SOLDER FREE INTERCONNECTS FOR MIXED SIGNAL (DC/ MICROWAVE) SYSTEMS

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ABSTRACT

A method of achieving high density interconnections is demonstrated through the use of solder free interconnects, between multilayer substrates in which a common technology can be used for both microwave and DC interconnects of large electronic systems.

INTRODUCTION

The ever continuing push towards lower cost, weight and size, electronic system requirements for higher density interconnects and integration become a driving factor in many designs. The goal of this effort was to design, develop and test a microwave interconnect method that would simultaneously meet a number of these parameters, low cost, low loss microwave transmission, high density, and be producible. The design was aimed at insertion in active aperture arrays for military radar [1], [2], but the approach is applicable to any system needing to interconnect large numbers of both RF/microwave and DC/logic signals (mixed signals).

The need for low cost and high density precluded the use of separate coax connectors for microwave and pins or ball grid arrays for DC/logic. A uniform technology that could accommodate both microwave and DC/logic interconnects was needed. The most straight forward interconnect technique is to use a ball grid array interconnect between the two substrates. This approach would be impractical over large areas (as in an active array antenna) for two reasons. First, the vertical tolerance stackup would be too large to support a ball grid array. Secondly, the ability to repair or replace components in the array would be extremely difficult. For these reasons, we pursued a solder free interconnect (SFI) approach, applying the technology already demonstrated on the Commanche program in which thousands of DC and logic interconnects are made using SFIs. The next step was to demonstrate microwave interconnects, as shown in Figure 1, using the same grid as the DC/logic SFI, thus allowing the same SFI to interconnect mixed signal multichip modules (T/R Modules). To achieve small size (i.e. high density) and low cost, the microwave connector was designed to the minimum standard SFI pitch of 50 mils. The microwave interconnect shown in figure 1 connects two ceramic substrates in a coaxial manner.

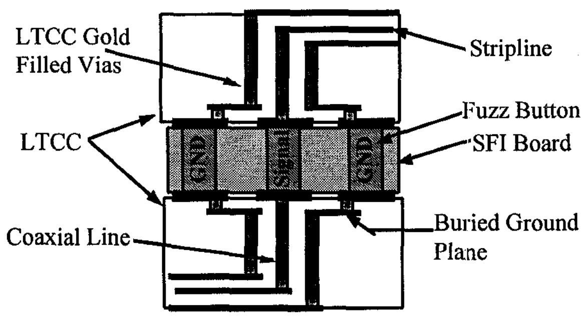

Figure 1 Cross Section of Microwave SFI Coaxial Interconnect.

Figure 2 shows a picture of an SFI board in which both microwave and DC/logic can be interconnected, using the same 50 mil grid spacing for both. The SFI shown in Figure 2 is used in an existing program for power and logic interconnects, but could also be used for

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microwave interconnects based on the design presented in this paper.

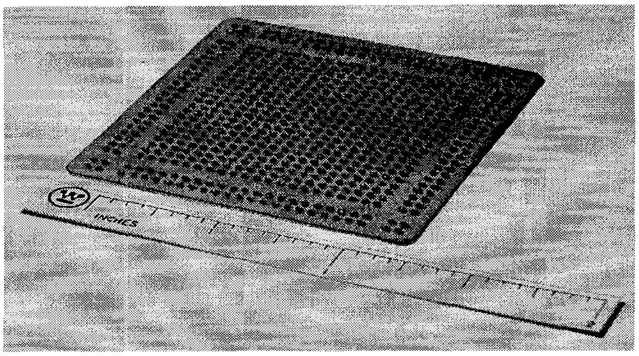

Figure 2 Grid Array of SFIs on 50 mil Pitch for Use with Mixed Signal Systems.

The SFI structure consists of only two parts, the metal contacts (fuzz buttons) manufactured by Cinch and the dielectric support. Figure 3

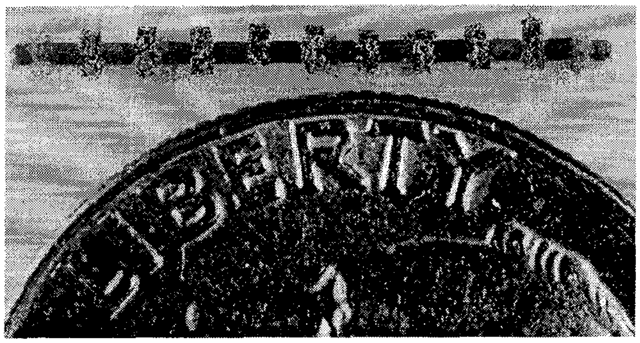

Figure 3 Cross Section of SFI, Including Metal Contacts and Dielectric Board.

shows a cross section of the two components (metal contacts and dielectric board) assembled into an SFI. The metal contact can be viewed as a 'brillo pad' made out of molybdenum, then nickel and gold plated. Using a refractory metal (molybdenum) as the base allows the metal contacts to be temperature cycled without losing their elasticity. The cost per contact is only cents (in quantity). The fabrication of the dielectric board is simply a two sided drilling operation which creates an 'hour glass' in the dielectric board to hold the fuzz button.

DESIGN APPROACH

The SFI development at WEC, demonstrated the SFI approach as a microwave interconnect between two ceramic multichip modules (MCMs), using a standard low cost SFI board previously used for DC and logic interconnects. Figure 4 shows a cross section of a planar array using SFIs to connect the DC/logic substrate with the microwave substrate. Test results will be shown for an interconnect between an SFI and a low temperature cofired ceramic (LTCC) substrate. The interconnect between high temperature cofired ceramic (HTCC) substrates is still under development, although, the approach described here is applicable to SFI interconnects between all types of multilayer substrates. The LTCC/SFI interconnect represents the microwave I/O that could be used for T/R modules. In addition to the microwave connection required of the SFI, one of the primary functions the SFI must perform is to allow for misalignment between the two ceramic MCMs, with minimal degradation in microwave performance.

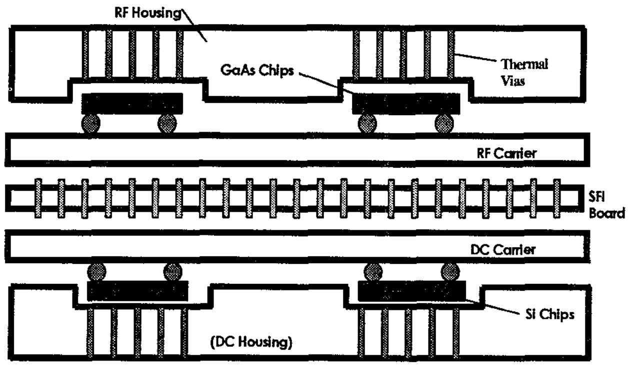

Figure 4 SFI Interconnect for T/R Modules in a Planar Array.

The first step undertaken was to model the SFI/LTCC transition based on the minimum grid array spacing presently available for the SFI which was a 50 mil pitch. The metalization on the top surface of the LTCC consisted of 30 mil diameter contact pads for the SFI, on a 50 mil pitch. The large pads on the LTCC served two functions. First, the SFI itself is a series inductive element of approximately .6 nH per fuzz button, in addition, at the 50 mil grid spacing used, the coaxial nature of the SFI presented an impedance of > 50 Ω (i.e. inductive). The large metal pads create a shunt capacitive effect helping tune out the SFI inductance, thus maintaining good return loss over the microwave bandwidth. Figure 5 shows simulated return loss of the LTCC/SFI interface. As can be seen from Figure 5, the bandwidth of the modeled LTCC/SFI transition clearly supports microwave operation which makes the structure suitable for most airborne active aperture applications.

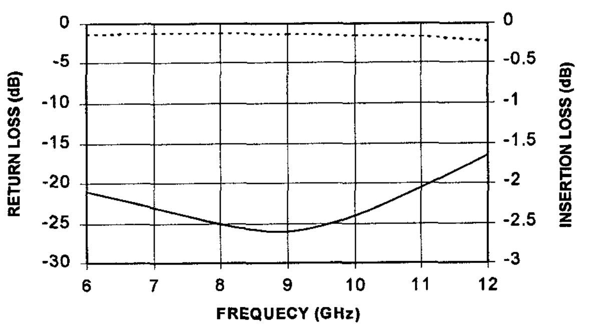

Figure 5 SimulatedInsertion Loss and Return Loss of LTCC/SFI Transition.

MEASURED RESULTS

Measurements involved tests of a number of different structures and configurations. It includes two types of dielectric boards, one 35 mils thick with an εr = 3.0, the other 20 mils thick with an εr = 6.0, the LTCC structure, included a vertical 'micro' coax transition. Contact repeatability tests were performed and measurements taken to determine electrical degradation due to misalignment between the two substrates. All testing was performed using SMA bulkhead connectors (P/N 2052-1215-00) modified to allow for a flush connection to the SFI, except for a small portion of the center pin used to 'key' the center contact of the SFI.

In order to validate the test structure, the connectors were first joined with a single SFI to verify that a low return loss was possible with the test structure. This test structure provided a return loss of better that -20 dB through 12 GHz. Figure 6 shows the configuration of both the validation/calibration structure and the test structure itself. With the test structure validated, the SFI/LTCC transitions could be tested with a high degree of confidence. The preliminary 'calibration' measurement of the two connectors and single SFI was made and stored in the network analyzer as a through calibration, so the SFI/LTCC measurement could subsequently be deembedded. The calibration measurement provided a return loss of better than -20 dB through 12 Ghz for both SFI structures. After the 'through' calibration was performed, an additional SFI and LTCC piece was inserted in the test structure, also shown in Figure 6. Network analyzer measurements of the SFI/LTCC transition using both the 35 mil thick εr = 3.0 SFI board and the 20 mil thick εr = 6.0 SFI board are shown in Figure 7. The transitions provide a well matched (less than -20 dB return loss) interconnect through 11 GHz with an extremely low insertion loss of nominally .05 dB through 11 GHz.

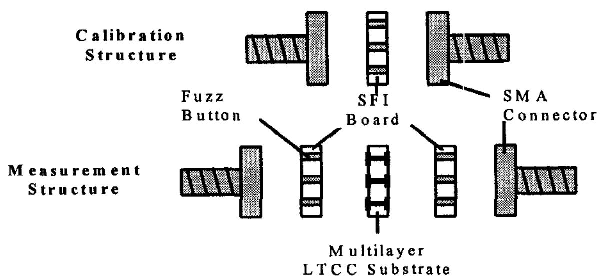

Figure 6 Calibration 'Thru' and Test Structures

In order for the microwave SFI approach to be viable in production, two additional attributes needed to be verified, first the repeatability of the microwave connection, and secondly, the

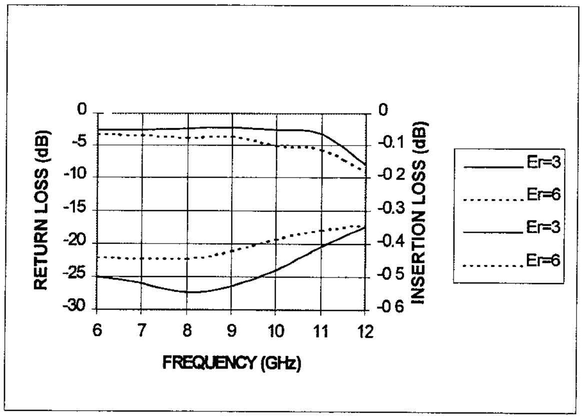

Figure 7 Measured Results of LTCC/SFI Transition.

ability of the microwave connection to withstand variations in alignment without degradation in microwave performance. To test the repeatability of the microwave connection, the test structure was disassembled and reassembled five times, Figure 8 shows all five plots. The data in Figure 8 is for the εr = 3.0 SFI board. A similar test was performed using the 20 mil thick εr = 6.0 SFI material with similar results.

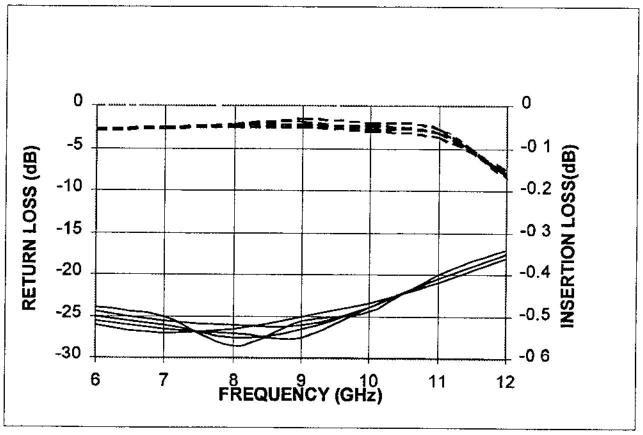

Figure 8 Measured Repeatability of LTCC/SFI Transition after five 'Makes and Breaks'.

To demonstrate the ability of the SFI/LTCC to withstand misalignment, LTCC pieces were cut with offsets, from 0 to 20 mils in 5 mil increments, from center. Each of these LTCC structures were tested in the fashion stated above and plotted. The series of plots is shown in Figure 9. Even at 20 mils offset from center the return loss degraded by less than 3 dB at 12 GHz.

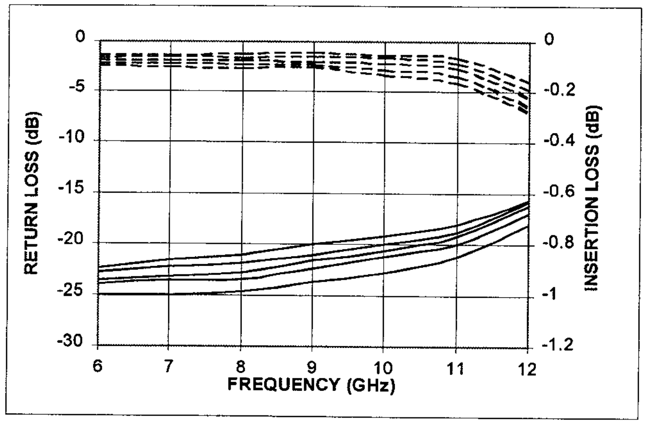

Figure 9 Measured Results of LTCC/SFI Transition, Offset in 5 mil Increments.

CONCLUSION

The ability to used a singular type of I/O for a mixed signal (microwave/RF and DC/logic) interconnect has been demonstrated. The microwave performance of the SFI to LTCC interconnect has been demonstrated, most importantly, it has been demonstrated that the interconnect can withstand large (20 mils) misalignments without significant degradation in microwave performance. The use of this type of solder free interconnect should help reduce cost, weight and increase the density of future phased array radar systems.

ACKNOWLEDGMENTS

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REFERENCES

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