A Multiphysics Simulation Flow for High Performance MMIC Products for Power 5G and RF Applications

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Introduction

Increasing pressure on cost and performance of modern products for high-power 5G and RF power applications requires electromagnetic (EM) optimization of designs to gain competitive advantage. Moreover, the need to reduce size requires packing many components in a limited space, leading to increased temperatures. To make sure that temperatures and mechanical stress levels remain within safe reliability limits, multiphysics simulations are needed at product and system level, including full chip, package, board and cooling blocks. To overcome this simulation nightmare consisting of tightly packed large integrated components with lots of minute details together with large system, Ampleon has developed a high-capacity, high-accuracy multiphysics analysis flow at chip and system levels which enables successful design of MMIC products for high power 5G and RF applications (Fig 1). In detail:

- The layout generated from the schematic (pre)design is simulated in RaptorX.
- The resulting S-parameter block is used in a new and more accurate schematic simulation.
- The schematic and layout are updated based on the gained insights.
- The layout is imported in Ansys AEDT/Mechanical, for system-level multiphysics simulations.
- Package and board designs are reviewed if needed. Layout is also eventually optimized.

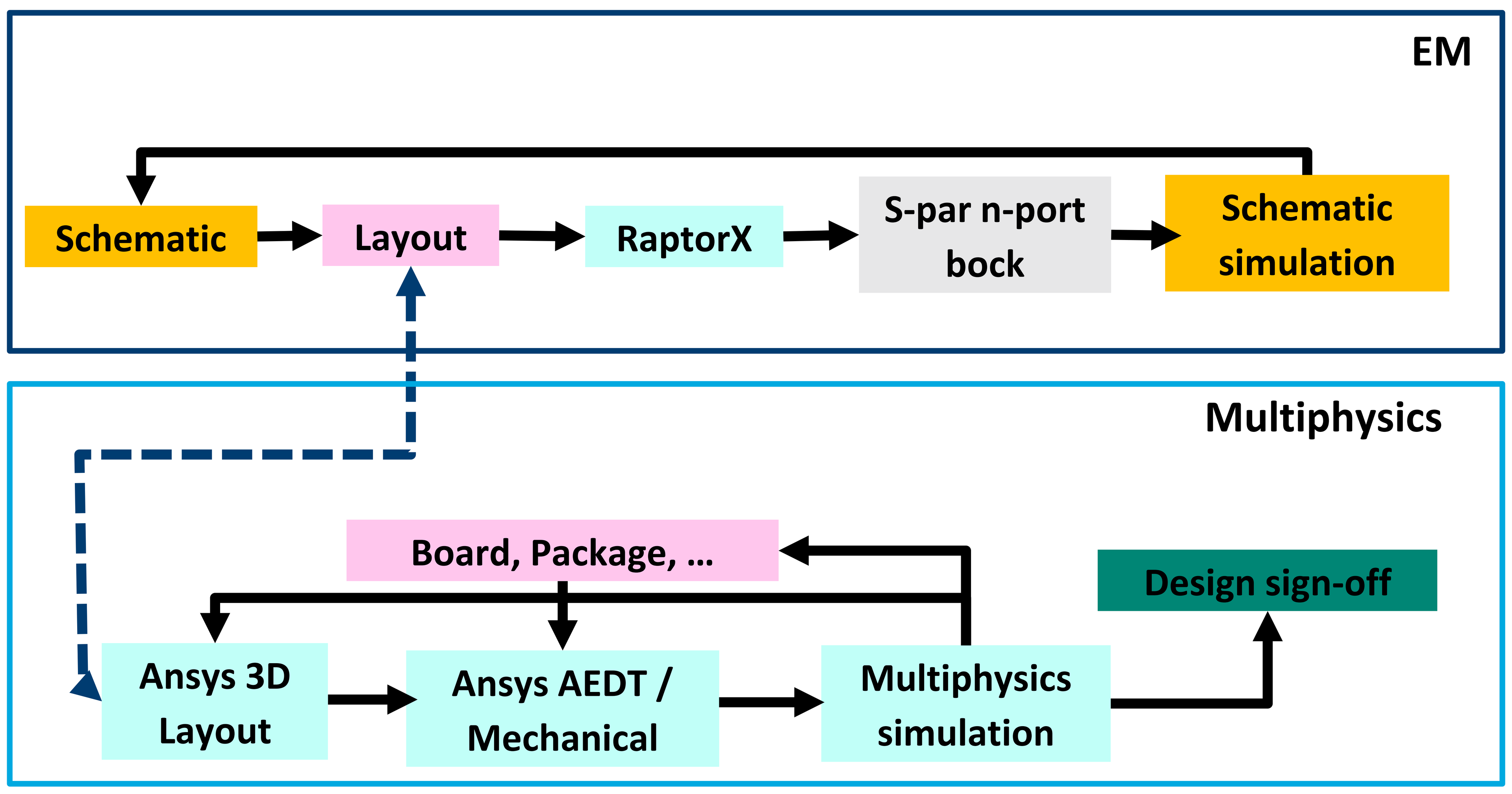


Figure 1 – Ansys-based Multiphysics simulation flow at Ampleon

Results – Electromagnetics

As an example, Fig. 3 compares the measurements and simulations (Raptor X) of a 20 mm^2 MMIC on a low-resistivity Silicon substrate (Fig. 2). The simulation of a large die with very minute details over this substrate is very challenging for traditional tools due to the on-set of slow-wave propagation mode.

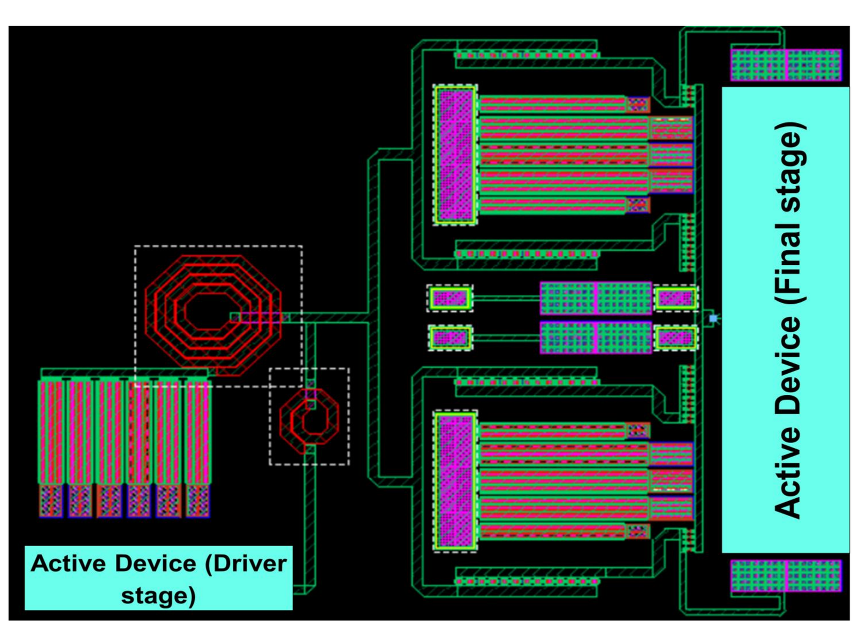
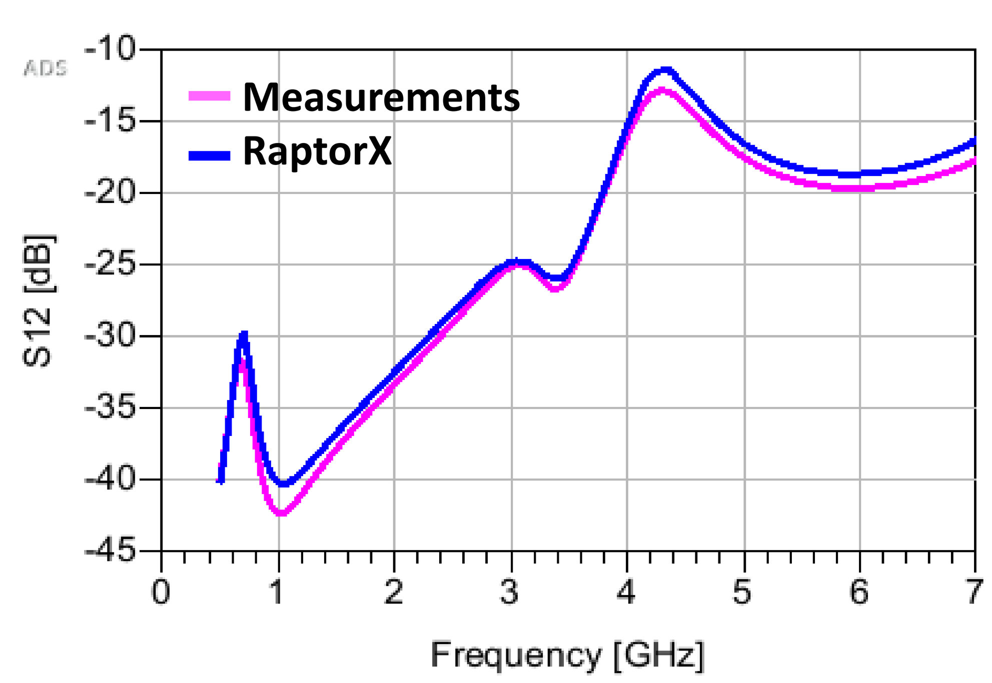
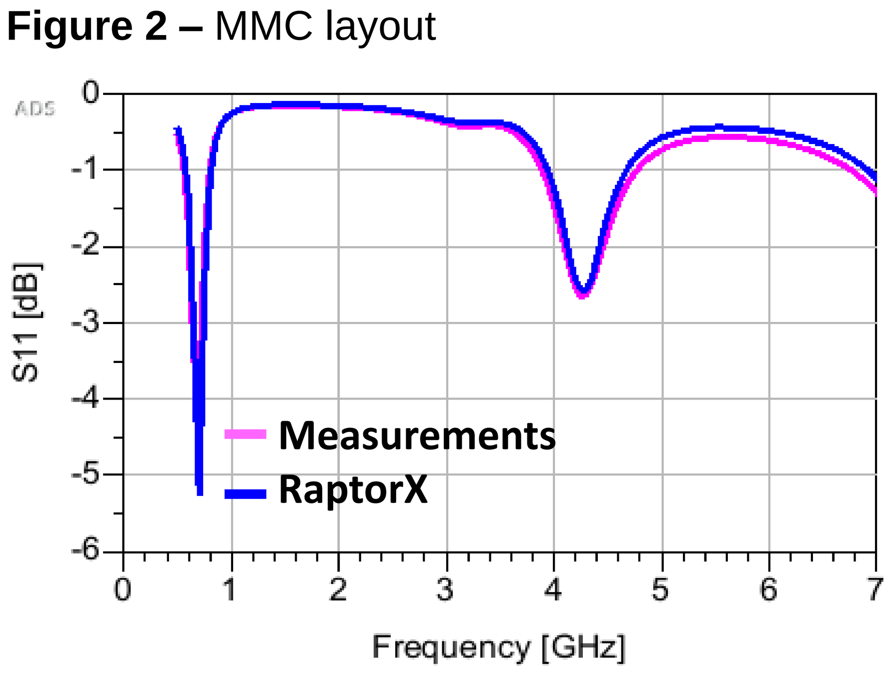


Figure 2 – MMC layout





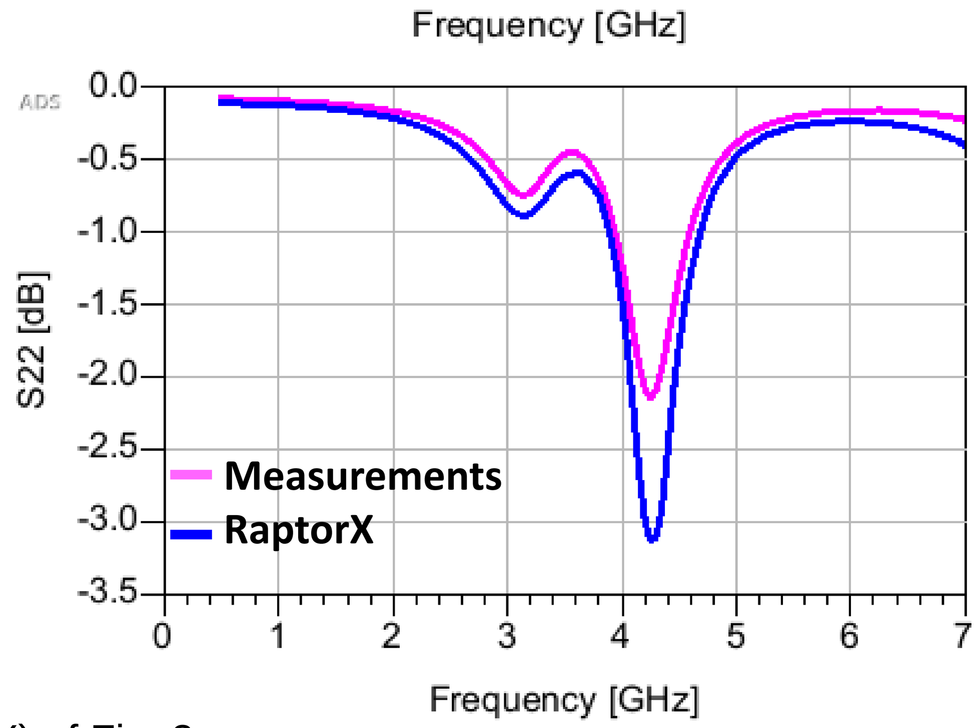


Figure 3 – Measurements vs simulations (RaptorX) of Fig. 2

Results - Multiphysics

The multiphysics simulation capabilities of Ansys AEDT/Mechanical allow Ampleon engineers to simulate the temperature distribution at system level including package, board and cooling blocks (Fig. 4) under real-life conditions and ensure that values remain below safe limits. In detail:

- Electro-thermal simulations allow to identify current crowding and hot spots (Figs. 5-6, Tab. 1).
- The efficacy of different cooling strategies (e.g., waterflow vs fan) can be explored (Fig. 7, Tab. 1)
- Temperature loads are used in mechanical simulations to check that stress and strain levels remain within safe limits in critical parts of the system (Figs. 8, 9)
- Thermal transient simulations help identifying the multiple time constants of the various parts in the system. These time constants can be order of magnitude different (Fig. 10)
- Simulations allow to gain insights in temperature distributions at component level under DC and RF conditions (Figs. 11 and 12) and its effect on thermal resistance (Tab. 3, second row)

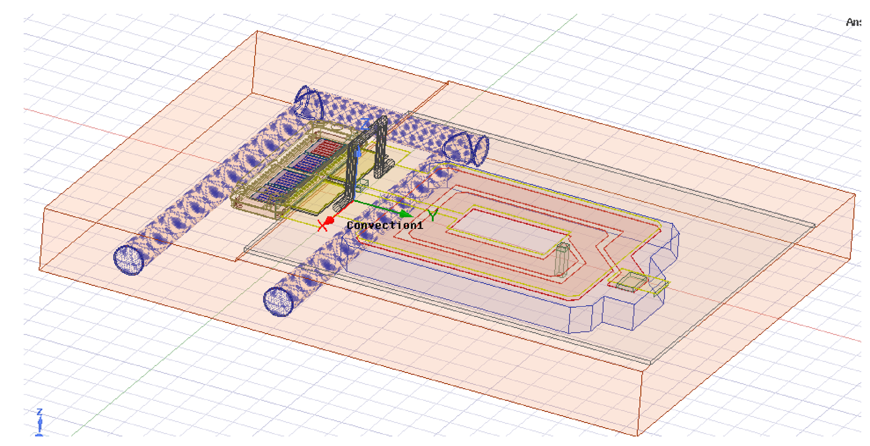


Figure 4 – Example of system with board

Location	Measured	Simulated	Air
Junction	114	113	125
Lead	102	100	114
Bondwires	104	103	118
Matching wire	114	112	122

Table 1 – System Temperatures [ºC]

Component	Measured	Simulated
Inductor DC	225	230
Inductor RF	N/A	320

Table 2 – Inductor thermal resistance [K•W^{-1}]

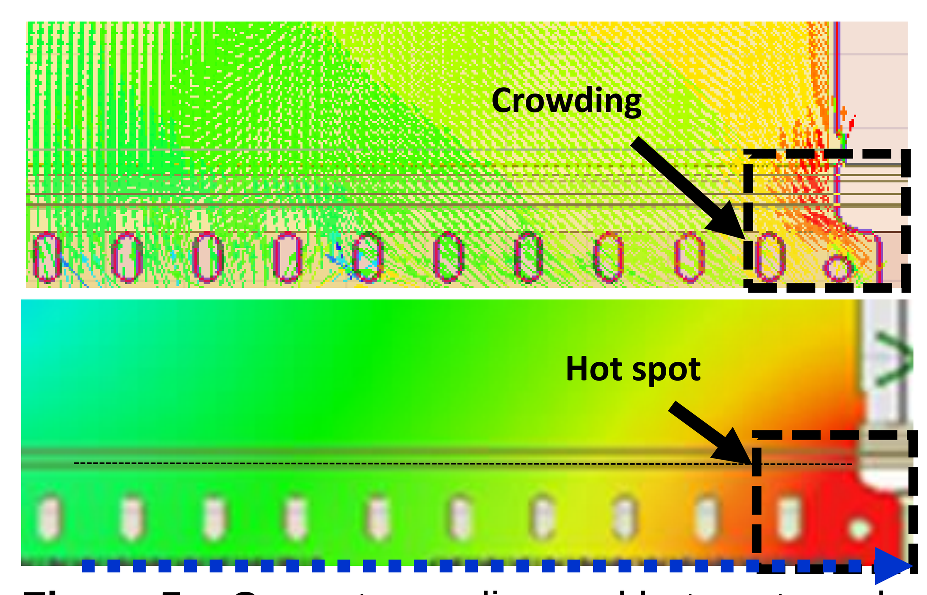


Figure 5 – Current crowding and hot spots on leads

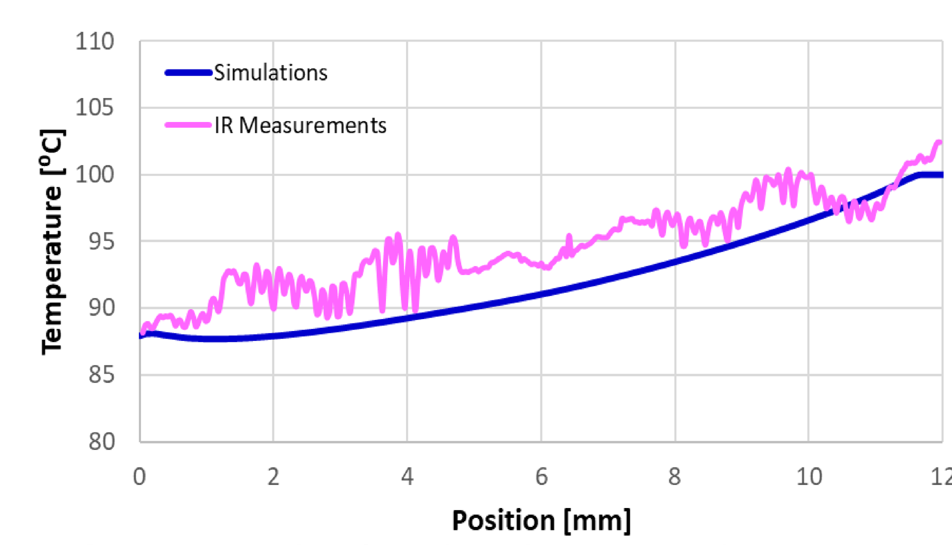


Figure 6 – Simulated and measured temperature on the leads along dotted line in Fig. 5

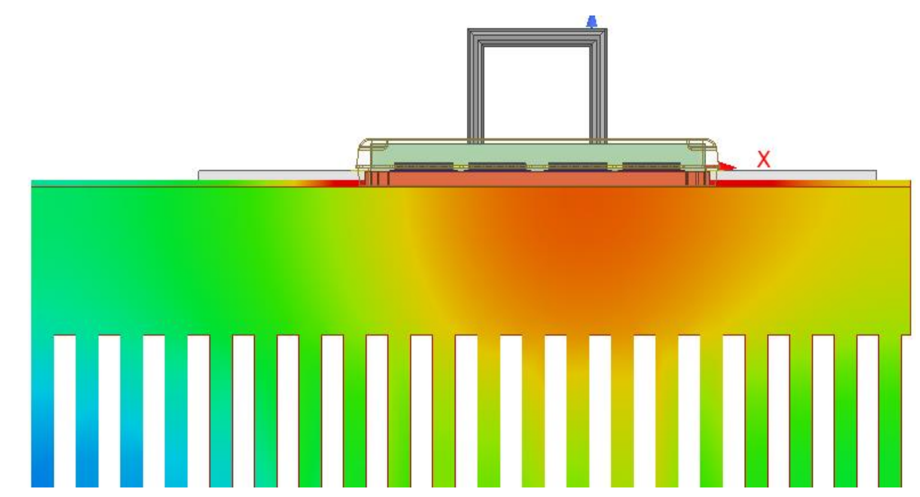


Figure 7 – Fan-cooled system configuration

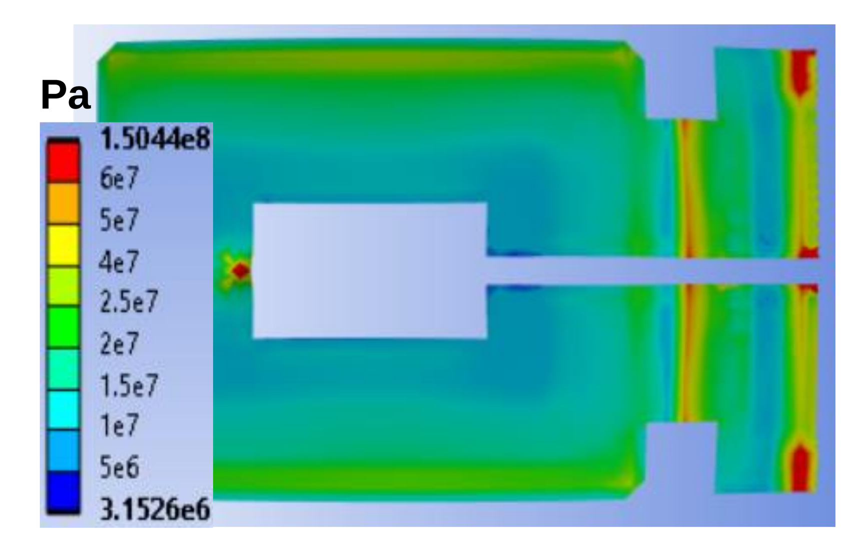


Figure 8 – Stress on the PCB metal

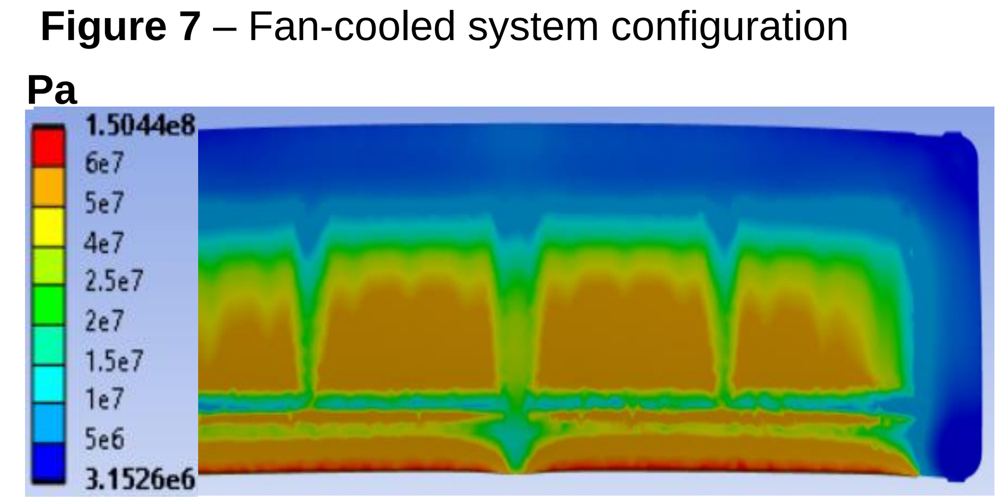


Figure 9 – Stress on the flange

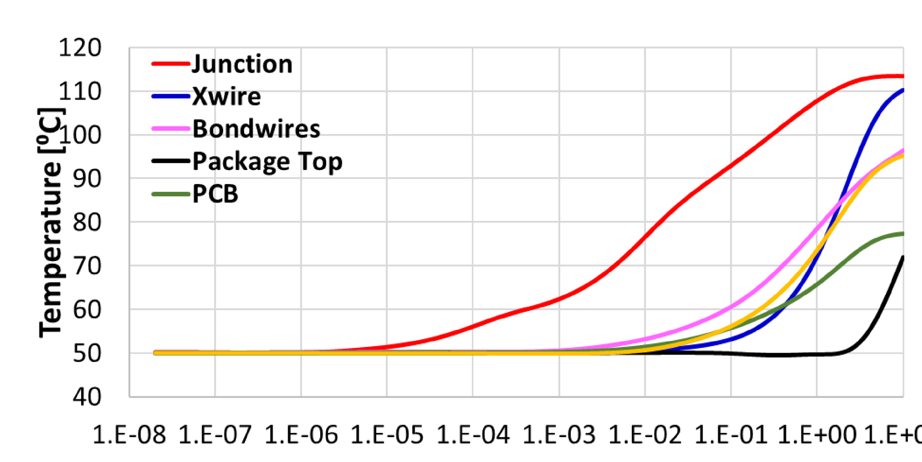


Figure 10 – Thermal simulation results

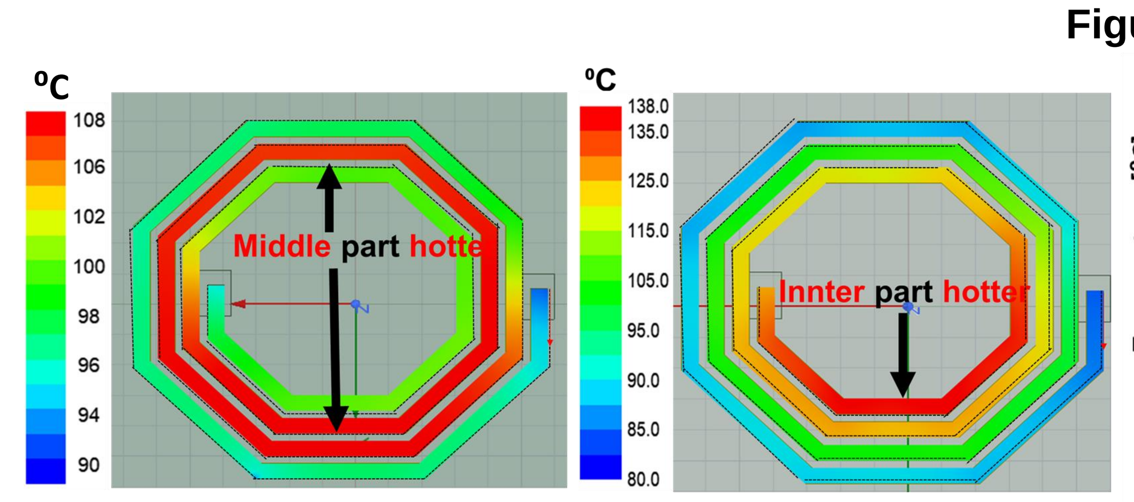


Figure 11 – Temperature on a coil in DC and RF conditions

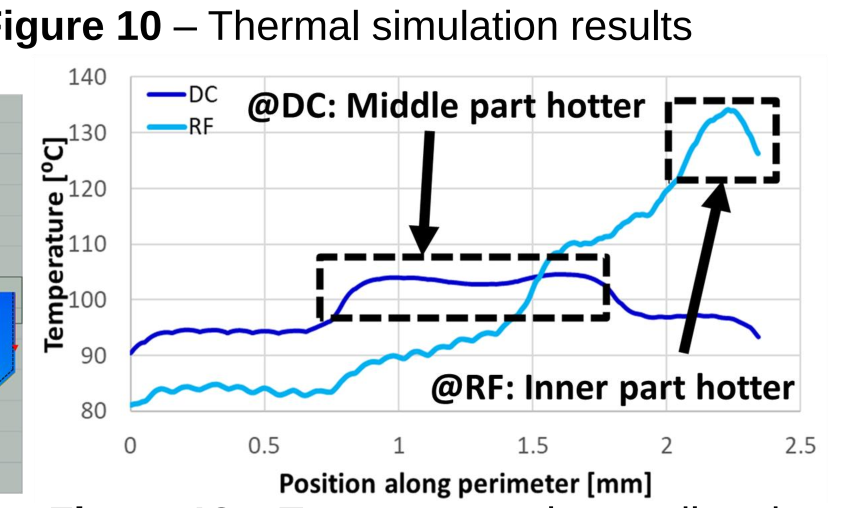


Figure 12 – Temperature along coil perimeter

Summary

Ampleon uses the high-capacity and high accuracy electromagnetic and multiphysics modeling solutions from Ansys to push the design of high-performance high-power MMIC products for 5G applications to its limits. In design stage, the use of Raptor X enables the EM simulations of MMIC products in mere hours where traditional solutions fail to simulate even a single component. Multiphysics simulations at system level allow ensuring that temperatures and stress remain within safe limits under realistic operating conditions. Simulations also enable to identify optimal system cooling strategies thus reducing costs. Having electromagnetic and multiphysics tools under one roof together with advanced technologies like "Mesh Fusion" boosts productivity and enables cutting-edge designs of high-performance products. The optimization of package and board designs allows Ampleon to save costs, gain competitiveness and design even more reliable products.

Acknowledgments

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