A NEW TRANSITION FROM MICROSTRIP LINE TO RECTANGULAR WAVEGUIDE

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ABSTRACT

A simple transition from microstrip to rectangular waveguide using an aperture coupled patch antenna radiating into the waveguide is proposed. In addition, two slightly modified versions are discussed, having some advantages with regard to ease of fabrication and therefore being more suitable for use in the mm-wave range. S-parameters of all three versions are calculated and measured. The analysis is based on a modified procedure of the well known spectral domain method.
The remarkable advantage of this new transition compared to recent approaches is the fact that waveguide structures are necessary only on the back side of the planar circuit.

I. INTRODUCTION

Although planar circuits have found widespread applications, the standard waveguide still is applied in the microwave and mm-wave field, e.g. for antennas.
A critical point is to combine both systems via appropriate transitions. A few possibilities are known, eg. /1/-/3/, among them the idea of using antenna - like planar structures radiating into the waveguide /1/.
Good performance can be achieved, but disadvantages with regard to ease of fabrication or, in the latter case, the need for placing another, $\lambda/4$ long piece of short-circuited waveguide on the opposite side of the planar substrate have to be mentioned. Therefore, an alternative method is proposed. The configuration is known as a feeding technique for patch antennas, e.g. /4/, and recently was also employed for coupling a cavity resonator to microstrip line /5/.
The general set-up of the transition and its modified versions are given in Figs. 1 and 2, respectively. Basically, the structures are open on the top side of the microstrip structure. Similar to the case of the open antenna /4/, however, the coupling slot is considerably shorter than half a wavelength; thus the microwave power is coupled nearly completely into the waveguide. No waveguide parts like a $\lambda/4$ short-circuited section are necessary on the top of the substrate; so a large microstrip circuit may extend directly around the transition.

II. THEORETICAL DESCRIPTION

Calculation is based on a modified spectral domain method /6/. The basic spectral domain method can not be applied directly here because of different lateral structures above and below the ground plane at y=0, see Fig. 3. As has been outlined in /7/, introducing magnetic surface currents M in the slot region

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allows for replacing the slot by a perfectly conducting plane. Thus, two separate structures I and II can be created, each of them suitable for spectral domain analysis (Fig. 3).
Both open and shielded structures as well as combinations of both can be analyzed using this modified method, thus a great flexibility is achieved. For the analysis performed here, both structures shown in Fig. 3 are shielded. The arrangement is considered as a resonator structure. Its S-parameter can be determined using a method described in /8/, /9/ by calculating a number of resonances. For reciprocal twoports like the transitions described here, three resonance experiments have to be carried out with variation of the waveguide and microstrip lengths.

III. RESULTS

As a first test, a transition from microstrip to rectangular waveguide has been optimized for use at 11 GHz. The structure allows a number of free parameters, but only 3 of them have been used in the optimization process, that is the open stub length of the microstrip line (l_s), the slot-length and the length of the patch (w_x) (see Fig. 3). Theoretical and experimental results of the basic structure given in Fig. 1 are shown in Fig. 4. A bandwidth of about 1 GHz (10%) is predicted by theory, the measured results are in close agreement in terms of bandwidth, frequency and return loss.
Slight deviations are assumed to be caused by small air-gaps due to imperfection in the experimental set-up. An additional measurement was performed connecting another waveguide to the top side of the microstrip circuit to look for the spurious radiation, which is indeed very small (-15 dB at the frequency of operation).
To avoid possible difficulties along with undefined air-gaps between the two substrates, a structure according to Fig. 2a has been investigated. The bottom substrate with the patch was turned and placed in the waveguide with a now larger and defined air-gap dimension. Additionally, the substrate now serves as a protecting waveguide window.
As could be assumed from the well known features of corresponding microstrip-antennas, an increased bandwidth compared to the original structure can be obtained, see Fig. 5.

For mm-wave applications, the proposed structure still may be not simple enough with regard to ease of fabrication. Therefore, another idea was to totally remove any substrate from inside the waveguide and replacing the patch by an appropriate metall strip which can be placed easily to the waveguide as a (printed) iris, see Fig. 2b.
Additionally, with this simplified structure, a remarkable improve in bandwidth (about 20%) has been achieved, see Fig. 6. It must be noted, however, that spurious radiation has increased (-11 dB at the frequency of operation), mainly due to the fact that the coupling slot now is longer than in the original set-up.

IV. CONCLUSION

Three different versions of a simple transition from microstrip line to rectangular waveguide have been designed and fabricated. In all cases, measured results agree well with theory. Spurious radiation is very small for all of these structures, so a waveguide short circuit is not necessary on the top side of the microstrip line.

Further improvement of the performance, especially concerning bandwidth, can be expected, because in all cases only a few parameters have been involved in the optimization process.

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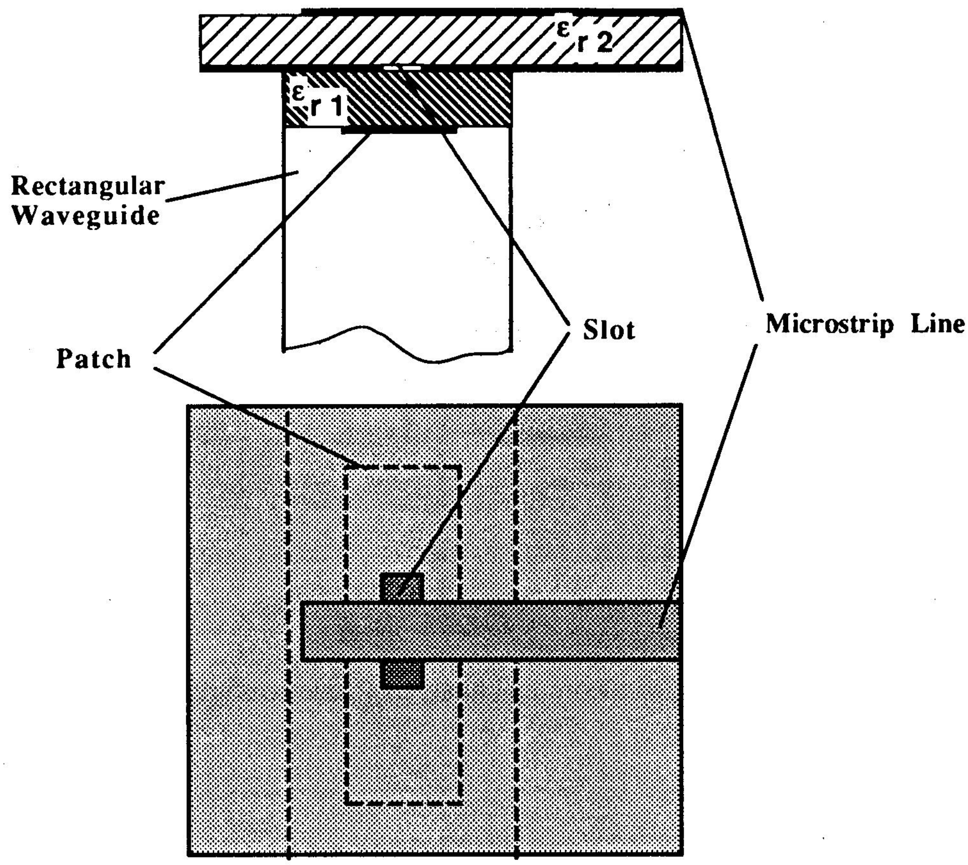

Fig.1: Basic configuration of the transition from microstrip to rectangular waveguide

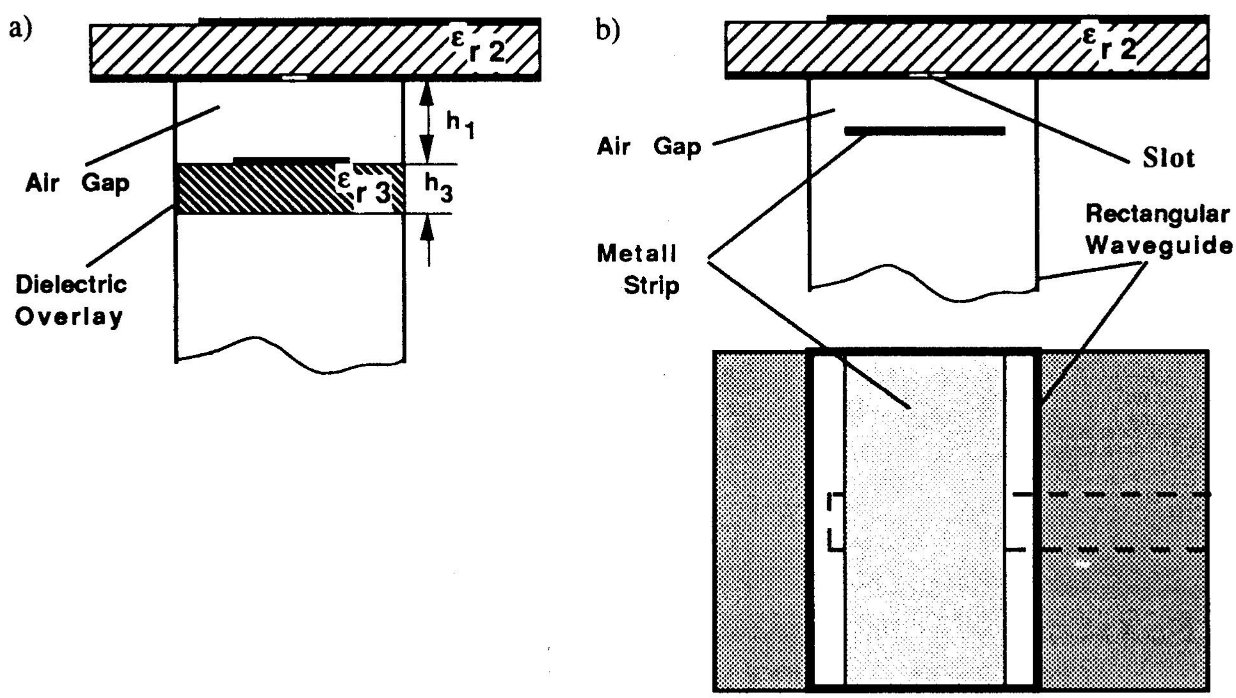

Fig. 2: Modified versions of the transition

a) with air gap and supporting substrate for the patch

b) with patch replaced by a metall strip, no substrate inside the waveguide

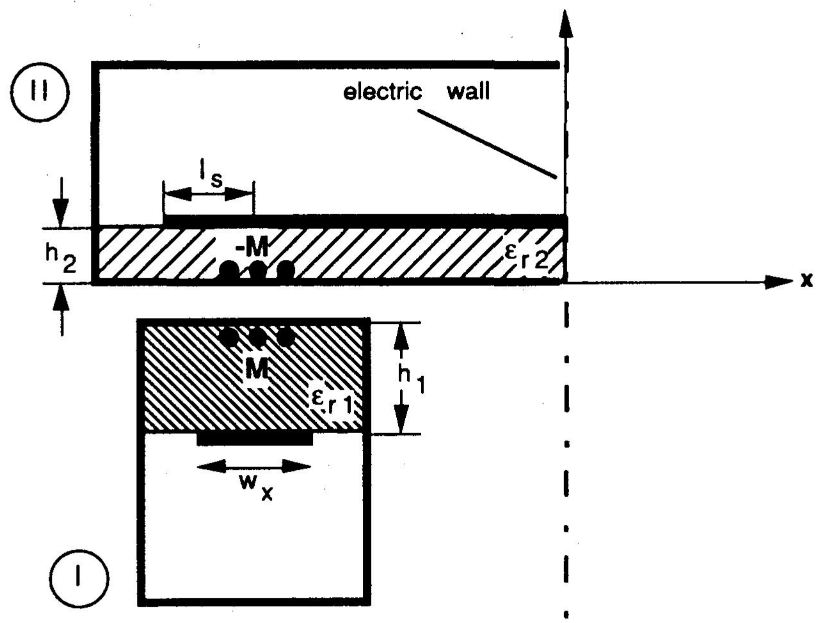

Fig. 3: Equivalent structures for theoretical analysis (basic configuration)

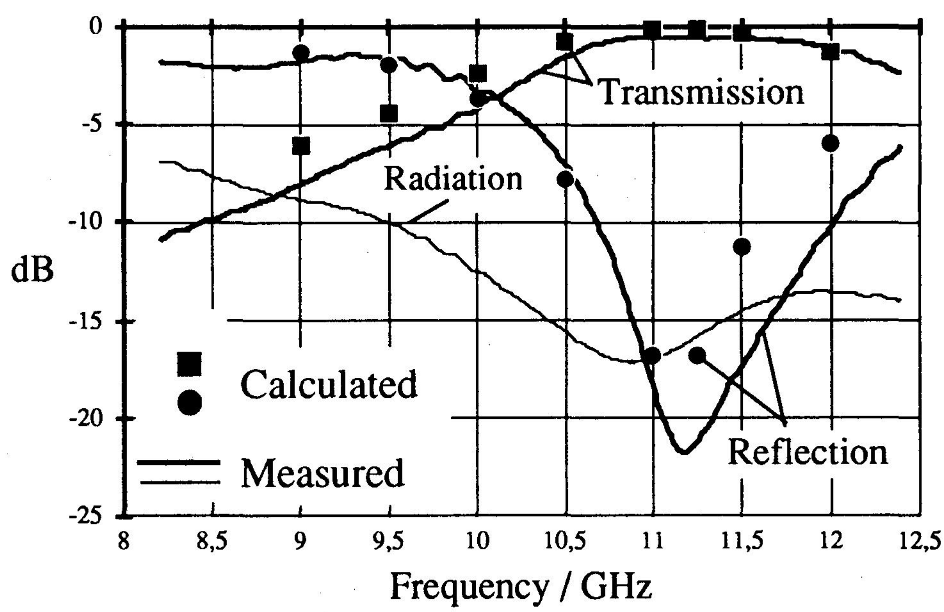

Fig. 4 : Experimental and theoretical results, basic configuration
(Patch 7 x 12 mm, slot 1 x 5 mm, waveguide 10.16 x 22.8 mm
$\varepsilon_{r1} = \varepsilon_{r2} = 2.33$, $h_1 = h_2 = 0.8$ mm, $l_s = 4$ mm)

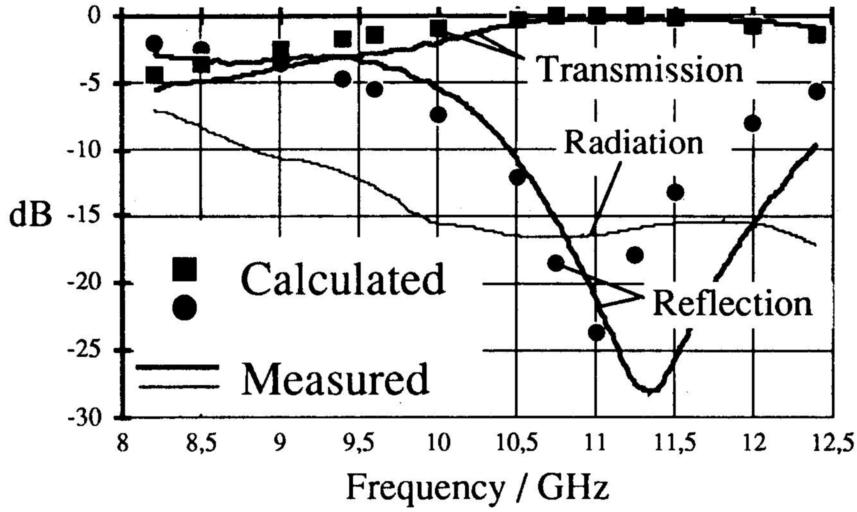

Fig. 5: Experimental and theoretical results, modified version according to Fig. 2a (Patch 8.1 x 12 mm, slot 1 x 7.5 mm, waveguide 10.16 x 22.8 mm, $\varepsilon_{r1} = \varepsilon_{r2} = 2.33$, h_1 = 1mm, $h_2 = h_3$ = 0.8 mm, l_s=4 mm)

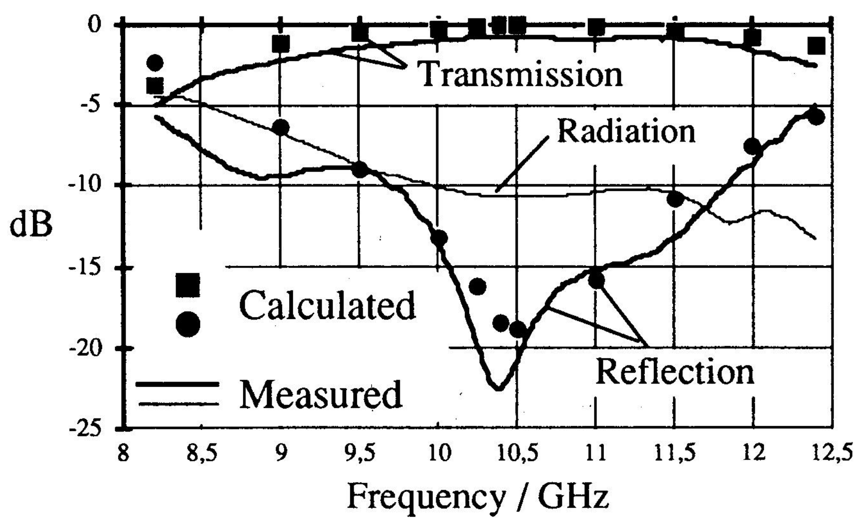

Fig. 6: Experimental and theoretical results, modified version according to Fig. 2b. (Width of metall strip 9.2 mm, slot 1 x 8.5 mm, waveguide 10.16 x 22.8 mm, ε_{r2}= 2.33, h_1 = 2mm, h_2 = 0.8 mm, l_s = 2mm)