Progress In Electromagnetics Research Letters, Vol. 60, 17–21, 2016

A Broadband GCPW to Stripline Vertical Transition in LTCC

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Abstract—Vertical transition structure between grounded coplanar waveguide (GCPW) and stripline by Low Temperature Co-fired Ceramic (LTCC) technology is presented in this paper. In this structure, the top ground of the stripline is used as the GCPW lower ground, while the signal via goes through the middle ground plane. With increasing vertical signal via height, it can be more widely used in the higher height of multilayer System in Package (SiP) module packaging. The circular openings in the ground plane and additional shield vias around the transmission lines can provide great advantage in the radiation loss and decrease parasitic effects. The measurement results show that the return loss is less than −10 dB from 6 GHz to 35 GHz. Meanwhile, the insertion loss is better than −2 dB up to 28.4 GHz.

1. INTRODUCTION

In order to implement wireless communication system, a compact and low-cost radio system is indispensable [1]. Multilayer LTCC substrates technology offers the opportunity for low cost, high volume and small size modules for various microwaves applications since it combines the well established screen printing technique with multilayer ceramic lamination at a low firing temperature [2]. This enables the integration of further materials to realize an increased functionality of the modules. The RF performance of the microwave integrated circuits in LTCC is critically dependent on the transitions and interconnections. Previous papers have presented some interconnections and transitions [3, 4]. They consist of microstrip to microstrip transition [5], microstrip to stripline transition [6], CPW to microstrip transition [9], CPW to CPW vertical transition [7], CPW to stripline transition [8]. However, there is still a useful and necessary transition for LTCC module development — the vertical transition between grounded coplanar waveguide (GCPW) and stripline.

In this paper, a GCPW-to-SL vertical via transition is presented. In previous works, several types of vertical transition have been presented, but the Signal Via vertical going through the middle ground plane is not mentioned.

2. TRANSITION ARCHITECTURE

The structure of grounded coplanar waveguide (GCPW) to stripline (SL) vertical transition is shown in Fig. 1. It is designed on the LTCC substrate Ferro A6M tape system. This transition consists of a 12-layer LTCC substrate with a relative dielectric constant of 5.9 and loss tangent of 0.002. The GCPW center conductor is placed in the top layer (layer 12), and the GCPW ground plane is placed eight layers below. The 50 Ω GCPW signal line width is 530 μm. Meanwhile, the distance between the ground on both sides and the signal line is 150 μm. The stripline is also designed for a characteristic impedance of 50 Ω, which is implemented on layer 2. The stripline ground is placed on layer 4 and the

Received 10 March 2016, Accepted 20 April 2016, Scheduled 11 May 2016

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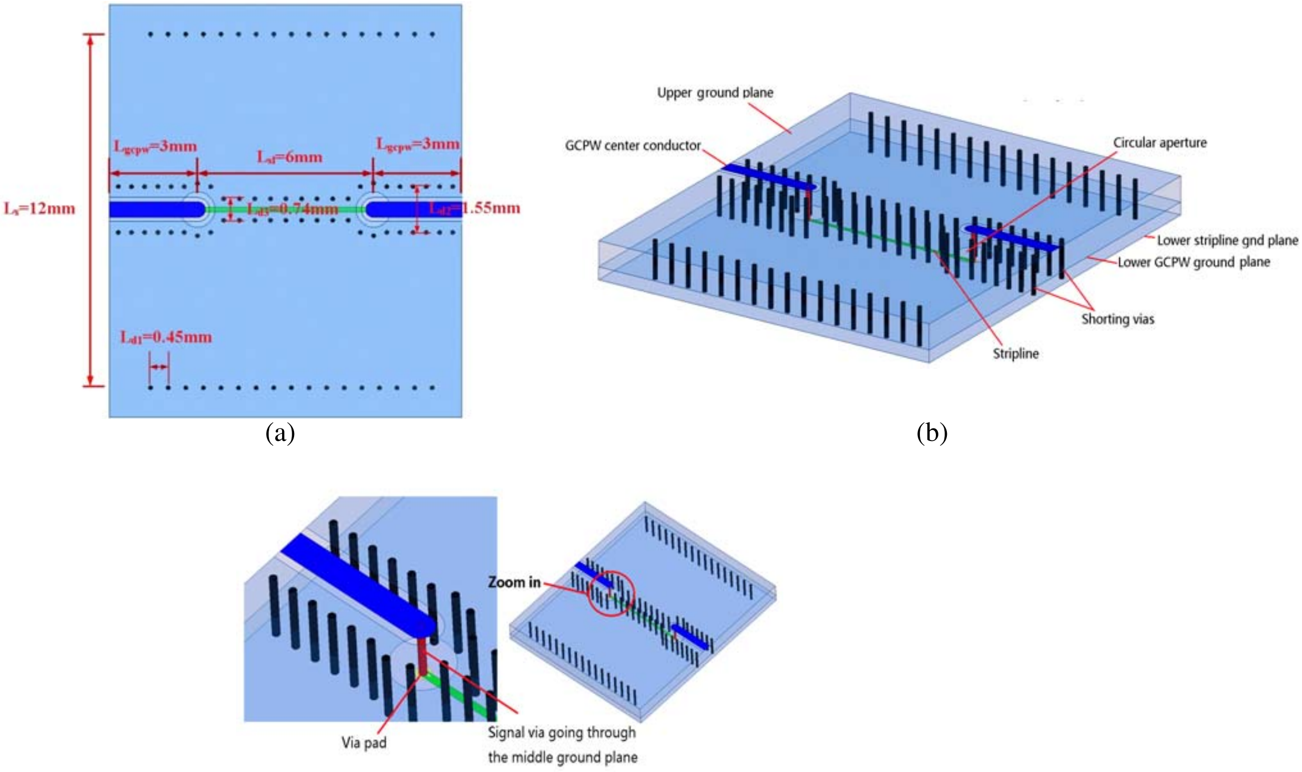


Figure 1. Configuration of a GCPW to stripline vertical transition: (a) Top view. (b) 3-D view. (c) Zoom-in view.

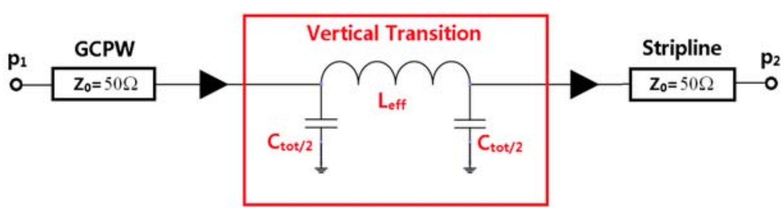


Figure 2. Equivalent circuit for GCPW to Stripline vertical transition.

bottom of layer 1. The top ground of the stripline is used as the GCPW ground plane. The diameter of metal-filled via holes (vias) is 150 μm. The total length of the transition structure is 12 mm, and the section of the buried stripline length (Lsl) is 6 mm, while the GCPW runs a length (Lgcpw) of 3 mm to the transition area.

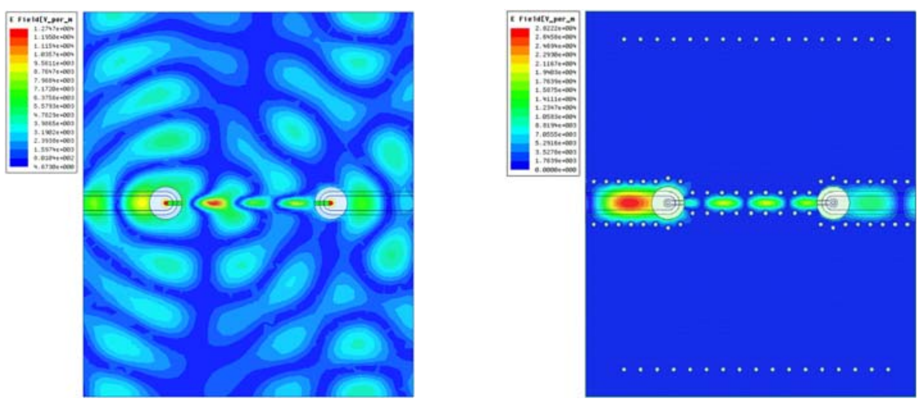
The vertical transition consists of a signal via (center via) going through holes in the GCPW ground plane. The mutation occurs in transmission line interconnection transition and brings no continuity, which will bring about the parasitic effect. The simplified equivalent circuit model of the transition is shown in Fig. 2. The effective inductance L_{eff} of the vertical transition is introduced by the vertical interconnect via. The C_{tot} is an effective capacitance between the transmission line and the ground plane. The cut-off frequency (f_c) can be approximated by Eq. (1). The effective inductance, L_{eff}, of the vertical transition is optimized by reducing the diameter of the via to the lowest permitted value in this process, 150 μm, and therefore increasing the f_c of the transition. The port impedance, $Z_0 = \sqrt{\frac{L_{eff}}{C_{tot}}}$, of the vertical transition must match that of the transmission lines used to feed the vertical transition to minimize reflections

$$f_c = \frac{1}{\sqrt{L_{eff} C_{tot}}} \tag{1}$$

In order to eliminate or decrease these parasitic effects, the optimum size for the circular openings in the ground plane and the via hole pad, and the spacing between the center conductor and the via fence is adjusted. The impedance of input port is 50 ohms, so the parasitic capacitance has to be increased to offset the parasitic inductance. Meanwhile, both the parasitic capacitance and parasitic inductance have to be reduced to increase the cut-off frequency. By using EM simulator for simulation and optimization, the circular openings diameter is selected to be 830 μm, the via hole pad diameter adjusted to 300 μm and the spacing between the signal via and the via fence optimized to 940 μm.

As shown in Fig. 1, some additional shorting vias are employed in the structure. These shorting vias can permit the connection of the GCPW ground to the bottom ground (SL-Ground). Some of them, located around the vertical signal via, can reinforce the coaxial effect. So they can provide a great advantage in the radiation loss. The vias around the transmission lines have the effect of shielding electromagnetic field. By using shielding vias can also avoid the excitation of parasitic modes, such as parallel plate wave-guide mode. The excitation of parasitic modes can appear at high frequency due to the discontinuity of the vertical transport transition. The E-field distribution of the transition structure is shown in Fig. 3. The parasitic modes appear in the structure without vias.

The comparison of the simulation results of S-parameter response between structures with and without shield vias is shown in Fig. 4. It can be observed that improvement is achieved for the S-parameter performance after the placement of the metal-filled shield vias. Simulation results of the



(a) (b)

Figure 3. E-field distribution of the vertical transition: (a) without vias, (b) with vias.

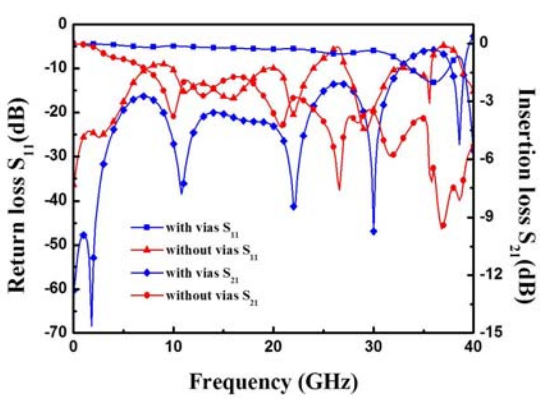


Figure 4. Simulation results of the vertical transition: with and without vias.

structure with surrounding vias show that the return loss of GCPW to stripline vertical transition is less than −20 dB from 9 GHz to 23.8 GHz and less than −15 dB up to 25 GHz. The insertion loss is better than 0.5 dB up to 31.4 GHz.

3. RESULTS AND DISCUSSION

In order to validate the transition design, the GCPW to stripline vertical transition structure was fabricated (shown in Fig. 5) by using a standard LTCC process with screen-printed conductor lines. The gold conductor is silk-screen printed on a Ferro A6M tape. The total thickness of this fabricated transition structure is 1.128 mm. All the vias were mechanically punched with a diameter of 150 µm. Measurements were performed on an R&S ZVA40 Vector Network Analyzer (VNA).

The comparison of the results between simulated and measured S-parameters of the transition structure is depicted in Fig. 6. The measurement results show that the return loss is less than −10 dB from 6 GHz to 35 GHz and the insertion loss better than −2 dB up to 28.4 GHz. The reasonable agreement can be obtained from the simulation and measurement results from 0.1 GHz to 30 GHz.

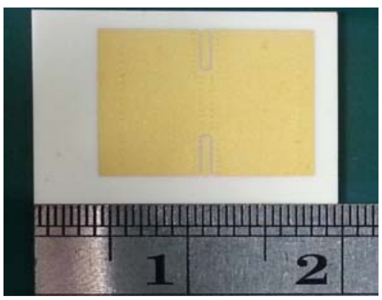


Figure 5. Photo of the GCPW to stripline transition.

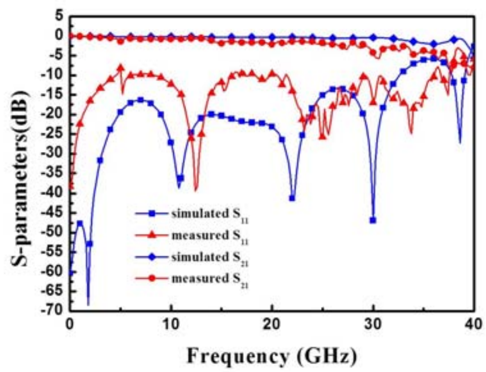


Figure 6. Simulation and measurement results of S-Parameters of GCPW-to-stripline transition.

Table 1 shows the comparison between our work and previous published works. It can be seen that the vertical signal via goes through more layers in this paper. The increase of vertical signal via height can be more widely used in the higher height of multilayer SiP module packaging.

Table 1. Performance comparison between different vertical transitions.

Ref.	Vertical Transition Type	Vertical Signal Via Height	Insertion Loss (Up to 24 GHz) (dB)	Return Loss (6 GHz to 30 GHz) (dB)
[6]	ML-SL	6 Layers	< 1	−20
[9]	CPW-SL	2 Layers	< 0.3	−18
[10]	MS-SL	6 Layers	< 0.8	−10
This Work	**GCPW-SL**	**10 Layers**	**< 1.5**	**−10**

4. CONCLUSION

A GCPW to stripline vertical transition is presented in this paper. The structure of a Signal Via vertical going through the middle ground plane is reported in this paper. The increase of vertical signal via height can be more widely used in the higher height of multilayer SiP module packaging. The technology of reducing the parasitic effect and adjusting the shield vias can improve the performance of transitions.

Measurements have been performed to validate the simulation results. Experimental results show that the return loss is less than −10 dB from 6 GHz to 35 GHz, and the insertion loss is better than −2 dB up to 28.4 GHz. This structure meets the actual requirements of LTCC SiP and other communication modules applications.

ACKNOWLEDGMENT

This work is support by the National Natural Science Foundation of China (Grant No. 61201044), New Star Team of Xi'an University of Posts & Telecommunications.

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