

# A 10 MHz to 100 GHz LTCC CPW-to-Stripline Vertical Transition

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**Abstract** — A broadband 50Ω coplanar waveguide (CPW)-to-stripline transition is presented which is capable of operation up to 100 GHz. This vertical transition is fabricated in low-temperature co-fired ceramic (LTCC), and it is appropriate for system in package (SiP) module packaging. It was designed for wafer probing an LTCC module containing an embedded stripline. This compact transition occupies only two layers of nominal 5 mil thick tape. Both simulated and measured s parameter results are shown for back-to-back transitions up to 110 GHz. Measured insertion loss for a single transition is less than 0.3 dB near 60 GHz and less than 1 dB up to 100 GHz.

**Index Terms** — transition, low-temperature co-fired ceramic (LTCC), millimeterwave, stripline

## I. INTRODUCTION

One of the most useful and necessary millimeter wave transitions for LTCC module development is the CPW-to-stripline vertical transition. The reasons for this include the fact that wafer probes use CPW launchers, and stripline offers a shielded, broadband, and non-dispersive transmission line structure that is readily compatible with LTCC fabrication practices and fully utilizes the multilayer capability of LTCC.

This type of transition has been published by numerous authors in recent years. Leib et. al. [1] presented such a transition for microwave frequencies that was fabricated using two layers of 25 mil RT/Duroid 6010. It demonstrated good performance up to about 9 GHz. Shuo Lei et. al. [2] presented a CPW-to-stripline transition design fabricated with six layers of Ferro A6M LTCC tape that was predicted to have about 2 dB of insertion loss over 50 GHz to 70 GHz. Perrone et. al. [3] demonstrated a two tape layer transition fabricated using DuPont™ GreenTape™ 951 LTCC. Good return loss (~20 dB) was measured up to 67 GHz, but no insertion loss data was presented. Lee and Park [4] published a much more complex CPW-to-stripline transition that included three staggered signal vias per transition plus two multi-layer air cavities per transition. Their transition used seven LTCC tape layers. They measured an insertion loss near 60 GHz of better than 2 dB for a pair of back-to-back transitions.

The CPW-to-stripline transition presented below is believed to be the broadest bandwidth LTCC transition published to date with a demonstrated bandwidth up to 100 GHz. It also has very good insertion loss, measured at better than 1.25 dB up to 100 GHz for a single transition and its excess line length

using identical back-to-back transitions. This transition design is also compact using only two tape layers, and it is straight forward to fabricate.

## II. DESIGN FEATURES

Fig 1 shows a cutaway view of the metal bodies that comprise the CPW-to-stripline transition. The gold conductors are the signal path. The red and green ground planes are the stripline ground, and the yellow ground plane is the CPW lower ground plane. All pink colored vias are grounding and shielding vias. Fig. 2 shows a wire frame view of two back-to-back transitions.

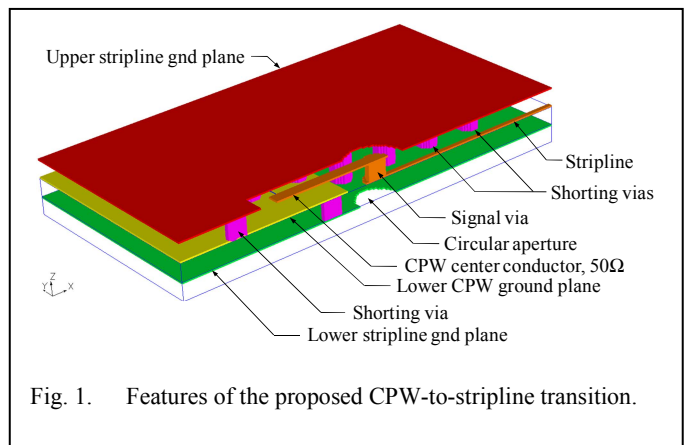


Fig. 1. Features of the proposed CPW-to-stripline transition.

This transition is designed and fabricated using DuPont™ GreenTape™ 9K7 LTCC tape, nominally 5 mils thick. Each tape layer has a post-fired thickness of about 108 μm with  $\epsilon_r = 7.0$  and  $\tan \delta = .0012$  at 60 GHz. Vias have a post fired diameter of 116 μm. All grounding vias have a period of 12 mils (305 μm) in the longitudinal direction, and the via transverse offset is also 12 mils from the centerline. Au metalization is employed. Three tape layers are shown in Figs. 1 and 2. However, only the upper two tape layers contain shorting vias.

This transition is fabricated using a laser ablation process to form the CPW. Fig 3 shows a keyhole-shaped trench cut through the topside metal and into the top LTCC tape layer to

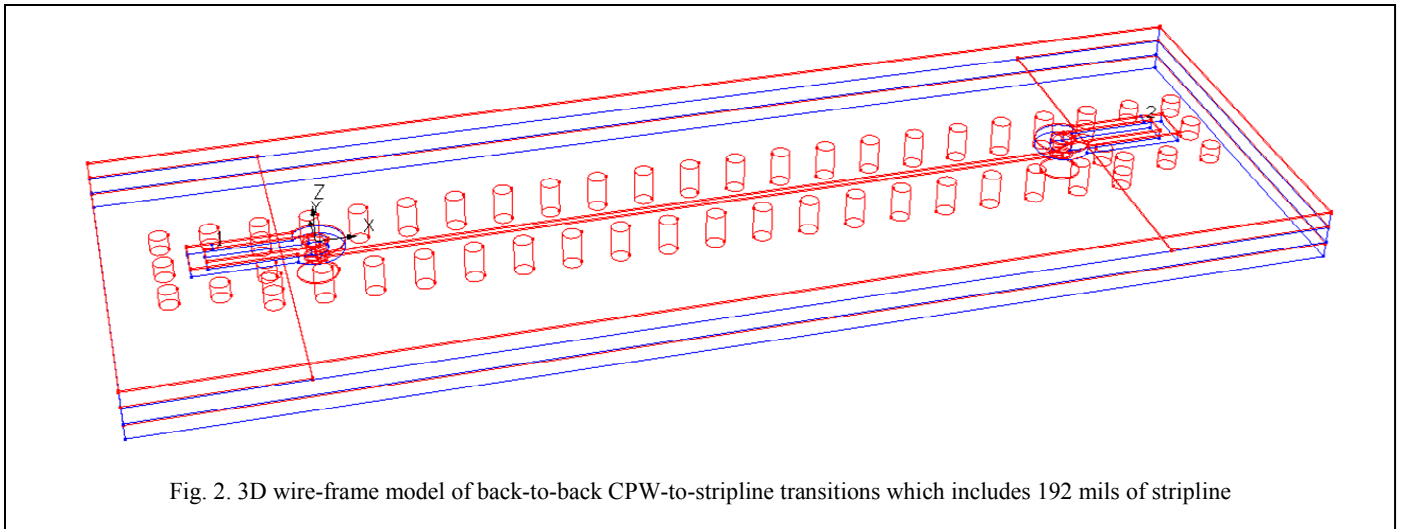


Fig. 2. 3D wire-frame model of back-to-back CPW-to-stripline transitions which includes 192 mils of stripline

a depth of about 50  $\mu\text{m}$ . The CPW center conductor and slots are nominally 135  $\mu\text{m}$  and 65  $\mu\text{m}$  in width, respectively. The nominal antipad radius of the annular slot is 178  $\mu\text{m}$ . The via pad radius is 76  $\mu\text{m}$ . The CPW center conductor has a length of 660  $\mu\text{m}$  from its open end to the center of the signal via pad.

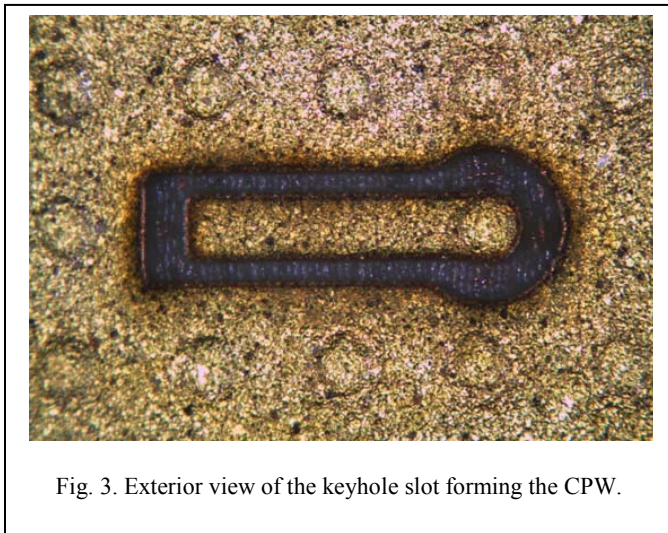


Fig. 3. Exterior view of the keyhole slot forming the CPW.

### III. PREDICTED PERFORMANCE

The proposed CPW-to-stripline transition was designed using Microstripes 2012, a full wave transmission line matrix (TLM) simulation tool available from CST. A circular aperture is formed in the stripline lower ground plane to minimize parasitic capacitance. This concept was suggested by Kangasvieri et. al. [5], [6] as a means to improve bandwidth for BGA transitions. This circular aperture of radius 127  $\mu\text{m}$ , combined with the CPW antipad, are both tuned to achieve 100 GHz of insertion loss bandwidth.

The predicted performance of a single CPW-to-stripline transition is shown in Fig. 4. The corresponding solid model, shown in Fig. 1, includes a 50 mil length of 50  $\Omega$  stripline.

Metals are simulated with a conductivity of  $3.3\text{E}7$  S/m, and the planar metal bodies are 10  $\mu\text{m}$  in thickness.

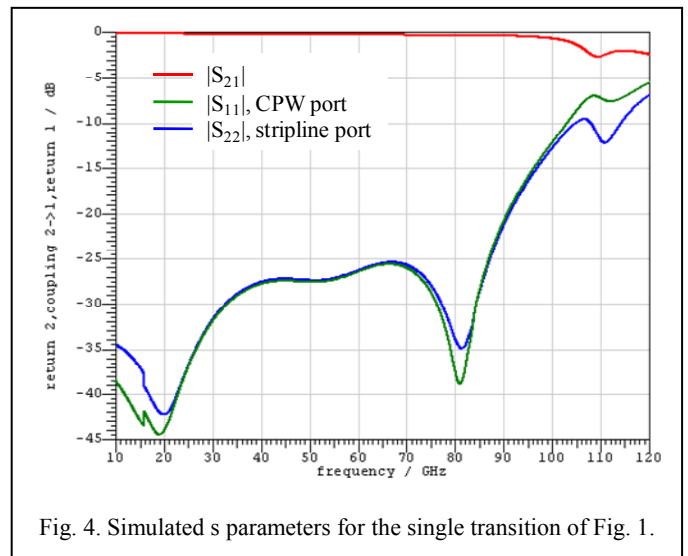


Fig. 4. Simulated s parameters for the single transition of Fig. 1.

### IV. EXPERIMENTAL RESULTS

Back-to-back transitions were fabricated in DuPont™ GreenTape™ 9K7 LTCC with stripline lengths of 192 mils, 396 mils, and 792 mils between centers of the signal vias. Fig 2 shows a 3D model used to simulate a back-to-back pair with 192 mils of stripline.

Measured data was recorded on transition test structures using an Anritsu model ME 7828 A Vectorstar VNA with millimeterwave test heads that allow full two port measurements up to 110 GHz. The LTCC test structures were wafer probed using a Cascade MicroTech probe station with 150  $\mu\text{m}$  GSG probes. Fig 5 shows the simulated and measured s parameters for the back-to-back transitions shown above in

Fig. 2. Predicted return loss is better than 20 dB out to 80 GHz, but the measured return loss is a little better than 10 dB up to 99 GHz. The difference is believed to come from alignment issues between the CPW traces and signal via.

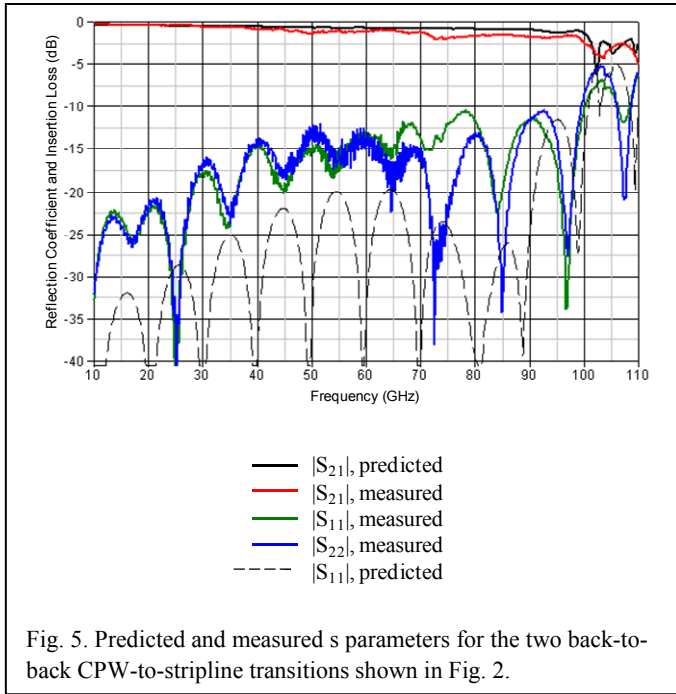


Fig. 5. Predicted and measured s parameters for the two back-to-back CPW-to-stripline transitions shown in Fig. 2.

Fig. 6 shows a detailed view of the predicted and measured insertion loss for the two back-to-back transitions of Fig. 2. Both curves show a transmission bandwidth of 100 GHz. The two cascaded transitions, including 192 mils of 50Ω stripline, have a predicted (measured) insertion loss of 0.71 dB (1.2 dB) at 60 GHz and a predicted (measured) insertion loss of 1.35 dB (2.49 dB) at 100 GHz. The stripline insertion loss is estimated to be .778 dB at 60 GHz and 1.86 dB at 100 GHz using measured data from test structures of dissimilar length. Therefore, one can estimate that the single transition measured insertion loss is about 0.21 dB at 60 GHz and 0.32 dB at 100 GHz assuming a zero length stripline.

Table I shows a comparison between simulation and measurement for various frequency points for both a single and back-to-back transitions. Note that the data for back-to-back transition includes a 192 mil long stripline.

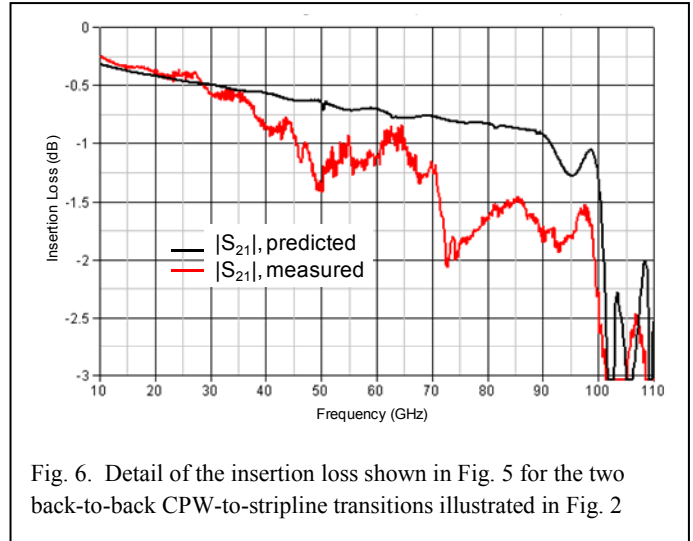


Fig. 6. Detail of the insertion loss shown in Fig. 5 for the two back-to-back CPW-to-stripline transitions illustrated in Fig. 2

To obtain a direct comparison of predicted versus measured insertion loss for a single transition, we assumed the stripline has a 50 mil length as shown in Fig. 1. The simulated insertion loss is the black curve in Fig 7, while the measured data is shown in red. Measured data was post-processed by first eliminating the mismatch loss from the insertion loss of two back-to-back transition test structures of different lengths to obtain their absorption loss. The difference in absorption loss allows the stripline loss per unit length to be calculated. Half of the absorption loss of the back-to-back transition with a 192 mil long stripline was further reduced by 46 mils of stripline loss to yield the absorption loss of a single transition with a 50 mil long stripline to match the simulated geometry. Fig 7 shows the 60 GHz measured absorption loss to be well under 0.3 dB, and the estimated absorption is less than 1 dB up to 100 GHz.

TABLE I  
MEASURED AND SIMULATED INSERTION LOSS

Frequency (GHz)	Single Transition*		Back-to-Back Transition**	
	Simulation (dB)	Measurement (dB)	Simulation (dB)	Measurement (dB)
20	0.136	0.102	0.421	0.364
40	0.195	0.225	0.568	0.871
60	0.246	0.218	0.705	1.108
80	0.287	0.469	0.831	1.662
100	0.663	0.438	1.348	2.487

\*Includes 25 mil CPW and 50 mil stripline

\*\*Includes 25 X 2 CPW and 192 mil stripline

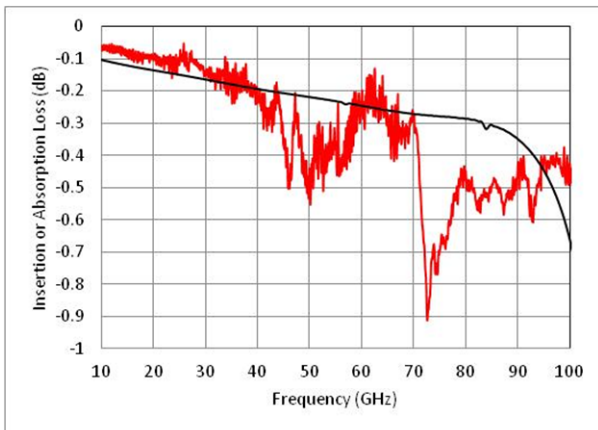


Fig. 7. Comparison of simulated insertion loss (black curve) to measured absorption loss ( $|S_{21}|$ -Mismatch Loss) (red curve) for a single CPW-to-stripline transition as shown in Fig. 1. This comparison assumes a 50 mil length of stripline.

## V. CONCLUSION

This paper presents a broadband, LTCC, CPW-to-stripline vertical transition that has less than 0.3 dB of insertion loss at 60 GHz, and less than 1 dB of insertion loss up to 100 GHz. This transition occupies only two layers of LTCC tape and a total height of less than 10 mils. It is well suited as a wafer probe interconnect on an LTCC module.

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