White Paper

High-Performance Electronic Design: Predicting Electromagnetic Interference

In designing electronics in today's highly competitive markets, meeting requirements for electromagnetic compatibility (EMC) presents a major risk factor, especially since small windows of opportunity are critical to business success. ANSYS provides best-in-class tools and a proven methodology for accurately simulating EMI characteristics of electronic systems. This benefits development teams by providing insight to implement design modifications well before regulatory certification submission.

The industry often speaks of electromagnetic interference (EMI) with a singular mindset: It's a problem. This stems from the fact that, too often, EMI is not seriously considered until a failure to comply report is issued by regulatory agencies during mandatory testing for radiated and conducted emissions. In reality, EMI is only a symptom, not the source of a design problem. Excessive EMI generated by an electronic system is an indicator of signal integrity and/or power distribution issues that manifest themselves as EMI.

The challenge in predicting EMI during the design process is that there is no way to know with certainty that whatever design best practices you employ will guarantee an acceptable result from an EMI perspective — until emissions tests are run. While filtering a signal, rerouting a trace, shielding a component, or enclosing the printed circuit board may be necessary to improve functional performance, doing more of the same in hopes of controlling EMI is premature

State-of-the-Art Simulation Methodology for Predicting EMI

This paper discusses a straightforward EMI simulation methodology to accurately characterize electromagnetic behavior of an electronic system, simulate its performance in real time, emulate regulatory EMI emissions tests, and capture simulation results to aid in identifying and isolating sources of interference if an EMI problem exists. Underlying this discussion are the tools and enabling technologies that ANSYS provides to make it all work.

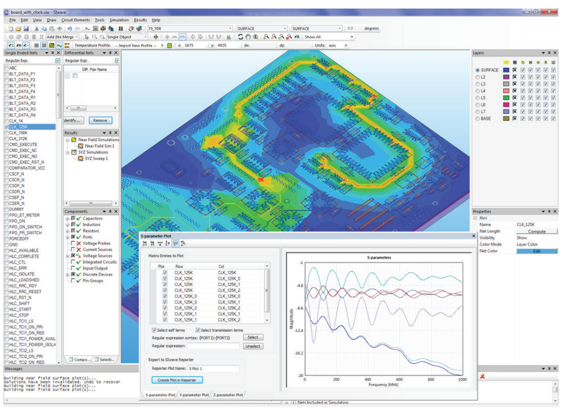
Core EMI Simulation Methodology

1. Capture the geometry of the system.

2. Model the electromagnetic response of the system over the frequency range of interest using an EM field solver.

3. Link the electromagnetic solution into a time domain circuit solver schematic, apply transient signal sources and terminations, and generate the real time system response.

4. Push the time domain results back into the electromagnetic model and calculate the electromagnetic response to the time domain excitation to capture the EMI signature



ANSYS SIwave is designed for the analysis of printed circuit boards and electronic packages. SIwave is optimized to provide a fast solution for full PCB geometries, making it ideal for the PCB-only EMI scenario. This solver can provide a simple frequency response at distance solution in minutes.

Scope of the EMI Simulation Problem

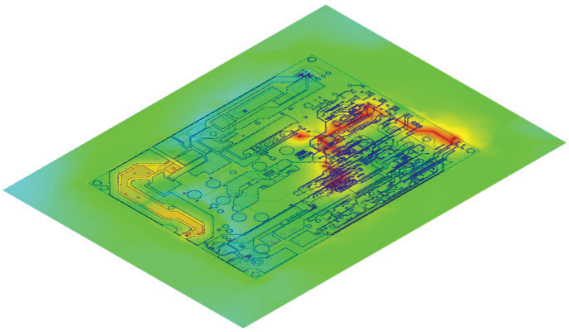
A show-stopper event in electronics design is failure to comply with regulations governing radiated and/or conducted emissions. Real development costs mount quickly in terms of the time and effort needed to diagnose and correct the problem, remanufacture the product, and resubmit it for testing. Because compliance reports document only the failure and provide no insight into why there was a failure, regulatory agency testing brings no value to that redesign process.

Predicting EMI is a complex challenge. The core requirement of an EMI-aware design methodology is the capability to perform EMI measurement simulations. Both electromagnetic field solvers and circuit solvers operating in a closed loop are necessary to accurately model and simulate system characteristics that are defined in three domains: time, frequency and space.

Every element of an electronic system has a three-dimensional physicality — from ICs and discrete components to printed circuit board and enclosure to interconnection and interaction with other adjacent electronics. It is this physicality that directly impacts those design parameters that engineers care about — signal degradation, transmission losses, signal coupling, harmonics, etc. These are the same parameters that are impacted by or contribute to emissions conducted through the power system or radiated into space. An electromagnetic field solver is the appropriate tool to accurately model the electrical response of a three-dimensional system.

While an electromagnetic solver addresses the frequency-response-in-space aspect of the EMI simulation problem, that frequency-domain system model provides only half the solution. Real information (such as with modern digital communications) travels in the time domain.

This moves the EMI simulation problem into the realm of time-domain circuit solvers. For the case of radiated emissions, in which the EM system model is extracted as a complex S-parameter network, a hybrid EM–circuit solver solution is required. By driving the electromagnetic system model with real signals, the hybrid circuit solver simulates the real-time performance of the system. In the case of conducted emissions, with the system typically extracted as a lumped-element model, a designer can use a traditional circuit simulator.



ANSYS HFSS is the accepted industry standard for electromagnetic analysis. With finite element, integral equation and hybrid EM solvers capable of solving any arbitrary 3-D structure, HFSS is the right solution for cases in which radiated emissions characterization requirements expand to include the PCB in an enclosure. A very high fidelity EMI characterization result can be achieved by including the receiving antenna in the HFSS EM model.

To predict EMI, one more stage of simulation is required. In the first stage, extraction of the electromagnetic system model provides the capability to calculate peak frequency response to an excitation. In the second stage, the circuit solver solution captures real-time response of the system. Now, you close the loop and use that real-time response as the driving excitation into the extracted electromagnetic system model to capture the true electromagnetic system response. For the case of radiated emissions, the loop is closed by driving voltage magnitude and phase information from the transient signal outputs in the time domain back into the system model in the frequency/EM solver domain. The electromagnetic response to this excitation is the radiated electric or magnetic field and represents the EMI of the system. For the case of conducted emissions, the frequency response of the power line network to the transient signal stimulation can be measured directly as part of the circuit solver solution to reveal the conducted EMI signature.

Mitigating Risk of Failure to Comply

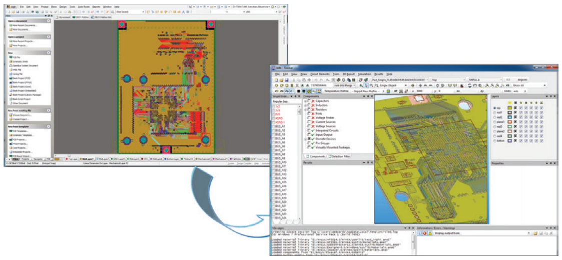
Regulatory agency EMI testing is typically executed at the end stages of product development. A lot rides on those test outcomes. Incorporating an EMI simulation methodology into the design process, the goal is to avoid any surprises at that stage. Although the subject of EMI is complex, the core methodology for simulating it is straightforward.

- Link the (extracted) electromagnetic solution into a time-domain circuit solver schematic, apply transient signal sources and terminations, and generate the real time system response.
- Push (drive) the time-domain results back into the (extracted) electromagnetic model and calculate the electromagnetic response to the time-domain excitation to capture the EMI signature.

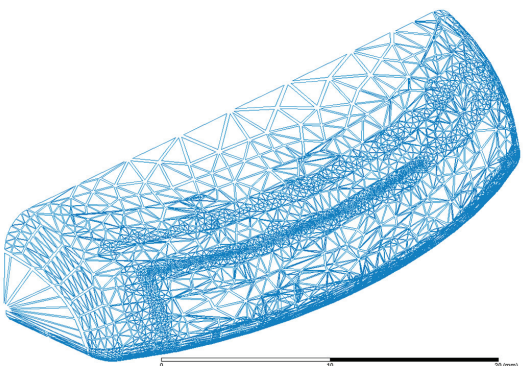
It is not easy to have this general methodology discussion without referring to specific methods, tools and capabilities enabled by the ANSYS solution to address different scenarios. In all cases, the methodology as defined here is the same even though you might employ different methods and tools.

The key to a positive outcome is to start monitoring EMI early in the design process and to continue to monitor it as the design of the system solidifies.

Radiated emissions simulations can start to add value to the design process as soon as you complete the initial PCB layout/design. Using an EM solver optimized to produce a fast solution to this simple planer geometry, you can obtain a quick EMI result, just measuring frequency response at a distance without a complicated EMI test chamber model. This is the appropriate level of EMI simulation complexity when you don't know if further layout changes are going to be made, if an enclosure is required, or what the composition and form factor of that enclosure would be.



EDA and MCAD design data is translated into the ANSYS environment.



The accuracy of an EM model is only as good as the mesh that is created to describe a geometry and its electromagnetic response

So early on, the development team is armed with knowledge to investigate the source of potential EMI issues and resolve potential signal integrity or power integrity issues that may exist at the board level. If and when an enclosure is added to the mix, you need to switch to an EM solver that can model an arbitrary 3-D structure, but the EMI simulation methodology remains the same.

Regulatory agencies issue a pass/fail compliance report. The ANSYS EMI simulation methodology provides much more. While solving EMI problems (accomplished by filtering, signal rerouting, shielding/enclosures, etc.) is outside of the scope of this discussion, the EMI simulation methodology provides the data needed to identify frequencies at which standards for emissions may be exceeded and to isolate the sources. Frequency response plots identify offending signals and harmonics. And single-frequency-point field plots identify where those signals are propagating. The mission to predict the symptoms and isolate the causes of electromagnetic interference can be accomplished — with certainty.

The ANSYS Radiated EMI Solution

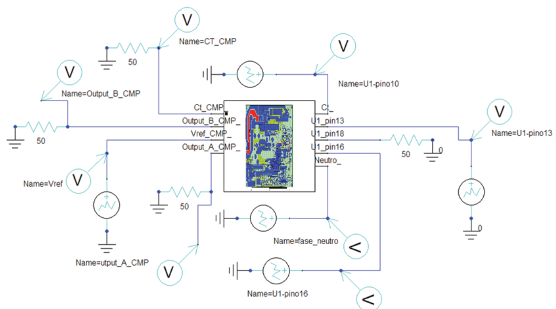
The core EMI simulation methodology addresses the question of what: What actions are necessary to calculate EMI through simulation? That leads to the question of how: How do I do that? There are the mechanics of executing the methodology, but the value in the ANSYS solution is that the designer needs to concentrate only on engineering issues. The tools take care of the rest.

Importing Design Data into the EMI Simulation Flow

The first step in the EMI simulation methodology is to capture relevant source data for use in the electromagnetic simulation environment. This where the seamless integration begins — and it is a major contributor to the accuracy of the solution. You do not need to create/recreate geometry for EM model extraction. Using ANSYS provided interfaces into industry-standard electrical and mechanical design environments, EDA and MCAD design data is translated directly into the ANSYS environment. This eliminates the chance for error in moving data from one database to another; it also ensures that the solution is based on a singular set of design data input.

Characterizing Electromagnetic Behavior of Physical Components

The second step in the EMI simulation methodology is to extract an electromagnetic model that accurately characterizes the imported design structures. A designer's EMI analysis requirements for radiated emissions can range from the simple — PCB only — to the complex — PCB in an enclosure on a rotating table inside an anechoic chamber with a receiving antenna. The ANSYS solution strikes the right balance of computing resources with accuracy of result appropriate for each level of complexity.



ANSYS Designer / HFSS Hybrid Model

By linking the extracted EM model from ANSYS HFSS or ANSYS SIwave to ANSYS DesignerSI the system can be driven with true transient signals and loads. This type of simulation enables the calculation of emmissions at each frequency point.

The accuracy of an EM model is only as good as the mesh that is created to describe a geometry and its electromagnetic response. The EMI simulation methodology provides a head start in accuracy with the direct import of EDA and MCAD design data. HFSS employs automatic adaptive meshing to create a finite element mesh that is absolutely conformal to all geometry and appropriate for the electromagnetics that are being solved. Similar automated adaptive techniques are employed by all ANSYS EM solvers. The benefit is that the design engineer does not need to be concerned with creating or refining the mesh. The tools guarantee an accurate solution.

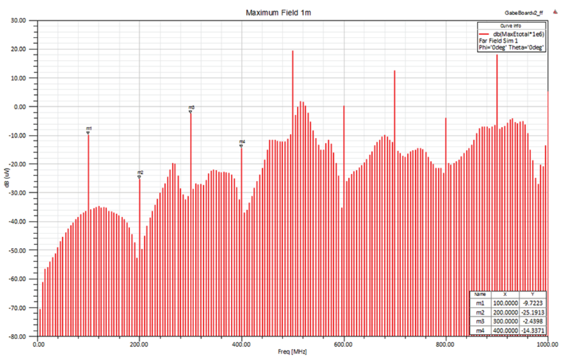
Simulating System Response to Real Signals in Real Time

The third step in the EMI simulation methodology is to characterize the real-time response of the system. ANSYS DesignerSI is a hybrid circuit solver capable of handling the complex S-parameter network extracted by the EM solver in a time-domain simulation. Within DesignerSI, the EM solver solution becomes real. The extracted EM model is linked into the DesignerSI circuit schematic. By driving the system with real transient signals and loading the outputs appropriately, the real-time system response can be simulated.

At this point, the EMI simulation methodology requires some decision making. These are engineering decisions that are a standard part of the product development process, so the design team should be aware of them already. Because this is a hybrid simulation, the analysis can become complex and lengthy to execute. So it is useful to limit the simulation to only those nets that are critical to system performance and that could contribute to EMI. These typically are the data stream, clocks and critical power signals. The concerns in capturing this set of results include signal integrity, integrity in the power distribution system and noise coupling — all potential culprits for EMI.

The EMI simulation methodology requires both frequency domain and time domain solutions to calculate emissions characteristics. Data from one domain drives the other and vice versa. Dynamic links is a key enabling technology to the DesignerSI hybrid solver solution that links the EM model into the time domain simulation. There is no data translation required by the user; once the connection is made, any changes in the EM model track dynamically in the time-domain simulation environment.

Push excitations is the enabling technology that drives the circuit solver solution back into the EM solver simulation. This closes the frequency–time-domain loop and enables the calculation of radiated emissions in the EM solver simulation environment. Using an automated translation, voltage magnitude and phase information are extracted from the transient simulation results and pushed back to the field solver. The field solver uses this data to calculate the emissions at each frequency point.



ANSYS HFSS includes a radiated emissions compliance plotting capability for emissions spectrum at a distance.

These key technologies enable the quality of result possible with the ANSYS EMI simulation methodology — a singular source of geometric structure, one source of electronic design data, and one source of driving signals modified only by the performance of the system through which they are driven.

Closing the Loop: Measuring Radiated EMI

The fourth step in the EMI simulation methodology is to characterize the electromagnetic system response in a driven state to measure EMI. For radiated emissions, this measurement is executed in the EM solver/frequency domain. All of the prior steps in the methodology are performed to enable this milestone step in the design cycle.

Executing the EMI measurement is straightforward, thanks to the integration between the ANSYS electromagnetic simulation and circuit simulation domains. Leading up to this point, the electromagnetic system model was extracted using the field solver. Then that electromagnetic solution was dynamically linked into the hybrid EM–circuit solver solution with which the time domain response was simulated. Now at this stage, the push excitations capability allows magnitude and phase information from that time domain solution to be pushed back into the electromagnetic model to generate EMI. The field solver uses the pushed magnitude and phase data to calculate emissions at each frequency point.

Capturing Results and Reports

The result that demands top priority is the radiated emissions compliance plot and report, which is generated at the push of a button in ANSYS HFSS. If the report indicates a pass and the design team is comfortable with the margins of compliance shown in the emissions plot (frequency response at a distance), then no action is required regarding EMI.

If the report indicates a failure to comply, or if the emissions plot reveals a potential for failure, then the available data from the EM and circuit simulations becomes the key to identifying and isolating the culprits. The emissions plot reveals frequencies of interest — a combination of intended signals and their harmonics along with unintended signals and any associated mixing products. Once those frequencies are identified, EM field plots at single frequency points can reveal where those frequencies are propagating so that sources of interference can be isolated. To aid in this process, suspect signals can be turned off in the DesignerSI schematic, the simulation can be rerun, and EMI can be recalculated to verify the impact.

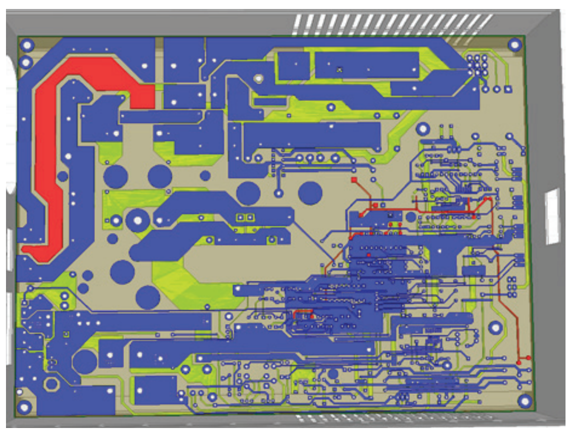
Case Study Example

This example from Inovax steps through the simulations of a radiated EMI measurement of a rectifier. In this case, the goal was to duplicate the full regulatory agency measurement setup. The solution platform was ANSYS HFSS coupled with ANSYS DesignerSI.

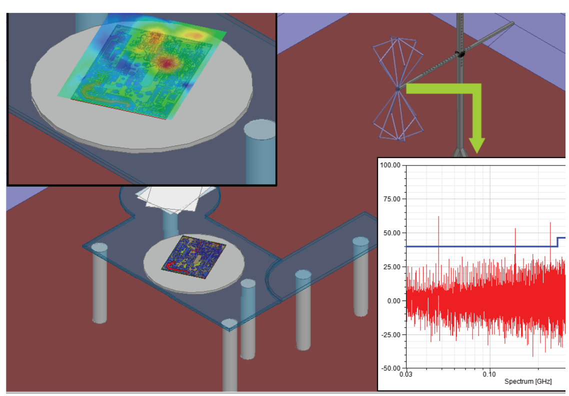
Inovax employed the EMI simulation methodology into their design process once they completed the layout of the printed circuit board.

Driving signals included in simulation and their combined spectral content over DC to 1 GHz band of interest. The signals have significant spectral content that may contribute to EMI, including a harmonic spaced every 55 kHz. If the radiated emissions test reveals excessive EMI, this information is useful to identify worst-case offenders.

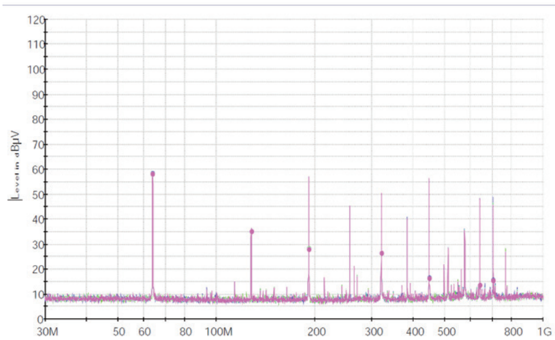
Original rectifier developed by Inovax. The company wanted to verify the device's performance by conducting a virtual EMI test.



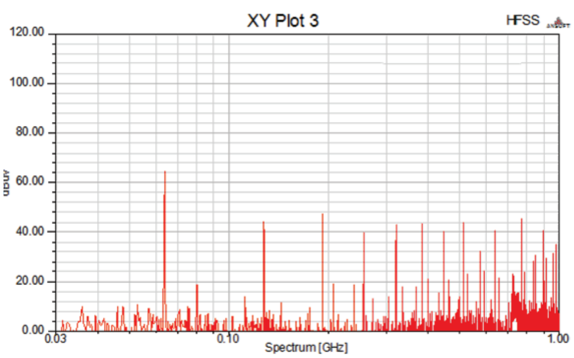
HFSS model of Inovax rectifier



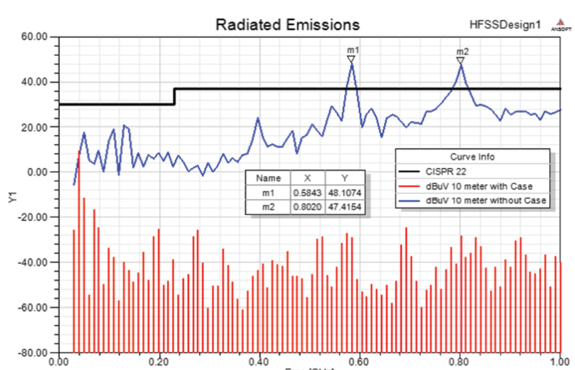
The virtual EMI chamber modeled in HFSS includes the Inovax PCB and a standard biconical measurement antenna. Simulated EMI measurement results are shown in the lower right.



Innovax measurement



HFSS simulation results of EMI compliance test



HFSS simulated radiated emissions test results of Inovax device with and without enclosure

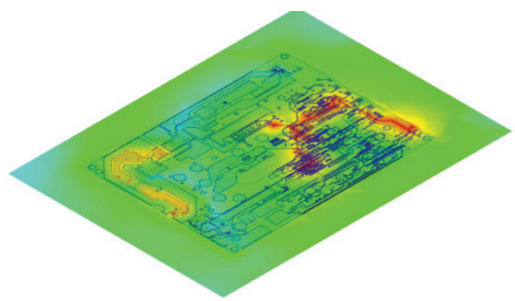
In this particular case, the full EMI chamber was modeled to measure radiated EMI. The model included the PCB, rotating table and receiving antenna. Dynamically linking this into DesignerSI required an additional output port to be added to the schematic for the receiving antenna.

In extracting the electromagnetic solution, only relevant nets were included for simulation to speed up the EM solver analysis. Ports were applied to the start and finish of each net, frequency was swept from DC to 1 GHz, and the S-parameter network was created.

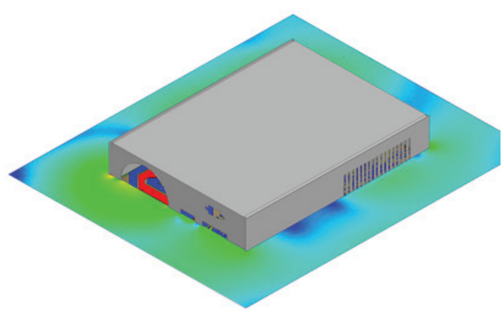
The simulated EMI measurements showed good correlation with actual measurements and revealed that the PCB exceeded radiated emission standards. One of the offending signals occurred close to 60 MHz. An HFSS field plot at that frequency revealed high field strength on a particular PCB trace. Modifying this trace or filtering the signal driving it can reduce EMI.

Upon further investigation, EMI was reduced by conditioning the signal of one of the drivers with added inductance at the output.

Earlier, it was mentioned that a mechanical housing was eventually incorporated into this design and included in the EMI measurement simulation. As can be seen from the emissions plot, this did eliminate any remaining radiated emissions concerns.



E fields without enclosure



E fields with enclosure

Summary

Predicting EMI is a complex challenge that can be addressed by conducting EMI measurement simulations early in the design process. A straightforward EMI simulation best practice is to accurately characterize electromagnetic behavior of an electronic system, simulate its performance in real time, emulate regulatory EMI emissions tests, and capture simulation results to help identify and isolate sources of interference if an EMI problem exists. Tools and enabling technologies from ANSYS help companies streamline this practice to comply with regulations as well as reduce time and costs required to diagnose and correct the problem, remanufacture the product and perform another test cycle.

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