Design of a Groove Gap Waveguide to Microstrip inline transition

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***Abstract*—In this paper the design of an inline transition between microstrip and groove gap waveguide operating at W-band is presented. The transition consists of two sections: a tapered microstrip line and a Chebyshev transformer. The simplicity of this design makes this transition appropriate for MMIC packaging at millimeter frequencies and above. Experimental validation has been carried out in the W-band. Good performance has been achieved: return loss better than 10 dB and mean insertion loss lower than 2 dB.**

***Index Terms*—groove gap waveguide, transition, microstrip.**

I. INTRODUCTION

Packaging of millimeter circuits can suffer from excitation of uncontrolled resonances which can cause unexpected reflections and in general degrade their performance [1]. Recently, an alternative packaging solution has been developed based on the so-called bed of nails [2]-[4]. These metallic periodic structures forbid propagation of electromagnetic waves in a certain frequency range and allows suppression of the excitation of the parasitic modes causing these resonances.

Moreover, these periodic structures can be used to create waveguides [5]. Their main advantage with respect to conventional rectangular waveguides is that they can naturally be cut in their H-Plane, without requiring a tight contact between the two waveguide parts. These waveguides can be integrated in packaging configurations or be used independently, thanks to their simple manufacturing and assembly.

This paper describes the design of an inline microstrip to Groove Gap Waveguide (GGW) transition. The transition follows a similar approach to that proposed in [6], [7], but adjusted to the peculiarities of the Groove Gap Waveguide.

II. TRANSITION CONFIGURATION AND DESIGN

The proposed inline transition is presented in Figure 1. The transition is formed by two sections: a linear transition from microstrip to dielectric filled GGW and a Chebyshev transformer from dielectric filled GGW to standard (air filled) GGW. Since the so-called vertical mode of the GGW is very similar to the rectangular waveguide TE_{10} mode, an approach similar to that used in [6], [7], based on a Chebyshev transformer, can be used. Even though this principle and the design procedure presented for this kind of transition is applicable to any frequency band, in this case the transition will be realized to work at W-Band.

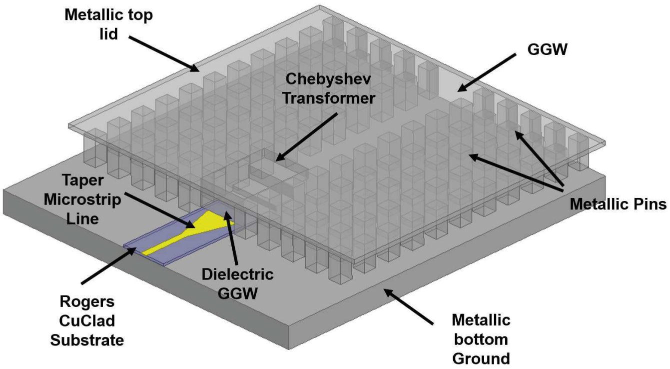

Fig. 1. The proposed microstrip to groove gap waveguide (GGW) transition.

A. Design of the bed of nails

The groove gap waveguide requires a bed of nails to be created. This bed of nails consists of a periodic arrangement of metallic square pins. Their dimensions have been adjusted following the design procedure in [4]. These dimensions are: $d = 1190\ \mu$m, $a = 600\ \mu$m, $h = 80\ \mu$m, $p = 1240\ \mu$m. The obtained response features a bandgap which covers the full W-band, as shown in Figure 2.

B. Design of the GGW

The GGW is created by creating an open region in between two bed of nails sections. This opens a propagation band in the bandgap, whose properties depend on the width of this region. In this case the width has been set to 2.45 mm, so that the direct connection between the GGW and a WR10 rectangular waveguide has reflection lower than -25 dB.

C. Design of the microstrip to dielectric filled GGW transition

The microstrip to dielectric filled GGW has been realized by means of a linear taper. The final width of the microstrip corresponds to the same impedance of the dielectric filled GGW.

D. Design of the dielectric filled GGW to GGW transition

The transition between the dielectric filled GGW and the air filled GGW has been designed as a Chebyshev transformer. Three sections are enough to cover the full W-band with return loss better than 15 dB.

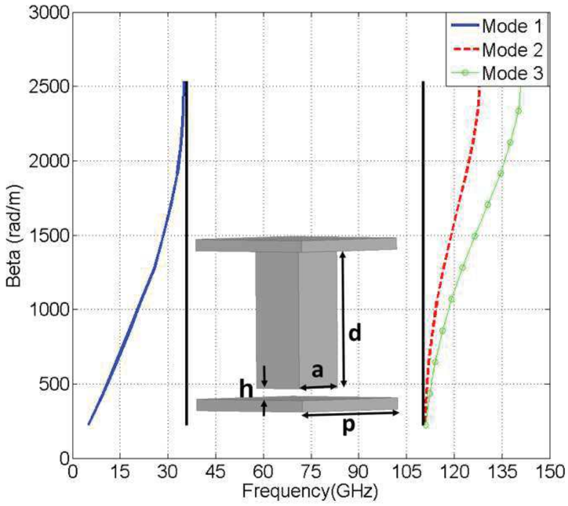

Fig. 2. Dispersion diagram of the used bed of nails. The vertical lines represent the limits of the bandgap. The inset shows the main parameters.

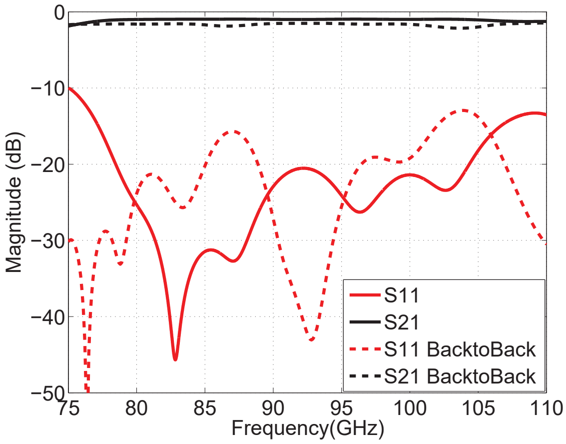

Fig. 3. Simulation of the scattering parameters for the microstrip to groove gap waveguide single (solid line) and back-to-back transitions (dashed line).

III. SIMULATION RESULTS

The simulations results of the transition are shown in Figure 3. This Figure gathers the results of the single transition and of a back to back configuration where the two transitions are separated by a 5.18 mm long microstrip line. In both cases the results show return loss higher than 10 dB for the whole W-band. If the losses in the microstrip line are removed, the insertion loss of each transition can be estimated to be 0.3 dB.

IV. MANUFACTURING AND TEST

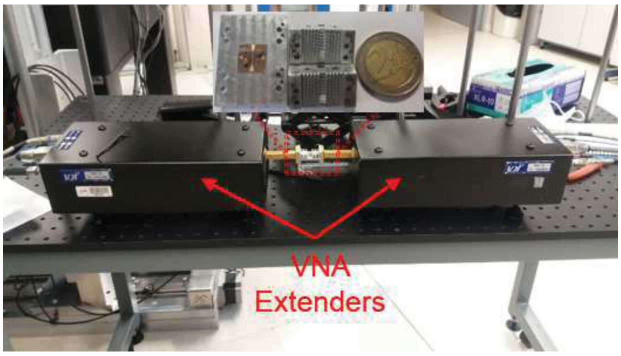

Fig. 4. Photographs of the fabricated prototype and measurement set-up. (a) Microstrip line printed on CuClad substrate on the bottom metallic block and the two bed of pins.

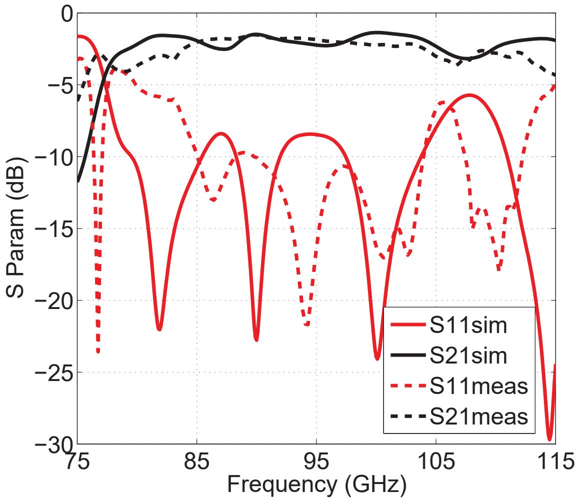

Fig. 5. Comparison between simulated (solid line) and measured (dashed line) back to back transition. The simulation results correspond to the dimensions of the manufactured circuits.

The back-to-back configuration was manufactured and tested. A 5.18 mm long microstrip line connected the two transitions. The losses of this line have been estimated as 0.5 dB. In addition, the GGW lines are 9 mm long. There is no transition to standard waveguide, given the fact that the width of the GGW has been selected so that the reflections caused by the direct connection to a rectangular waveguide are lower than 25 dB. Therefore, the prototype was connected directly to the WR10 rectangular waveguides of the W-band millimeter wave extenders.

The metallic block was micromachined in aluminium. The pins are machined in the top metallic blocks, the other one being flat. The microstrip circuit was photolitographically manufactured. Photographs of the fabricated prototype can be seen in Figure 4.

The manufactured back to back configuration was characterized in terms of return and insertion loss, see Figure 5. The average insertion loss is 3 dB, and the return loss is higher than 10 dB for the central part of the W-band. There is a noticeable shift towards higher frequencies, ascribed to the manufacturing errors. As a matter if fact, if the dimensions of the manufactured circuits are included in the simulations reasonable agreement between both results is achieved.

V. CONCLUSION

In this paper the design of an inline transition between microstrip and groove gap waveguide operating at W-band has been presented. This transition can be of interest when the bed of nails is used as a packaging solution.

The transition has been manufactured and tested in the W-band. Good agreement with the simulations and performance have been achieved. Measured return loss is better than 10 dB and the mean insertion loss is lower than 2 dB.

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