Two Right-Angle Microstrip to Waveguide Transitions Suitable for Metal Backed Substrates

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***Abstract* — For some applications the use of metal backed substrates is advantageous. The solid backside-metallization provides a good heatsink and gives the possibility to produce MMIC-cavities by milling. However, the circuit design is bounded to one layer, and therefore the choice of suitable waveguide transitions is limited. Especially if right-angle transitions are needed, no structures are known to the authors that can be produced easily by single-layer etching and milling processes.**

In this contribution two microstrip line (MSL) to rectangular waveguide transitions are presented that can be used with metal backed substrates. One of the transitions can be fabricated even without via holes. Designs are presented for the E-band and the Ka-band, but the principles can be scaled to other frequency ranges.

1 Introduction

Right angle MSL to waveguide transitions are very useful for the design of mm-wave modules, because they help realizing a compact circuit layout. In literature many different approaches are described. Most of them are based on a radiating patch protruding into the waveguide a quarter wavelength apart from a backshort [1][2]. All of these transitions require a double sided structuring of the microstrip substrate and via-holes. The MSL to rectangular waveguide transitions presented in this letter can be fabricated on a single layer and are therefore suitable for metal backed substrates.

Transition 1 is oriented “downwards”. That means that the waveguide flange is located underneath the microstrip circuit. This setup is useful if the planar circuit has to be accessible during operation (e.g. for testing).

Transition 2 can be used in configurations where the waveguide is oriented “upwards” and can be fabricated without any via holes.

2 Transition 1

The downward transition (Fig. 1) is based on a combination of well known techniques. First the microstrip line is transformed into a via bounded substrate-integrated waveguide (SI-WG). Several structures are reported for this purpose [3], a simple tapered transition was used in this case.

The substrate integrated waveguide is then transformed into a partially air-filled waveguide. To obtain a broadband matching this is done with two quarter wave sections.

The third part of the overall transition is a right angle bend in the E-plane. The matching of this bend was improved using a single step as in [4].

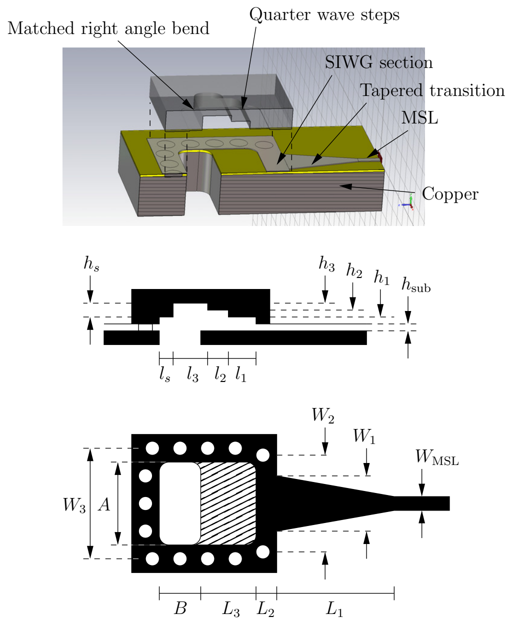

Figure 1: Schematic (top) and dimensional drawing (bottom) of the substrate-integrated waveguide based transition. The cover is lifted for clarity.

Two implementations of transition 1 have been fabricated. The first one was designed for the E-Band (60 GHz–90 GHz) on a *Taconic TaclamPlus* [5] metal backed substrate. The second one has been produced on Rogers RO3003 and was intended to cover the Ka-Band (26.5 GHz–40 GHz). Both have been simulated and optimized using *CST Microwave Studio*. Fig. 1 and Tbl. 1 summarize and compare the dimensions of both transitions.

2.1 Implementation for the E-band

Due to the high frequency, only scalar measurements were performed in a back–to–back configuration. Hence, an exact deembedding of a single transition was not possible. However, the measured data could be compensated for the line losses ($\sim$ 1 dB /10 mm) estimated by two identical setups with different line

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lengths. The results are depicted in Fig. 2. The transition shows a very flat and broadband behavior. The

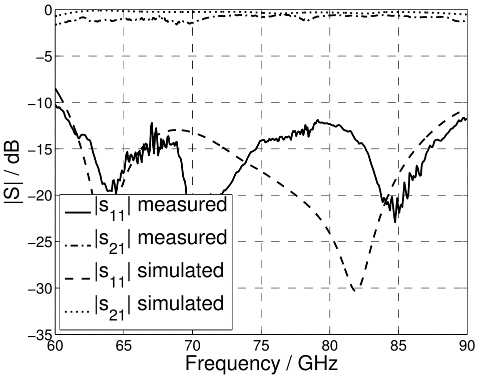

Figure 2: Simulated and measured S-parameters of the substrate-integrated waveguide based transition for the E-band.

insertion loss is better than 0.5 dB in the simulation and less than 2 dB in the measurement. Return loss is greater than 10 dB from 61 GHz–90 GHz in both simulation and measurement. The comparison of measured and simulated results shows a good agreement.

2.2 Implementation for the Ka-band

The design principle shown above has also been adopted for the Ka-band. A vectorial measurement setup was available for this frequency range. Hence the behavior of a single transition could be obtained by measuring two back–to–back setups with slightly differing lengths and appropriate deembedding of the results. Fig. 3 shows a very good agreement between simulation and measurement. The simulated insertion loss is less than 1 dB. The measured transmission is similar but drops a little bit below -1 dB for frequencies less than 27 GHz. Return loss is better than 15 dB in both simulation and measurement.

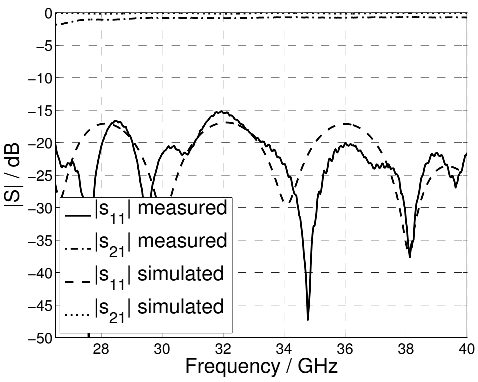

Figure 3: Simulated and measured S-parameters of the substrate-integrated waveguide based transition for the Ka-band.

Table 1: Dimensions of transition 1 for the respective implementation

Name	E-Band	Ka-Band	Description
W_{MSL}	0.3 mm	0.60 mm	width of the MSL
L_1	3.3 mm	9.40 mm	taper length
W_1	1.64 mm	3.15 mm	final taper width
L_2	1.05 mm	3.23 mm	length of SI-WG
W_2	2.9 mm	6.50 mm	via spacing of SI-WG
L_3	2.61 mm	4.74 mm	transformer length
W_3	3.5 mm	8.11 mm	via spacing
l_1	0.89 mm	1.84 mm	length of $\lambda/4$ section 1
h_1	0.19 mm	0.13 mm	height of $\lambda/4$ section 1
l_2	0.86 mm	2.36 mm	length of $\lambda/4$ section 2
h_2	0.57 mm	0.85 mm	height of $\lambda/4$ section 2
l_3	1.85 mm	2.44 mm	length of horiz. waveg.
h_3	0.86 mm	1.85 mm	height of horiz. waveg.
l_s	0.56 mm	1.65 mm	length of matching step
h_s	0.69 mm	0.04 mm	height of matching step
A	3.1 mm	7.11 mm	width of waveguide port
B	1.55 mm	3.56 mm	height of waveguide port
h_{sub}	0.1 mm	0.254 mm	substrate height

3 Transition 2

The second microstrip line to waveguide transition is based on a slot resonator excited by a microstrip line (Fig. 4) [6]. To avoid the use of vias, RF ground is provided by a quarter wave stub. The field distribution within the slot is equivalent to the transversal field distribution of a TE_{10} waveguide mode. If the metallization surrounding the slot is extruded perpendicular to the MSL plane, a rectangular waveguide is generated, which is able to guide the wave launched by the slot resonator. One problem is the mechanical attach-

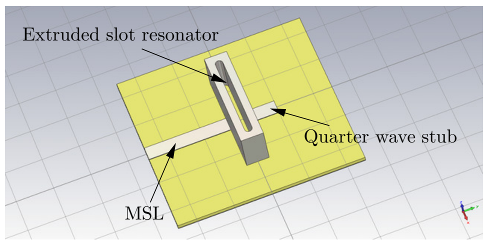

Figure 4: Extruded slot resonator excited by a microstrip line.

ment of the waveguide without disturbing the field of the feeding MSL, the quarter wave stub and the slot resonator. This is solved using a solid plate with a groove surrounding the microstrip structure and the slot resonator (cf. Fig. 5). The depth of this groove is approximately a quarter wavelength to suppress parallel plate waves between the microstrip ground plane and the solid plate incorporating the actual transition. Of course the slot resonator does not have standard waveguide dimensions. To provide a standard interface, an impedance transformer was included.

This waveguide transition has been designed and optimized for the E-band. The dimensions are summarized in Fig. 5 and Tbl. 2. Fig. 6 shows a comparison between the simulated and measured results. A significant frequency shift of approximately 4 GHz and a lower return loss can be observed in the measurement. This is most probably due to fabrication tolerances. However, the bandwidth is the same. In simulation the insertion loss is less than 1 dB from 64 GHz–86 GHz. The measurement results show some ripples due to resonances in the back–to–back setup. The insertion loss can be estimated to be lower than 2 dB from 68 GHz–90 GHz.

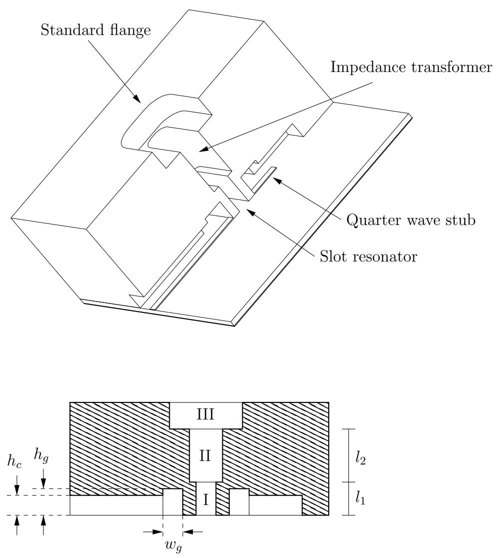

Figure 5: Schematic (top) and dimensional drawing (bottom) of the slot resonator based waveguide transition.

Table 2: Dimensions of transition 2

Name	Value	Description
a_{I}	2.6 mm	length of slot resonator
b_{I}	0.3 mm	width of slot resonator
l_{I}	0.75 mm	length of waveguide section I
a_{II}	2.9 mm	height of waveguide section II
b_{II}	0.6 mm	width of waveguide section II
l_{II}	0.5 mm	length of waveguide section II
a_{III}	3.1 mm	height of connecting waveguide III
b_{III}	1.55 mm	width of connecting waveguide III
h_c	0.4 mm	height of the MSL channel
h_g	0.5 mm	height of the groove
w_g	0.4 mm	width of the groove

Fig. 7 shows the three parts of the fabricated structure. It has been designed to simplify the manufacturing process and to reduce the impact of alignment tolerances.

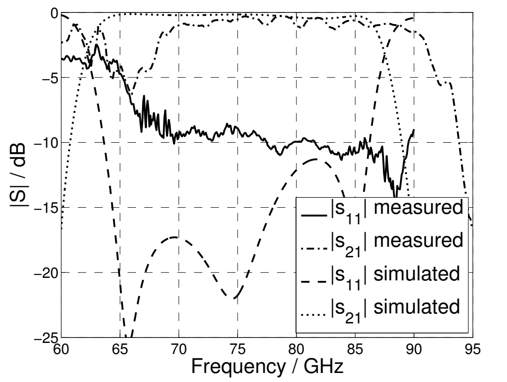

Figure 6: Simulated and measured S-parameters of the slot resonator based MSL to waveguide transition.

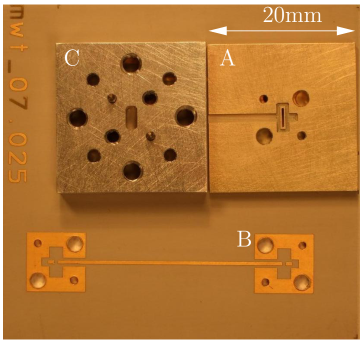

Figure 7: Mechanical details of the MSL to waveguide transition.

The aluminum plate (A) contains the impedance transformer and the slot resonator. It is important to note that the latter one is realized only in the aluminum plate (A) and not in the microstrip circuit (B). Therefore a slight misalignment is not critical. The standard WR-12 waveguide flange (C) is attached to the other two parts using alignment pins and screws from the back side.

4 Conclusion

Two types of microstrip line to waveguide transitions are reported in this paper. Both are compatible with metal backed substrates and can be fabricated using single layer PCB processing and milling.

Transition 1 requires only standard precision manufacturing even in the E-band. A 40% bandwidth is covered with more than 10 dB return loss. Furthermore the design can be easily scaled, which has been demonstrated for the Ka-band.

Transition 2 is oriented upwards and can be realized without any via holes. It covers almost the complete

E-band. Especially at mm-wave frequencies, low fabrication tolerances are more crucial than for the first transition. However, if a via process is not available (e.g. when using PTFE based substrates), this transition can be very useful.

References

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