Coaxial-line Structured SMT Pad for LTCC SiP Applications

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Abstract— In this work, a surface-mount type (SMT) pad using a coaxial-line structure is presented for low temperature co-fired ceramic (LTCC) SiP (system-in-package) applications. The vertical via transition is devised in type of the coaxial line. An overlap part between its outer conductor and a transmission line on the main board is cut off in order to eliminate their interaction. A cap on the top layer of the vertical via transition is designed in order to reduce radiation due to discontinuity. The designed SMT pad was fabricated using the standard LTCC process. The measured return and insertion loss are below −14 and −1.0 dB, respectively up to 15 GHz.

1. INTRODUCTION

SiP (system-in-package), 3-dimensional (3D) integration approach of radio systems [1, 2], have been widely used for microwave and millimeter-wave (mm-wave) package applications, because of its low loss, integration capability, similar value of temperature coefficient of expansion (TCE) to MMICs, and cost effectiveness. Most of SiP modules have been implemented in type of a surface-mount type (SMT) because of easy and lowcost assembly.

Low-loss interconnection between a main PCB board and SMT pad and the excitation [3] of package modes are key issues for mm-wave SiP applications. In general, low-loss transitions between a SMT pad and signal path in the SiP module have been investigated using vertical via structures [5–9]. Various vertical via transition such as Coplanar waveguide (CPW)-to-stripline (SL) [4, 5], microstrip (MSL)-to-SL [6, 7] and CPW-to-CPW transition [4, 8] have been developed for radio system integration. In these previous researches, several approaches have been tried for improved RF performance. There are two categories: impedance matching [5, 6, 8] and parasitic compensation [4, 5]. In order to match the impedance close to 50 Ω, the coaxial-type transition using shielding vias [6, 8] and intermediate ground planes [5] have been presented. In order to reduce inductive and capacitive effects in the transition region [5, 6], S. Lei et al. [5] presented additional pads in the vertical vias to reduce the inductive effect at the transition F. J. Schmuckle et al. [6] designed the critical ground part in the SL. In addition, In order to suppress unwanted resonance modes, PBG structure in the cavity was designed, forming a kind of bandstop filter at the operation frequency [3].

In this work, the SMT pad using a coaxialline structure has been presented for mm-wave LTCC SiP module applications. Using a 9-layer LTCC dielectric substrate, CPW-to-Coaxial line-to-SMT pad transition is designed and fabricated. The SMT pad was designed and analyzed by using a 3-D Finite Integration Technique (FIT) simulator [10].

2. DESIGN OF A SMT PAD-TO-COAXIAL LINE-TO-CPW TRANSITION

A SMT pad is designed using a coaxial line-to-CPW vertical via transition in a 9-layer LTCC dielectric as shown in Fig. 1(a). For the coaxial line, a diameter of the inner conductor, which is the same as that of via for the signal path is fixed as 135 μm and an outer one is 695 μm. In order to maintain 50 Ω impedance the outer diameter of 1,226 μm is required. However, it leads to increase the size of the pad. Through the size optimization of the coaxial line in terms of transition loss and size, the outer diameter is determined and its impedance of the coaxial line is 37 Ω. The CPW line on the seventh layer (L7) is integrated into the cavity which consists of 8th and 9th layer for interconnection with other devices or measurement. A ECPW (embedded CPW) on the same layer as the CPW in the LTCC substrate is designed for interconnection between the coaxial line and CPW. The width of the CPW and ECPW is 144 and 90 μm, respectively. Their gaps are 83 and 95 μm, respectively. Their height of the substrate is 100 μm. In order to analyze crosstalk around SMT pad, electric (E)-field distributions of the cross-sectional parts of the whole SMT pad including a LTCC and PCB substrate are presented in Fig. 1(b). The dashed rectangular shows that the outer conductors used as the ground (GND) of the coaxial line overlap with the CPW line and GND planes on the PCB board. Therefore, in the overlapped part, EM-fields are concentrated and that leads cross-talk between the PCB and pad.

Figure 2 shows the designed results of the SMT pad using the coaxial line transition. As frequencies increase above 11 GHz, return losses (RL) are severely degraded over −10 dB. At 15 GHz, an insertion loss (IL) is lower than −2 dB. The degradation of the RL and IL results from the concentrated E-fields in the overlapped part. In order to improve the performance, the structure related to the concentrated E-fields should be modified.

Figure 3 presents that (a) a perspective view of the SMT pad transition using a modified coaxial-line transition and (b) its E-fileds distributions at the transitions. The overlapped parts between the LTCC substrate including coaxial-line outer conductor and CPW on the PCB are cut off. In addition, in order to reduce the radiation due to discontinuities at the interconnection part of the coaxial line and CPW, a cap with a radius of 928 μm on the 9th layer (L9) of the LTCC substrate is designed.

Figure 4 shows that the simulated characteristics of the modified SMT pad transition with a cap. Compared to the previous transition in Fig. 2, the performance is clearly improved. From DC to 18 GHz, the return losses are below −10 dB.

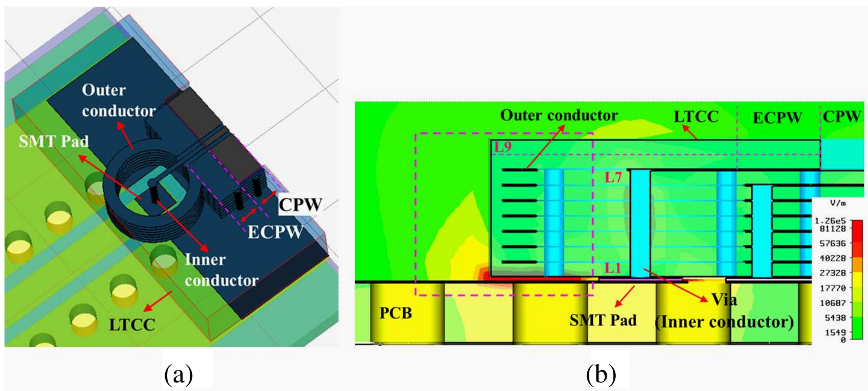

Figure 1: (a) 3D view of a SMT pad using a coaxial line transition and (b) electric (E)-field distributions the cross-sectional parts of the whole SMT.

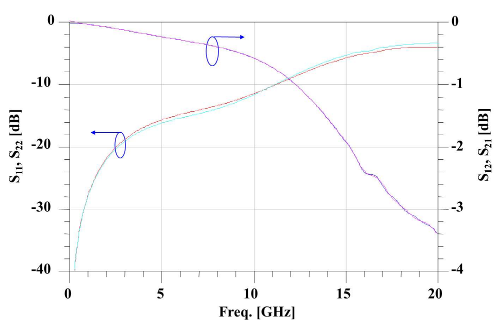

Figure 2: Designed results of the SMT pad using a coaxial line transition.

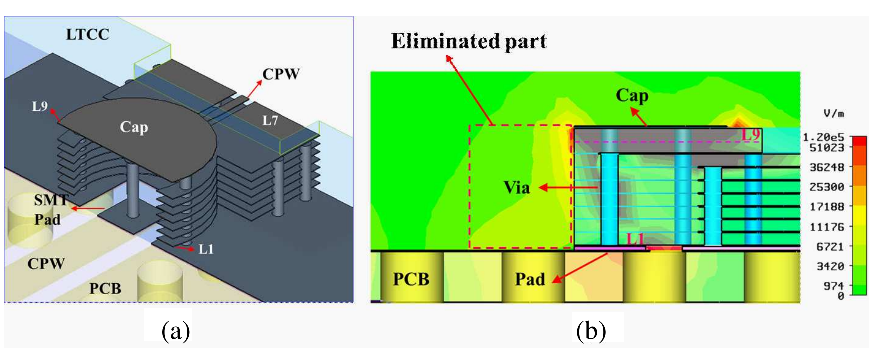

Figure 3: (a) 3D view of the modified SMT pad transition and (b) its E-filed distribution.

3. FABRICATION AND MEASURED RESULTS

The modified SMT pad transition was fabricated on nine LTCC dielectric layers with a dielectric constant of 7.8 and its thickness between the metal layers is 100 µm. The Ag and Ag/Pd conductors were screen-printed on the unfired green-sheet layers for internal and external conductors, respectively. The fabricated SMT transition is shown in an inset of Fig. 5.

Using a probing method on the probe station, the fabricated SMT pad transition was measured with a VNA (vector network analyzer). Fig. 5 shows the measured characteristics of the fabricated LTCC SMT pad transition on the PCB board The measured insertion loss is below −1.0 dB from DC to 15 GHz. The return losses are below −14 dB at the same frequency range. This SMT pad can be used for X- or Ku-band applications.

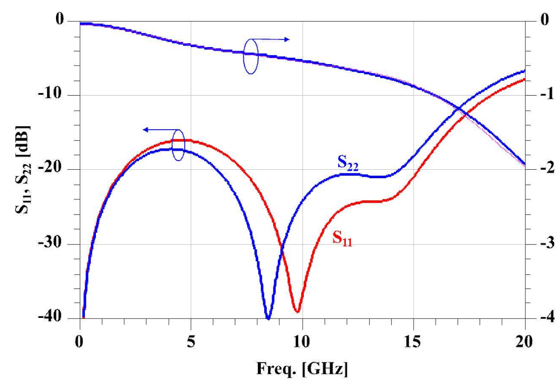

Figure 4: Designed return and insertion loss characteristics of the modified SMT pad transitions with a cap.

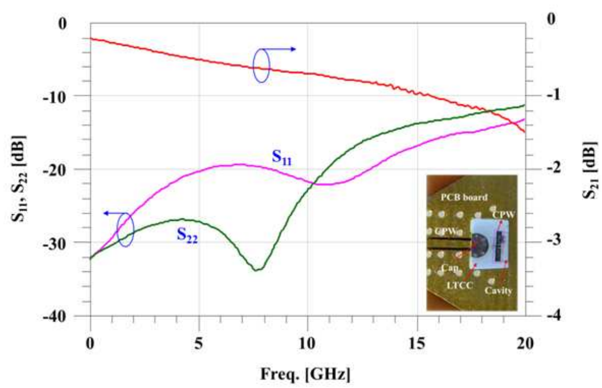

Figure 5: Measured characteristics of the fabricated SMT pad transitions [An inset: the fabricated LTCC SMT pad transition on the PCB board].

4. CONCLUSIONS

In this work, a coaxial-line structured SMT pad has been presented for LTCC SiP applications. The vertical via transition is devised in type of the coaxial line. In order to eliminate crosstalk and radiation, the overlapped parts between the LTCC substrate including coaxial-line outer conductor and CPW on the PCB are cut off and a cap at the interconnection part of the coaxial line and CPW is proposed, respectively. The designed SMT pad was fabricated using the standard LTCC process on nine LTCC dielectric layers. The measured return and insertion loss are below −14 and −1.0 dB, respectively, up to 15 GHz.

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