Design of Riblet-Type Couplers for Ka Band Applications

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Abstract

The full-wave modeling and design of short-slot Riblet waveguide couplers are addressed in this contribution. These types of directional couplers are commonly used by their compact size in comparison with other waveguide configurations. The main features of the Riblet coupler are discussed and its modeling with different input/output excitations is described. Two different designs are shown, with either rectangular waveguide input/output ports or coaxial interfaces. The expected simulated results of two manufactured prototypes operating at 19 GHz are compared with their experimental measurements.

I. Introduction

Directional waveguide couplers are found in many microwave systems. They can be designed in diverse technologies and can take many configurations. This wide range of options is motivated by the diverse functions that they can carry out [1], [2]. For instance, one common application is power monitoring or power division/combination [3] in balanced amplifiers and mixers. They can be also found in beam-forming networks for multi-beam array antennas. In this context, they are used in Butler matrices [4].

The most suitable configuration for a specific application is determined by the frequency of operation, bandwidth, insertion losses and power handling capabilities [1], [2]. In addition, the selected structure must be able to provide the desired coupling and its size must comply with the mass and volume restrictions of the system. From this last point of view, the short-slot Riblet coupler [5] presents very interesting properties, because of its compact size and less weight. It can be used to implement the hybrid junction used in many microwave circuits, with high isolation and low return loss. It is usually shorter than other types of couplers such as the branch-line or the multiple-slot configurations, which is a significant advantage for spatial applications. Another relevant feature is its simple manufacturing, since it can be implemented in E-/H-plane configuration. This communication is focused on this type of couplers, showing two different designs with its associated modeling and experimental results.

II. Modeling and Design Considerations

The coupler configuration is represented in Fig.1.a. The kernel of the structure is a four-port *H*-plane waveguide junction made up of two parallel waveguides. They are coupled by a single aperture obtained by removing the common narrow wall between them. In addition, three waveguide bends are attached to ports 2,3 and 4 in Fig.1.a.

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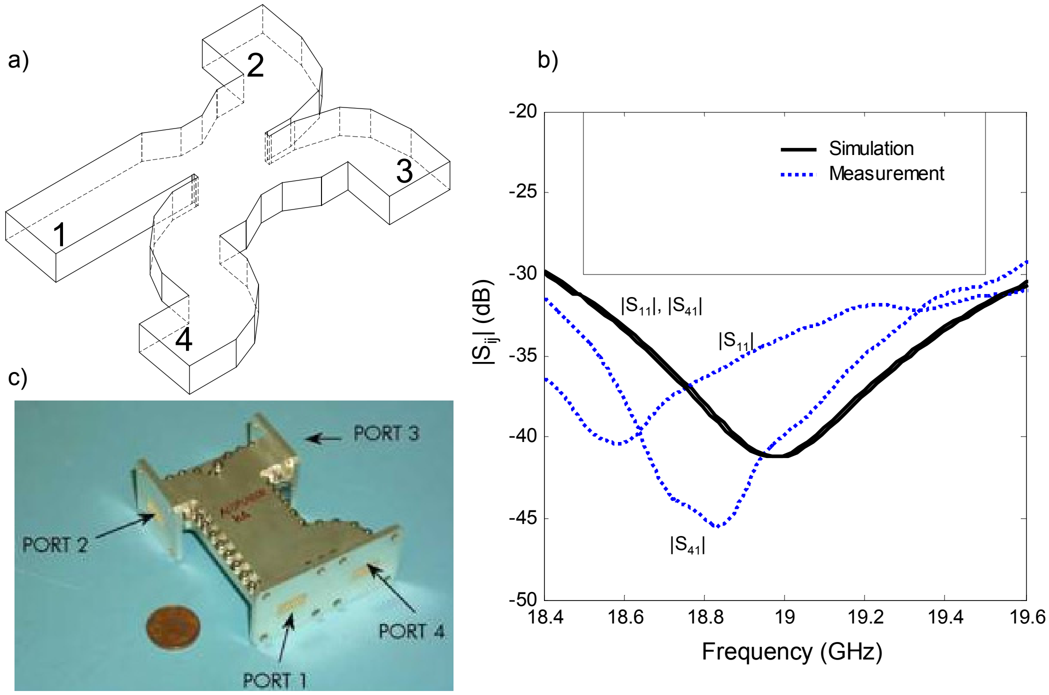

Fig. 1. *H*-plane short-slot coupler with 90º bends at ports 2,3 and double bend at port 4: a) wg. configuration, b) simulation and experimental results, c) photograph of the manufactured device

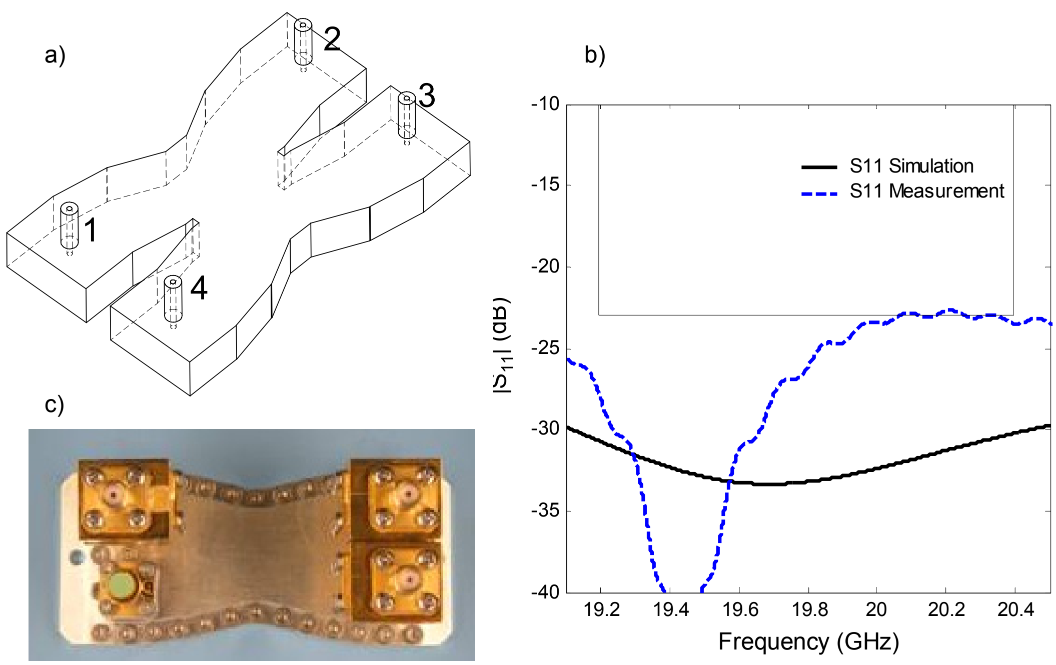

Fig. 2. *H*-Plane short-slot coupler with coaxial input/output ports: a) wg. configuration, b) simulation and experimental results, c) photograph of the manufactured device

The routing bends allow enough distance between ports to place the waveguide flanges. Their shapes (ports 2, 3 have 90º bends and port 4 has a double bend) are selected according to the remaining interfaces of the system. Another suitable option, shown in Fig. 2.a, is the use of coaxial input/output ports, which replace the routing bends and lead to a more compact device.

The kernel of the Riblet coupler (without the bends/coaxial interfaces) has two symmetry planes and its general theory is described in terms of even and odd modes [5] (TE_{10} and TE_{20} modes, respectively, of the coupling region). Capacitive obstacles (such as pins or tuning screws) can be placed in the coupling region in order to obtain the required phase balance between the two modes. Nevertheless, the structure (as in Figs. 1.a and 2.a) can be also designed without these elements [6], which may simplify the manufacturing. Six-port Riblet couplers have been also designed in [7], with equal power division for the three output ports. From a CAD point of view, the structure is an H-plane structure (the E-plane case would be dual) and its analysis and design can be carried out very efficiently by general techniques such as the Finite Element Method (FEM) or by modal techniques such as the Boundary Integral-Resonant Mode Expansion (BI-RME) [8] or the Boundary Contour Mode-Matching method (BCMM) [9]. The routing elements can be also analyzed by these techniques. If they are close to the coupler and there is higher-order mode interaction, their multimode responses can be conveniently cascaded.

The comparison between the simulated (BCMM) and measured response is presented in Fig. 1.b for the first designed coupler. The measured return loss and isolation are better than 30 dB in the design band. The measured phase difference between ports 2 and 3 when the structure is excited by port 1 is presented in Fig. 3. It is very close to the expected 90º. The coupling to the ports 2, 3 is also represented in Fig. 3. The return loss for the second design is depicted in Fig. 2.b, where the manufacturing tolerances (0.04 mm, determined by the manufacturing process and its cost) have led to a measured response with worse performance than the expected. The group delay and the coupling are plotted in Fig. 4, both simulated and measured.

III. Conclusions

Two different designs of Riblet couplers in Ka band have been presented. Their main properties and modeling have been described, with special emphasis on their compact size and electrical properties. Their reduced mass and volume and easy of manufacturing are very interesting properties for spatial applications. The experimental results have been compared with the simulations results. Other different alternatives in the design of narrow-wall couplers will be discussed in the presentation.

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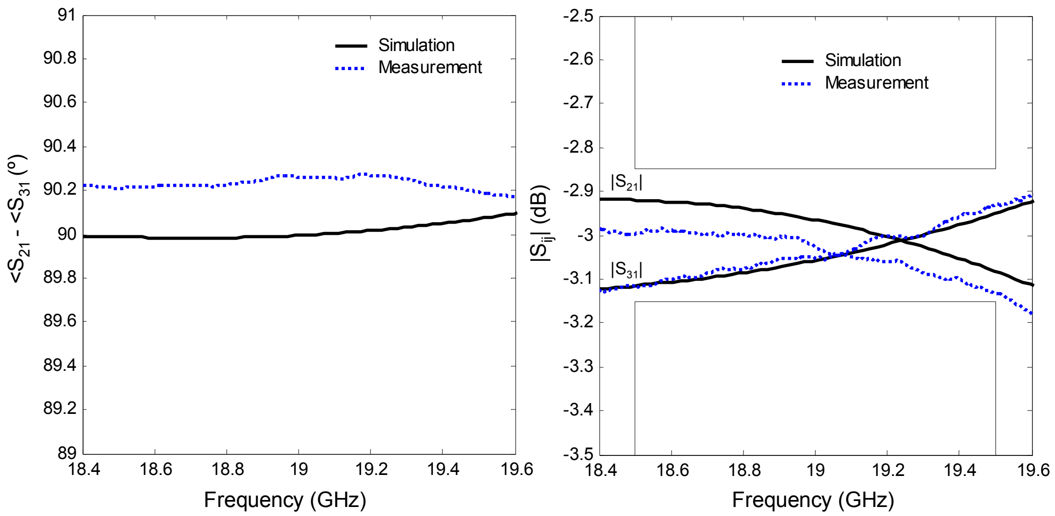

Fig. 3. Simulated and measured phase difference between ports 2 and 3 and coupling to ports 2 and 3 for the short-slot coupler with H-plane bends in Fig. 1.

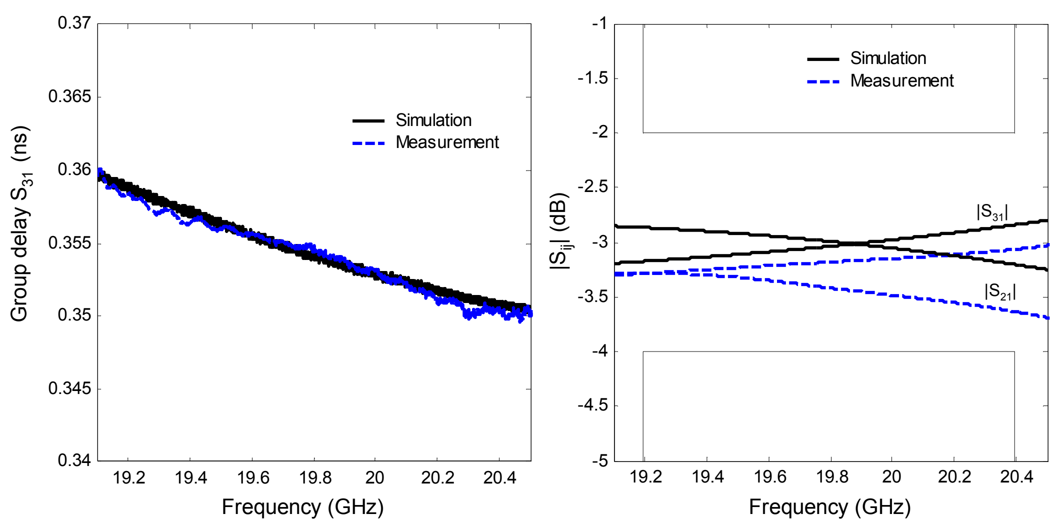

Fig. 4. Simulated and measured group delay (between ports 1 and 3) and coupling to ports 2 and 3 for the short-slot coupler with coaxial ports in Fig. 2.