PACKAGING AND INTERCONNECT FOR RF AND MICROWAVE

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Abstract: The paper will review different packaging and interconnect issues in the telecom market where RF properties dominate. A short review of single chip packages for different frequency ranges will be followed by a deeper view into multichip modules of different constructions. Last the growing importance of passives and the opportunities to integrate them will be discussed. The view is from a system house that needs to source or subcontract all components and most assemblies.

Tehnologije montaže in povezav za potrebe RF in mikrovalovnih vezij

Ključne besede: montaža, povezave, ohišje z eno tabletko, moduli z večimi tabletkami, radijske frekvence, telekomunikacije

Izvleček: V prispevku obravnavamo različne načine zapiranja in povezav izdelkov za telekomunikacijski trg, kjer prevladujejo RF lastnosti komponent. Kratek pregled ohišij z eno tabletko za različna frekvenčna območja nadaljujemo z globljo analizo modulov z več tabletkami z različnimi konstrukcijami. Nazadnje poudarimo naraščajočo pomembnost pasivnih komponent in obravnavamo možnosti za njihovo integracijo. Opišemo stališče sistemske hiše, ki mora bodisi kupiti ali dati v izdelavo vse komponente in večino sistemov.

1. Introduction

For RF chips, the electrical performance is dominating package construction and assessment work. The aim is to avoid loosing signal strength, avoid electromagnetic interference and still keep the chip cool enough during all use environments. Of course the solutions need to be easy to manufacture, cheap and reliable.

For Micro- and Millimetre- wave chips many semiconductor manufacturers are only now starting to consider delivery in single chip packages and performance is generally specified on bare chip level. Reduced bond-wire length packages are now developed and so are signal compensation elements integrated in package and/or on chip.

Multichip Modules have continuously had a stronghold in RF and High-speed packaging but with the fast growing volumes of RF for Telecom the price pressure is multiplied and very different solutions are needed. Work is ongoing simultaneously on substrate technologies, chip attach and wiring, reliability without hermeticity and last but not least MCM to board second level interconnect reliability and performance.

With the higher integration rate on chips follows a larger number of accompanying passive elements. In RF and analog functions passives dominate. In spite of low cost of passive components their logistics and assembly add to manufacturing cost. As most solder joints in a traditional assembly are for discrete passives their theoretical impact on reliability is big. Both high-speed performance, reliability and substrate space can be greatly improved with integrating the passives instead of using discretes. LTCC has been analysed as a solution for RF MCM-C with integrated passives.

2. MCMs in Telecommunication

In infrastructure telecom equipment performance and cost are biggest development drivers but simultaneously small size comes as a bonus in new packaging and interconnect (P&I) technologies, which also typically has a positive impact on performance and cost. Smaller capacitance and inductance in interconnects and shorter distances to travel all improve signal integrity and minimizes losses.

Main performance limitations have so far come from the chips but as chip design mature and chip size and complexity is approaching a upper limit and as at the same time frequency goes up the need for improvements is coming more focused on the packaging and interconnect technologies.

In Micro- and mm-wave applications, 10 - 60 GHz bare die has been the only format available due to performance losses in single chip packages. The chips have so far been assembled on multiple small special boards layed down in very expensive machined enclosures and have kept this frequency area limited to few and expensive application. Multilayer ceramics has enabled designers to avoid metal enclosures. Limiting assemblies when possible to planar constructions and making these MCMs surface mountable have together limited cost by 2 to 3 orders of magnitude, opening wide avenues of new applications.

3. Passive integration

As complexity is growing so are the number of passive elements. As passives are much bigger than transistors their P&I is becoming more important. Multilayer ceramics and thin film are two preferred methods for this integration. RF and mm-wave functions can be cost efficiently realised in integrated passive elements reducing the need for semiconductor elements. In these high frequency applications multilayer ceramics is the most preferred solution, especially the high conductivity in noble conductors in LTCC in combination with arising offerings of mixed dielectric constants are promising. Thick and thin film resistors complete the technology palette.

By integrating passive elements in a substrate and attaching active chips on top, Multichip modules get an increased significance and competitive edge. Cost efficiency is achieved when known good functional building blocks are the result.

4. RF and Microwave elements and features

Many microwave functions such as filters, hybrids, couplers and baluns can simply be realised with metal strips on one or more dielectric layer, perhaps including resistors but totally without semiconductor components.

There are straightforward design and simulation packages for generating these elements but there are two problems included. On one hand RF and millimetre wave elements always have an area of interaction around them. This give rise to unwanted interference with neighbour elements and also changes in functionality when materials like overcoat or underfill are added. These are much more difficult to forecast and manage in 3D geometries. The other difficulty is the impact of geometrical and material property variances and tolerances and their impact on functionality and functional tolerances. This is a much bigger problem if the supply chain is long and the end-product designer has no direct contact with the substrate manufacturer sourcing the MCM manufacturer.

As applications for millimetre wave arise there is a total lack of substrate suppliers offering fully characterized LTCC substrates and design libraries for these. The only alternative is to make an estimation of performance and run a number of prototype rounds. Can shared test circuit panels be used the same way as multi purpose wafers for semiconductor development? At least we can design test panels with same elements but a variance of dimensions to test out best performance as function of dimensions.

It is thus not very easy to embed these RF elements in the substrate but if so done the top surface can be reserved for other functions demanding active chips.

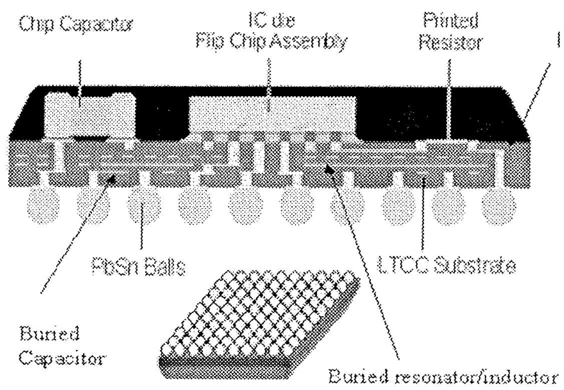

Fig. 1 A schematic picture of a MCM-C for RF applications

5. Subcontracting RF MCM-C

Many modern telecom manufacturer is not at all vertically integrated but has to purchase or subcontract all components and boards. Many semiconductor components are easy to buy off the shelf but most MCMs are custom designed. RF and mm-wave modules are very difficult to design and product management is possible only if a close working collaboration is established between supplier and end product manufacturer. In the relationship also technology responsibility need to be shared down the supply chain, the end product manufacturer can take responsibility only for developing the market and his product for it. What he needs is fully functional SMD MCMs to be applied as supercomponents in his products.

In few last years the LTCC technology has been developed a lot providing cost efficient supply. In the western world these manufacturers use mainly commercial materials that are very well characterized and known. As soon as more special materials are brought into the market place an external designer is on really deep waters as all aspects are not yet documented and second sourcing may be impossible to get.

In Asia the approach is the opposite: LTCC manufacturers have their own proprietary materials that they know them selves but may be difficult to understand totally in a distant country where end product is developed. Second sourcing can be achieved only by internal second sourcing with geographycally separated factories.

In spite of all know how and design help the RF and mm-wave elements and especially the whole module is so hard to design with today's tools and material knowhow that the rule is to have at least three design rounds before satisfactory results are achieved. Running these trial rounds take time if the physical and organisational distance between designer and substrate manufacturer is long. Partnership is here needed for smooth collaboration. Fortunately tooling and running multilayer ceramic rounds is nothing compared with semiconductor rounds, takes weeks instead of months. But in many cases both are needed: Some custom chips are developed with few months turn around and when they finally arrive the manufacturer would like to have ready proved ceramic substrates. If these then are not fully compatible, the hope is that corrective actions can be implemented on ceramics only thus allowing next round to take only weeks.

In fact there is normally a third level of interconnect, the PWB motherboard, where performance still need to be excellent. Not to speak about the 3D integration of boards, external components and perhaps wave guides.

6. Environmental issues

P&I dominate the environmental impact of electronics products . Higher integration level normally diminishes the impact. This is especially true when Pb containing solder joints of discrete passive elements are replaced by the in situe interconnects in the ceramic substrate. In the case of semiconductor components, Pb solder joints may be replaced with wirebonds or Pb free, miniaturised FlipChip joints.

Some high K dielectrics, either in discrete components or integrated in a multilayer ceramic contain Pb. Some manufacturers have a total Pb-free policy and have been able to realise all their products with such Pb free ceramics.

The other emphasized environmental threat comes from the fire retardant halogens. Here all ceramic solutions like MCM-C have an inherent fire retardance due to the nature of the ceramics.

7. Conclusion

Passive integration is the best in multilayer ceramics based MCMs.

Need for passive integration give new speed to MCM utilisation.

Multilayer ceramics material and processes developing fast, knowledge of their microwave properties and tolerances in production are lacking.

Design tools are improving but integrated solutions and tools are only slowly appearing.

Prototyping turnarounds are typically short, few weeks in teory, actual time is depending on partnership relation.

Pb-free solutions are existing.

MCM-Cs are inherently safe without fire retardants.

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