Wideband Coplanar Waveguide-to-Rectangular Waveguide Transition Using Fin-Line Taper

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***Abstract*—This letter introduces a new wideband coplanar waveguide-to-rectangular waveguide transition. The transition uses a uniplanar circuit in line with the waveguide, which eases the design and fabrication. The design does not require airbridges. Simulations and measurements of X-band (8.2–12.4 GHz) transitions based on both a low- and high-permittivity material ($\varepsilon_r = 2.33$ and 10.8) show that the transition works fine over the full frequency band. For $\varepsilon_r = 2.33$ the measured return and insertion loss of a back-to-back transition are more than 16 dB and less than 0.4 dB, respectively. The corresponding values for $\varepsilon_r = 10.8$ are more than 10 dB and less than 1.0 dB, respectively, over 90% of the frequency band. The measured insertion loss values indicate losses of less than 0.14 dB and 0.36 dB at the center frequency for a single transition on a substrate with $\varepsilon_r = 2.33$ and 10.8, respectively.**

***Index Terms*—Coplanar waveguide (CPW), rectangular waveguide, transition, wideband.**

I. Introduction

Recently, new wideband uniplanar transitions between a coplanar waveguide (CPW) and a rectangular waveguide, aligned in the propagation direction of the waveguide, were introduced [1]–[4]. Common to all of these transitions is that they use a probe to couple the energy from the TE_{10} waveguide mode to the CPW mode. The design in [1] is based on a quasi-Yagi antenna and coplanar strips-to-CPW transition. Designs in [2] and [3] apply a slotline probe and slotline-to-CPW transition. In [4], a probe directly couples the energy to the CPW. These transitions offer a different possibility for device assembly compared to perpendicular transitions, e.g., [5], applied in typical assemblies, e.g., [6] and [7]. Unlike in typical assemblies, these transitions do not require additional waveguide bends to implement input and output ports in line.

This letter introduces a new transition structure based on a fin-line taper and fin-line-to-CPW transition. Waveguide-to-CPW transitions in [8] and [9] use also the fin-line taper. However, the design in [8] with an antipodal fin-line has a complex structure and requires two-sided fabrication. The design in [9] suffers from resonances limiting the usable frequency band. The uniplanar transition, proposed in this letter, has a simple structure providing a wideband, low-loss operation over the waveguide frequency band.

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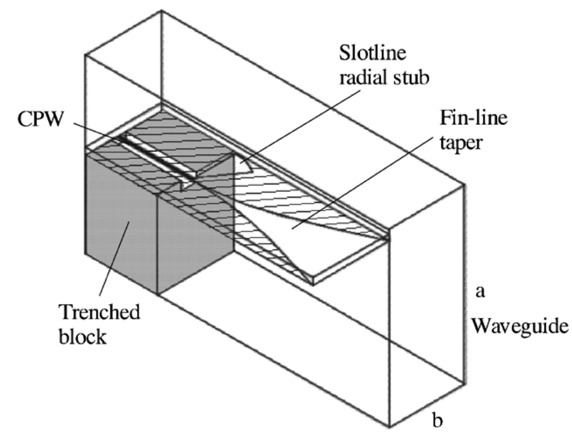

Fig. 1. Overall picture of the CPW-to-rectangular waveguide transition using a fin-line taper.

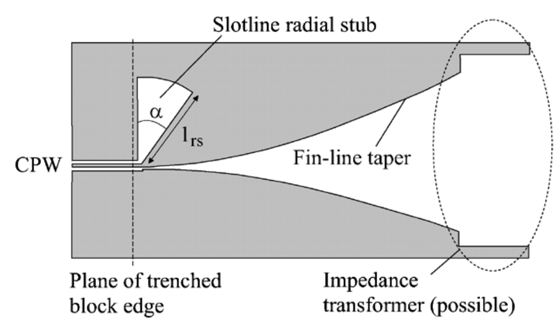

Fig. 2. Circuit layout of the waveguide-to-CPW transition using a slotline radial stub in the CPW-to-fin-line transition.

II. CPW-to-Rectangular Waveguide Transition

Figs. 1 and 2 show the overview and circuit layout of the designed transition, respectively. With the fin-line taper the TE_{10} waveguide mode converts to a unilateral fin-line mode. The final step from the fin-line to the CPW is based on a wideband slotline-to-CPW transition with a slotline radial stub, see, e.g., [10], [11]. Other approaches are possible as well, like twin-spiral slotlines, a circular slotline end, or slotlines with a 180° phase difference as presented in [12], [13], and [3], respectively. The dielectric substrate lies in the center of the E-plane of the full-height rectangular waveguide partly on top of a trenched metal block forming a shielded CPW channel [1]. The channel allows the propagation of the CPW mode while suppressing the coupled slotline mode. In this way, there is no need for air-bridges. Different types of a fin-line taper can be applied, i.e., exponential, parabolic, cosine, cosine-squared, circular, or linear. In case of low-permittivity substrate materials, the taper can start right from the broad walls of the waveguide. For high-permittivity

TABLE I
PARAMETER VALUES FOR X-BAND (8.2–12.4 GHz) CPW-TO-RECTANGULAR WAVEGUIDE TRANSITIONS

			SUBSTRATE 1	SUBSTRATE 2
Substrate:	permittivity	ε_r	2.33	10.8
	height		787 μm	635 μm
	plating thickness		30 μm	15 μm
	loss tangent		0.0012	0.0023
CPW:	center conductor width		0.4 mm	0.4 mm
	ground-to-ground spacing		1.1 mm	1.3 mm
CPW channel:	width		2.0 mm	1.5 mm
	height		1.0 mm	0.5 mm
Fin-line:	width		130 μm	130 μm
π/2-cosine taper:	length		20 mm	15 mm
Slotline	angle	α	35°	80°
radial stub:	length	l_{rs}	5.46 mm	4.42 mm

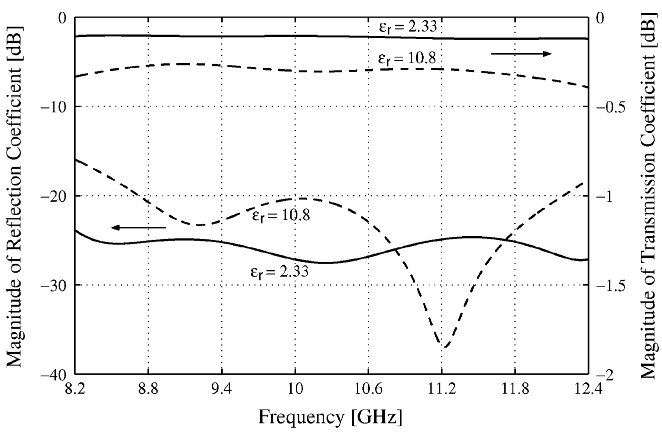

Fig. 3. Simulated magnitude of the reflection and transmission coefficient of a single X-band CPW-to-waveguide transition. Solid lines are for ε_r = 2.33 and dashed lines for ε_r = 10.8.

materials it might be better to use a part of the substrate end as an impedance transformer in front of the taper section (Fig. 2).

III. X-BAND TRANSITIONS

The design was tested with two X-band (8.2–12.4 GHz) transitions. To simulate and optimize the structures, a finite element method-based electromagnetic structure simulator (Agilent HFSS) was used. The transitions are based on low- and high-permittivity substrates (permittivity ε_r = 2.33 and 10.8) in a WR-90 waveguide (width a = 22.86 mm, height b = 10.16 mm). The gold-plated waveguide block is made using split-block techniques. The parameters and dimensions of the substrate and circuit are shown in Table I. The dimensions of the fin-line and CPW were chosen in view of easy fabrication. For ε_r = 2.33, the CPW characteristic impedance $Z_0 \approx 100\ \Omega$ and, for $\varepsilon_r = 10.8, Z_0 \approx 57\ \Omega$. In case of ε_r = 10.8, the substrate end forms an impedance transformer (Fig. 2) with a length of 5 mm and width of 10.16 mm (=b) so that, in the beginning of the taper ($\pi/2$-cosine), the fin-line is 6.96-mm wide. The length of the transitions was set to be same, i.e., 20 mm corresponding to $\sim\lambda/2$ in the waveguide at the center frequency f_c = 10.3 GHz.

Fig. 3 shows simulation results of the two single transitions (ε_r = 2.33 and 10.8). In simulations of a single transition, the two-port structure was similar to that in Fig. 1, one port formed by the rectangular waveguide and the other one by the CPW. The return loss is more than 24 dB for ε_r = 2.33 and more than 16 dB for ε_r = 10.8 over the full frequency band, whereas the insertion loss is less than 0.13 and 0.4 dB, respectively. The insertion loss values include losses of a 10-mm long waveguide and 15-mm long CPW section. In addition to substrate losses, the simulations comprised also losses of the circuit metal plating and waveguide (conductivity $\sigma = 5.8{\cdot}10^7$ S/m and $4.1 \cdot 10^7$ S/m, respectively).

For testing, back-to-back double transitions were constructed according to values of Table I. A 30-mm long ($\sim$1.3λ at f_c for ε_r = 2.33 and $\sim$2.2λ for ε_r = 10.8) CPW section separates the back-to-back transitions. Measurements were carried out with an HP 8510C network analyzer and a pair of coaxial line-to-waveguide adapters calibrated with a TRL (thru-reflect-line) calibration method. Simulated and measured results for the back-to-back transitions are shown in Figs. 4 and 5. In Fig. 4, the measured return and insertion losses for ε_r = 2.33 are more than 16 dB and less than 0.4 dB, respectively, over the frequency band. Furthermore, the return loss is more than 20 dB over 95% of the band. For ε_r = 10.8 (Fig. 5), the return and insertion losses are more than 10 dB and less than 1 dB, respectively,

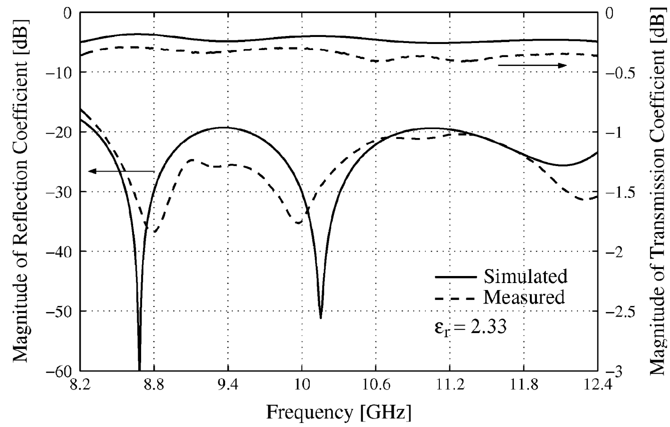

Fig. 4. Simulated and measured magnitude of the reflection and transmission coefficient of a back-to-back double X-band CPW-to-waveguide transition (ε_r = 2.33). Solid lines are for simulated and dashed lines for measured results.

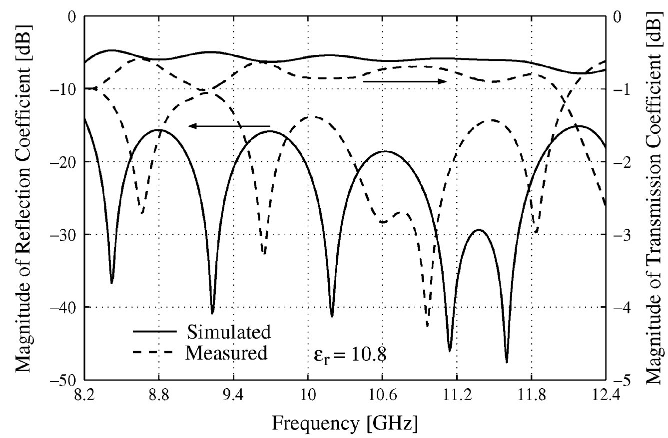

Fig. 5. Simulated and measured magnitude of the reflection and transmission coefficient of a back-to-back double X-band CPW-to-waveguide transition (ε_r =10.8). Solid lines are for simulated and dashed lines for measured results.

over 90% of the frequency band. Above 12 GHz the values degrade. By taking into account the loss of the CPW between the transitions, insertion losses of less than 0.14 dB and 0.36 dB can be estimated for single transitions at f_c. With ε_r =10.8 the correspondence between simulated and measured results is not as good as with $\varepsilon_r = 2.33$. This is mainly due to the tolerances of our experimental fabrication process which does not have adequate quality in case of $\varepsilon_r = 10.8$.

IV. Conclusion

A new CPW-to-rectangular waveguide transition based on a wideband CPW-to-fin-line transition and a smooth fin-line taper has been designed, constructed, and measured. By using a special CPW housing, there is no need for air-bridges. The transition is wideband, low-loss, and simple to design and construct. Both a low- and high-permittivity material can be used making the transition suitable also for microwave integrated circuits. Measurements of X-band transitions (8.2–12.4 GHz, $\varepsilon_r = 2.33$ and 10.8) verified that the transition performs well.

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