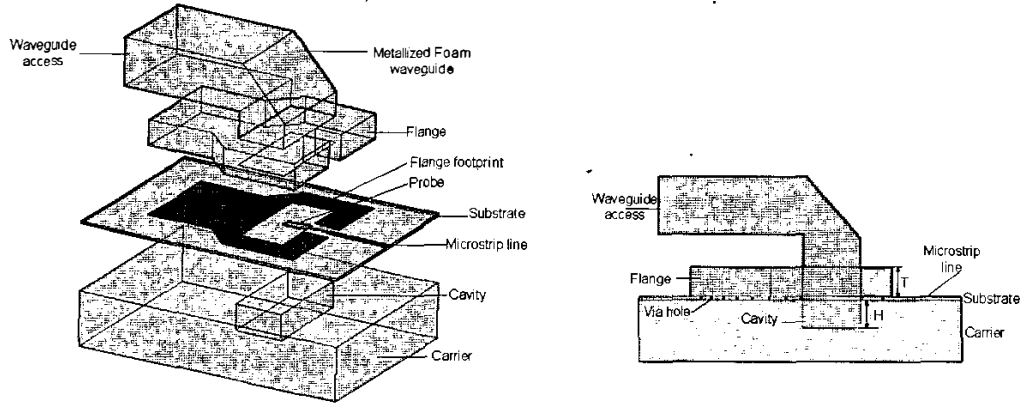


Fig. 1: The SMD waveguide-to-microstrip transition, before/after assembly.

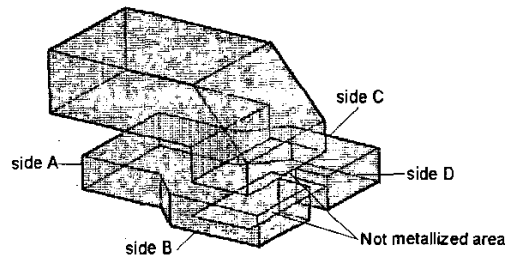


Fig. 2: The foam single block waveguide-flange no-metallization areas.

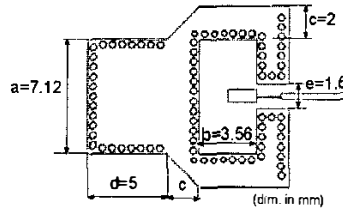


Fig. 3: Dimensions of the flange footprint.

The electromagnetic behavior of the transition has been analyzed by finite element method (ANSOFT/HFSS), and the concept validated considering a WR28 waveguide and a very low-cost substrate (ROGERS/RO4003, 0.2mm-thickness). The foam material used is the commercially available ROHACELL/HF71, which features a very low dielectric constant and low dielectric loss ($\epsilon_r=1.09$, $\text{tg}\delta=0.001$ up to 60GHz [6]).

The transition design has been optimized in order to enable the integration of a filter featuring a relatively narrow band around 30GHz. The simulated results presented in Fig.4 illustrate the resonance occurrence due to the flange width (d). As shown, the parasitic resonance has been shifted to the lower band by increasing d up to 5mm. In this case, the EM simulation predicts return loss better than -20dB from 29.2GHz to 30.3GHz.

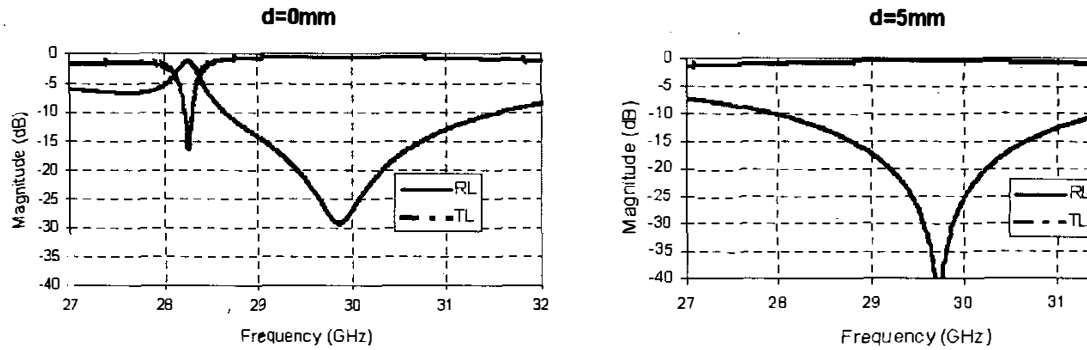


Fig. 4: Simulated return and transmission loss of the single transition, for $d=0$ and 5mm.

So as to allow an experimental validation, the transition design has been also simulated using a back-to-back configuration (Fig.5), inserting a straight waveguide between two transitions. The return loss level is close to the one obtained for the single transition around 30GHz, and the simulated insertion loss is lower than 1.5dB for a waveguide length of 42mm.

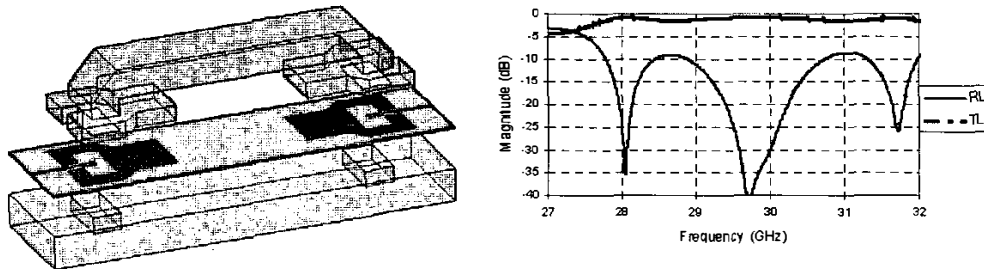


Fig. 5: Structure of the back-to-back microstrip-to-waveguide transition, simulated results.

Filter Integration

Once the new SMD transition validated, it has been applied for the integration of waveguide filters that can be surface-mounted in a transmission chain of a VSAT system operating in the [29.5-30.0]GHz band.

The first filter is a 3-pole bandpass filter made up by inductive iris coupled cavities and featuring a Chebyshev response. In Fig.6 is depicted the foam waveguide filter equipped with its two flanges that can be soldered onto the test board. The EM simulation of the filter with the microstrip input/output access lines shows insertion loss lower than 1.6dB, and return loss close to -20dB in the useful band.

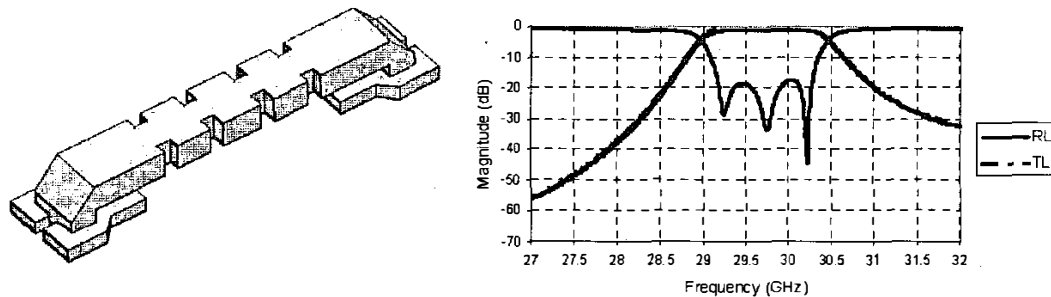


Fig. 6: The Chebyshev response SMD-type filter and relating simulated performances.

The Fig. 7 shows another filter that features an asymmetrical transmission response. Two stubs have been added to the previous design in order to create two transmission zeros [7] and to provide more than 50dB attenuation around 28.5GHz, complying so with ETSI specifications. With this pseudo-elliptic response filter return loss around -18dB and insertion loss lower than 1.8dB have been achieved in simulation.

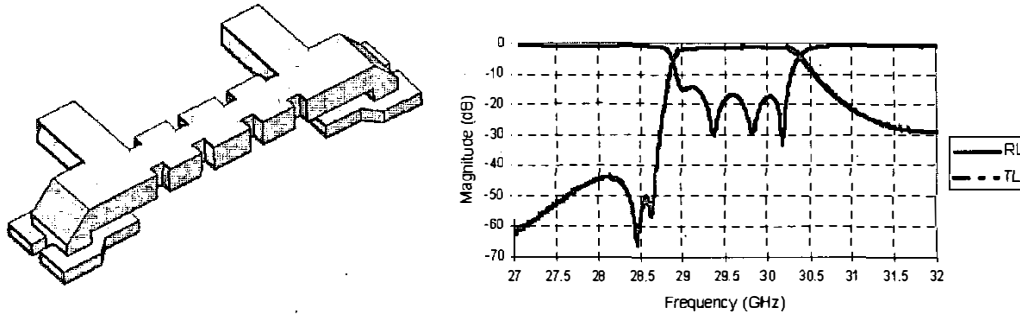


Fig. 7: The pseudo-elliptic response SMD-type filter and relating simulated performances.

At the time of this writing, the fabrication of the designs introduced here are in progress. Hence, experimental results would be only presented during the conference.

Conclusion

A novel design and simulation results of an SMD-type transition between a waveguide and a microstrip line have been introduced. The waveguide structure is based on a foam material that enables low-cost and mass producible milled/molded designs. The proof-of-concept of this novel approach has been performed around 30GHz by the design of two SMD-type filters for VSAT application. However, the transition presented will also permit interconnection of PCB to other 3D structures, such as orthomode transducer, feed horn and antenna.

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