

Solderless connection for space application : from DC to microwave frequency and reliability results

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I. INTRODUCTION

DC or RF/microwave connection without soldering is possible through solderless connectors which operate with pressure contacts. This is more and more under consideration because of the easy mounting, easy de-mating ability of the connection and the capability to design very integrated solutions as it is required for instance for satellite sub-assemblies. This paper presents an overview of the activities done in Thales Alenia Space – France (TAS-F) in this area, beginning by mechanical and electrical design (for both DC and microwave applications) and then presenting reliability evaluation of the connection applied to space environmental conditions.

II. EXISTING CONCEPTS OF SOLDERLESS CONNECTIONS

The solderless connections ([1 -10]) can be divided in four main families (name of the companies who developed the concept) :

- bent metal family : this consists of relatively fine pieces of metal formed into a curvilinear shape in order to provide a cantilever effect that grants them compliance. These contacts are normally then inserted - molded or stuffed into a nonconductive carrier. Some examples : InterCon Systems cLGA[®] system (Amphenol), Elasticon connector (IBM),
- conductive elastomer family : this technology is based on the use of a composite of conductive metal partially embedded in a matrix of elastomer. The compliance of the elastomer is used to develop the necessary compressive force across each contact and to provide the range of motion required to accommodate the nonplanar aspects of the components being assembled. Some examples : MPI (TYCO, SHIN ETSU), PARIPOSER (PARICON), Zebra[®] solutions (FUJIPOLY, SHIN ETSU),
- pogo pin family : it consists of two small tubular sections joined together with an internal spring and with a contactor (or plunger) formed on the end of the smaller tube. Some examples : RFF contacts (HYPERTAC), spring contacts (SYNERGETIX),
- fuzz button family : the contact is a small column of kinked molybdenum wire, typically contained in a cylindrically shaped housing. The wire itself is much smaller in diameter than the column and it is formed in a pseudorandom pattern so that the contact resembles a miniature steel wool pad. Because of the shape and the

hardness of the wire, the column or fuzz button can be compressed elastically over a relatively large axial displacement, and the force/deflection characteristics of the button can be reasonably controlled. Some examples : CIN::APSE[®] (CINCH), fuzz button technology (TECKNIT).

III. DESCRIPTION OF THE CIN::APSE[®] TECHNOLOGY

TAS-F has been involved since a long time in solderless connector for both DC and microwave applications through the CIN::APSE[®] system. This technology offers exceptional mechanical and electrical performances. Custom made to meet specific needs, CIN::APSE[®] utilizes a multipoint contact that can be as small as 0.8mm in height, comes in 1mm centers, and can handle signal frequencies up to 20 GHz. The basic button contact configuration consists of a single button installed in a patented “hourglass” design. The hourglass cavity retains the CIN::APSE[®] contact securely. It allows also the button to float (typically 75µm protrudes from the top and the bottom of the insulator) and, therefore, stay in contact even under extreme thermal amplitude mismatch between mated substrates (cf. Figure 1).

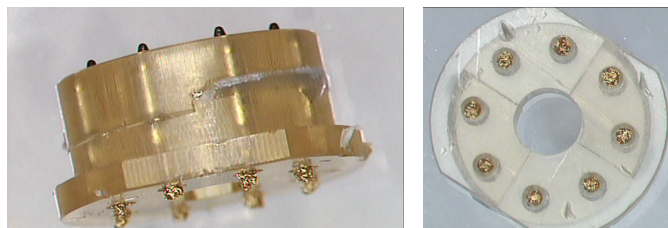


Figure 1 : Example of CIN::APSE connector designed by Thales Alenia Space - France.

The insulator material is typically ULTEM[®] (with mechanical machining of the dielectric material) for small quantity and LCP (liquid crystal polymer) for large quantity (with a molding operation for the manufacturing of the dielectric). Unlike other z-axis technologies, such as elastomeric connectors, CIN::APSE[®] buttons have a high modulus of elasticity which means they can be compressed thousands of times without taking a compression set. CIN::APSE[®] buttons are also very lightweight and thermally stable which makes them extremely resistant to intermittent signals caused by shock/vibration or thermal cycling.

TAS-F used this system in two areas :

- as a 3D microwave interconnection between 2 printed circuit boards showing excellent features (0.15dB loss at 10GHz and 0.3dB at 20GHz),
- as a very integrated DC connector for the biasing of active devices in the frame of a Focal Array Fed Reflector antenna (with reliability tests according to space requirement).

IV. 3D MICROWAVE SOLDERLESS DESIGN

The fuzz button solution has been investigated for the vertical interconnection between two multilayer printed circuit boards separated by a 4.2mm thick Aluminium structure. The configuration of the connector is button/plunger/button for a total length of 4.2mm and a diameter of 2.2mm (diameter of the button is 0.5mm). A metallic plunger is required to get the total thickness of the connector.



Figure 2 : Connector based on a button/plunger/button configuration.

Each multilayer board is based on the RT6002[®] laminates from ROGERS Corporation, a Teflon-based material well-suited for microwave design. The board is the assembly of 2 substrates (0.25mm and 0.5mm thickness) through a dedicated bond-ply system. Electrical simulations have been performed on HFSS (a 3D EM software by ANSOFT) to design and optimise a coaxial type interconnection up to 18GHz (cf. Figure 6). A test-vehicle constituted of 2 vertical interconnections (in order to be in the same test-plan) has been manufactured and assembled (cf. Figure 3).

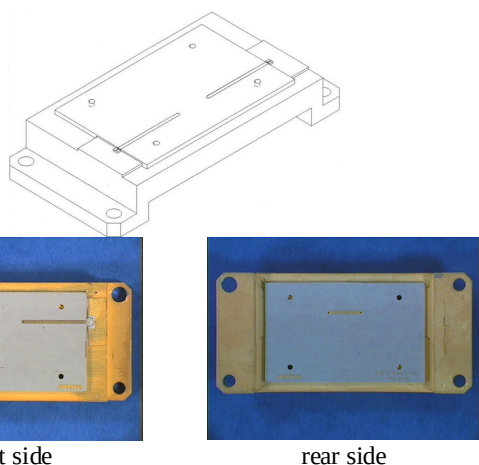


Figure 3 : Test vehicle of the button/plunger/button configuration.

Due to the soft nature of this substrate, special care is needed in the optimization of contact pressure vs. contact resistance. The return loss of this double interconnection vehicle is below -15dB up to 18GHz and the insertion loss is 1dB maximum. In comparison with a straight 50 Ohms line in the upper board, a

single solderless interconnection can be assessed at 0.1dB at 5GHz and 0.25dB at 15GHz (see Figure 7).

V. INTEGRATED SOLUTION FOR BIASING SYSTEM

A very compact low noise amplification (LNA) section for a focal array fed reflector antenna has been proposed by TAS -F [11]. The biasing of the active devices was solved thanks to the design of a very integrated solderless connector based on a CIN::APSE[®] approach. Finally, this solution allowed the connection of a flex/polyimide board to a RO4003[™] double sided board (a non PTFE woven thermoset resin material from ROGERS Corporation) populated with the active components (GaAs MMICs, silicon transistors). For this application, the contact configuration elected is a plunger-button assembly: the contact construction consists of 508µm randomly wound gold plated molybdenum wire formed into a cylindrical shape (button) and an additional gold-plated brass element (plunger) to achieve the required height, both are installed into a customized ULTEM[®] plastic insulator (cf. Figure 1 and Figure 4). The total thickness of the connector is 3.5mm and the diameter is 8mm.



Figure 4 : Button/plunger configuration.

As the LNA module is for a space application, a reliability test-plan has been proposed to evaluate the reliability of this system according to severe environmental constraints. The reliability tests are divided in three test files :

- mechanical tests : sine vibrations + random vibrations + 500 thermal cycles in the [-55°C, +125°C] temperature range (4 samples)
- life-test for 1000 hours at 125° C (2 samples)
- humidity test for 6 days at 60°C/95%HR (2 samples)

The nature of board plating is a key parameter to achieve a very reliable contact. To evaluate this aspect, different standard solutions have been investigated :

- thick electrolytic pure Gold (3µm +/-1µm) over Nickel plating,
- thick electrolytic pure Gold/Cobalt (3µm +/-1µm, also known as "hard gold") over Nickel plating,
- ENIG (electroless Nickel immersion Gold) plating with 0.05-0.12µm gold,
- standard fused SnPb (8 -12µm thick).

Prior to these tests, in order reproduce a worst case scenario of mate and de-mate cycles during assembly integration and test, the assembly/disassembly procedure was done five times to each connector sample (with visual inspection and electrical test after this procedure).

For both thick gold solutions, all the reliability tests were successful with the following results :

- the isolation resistance is better than 25GOhms,
- the contact resistance evolution is better than 2% after the mechanical test, 1.5% after the life -test and 3.7% after the humidity test,
- we can also notice no electrical breakdown with a very precise monitoring of the DC continuity after 10 thermal cycles in the $[-55^{\circ}\text{C}, +125^{\circ}\text{C}]$ temperature range (slope of $2^{\circ}\text{C}/\text{mn}$).

For the ENIG plating, a storage at 125°C for 1000 hours reveals a strong variation of the contact resistance. After visual inspection, we can note some modifications on the plating appearance (cf. Figure 8). An EDX analysis done on the evaluation sample presents Gold, Ni but also Copper and Oxygen elements (cf. Figure 5). This probably is due to the Cu diffusion to the surface, through the NiAu finish, and to the following oxidation that could explain the high measurement increase for the electrical resistivity with this plating.

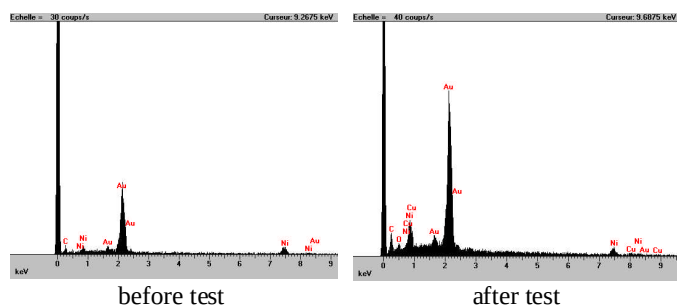


Figure 5 : EDX analysis before and after high temperature storage.

For the fused SnPb solution, visual inspection during life test and thermal cycles reveal that both button and plunger pads are strongly impacted with a flowing of the SnPb solder. This point can be explained by the deformation of the SnPb solder under the combination of the pressure applied, by the ULTEM body of the connector, and a high temperature (visco-plasticity effect). This modification could lead to an irreversible defect (short circuit). At lower temperature conditions (typically below 80°C), the problem would probably not occur.

VI. CONCLUSION

Connection without brazing is more and more under consideration because of the easy rework ability of the connection and the capability of new design of very compact sub-assemblies. TAS-F has been involved in this frame for many years. Over the very large existing technical propositions, the CIN::APSE system has been selected as a very efficient solution for the design of both DC and microwave interconnections. To evaluate the microwave features of this system, a test-vehicle has been manufactured and assembled. The connector is based on a 4.2mm length connector, designed in a coaxial-like solution. The electrical characterization showed 0.1dB and 0.25dB insertion losses respectively at 5 and 15GHz and a return loss better than -15dB over the full frequency band. For the need of a very compact antenna front-end, a CIN::APSE connector was designed in a plunger/button configuration to allow the biasing (through a flex/rigid

polyimide board) of the active devices attached on a double sided board. This solution was evaluated through an intensive reliability test-plan in agreement with environmental space constraints. As a key parameter, 4 different plating solutions on both boards were evaluated in parallel : thick electrolytic pure gold, thick "hard gold", ENIG and standard fused SnPb. These two last options revealed some defects during the tests, respectively with a visco-plastic effect (that can lead to a definitive short circuit) and some oxidation of the surface (that tends to increase the resistivity of the connection). On the other hand, both thick and hard gold solutions presented acceptable electrical deviation and no modification of the visual aspect during all the reliability tests. These two gold based systems can then be defined as preferential plating solutions for a CIN::APSE connection between two printed circuit board substrates.

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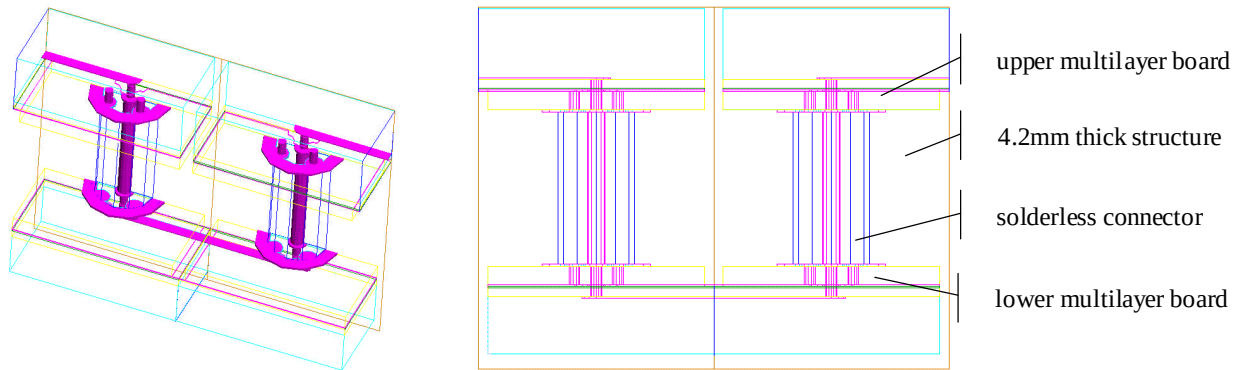


Figure 6 : Design of the 3D solderless interconnection between 2 multilayer printed circuit boards .

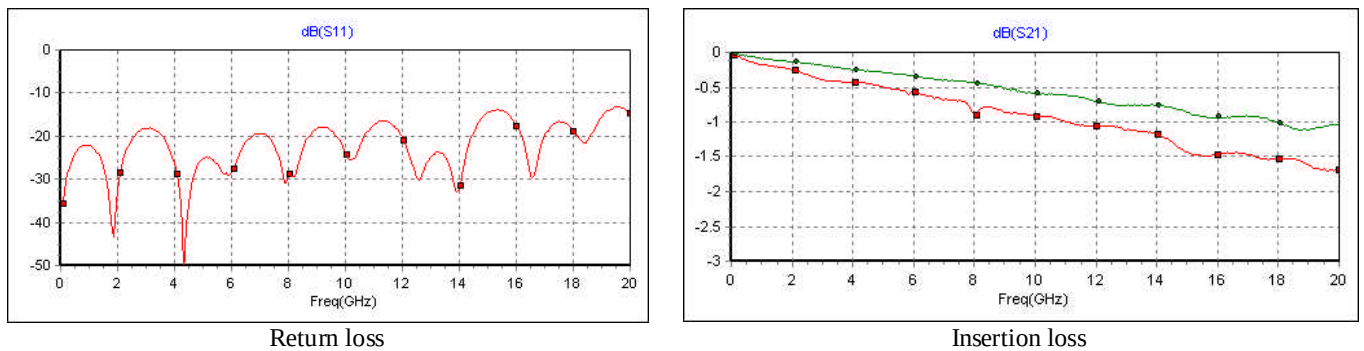
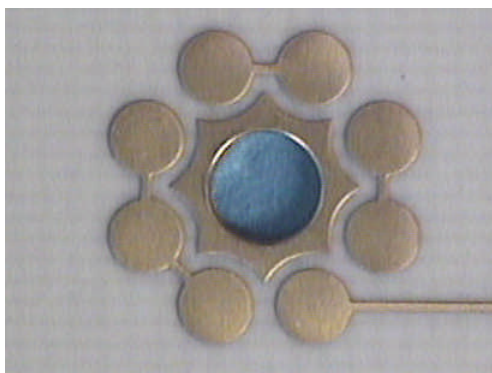
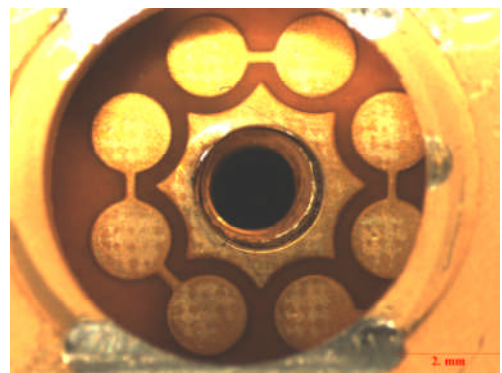


Figure 7 : Measurement of a double 3D solderless interconnection (red square) and comparison with a 50 Ohms straight line (green dot) .

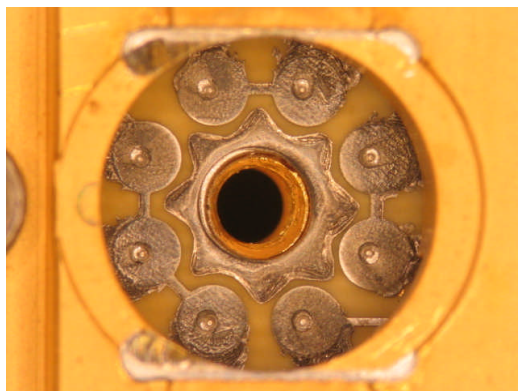


Before test



After test

Figure 8 : Visual inspection of the ENIG plating before and after high temperature storage at 125°C .



Pads of the board at RO4003[®] level ("plunger" side)



Pads of the board at flex/polyimide level ("button" side)

Figure 9 : Visco-plastic effect on the SnPb plating after thermal cycle and life test at 125°C .