Innovative PCB-integrated cooling system for active arrays antennas

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***Abstract*— This contribution the measurement results of an active, liquid cooling system embedded in a RF PCB, for efficient thermal dissipation of the heat produced by active components in an antenna array.**

***Index Terms*—3D printing, embedded cooling, additive manufacturing**

I. INTRODUCTION

The density of integration of active components in printed circuit boards (PCB) poses increasingly problems related with thermal dissipation. This heat produced by the active components needs to be dissipated from the circuits, to avoid damages. In ACASIAS, two different approaches are compared. The first consists in integrating a copper core in the PCB. The second involves embedding a 3D-printed active cooling device directly into the PCB. This printed structure can be custom tailored to the geometry and position of the active components.

II. PCB WITH INTEGRATED ACTIVE COOLER

A nickel-based cooler is manufactured using a Selective Laser Melting (SLM) process. With this process it is possible to build high resolution, completely closed structures, which would be impossible using other manufacturing processes [1] – [3]. This cooler can be integrated in a standard RF- multilayer PCB, as shown in Fig. 1. In the case of ACASIAS, the cooler was embedded in FR4 material and integrated into a multilayer RF-PCB structure on Panasonic's Megtron 6. The cooler has to be robust enough to survive a standard PCB manufacturing process with multiple pressing cycles. Vertical transitions with galvanic connection through the cooler can be implemented, which facilitates the routing of DC and RF signals.

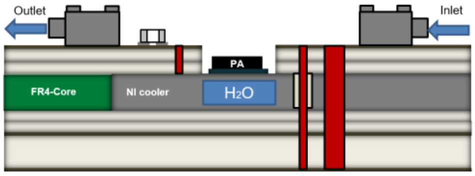

Fig. 1. Multilayer PCB with 800µm-thick embedded 3D-SLM-printed Ni-cooler

A cooling liquid (e.g. deionised water) can then be pumped in the cooler to transfers the heat from the critical points of RF-circuits to a radiator outside of the antenna. By designing the cooler at the same time as the layout of the PCB, it is possible to place it directly under the devices that are generating the heat, as shown in Fig. 2. This solution allows really high power dissipation (up to 1 kW).

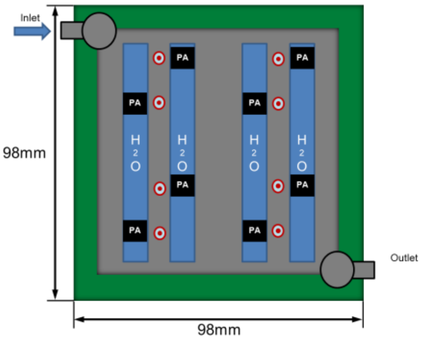

Fig. 2. Topology of the active ACASIAS PCB with integrated coolers.

III. THERMAL PROTOTYPE

A breadboard with a customised Ni-cooler was manufactured to evaluate thermal dissipation performance of the embedded cooler. Fig. 3 shows a schematic view of the board. The power amplifiers on the board were emulated using 64 thin film SiO2 resistors, dimensioned to dissipate the same heat as the active components to be used in the ACASIAS transmit-tiles. The temperature variation on the surface of the board is registered using temperature-dependent resistors close to the heat-generators. Additionally, a PTC100 temperature sensor placed by the outlet of the cooler is used as a reference. The final assembly is shown in Fig. 4.

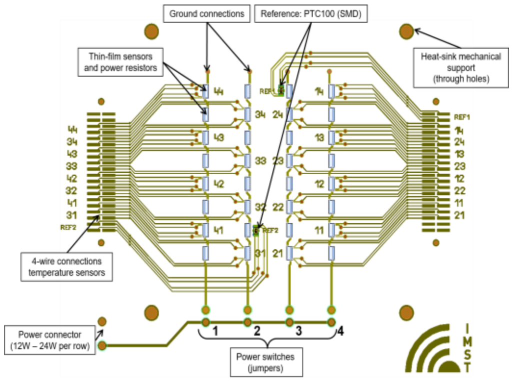

Fig. 3. Layout of the thermal test boards

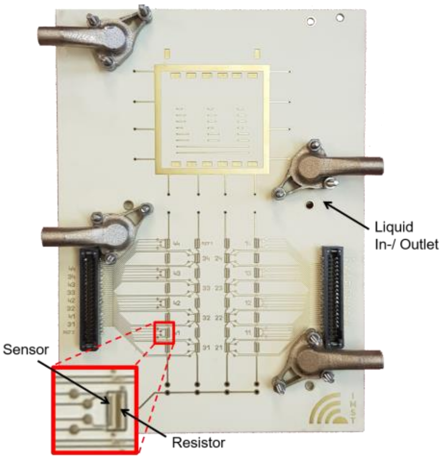

Fig. 4. Thermal test board with integrated liquid cooling

IV. MEASUREMENT RESULTS

The thermal demonstrator was measured in a temperature-controlled environment, using the setup presented in Fig. 5. In addition to the sensors on the board, the temperature on the surface of PCB was monitored with a thermal imaging camera. Fig. 5 also shows how the surface temperature can reach high valued after only a few seconds, if no cooling is used.

Fig. 5. Measurement setup for the thermal demonstrator bords (left) and Temperature on the surface of the PCB (right).

Fig. 6 displays the evolution of the temperature detected by the different sensors integrated in the board (T1 – T6) as a function of time (horizontal axis) for a total dissipated power of 97 W. The differential pressure of the cooling liquid was varied between 0.4 and 2.4 bar (red dashed line, delta p). The blue dashed line (delta_T) shows the temperature difference between the inlet and outlet (i.e. the temperature increase of the cooling medium).

The results show that these embedded coolers have a huge potential for heat management, far beyond the performance achieved with conventional solutions such as embedded copper cores. The steady state is quickly attained, so that the working point of the RF active components can be circuits can be controlled

V. CONCLUSIONS

The measurements performed on the ACASIAS thermal prototype demonstrate that using embedded coolers with refrigerating liquid are a viable and powerful solution for the heat dissipation problems of active antenna arrays.

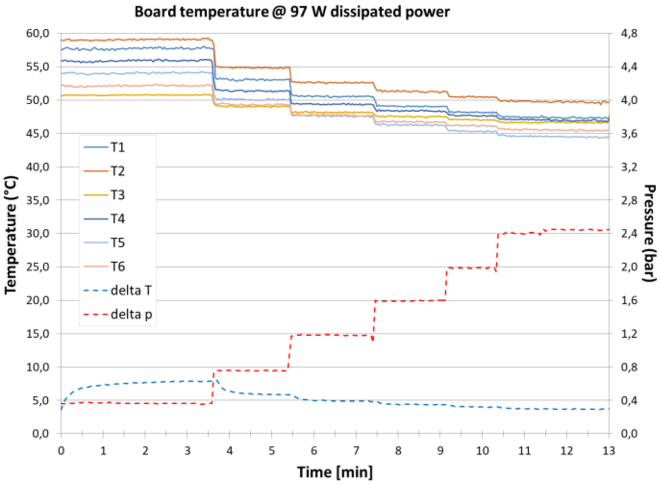

Fig. 6. Temperature detected by the sensors.

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