Design of a Transition from WR-15 to Microstrip Packaged by Gap Waveguide Technology

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Abstract – **The gap waveguide technology is an advantageous way of packaging passive microstrip components. This work presents a wideband transition from a standard microstrip line packaged by using a bed of nails, to a rectangular waveguide operating in V band. The transition is designed by means of a T-shaped patch that couples the fields into a rectangular waveguide extending vertically from the microstrip circuit. The simulated results show more than 28.5% bandwidth with S_{11} lower than -10 dB. This transition is intended to be used as a WR-15 port of a planar array antenna for 60 GHz applications, where the array elements are fed by microstrip distribution networks packaged by gap waveguide technology. Thereby, radiation is avoided from the distribution network itself.**

Index Terms **— Gap Waveguide, Artificial Magnetic Conductor (AMC), Microstrip, Rectangular Waveguide, Packaging, Transition.**

I. Introduction

Microstrip technology is typically used in millimeter-wave applications because it is a compact, planar, simple to manufacture and cost-effective transmission line. In addition, the integration between active components, passive components and antennas in the same module is easier in microstrip than when using other technologies like standard rectangular waveguides. However, a critical drawback of microstrip technology is that it suffers from high losses. An important contribution to the loss in a microstrip circuit, which is not suitably packaged, is the radiation loss. Radiation can appear in the form of radiated waves, leaky waves or surface/substrate waves that also will cause spurious coupling and interference that can affect critical parts of the circuit and destroy its performance [1]. Radiation in microstrip array antennas or microstrip feed networks, together with the dielectric and conductive loss; can lead to a considerable reduction of the radiation efficiency or appearance of high side lobe levels [2], resulting in a severe reduction of the realized antenna gain.

The so-called gap waveguide technology was introduced in 2009 [3] and later validated experimentally [4], with a huge potential to be applied at frequencies up to THz range. The gap waveguide is based on the parallel-plate cutoff principle. This principle consists of the presence of two parallel Perfect Electric Conductor (PEC) and Artificial Magnetic Conductor (AMC) layers, which are separated by a distance smaller than $\lambda/4$. A cutoff of high order modes is ensured in the airgap between the two mentioned layers. Only local waves are allowed to propagate along a metal ridge, strip or groove that is embedded within the AMC plate.

It has previously been demonstrated that the gap waveguide suppresses parallel-plate modes, cavity modes and unwanted radiation when it is employed as a packaging method of microstrip circuits [5]-[6]. Moreover, the gap waveguide packaging improves the isolation performance within MMIC modules [7]. Therefore, the gap waveguide packaging is very suitable to be integrated into microstrip-based feed networks for millimeter-wave antenna arrays. It will improve the overall antenna system performance since the gap waveguide eliminates any possible radiation due to discontinuities and asymmetries present in the microstrip circuits.

This paper deals with the design of a wideband transition from a microstrip line packaged by using gap waveguide, to a standard rectangular waveguide port on the back side of the AMC plate. The transition presented here is aimed to cover the whole unlicensed 60 GHz band (57-64 GHz) which is especially interesting for high data rate Wireless Local Area Networks (WLANs). The design has been analyzed in back-to-back configuration, and simulations in terms of S parameters are shown.

II. Transition Design and Simulation Results

The investigated geometry consists of two metal plates opposite to each other. The top plate contains the PCB with a microstrip circuit. The lower metal plate includes a bed of pins that keeps the upper PCB packaged, and a rectangular waveguide opening which is surrounded by pins. This rectangular waveguide opening has the same dimensions as the standard WR-15 that operates from 50 to 75 GHz. The cross section of the complete transition geometry is shown in Fig. 1.

The microstrip circuit is formed by a 50 Ω feeding line and a T-shaped probe exciting a rectangular waveguide opening just below it, in the lower AMC plate. An important part of this transition is a cavity backshort embedded in the upper smooth metal plate (see Fig. 1). This backshort provides the large bandwidth by forcing the microstrip electromagnetic fields to couple into the rectangular waveguide. The

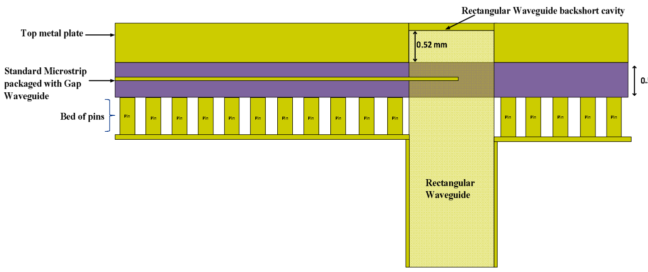

Fig. 1. Side-view of the complete transition geometry.

dimensions and position of the probe and cavity backshort have been fine-tuned in order to optimize the impedance matching, and they are illustrated in Fig. 2.

The chosen substrate material is Rogers RO3003 with permittivity $\varepsilon_r = 3$, thickness $h = 0.25$ mm and loss tangent $tan\delta = 0.0013$. The air gap (distance between the substrate and the top of the pin), $g = 0.25$ mm, has been filled with Rogers material in order to provide better mechanical support between the upper and lower plates. The pin dimensions and the corresponding dispersion diagram are represented in Fig. 3.

Two back-to-back transitions according to the above description have been computed by using CST Microwave Studio. The S parameters show a return loss larger than 10 dB in more than 28.5% bandwidth. The total insertion loss is around 2 dB over the same bandwidth. Separating the loss

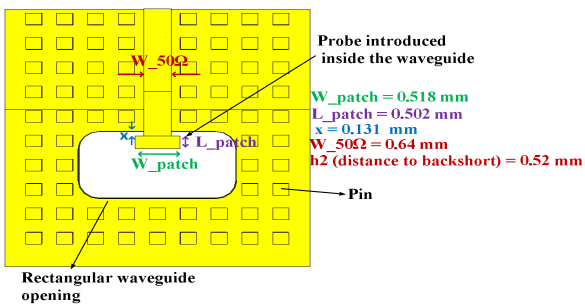

Fig. 2. Dimensions and location of T-shaped probe (the substrate material and the upper metal lid that contains the backshort are hidden in the picture).

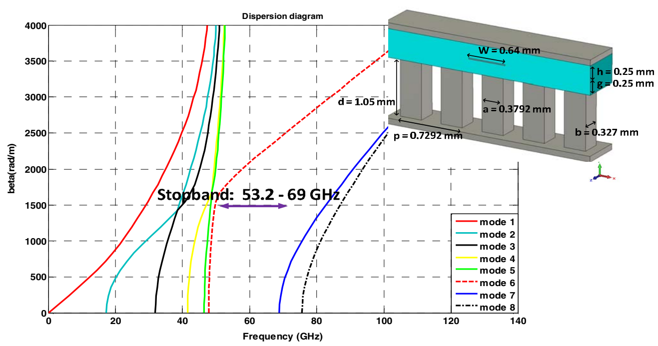

Fig. 3. Dispersion diagram of a row of pins packaging a microstrip line, inifite along z direction.

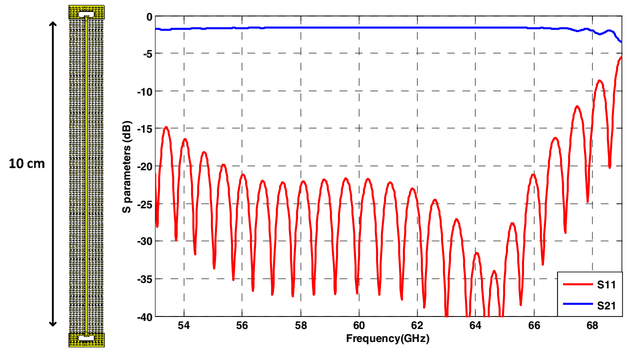

Fig. 4. Simulated S parameters for two back-to-back transitions.

due to the long straight line and extracting the mismatch loss, the corresponding loss for a single transition would be approximately 0.2 dB. Fig.4 illustrates the obtained S parameters and a sketch of the back-to-back configuration.

III. CONCLUSION

The presented transition design has a very large bandwidth which is very promising for integration into microstrip corporate feed network packaged by using gap waveguide technology for antenna array applications.

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