# Thermal and Solid-Mechanics FEM Simulation of a Microwave Spatial Power Combiner Amplifier

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## Abstract

INTRODUCTION

This paper describes the Thermal and Structural combined simulation in COMSOL Multiphysics® of a Microwave (MW) Fin Taper (FT) Spatial Power Combiner (SPC) Power Amplifier (PA), based on a rectangular Waveguide (WG). The analysis is focused on the characterization of the main card, in which the amplification devices and the combining structures are located.

In the SPC based PA's, the captured power is feeded by microstrip transmission lines (µSTL's) to Monolithic Microwave Integrated Circuit (MMIC) Solid State Power Amplifier (SSPA's).

The power dissipation of the MMIC SSPA's produces a considerable temperature increase and induces a thermal expansion of both the PA's and the connected structure, with stresses and strains, which can alter the desired Electromagnetic (EM) behavior of the SPC. Furthermore, an uncontrolled temperature increase can damage the SSPA's.

USE OF COMSOL MULTIPHYSICS®

Since the device efficiency depends critically to the FT profile and the SSPA's operating temperature, a Thermal-Structural (TS) analysis is necessary in order to study the effect of these critical influencing factors.

Power amplifiers are composed by a driver stage and final stage transistors. Thus the power dissipation and thermal expansion are unequally distributed in the SSPA's volume, due to the different power consumption of these components.

Actually thermal power dissipation analyses are performed considering the amplifiers as single heat sources. The problem of this approach is that it doesn't allow to understand if a determined area of the integrated circuit exceeds the maximum rated temperature. For this reason, in the proposed analysis the transistors have been considered as different causes which contribute to the total effects, in order to ensure the correct heat-sink, by estimating the reached temperatures in the different areas.

By setting the minimum mesh element size as the smallest edge length of the SSPA's domain, which is 10^-4 m long, an accurate discretization has been reached with moderate computational cost.

In order to ensure great model reliability, all the materials are temperature dependent and characterized in the temperature range of simulation, which is from 20°C to 160°.

The model is organized by using the Heat Transfer in solids (HT) and Solid Mechanics (SM) Interfaces from COMSOL Multiphysics®.

Since it has been assumed that the temperatures are independent of the displacements, a separate computation has been adopted, for temperature, using the HT Interface and for the displacement using the SM.

RESULTS

Stress and displacement under operative conditions have been computed. For the selected SSPA's, the maximum power output is of 20W, of which 16W are dissipated by the Final and 4W By the driver.

By imposing these values, the HT stationary analysis has shown a maximum temperature over the SSPA's of 140°C, perfectly respecting the maximum temperature allowed at the maximum power output of the chosen SSPA's.

The maximum stress is near the oblique angles of the cards and locally reaches 0.66 GNm^-2, and the maximum displacement is located near the interface between the innermost SSPA's and the slab copper support, which is of 4.9 µm, enough negligible from the guiding properties of the structure.

## Reference

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[4] Heat Transfer Module User's Guide Version : May 2012COMSOL 4.3
[5] COMSOL Structural Mechanics Module User's Guide Version : May 2012 COMSOL 4.3.
[6] COMSOL Surface Resistor: Thermo-Mechanical Analysis, Model Documentation, © 2013 COMSOL

## Figures used in the abstract

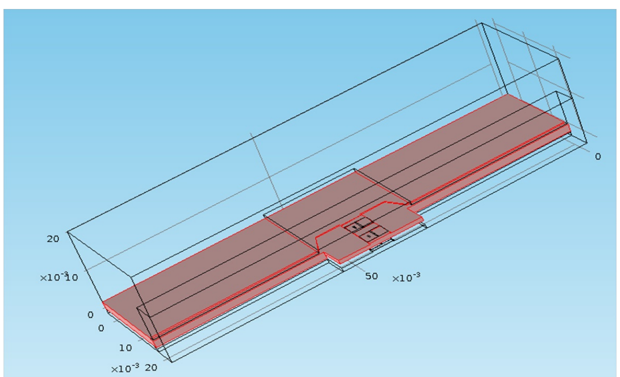

**Figure 1**: Card Profile

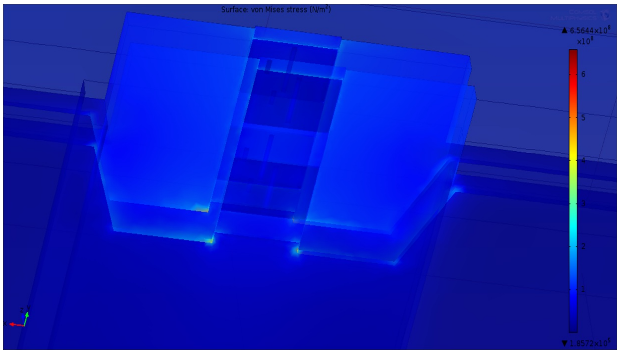

**Figure 2**: Stress - critical area

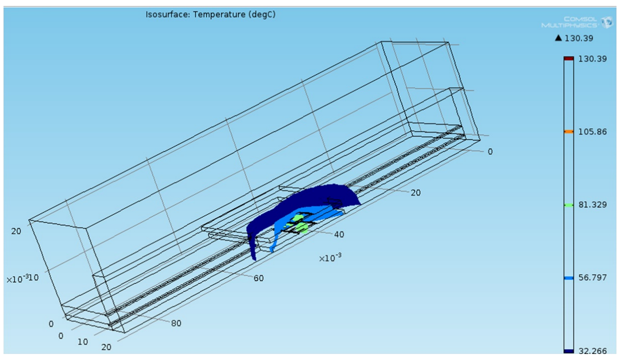


**Figure 3**: Temperature - critical area

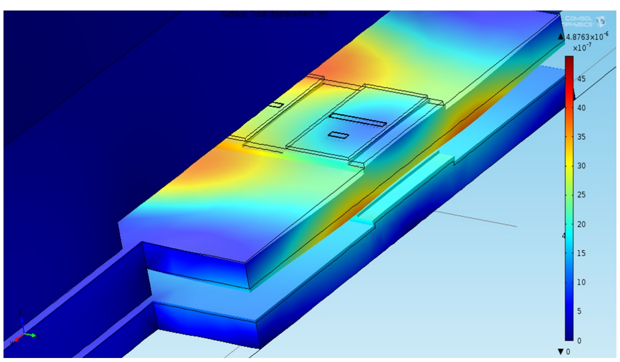

**Figure 4**: Displacement - critical area