Short Papers

Microstrip to Waveguide Transition Compatible With MM-Wave Integrated Circuits

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***Abstract*—Microstrip to waveguide transitions used presently typically require a relatively complex waveguide mount extending on both sides of the planar circuit. Additionally, the planar substrate has to be cut into specific forms limiting the flexibility of the planar circuit design and complexity. In this paper, a new type of transition is described based on the principle of slot coupled antennas radiating into the waveguide. In this way, the extension of the planar circuitis not restricted, and at the same time, the involved antenna element can be used to hermetically seal the microwave/mm-wave input.**

I. INTRODUCTION

Although hybrid and monolithic integrated circuits are used more and more in microwave and mm-wave systems, metal waveguide still plays a major role in specific types of circuits like antennas, high-Q filters, high-Q oscillators, or nonreciprocal components, e.g. circulators. A critical point is to combine both systems via appropriate transitions, especially in the mm-wave frequency range. A few types of transitions are known, e.g. the (E-plane) probe type transition [1], [4], the transition via antipodal finline [2], or via a ridged waveguide [3]; they provide reasonably good results, but they typically are not very well suited for a simple and compact integration with the planar circuits. Partly, these transitions are rather long, in all cases, the metal waveguide structure extends to both sides of the planar substrate, and the planar substrate has to be cut to specific forms. Especially the last two items rend it rather difficult to integrate more than one transition with a complex circuitry. Furthermore, a hermetic sealing of a package for the planar circuit at the waveguide port partly gets difficult due to the required split-block technique for the waveguide mount.

A completely different type of transition (Fig. 1(a)) firstly proposed by the authors in [5] is based on the concept of slot-fed microstrip antennas, e.g. [6]. The microwave energy is coupled from the microstrip line via a slot in the ground plane to a patch antenna element placed on an additional, small substrate in the waveguide. With this transition, the planar circuits can extend arbitrarily without the requirement of a special form, and the metal waveguide structure is situated on the backside of the microstrip circuit only. Due to the specific choice of geometry, nearly the complete rf power is coupled through the slot to the patch and radiated into the waveguide.

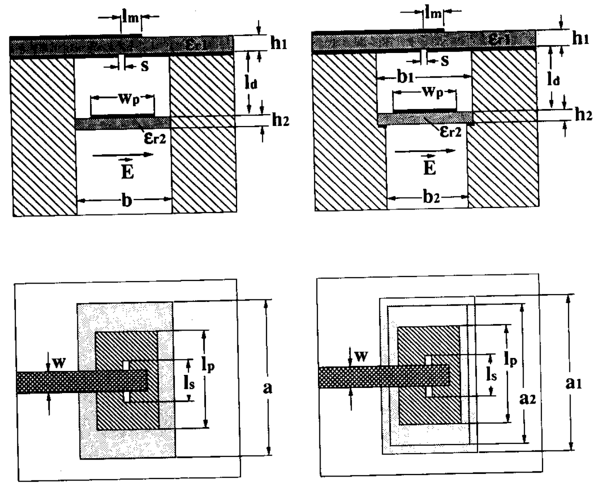

Fig. 1. Basic (a) and modified (b) configuration of new waveguide to microstrip transition.

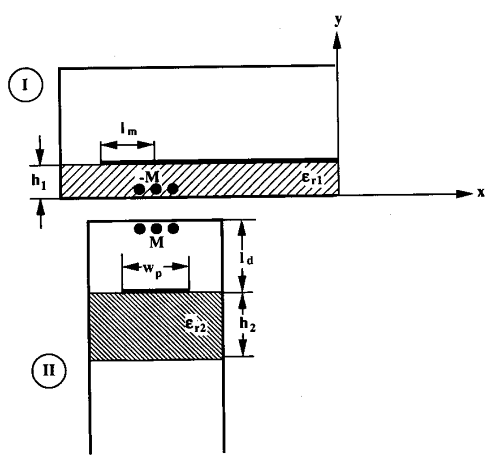

Fig. 2. Set-up for theoretical calculations.

II. MODIFIED TRANSITION FOR mm-WAVE APPLICATIONS

The transition according to Fig. 1(a) has been designed and testet successfully at microwave frequencies, together with some modifications of the substrate and patch arrangements [5]. Some problems, however, occur at mm-wave frequencies fixing the substrate with the patch antenna in the waveguide. To solve this, a modified transition was tested including a step in waveguide widths as shown in Fig. 1(b). The additional substrate with the radiating element now is positioned automatically and can easily be fixed on the waveguide step. Providing a metallization rim on the lower side of the substrate, it can be soldered or glued hermetically to the waveguide edge.

The design of this modified transition is not as easy as that of Fig. 1(a), so a first, preliminary calculation of the structure of Fig. 1(a) is done. The complete transition is separated in two parts introducing magnetic currents in the slot (Fig. 2). Following this, full-wave spectral domain calculations are used to compute the scattering parameters of the transition [5], [8]. A shielding enclosure is chosen for the microstrip section; in this way, the cumbersome evaluation of the poles in the Green's function is avoided. With these calculations, some amount of computer optimization is done to meet the required center frequency together with a reasonable bandwidth of the transition.

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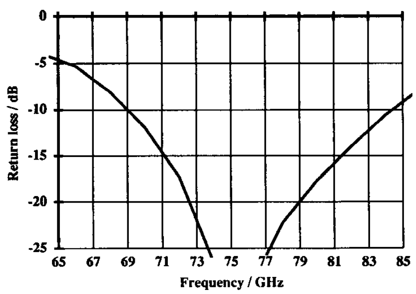

Fig. 3. Theoretical calculation of waveguide to microstrip transition for 76.5 GHz (according to Fig. 2, $a_1 = a_2 = 3.1$ mm, $b_1 = b_2 = 1.55$ mm, $h_1 = 0.154$ mm, $h_2 = 0.11$ mm, $s = 0.2$ mm, $w = 0.154$ mm, $\varepsilon_{r1} = 9.8$, $\varepsilon_{r2} = 3.75$).

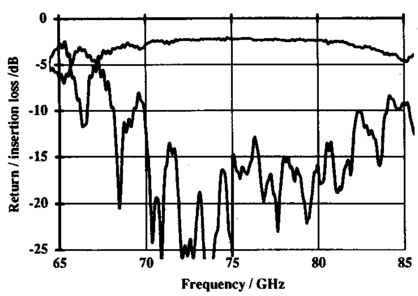

Fig. 4. Experimental results of two modified waveguide to microstrip transitions for 76.5 GHz ($a_1 = 3.7$ mm, $b_1 = 2.15$ mm, $a_2 = 3.1$ mm, $b_2 = 1.55$ mm, $s = 0.2$ mm, $w = 0.154$ mm, $h_1 = 0.15$ mm, $h_2 = 0.11$ mm, $\varepsilon_{r1} = 9.8$, $\varepsilon_{r2} = 3.75$, microstrip line length 21.4 mm {between centers of slots}).

The design of the modified structure of Fig. 1(b) is based on an initial numerical calculation according to the basic transition. Following this, to compensate for the change of the waveguide size between the two substrates, the distance between the two substrates is reduced. A final optimization of the center frequency of the transition was then made experimentally. It was found, however, that the transition was not too sensitive concerning these modifications.

III. RESULTS

Fig. 3 shows the calculated return loss of the basic structure (Fig. 1(a)) designed for a center frequency of 76.5 GHz, a frequency of increasing interest for traffic applications, e.g. collision avoidance. As microstrip substrate, alumina of 0.15 mm thickness, and for the radiating element, fused quartz with 0.11 mm thickness was chosen. For a return loss of 15 dB, a 10 GHz bandwidth is achieved.

The measured results of two realized transitions according to Fig. 1(b) connected via a 21.4 mm long microstrip line are plotted in Fig. 4. For 15 dB insertion loss, a bandwidth of more than 10% can be observed. To determine the insertion loss, two of these arrangements with different microstrip line lengths were fabricated and tested. Fig. 5 gives their transmission coefficients in an enlarged scale. From this figure, a microstrip loss of 0.08 dB/mm can be derived. Taking into account an overall loss of 2.2...2.4 dB with 21.4 mm of microstrip line, a net loss for each transition of as low as about 0.3 dB (reference plane in the center of the slot) can be calculated. That indicates, on the other hand, that radiation from the top side of the substrate is extremely low.

To verify the design, another transition at higher frequencies with 85 GHz center frequency was designed, too. As can be seen from Fig. 6, similar performance could be achieved.

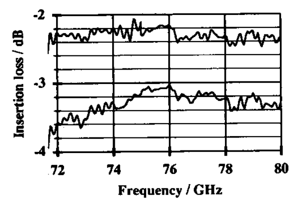

Fig. 5. Comparison of two sets of transitions with different microstrip line lengths($l_1 = 21.4$ mm, $l_2 = 31.4$ mm).

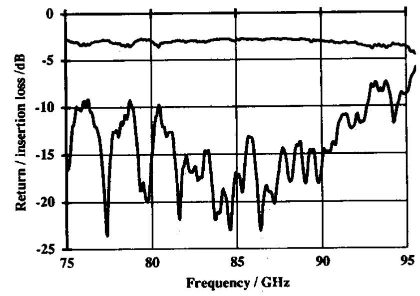

Fig. 6. Experimental results of two modified waveguide to microstrip transitions for 85 GHz ($a_1 = 3.7$ mm, $b_1 = 2.15$ mm, $a_2 = 3.1$ mm, $b_2 = 1.55$ mm, $s = 0.2$ mm, $l_s = 0.64$ mm, $l_d = 0.16$ mm, $l_m = 0.12$ mm, $w_p = 1.04$ mm, $l_p = 0.61$ mm, $w = 0.154$ mm, $h_1 = 0.15$ mm, $h_2 = 0.11$ mm, $\varepsilon_{r1} = 9.8$, $\varepsilon_{r2} = 3.75$, microstrip line length 21.8 mm {between centers of slots}).

IV. CONCLUSION

A new transition from microstrip to waveguide has been described based on the principle of slot-coupled microstrip antennas. This transition is optimally compatible with extended integrated circuits, as the metal waveguide structure is situated only at the backside of the microstrip circuit. The required additional substrate in the waveguide carrying the radiating element is positioned automatically, and it can be equally used to seal the waveguide hermetically. Due to these properties, this type of transition is ideally suited for mm-wave system applications as they are expected, for example, in traffic applications.

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