Predicting Probable Cavity Resonance with a 3D EM Tool

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Electromagnetic analysis can be used to predict resonances inside microwave modules, allowing the designer to implement measures to avoid poor performance and instability

Cavity resonance is commonly encountered when the PCBs and RF components are placed in an enclosure. Due to the module height and the housing structure, the standing wave with characteristic such that the E and H fields are 90° out of phase with each other. The impedance will therefore fluctuate wildly across the cavity causing unknown effects on circuitry, including the introduction of instability to active devices [1].

A few practical approaches have been demonstrated by Yeap, et al. [2] to suppress the cavity resonances within a high power amplifier (HPA) module by using an isolation block and tantalum capacitors at the DC bias network. To further understand the behavior of electromagnetic (EM) propagation within this HPA module, we extend that earlier work to predict the possible cavity resonances scenario via EM field analysis and Eigen-mode computation using the Eigen-mode solver in CST MICROWAVE STUDIO® [3]. By adopting this approach, we show the likely phenomenon that can be observed with and without the existence of an isolation block.

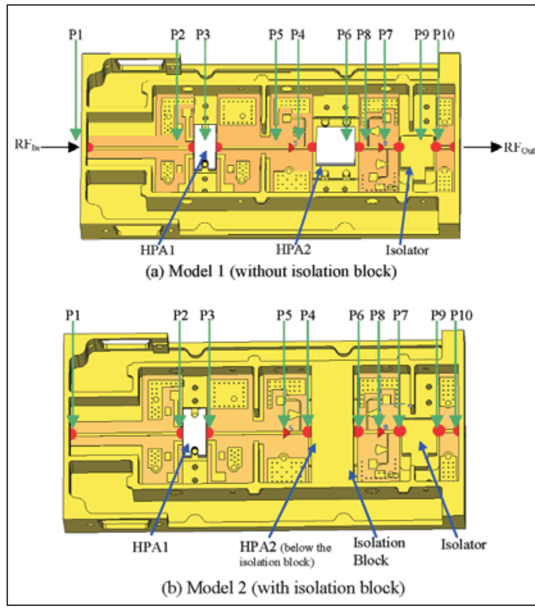

Figure 1 · Models imported to CST Microwave Studio for resonance analysis.

Model Description of HPA Module

The PCB layout of the HPA was initially designed in Agilent Advance Design System (ADS), and the module enclosure was designed in AutoCAD. PCB layers were exported as 2D DXF to CST MWS and further extruded in the *z*-axis to form the 3D object. The module enclosure was exported in IGES format from AutoCAD to CST MWS environment. Two different HPA modules were used in this study. The main difference between the models is that there is an "isolation block" extended over the HPA2 in Model 2, as shown in Figure 1(b). The effects of adding the isolation block is then demonstrated by the visualization of EM field distribution and cavity resonant frequencies between the two models. Model 1 is identical to the hardware developed in [2], however the lumped components, solder and connectors are not included in the simulation. The heights of the components (HPA1 = FMM5057VF [4], HPA2 = FLM7785-12F [5], Isolator = 2RI119 [6]) were modeled according to the units specified in the data sheet. The

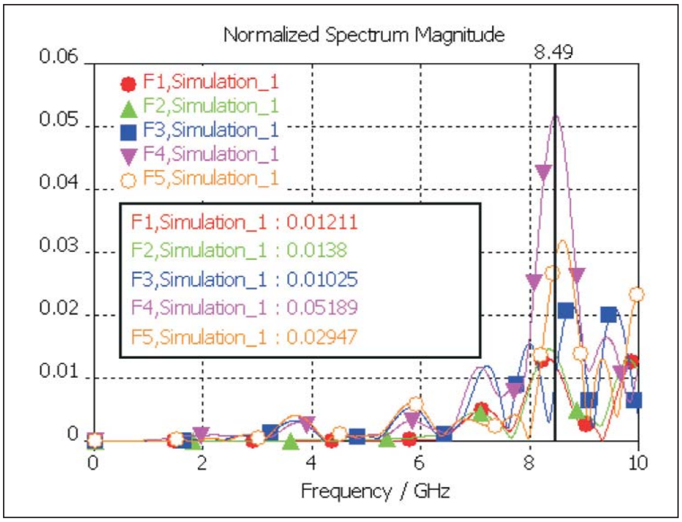

Figure 2 · Normalized spectrum magnitude captured by ports P1-P5 of Model 1.

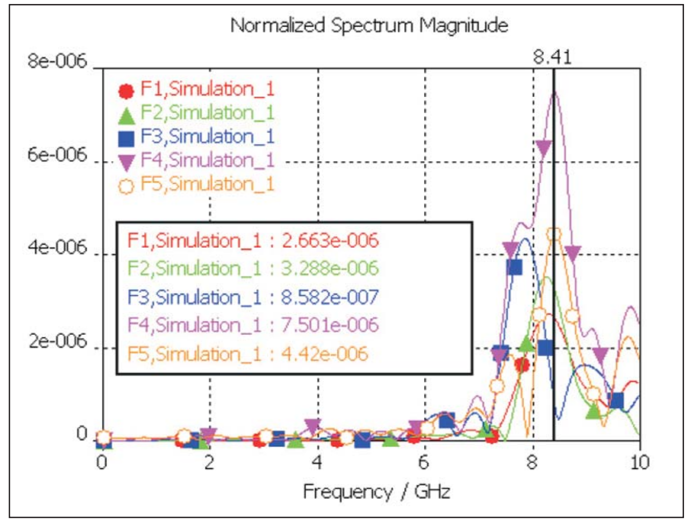

Figure 3 · Normalized spectrum magnitude captured by ports P1-P5 of Model 2.

substrate is defined based on the properties of RO4003 [7]. The "red dots" in Figure 1 are the discrete ports defined in CST MWS, which are used to excite signal to the RF traces as well as to receive EM fields. There are a total of ten discrete ports, denoted as P1 to P10 in each model.

Part 1: EM Fields Analysis in CST MWS

Both models were simulated with "Time Domain Solver (T Solver)" in CST MWS. Only P6-P10 (P6, P7, P8, P9 and P10) were activated for simultaneous port excitation. P1-P5 (P1, P2, P3, P4 and P5) act as "EM field receiver." If the EM field does not loop back to the input of the module, P1-P5 will receive very low EM field energy. Figure 2 and Figure 3 show the normalized spectrum magnitude captured by P1-P5 in Model 1 and Model 2 respectively. It is shown that Model 1, which has no isolation block, has a normalized spectrum magnitude of 6900 times (or 38 dB) greater than that of Model 2. This implies that there is strong coupling from P6-P10 to P1-P5 in Model 1, potentially creating a positive feedback within the module.

To visualize the EM field distribution in these modules, we will observe the electric and magnetic fields at 2 GHz (an arbitrary frequency selected for comparison purpose) and 8.3 GHz (operating frequency of the HPA). In

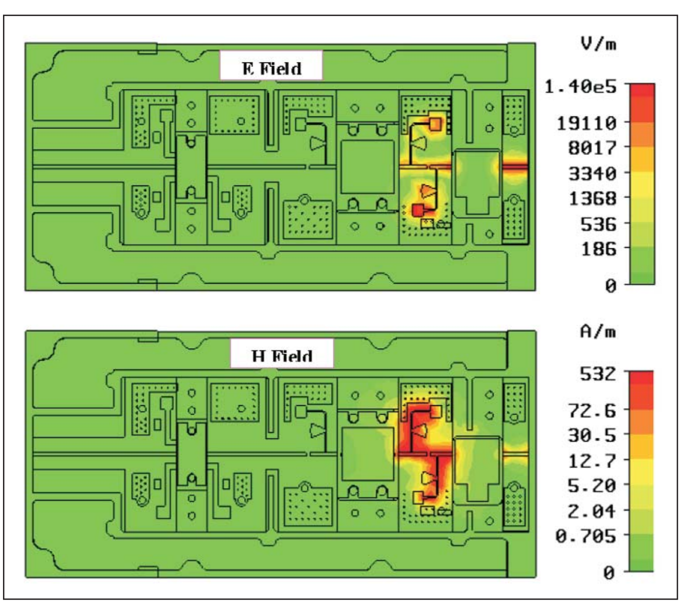

Figure 4 · Absolute E and H field strength of Model 1 at 2 GHz.

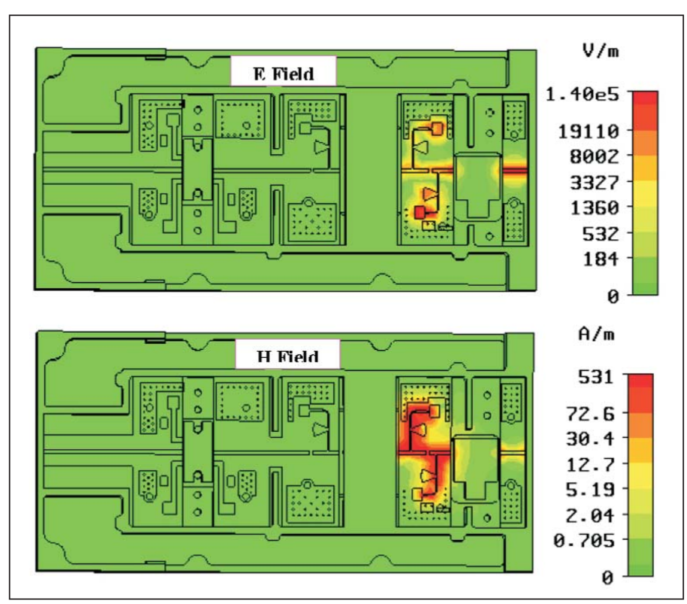

Figure 5 · Absolute E and H field strength of Model 2 at 2 GHz.

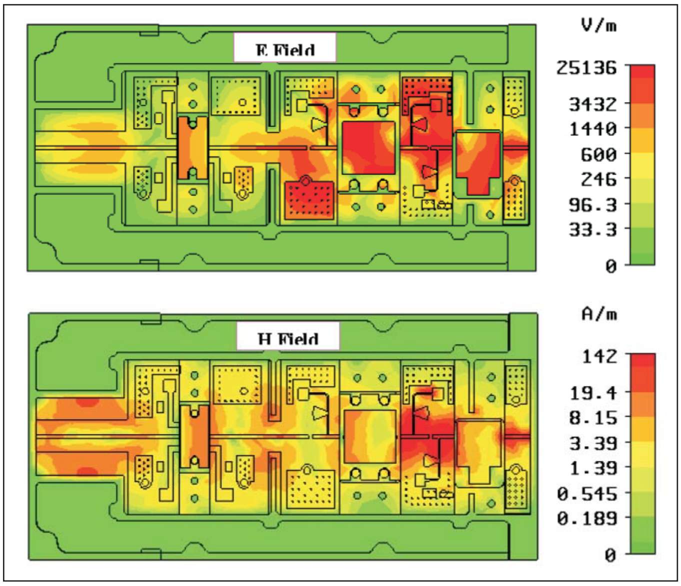

Figure 6 · Absolute E and H field strength of Model 1 at 8.3 GHz.

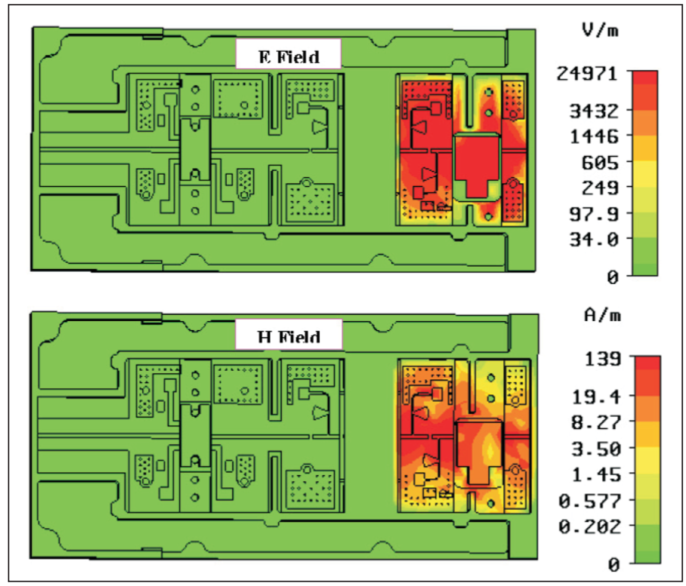

Figure 7 · Absolute E and H field strength of Model 2 at 8.3 GHz.

both models, Figure 4 and Figure 5 show that the E and H field only gathers around the RF traces. However, it is shown in Figure 6 that the E and H fields in Model 1 have spread around the whole module without the presence of isolation block. This phenomenon could lead to a loop-back, causing the amplifier to oscillate.

On the other hand, Figure 7 shows that, with an isolation block used in Model 2, most of the E and H field are blocked from spreading all around and bounded within the compartment.

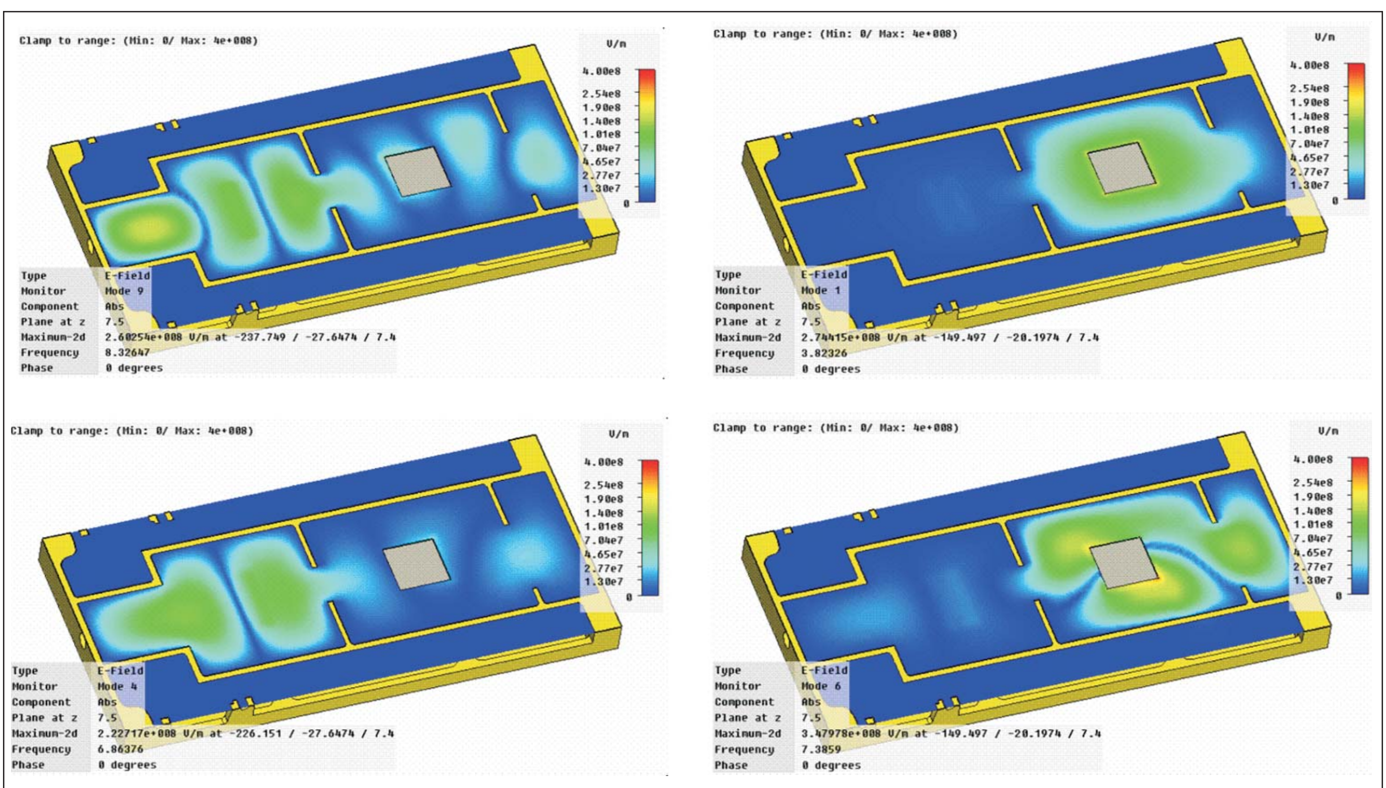

Figure 8 · Four Eigen-modes of the HPA cavity.

Part 2: Resonances Prediction with Eigen-mode Solver

From the previous section, we have shown that the cavity resonance might cause coupling between the input and output stage of the amplifier in Model 1. These Eigen-modes reflect the potential frequency for HPA oscillations as a result of positive feedback in the enclosure. To investigate this problem in greater detail and to find these resonant frequencies, the CST MWS Eigen-mode Solver (E Solver) can be used. Figure 8a-d shows four different Eigen-modes of the cavity.

If these resonance frequencies are compared to the amplitude spectrums in Fig. 2, it can be noticed that each mode corresponds to a coupling peak in the spectrum. By analyzing the field distribution of these modes, the best position for absorbing and isolation blocks as well as shorting vias can be revealed. While the transient simulation as described in the first section of these paper includes all structure details (e.g. all PCB traces terminated with ports), the Eigen-mode simulation is performed on a simplified model excluding some of the traces. Since the Eigen-mode simulation (by definition) does not included any ports, all "free floating" traces have either been shorted to GND or been removed. This is done to eliminate "static" modes in the simulation. It is expected, that the presence of the traces only has a minor effect on the Eigen-modes and the results of the simplified Eigen-mode simulation and the transient simulation of the full model agree very well.

Conclusion

The cavity resonances excitation within a high power amplifier (HPA) module is demonstrated here using a commercial 3D EM simulator. The simulated normalized spectrum magnitude captured at various positions in different compartment indicates a strong signal coupling occurs inside the cavity. This result is confirmed by the visualization of both the predicted EM fields and cavity Eigen-modes at the operating frequency of the HPA.

The modeling of a RF circuit enclosure for natural resonances is always a good practice and should be included in the development flow. The simulation and visualization of 3D EM fields distribution within a metallic enclosure is useful for preventing cavity resonance during the design stage and, hence, avoiding all the troubleshooting effort in the much later stage of prototyping work.

References

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Linus Lau obtained First Class honors BEng in Mechatronics engineering, Master of research in Mechanical Engineering and PhD in Microwave Engineering from University of Manchester Institute of Science and Technology (UMIST) in between 1995-2003. He then returned to Malaysia, joining Intel Penang as a Senior Test module Development Engineer (2004-2005). He was working in the area of test module development for Intel Centrino Wi-Fi Transceiver chipset; conducting performance study of an RF test module using 3D EM simulation tool and setting up measurement verification studies on test-related challenges, i.e signal integrity, EMC, thermal and mechanical test. He is now attached to Computer Simulation Technology (CST) as the main technical consultant for South East Asia region. He is responsible for both business development and technical support for customers in this region and is currently based in Kuala Lumpur, Malaysia.