HIGH FREQUENCY HERMETIC PACKAGES USING LTCC

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ABSTRACT

This paper presents an experimental comparison of stripline versus modified coplanar waveguide transitions for use in high frequency hermetic packages. Low temperature co-fired ceramic is used as the substrate and wall material. It is shown that these hermetic wall transitions have low insertion loss at the designd frequency range from 30 GHz to 40 GHz, thus usable for an assortment of millimeter-wave packaging applications.

I. INTRODUCTION

The development of high performance package for microwave monolithic integrated circuits (MMICs) and multi-chip modules rely on the ability to integrate and operate a large amount of complex circuitry in a small physical volume. Electronic packaging technology is becoming an important issue in microwave and millimeter wave circuit applications due to the lack of appropriate packaging configuration for use in circuit design. All metal hermetic packages are frequently used in microwave integrated circuits for sealing and isolating parts of the circuit. The metal hermetic packages provide shielding against electromagnetic interference and physical protection from hostile environments. Successful MMIC integration requires that the package be carefully designed to enhance circuit performance in addition to improving thermal and mechanical characteristics [1]-[3].

A poorly designed electronic package could degrade the RF electrical performance of the MMIC or hybrid circuits. The performance degradations are due to the input and output wall reflection and insertion loss, the transmission line loss between package walls, and possible package resonancse and related effects [4].

Low temperature co-fired ceramic (LTCC) offers a low cost solution to the above problems. The LTCC is a recrystallizable ceramic tape, which can be stacked and fired to fabricate custom packages, circuits, and modules. The use of LTCC allows multi-layers for RF and DC electrical distribution, and buried capacitors and resistors reducing the circuit size, weight, and parasitic effects.

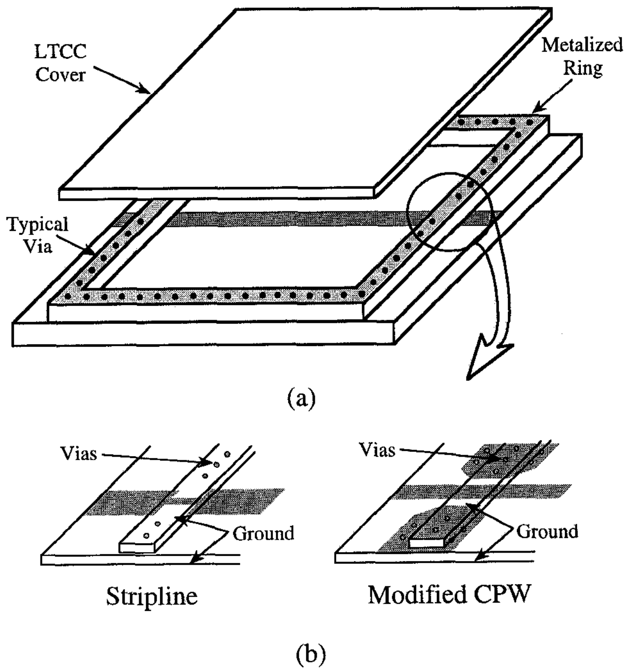

Fig. 1 (a) Design layout of the high frequency hermetic package; (b) Expanded view of the transition region.

In this paper, two LTCC packages were designed and fabricated for the operating frequency of 30 GHz to 40 GHz. Fig. 1 shows the general form of the LTCC packages; the only difference being one package uses a stripline wall transition and the other a modified coplanar waveguide (CPW). CPW exhibits lower dispersion and less radiation loss as compared to a microstrip design [5]. The LTCC is used as the substrate and wall material. From the input to output, the package consists of a 50 Ω microstrip line, a stripline/CPW transmission line beneath the wall, a shielded 50 Ω microstrip line, another

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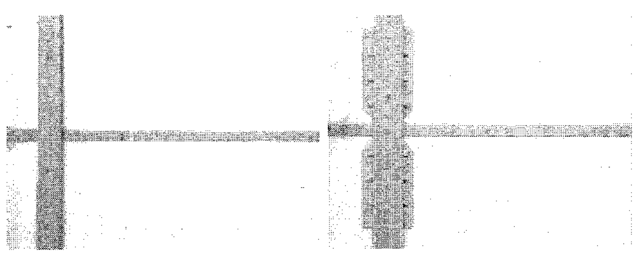
stripline/CPW transition, and a output 50 Ω microstrip line. A ceramic/metal cover is used to hermetically seal the package using low temperature brazing or solder seal technology. The measured S21 and S11 parameters for both cases are compared.

II. DESIGN, FABRICATION AND MEASUREMENT

The package was designed using Sonnet EM analysis and HP-EEsof Libra software. The Ferro A6 LTCC multilayer tape system was chosen for this design because of the low dielectric constant of 5.8 and a loss tangent of 0.002. Gold conductors and vias were used as the metalization system for this application. The substrate design consisted of eight layers of ceramic tape, each layer being 0.095 mm thick after being fired. The substrate was fabricated by printing a ground plane on the bottom side of the first layer of the tape. Then two unmetalized layers were added for substrate thickness. The transmission line structure was printed on the top side of the forth layer of tape. The cavity was formed by adding three unmetalized and a metalized top layer above the stripline/CPW transition area as shown in Fig. 1. The bottom ground plane was interconnected to the top seal ring/top ground plane using 0.381 mm diameter vias. The vias are placed 1.27 mm away from the stripline/CPW at the wall transition as shown in Fig. 2, and then repeated around the entire ring at 1.27 mm spacing. The LTCC substrate was co-fired to form a single microwave ceramic package.



(a) (b)

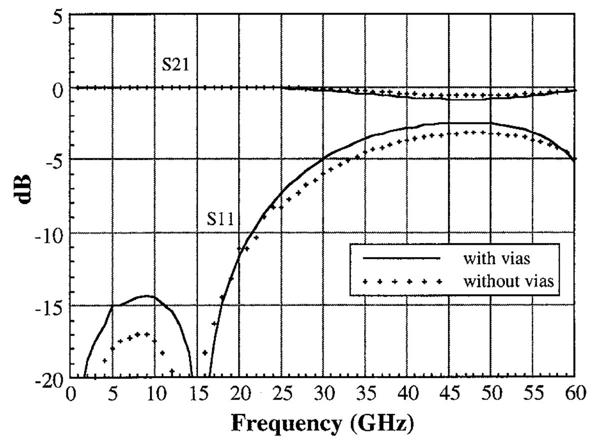
Fig. 2 The top view of the wall region of the hermetic package by using (a) stripline, (b) modified CPW transitions.

The test measurements were performed on a HP 8510C Network Analyzer from 45 MHz to 50 GHz. The package was mounted in a Wiltron test fixture and the S-parameters measured and recorded.

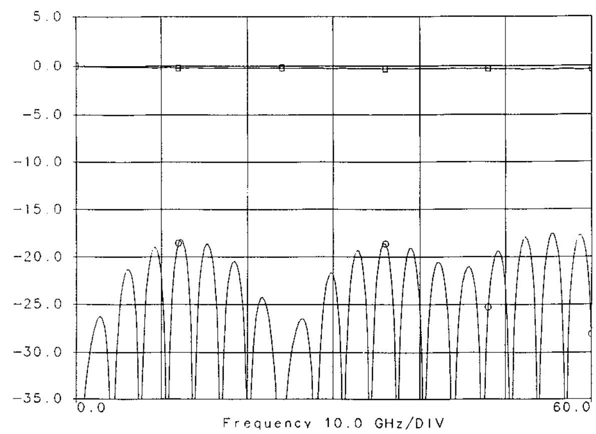
III. RESULTS AND DISCUSSIONS

A. *Stripline as Wall Region*

The high frequency transition for the wall region was designed using EM analysis resulting in a 50 Ω stripline width of 0.233 mm. The simulated results for a single wall region with and without vias is shown in Fig. 3(a). The insertion loss of the via structure is about 0.5 dB better than the one without vias at frequency above 30 GHz. At lower frequencies, the difference is negligible. After the EM analysis, the whole package that includes the microstrip lines and two transition walls was simulated on Libra. The simulated results for this package without vias is shown in Fig. 3(b). The maximum insertion loss is about 0.5 dB over the broad bandwidth. The ripple of the S11 is due to the standing wave effect of the long transmission line in the package.



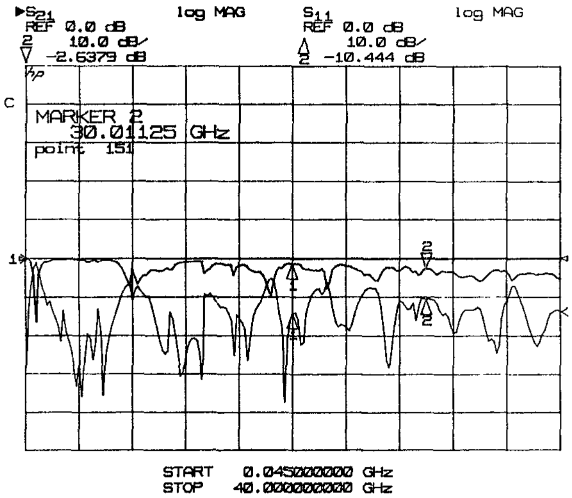
(a)



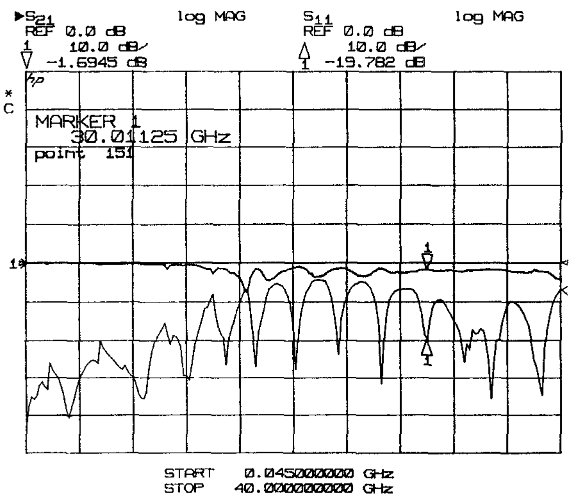
(b)

Fig. 3 The EM analysis on Sonnet for the stripline as wall region with and without vias; (b) The transition characteristics of the whole package simulated by the HP-EEsof Libra.

The above simulated data was then used to fabricate the package. The measured microstrip line through the stripline transition with and without vias in the wall region is presented in Fig. 4. The sweep frequency is from 45 MHz to 40 GHz. As shown in the figure, the insertion loss for the package without vias is about 1 dB higher than the one with vias. This is because the vias connect the top and bottom ground plane of the stripline at the wall regions which makes a true stripline. The S21 for the package with vias at frequency below 10 GHz is quite small. A concave region is observed at frequency about 15.5 GHz due to the resonance of the cavity mode. At frequency above 20 GHz, the insertion loss is about 1.5 dB ± 0.5 dB, which is usable for the MMIC applications.



(a)



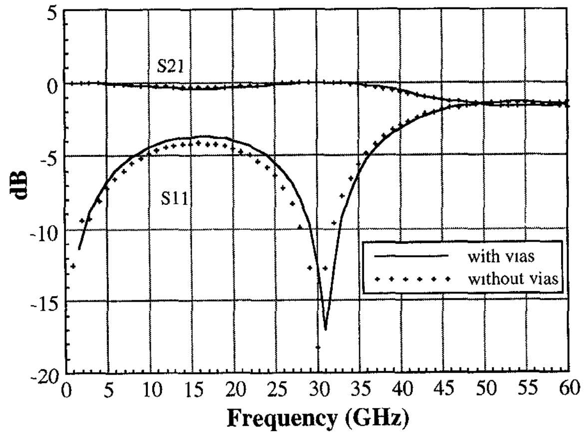
(b)

Fig. 4 The measured S-parameter of hermetic package by using stripline as wall region; (a) without vias, and (b) with vias.

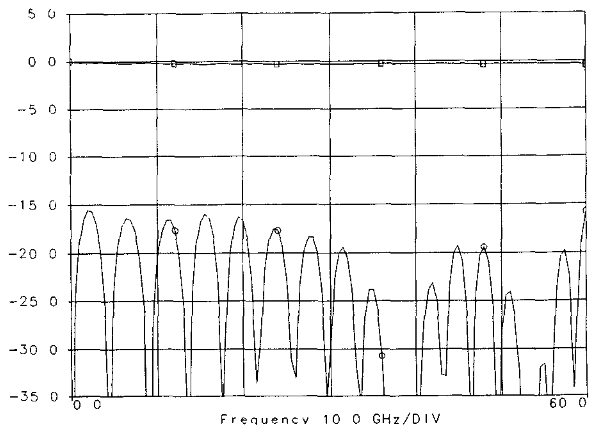
The main loss at higher frequency is due to dispersion. The measured insertion loss for a 50 Ω microstrip line without wall transition is about 0.3 dB/cm at frequency range of 30 GHz to 40 GHz. By subtracting the loss of 50 Ω microstrip line, the loss for each transition wall is about 0.6 dB.

B. Modified CPW as Wall Region

Another type of commonly encountered feed through transition configuration is the CPW structure. The CPW is becoming widely used due to several advantage it offers over the conventional microstrip lines or striplines in the state-of-the-art MMIC packaging [5]. Therefore, it is interesting to compare the performance for both cases in terms of the package points of view.



(a)



(b)

Fig. 5 The EM analysis on Sonnet for the modified CPW of wall region with and without vias; (b) The transition characteristic of the whole package simulated by the HP-EEsof Libra

The modified CPW was designed using EM analysis. In this design, the slot width is chosen as 0.123 mm, while the center conductor width is 0.59 mm. This corresponds to a impedance of 50 Ω. In order to avoid the excitation of the parallel plate waveguide modes, the vias are used to eliminate the unwanted resonances. The EM analysis for a single wall region with and without vias is shown in Fig. 5(a). It is clear that the performance is very similar with and without vias. The data is then put into the EEsof-Libra to construct the whole package which include the microstrip lines and another wall. A 0.5 dB insertion loss is observed over the broad bandwidth.

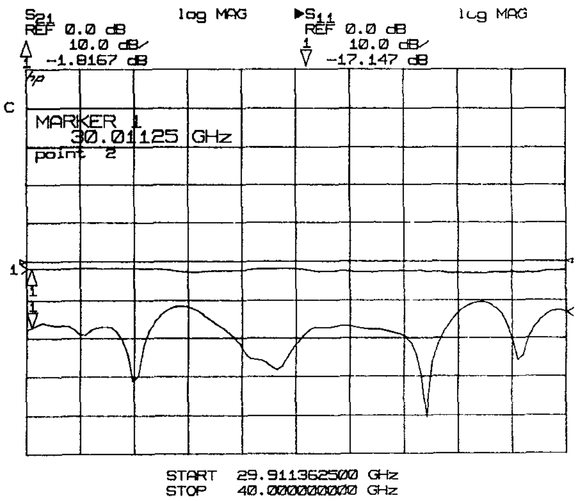


Fig. 6 The measured S-parameter of hermetic package by using modified CPW as wall region.

The measured microstrip line through the modified CPW transition with vias in the wall regions is presented in Fig. 6. The sweep frequency is from 30 GHz to 40 GHz. The vias balance the potential between the top and bottom layer, and play a key role in the performance of this transition. As shown in the figure, the overall insertion loss for the package with vias is 1.8 dB ± 0.3 dB. The main loss at higher frequency is due to the material dispersion. As compared to Fig. 4(b), the measured insertion loss for both stripline transition and modified CPW transition are very similar to each other.

IV. CONCLUSIONS

We have demonstrated two high frequency hermetic packages using LTCC. Both packages are identical except for the wall transition area, in which one package uses a stripline transition and the other a modified CPW transition. Both packages were designed for the 30 to 40 GHz range. Commercially available CAD packages were used to simulate the packages. The results for both types of packages were promising for the designed frequency range. The wall area suffer 0.6 dB of loss per transition. This loss is tolerable due to the advantages of using the multi-layer LTCC technology for the packaging of MMIC multi-chip module [6].

V. REFERENCES

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