Plastic Microwave Multi-Chip Modules for Wireless Communication Applications

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ABSTRACT

This paper describes a high density, microwave plastic multi-chip module (MCM) with vertical feed throughs providing RF/DC I/Os at the module backside allowing for a low thermal resistance solder attach to a printed circuit board. A return loss of better than -20 dB up to approximately 3.8 GHz was measured for the coplanar vertical interconnect from the plastic module to a printed circuit board. Functional T/R modules operating between 1.60 GHz and 2.0 GHz were also fabricated with this technology.

I. INTRODUCTION

There is a growing need, especially in the wireless community, for lower cost microwave modules with reproducible performance, low thermal resistance, high density, and a low parasitic solder connection to a printed circuit board (PCB). Plastic microwave packaging is one technology which holds the most promise . One packaging approach is the Chip-on-Flex (COF) plastic MCM technology developed by Lockheed Martin / GE [1]. The cross-section for one type of microwave COF module with vertical feed throughs is shown in Fig. 1. The thickness of the microwave modules is typically less than 1.0 mm . The RF/DC I/O's and heat transfer is through the module backside. A ball grid array solder attach of the plastic microwave module backside to a PCB provides a repairable low parasitic and low thermal resistance second level interconnect. Previous works have focused on vertical interconnects for second level assembly of ceramic based MCMs using fuzz buttons [2]. This work is novel in that vertical feedthroughs are used in plastic microwave module for low cost solder assembly onto PCBs.

II. PLASTIC MCM TECHNOLOGY

For the COF plastic MCM technology, active and passive components are die attached onto a polyimide flex film and subsequently encapsulated in plastic. Laser drilled vias are used to contact the bond pads and a multi-layer polyimide interconnect is formed with subsequent layers of patterned metal and polyimide dielectric films. The metalization for the interconnect is Ti / Cu / Ti and the polyimide dielectric used is laminated with an adhesive. The RF signals in the interconnect are transported as microstrip transmission lines on the top interconnect layer with the interconnect ground plane situated in a lower layer. This can be seen in Fig. 1. 50 Ohm impedance matching from the interconnect to the MMIC can be achieved in this technology. The vertical feed throughs transport the RF/DC signals from the interconnect on the top side to the backside of the module facilitating a ball grid array solder attach to a PCB. The RF signals are transported as vertical coplanar 50 Ohm transmission lines in the feed throughs . The vertical feed throughs, procured as a passive component, consist of a rectangular plastic piece with an embedded row of Cu wires . The pitch and sizes of the Cu wires were chosen to provide a 50 Ohm coplanar vertical transmission line. The RF signal from the plastic module therefore traverses a path from the microstrip interconnect to a coplanar transition to the coplanar vertical feed throughs to the backside of the module and finally to a PCB. A number of discontinuities exist in the path and will their combined behavior determine the return loss of the module connection to a PCB. Fig. 2 depicts a top view of a plastic module with a coplanar launch and the above mentioned RF transitions to the vertical feed throughs. There are two grounds which exist for this plastic MCM. From Fig. 1, the first is the RF ground plane for the microstrip interconnect and the second is the RF/DC ground at the backside of the module. Both of these grounds are connected through the MMIC ground vias and

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vias in the interconnect. The inductance of this path is low and therefore both planes should be at the same potential. Concerning heat transfer, all the microstrip MMICs are mounted onto metal shims and these shims are exposed at the backside of the module, providing a good backside ground and a low thermal resistance path from the MMIC to the PCB through the solder balls.

III. PLASTIC T/R MODULE

In order to demonstrate this plastic packaging technology for wireless applications, a T/R module consisting of a two stage power amplifier MMIC, a single stage dual gate low noise amplifier MMIC, and a T/R switch MMIC was fabricated. Fig. 3 shows this plastic module. The plastic T/R module size is 25 mm x 25 mm x 0.76 mm which includes a number of calibration structures. The size of the module could be reduced to 18 mm x 13 mm x 0.76 mm. The microstrip MMICs were fabricated at Lockheed Sanders with a 0.5 um gate MESFET technology on a 125 um thick GaAs substrate. The T/R modules were operated from 1.60 GHz to 2.0 GHz. Four modules were measured and Table I shows a comparison of the packaged results versus the average specifications for the unpackaged MMICs. From Table I, we observe a degradation in the performance for the packaged devices . For the T/R switch + LNA path, the gain versus frequency data is shifted lower by about 0.2 GHz and the peak gain is reduced by approximately 1dB. Interestingly, the noise figure for this path is at or within the specifications. This drop off is possibly due to the polyimide coating/interconnect above the MMICs. The polymide coating is approximately 12 um thick. Above this polyimide coating is approximately 70 um of polyimide interconnect. Both layers have a dielectric constant ranging between 3.00 and 3.30. This polyimide overlayer can produce de-tuning of the matching section, which is reactive, and increase the Cgs, Cgd, and Cds of the MESFET resulting in reduced gain and roll off. The effect of polymer overlayers on altering MMIC performance has also been studied extensively by M/A-COM [3]. They observed that Benzocyclcobutene (BCB) coatings on MMICs de-tuned and in some cases degraded MMIC performance [3]. Of course, this effect is strongly dependent on the matching structures, bandwidth, number of stages, and type of devices used in the MMIC. For the HPA + T/R switch path, the power at the one dB compression, P1dB, was within 2 dBm of expected results (23 dBm) but the gain was lower than expected. Further investigation is needed to understand the results for this path. Nevertheless, polyimide overlayers on MMICs provide a number of advantages for manufacturability of plastic packages of microwave systems. Some of these advantages are: (1) mechanical protection, especially of air bridges on MMICs and (2) enivronmental protection. As an example of plastic package reliablity , the GE/LM COF plastic packages have withstood 950 thermal cycles from -40C to 125C and 1000 hours at 85% relative humidity at 85C. For insertion into wireless applications which are used in widely varying environments, reliablity of plastic packaging will be of paramount importance.

IV. VERTICAL FEED THROUGHS

The RF characteristics of the vertical feed throughs was separately evaluated by solder attaching a plastic module (41 mm x 43 mm x 0.76 mm) with feed throughs to a PCB with coplanar lines terminated to 50 Ohms. This is shown in Fig. 4. The plastic module has one row of vertical feed throughs on each side. Each row consisted of 40 vertical feed throughs with a feed throughs diameter of 10 mils and a pitch of 22.5 mils. Larger diameter feed throughs with larger pitches can be used for lower I/O plastic modules. Only one row of feed throughs was used as coplanar vertical transmission lines. A coplanar launch with a short microstrip transition followed by a coplanar transition to the vertical feed throughs was fabricated on the module interconnect. This can be seen in Fig. 2. The return loss of the RF path from the launch on the plastic module through the vertical feed throughs to the 50 Ohm terminated coplanar lines on the PCB was measured. A return loss of better than -20 dB can be observed in Fig. 5 up to approximately 3.8 GHz. The observed frequency performance is a combination of a number of transitions on the RF path and the vertical feed throughs. Further work is needed to de-embed the performance of the transitions from the vertical feed through to optimize this microwave second level interconnect for higher frequency operation. Nevertheless, this data indicates a very low parasitic microwave second level interconnect from a plastic module to a PCB for applications below 3.8 GHz.

For next generation wireless systems, a number of these plastic modules (single and/or multi-chip) can be solder attached on to a PCB to

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form a very high density, and potentially low cost microwave sub-system. The number of single and multi-chip plastic modules can be chosen on the basis of die yield to optimize the yield of the overall microwave sub-system.

V. SUMMARY

A plastic MCM technology was used to fabricate functional T/R modules for wireless applications operating from 1.6 GHz to 2.0 GHz. Some de-tuing and degradation of the packaged MMICs was observed possibly due to the effect of the polymer over layer. A second level interconnect was developed for this plastic MCM consisting of coplanar vertical feed throughs providing RF/DC I/O's to the module backside allowing for a low thermal resistance solder attach to a PCB. A return loss of better than -20dB was measured up to approximately 3.8 GHz for this second level interconnect.

ACKNOWLDEGEMENTS

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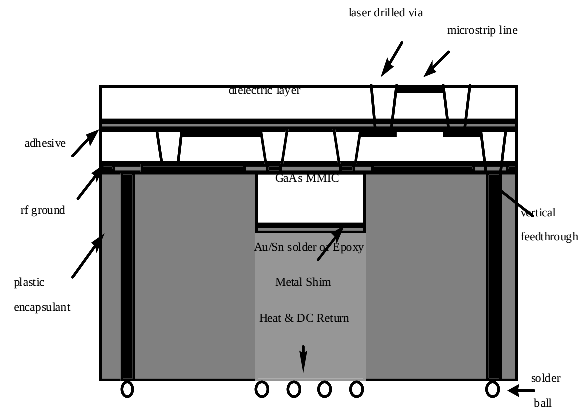

Fig. 1. Cross section of a "Chips on Flex" (COF) plastic module with vertical feed throughs

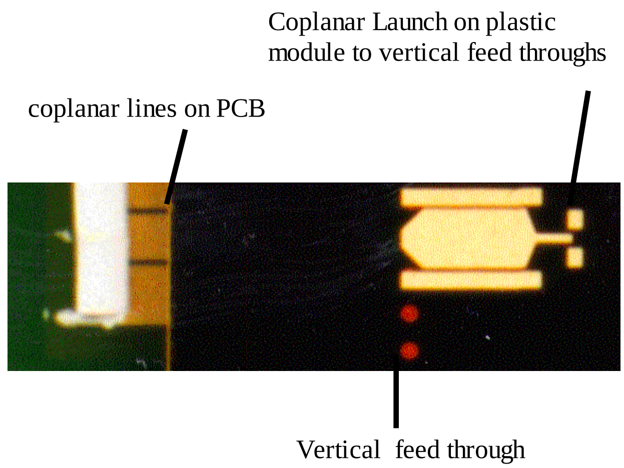

Fig. 2. RF transition from plastic module to PCB. The plastic module is solder attached to the PCB. Two 100 Ohm resistors are attached as terminations on the end of the coplanar line on the PCB.

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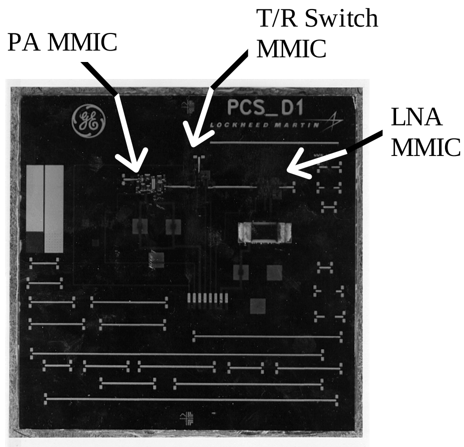

Fig. 3. Plastic T/R module including calibration structures in a 25 mm x 25 mm x 0.76 mm size operating from 1.8 GHz to 2.0 GHz .

Table. I. Comparison of the plastic packaged T/R module with the specifications for the unpackaged MMICs

Comp.	Frequency (Ghz)	Gain (dB) Measured	Gain (dB) Spec.	NF (dB) Measured	NF (dB) Spec.
T/R Switch + LNA	1.6	14.6	13	3.7	-
T/R Switch +LNA	1.7	15.4	14.5	3.4	-
T/R Switch + LNA	1.8	14.9	15.5	3.4	3.2
T/R Switch + LNA	1.9	13.3	15.5	3.1	3.2
T/R Switch + LNA	2.0	11.1	14.5	3.0	3.2

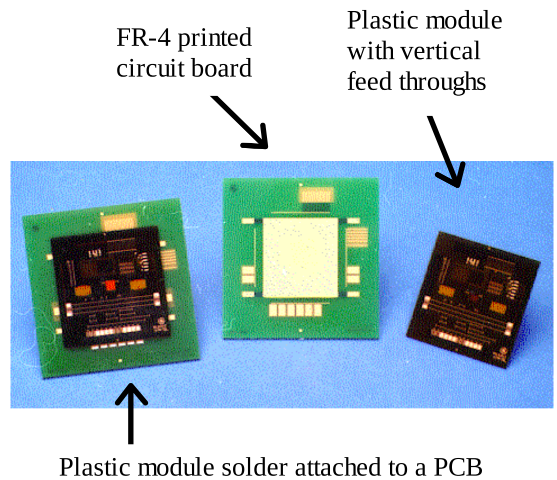

Fig. 4. RF characteristics of the vertical feed throughs was evaluated by solder attaching a plastic module (41 mm x 43 mm x 0.76 mm) with feed throughs to a PCB with coplanar lines terminated to 50 Ohms.

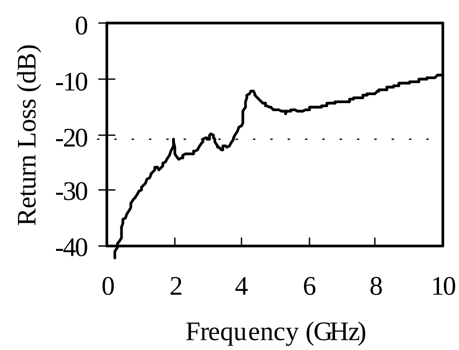

Fig. 5. Return loss versus frequency for plastic module solder attached to 50 Ohm terminated coplanar lines on a PCB as seen in Fig. 4.