

Verifying Electromagnetic Simulation Results with Measurements

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ABSTRACT

Whenever a new simulation tool or method is introduced into a product development process, immediately the tool is required to prove its worth before it can be trusted. Typically, this requires a reproduction of results that were originally obtained using physical measurement equipment. Proving out a simulation tool or method has challenges. The challenges include the need to engineer a test representative of the problems that the tool will need to solve but be simple enough for the results to be easily understood. Electromagnetic modeling and simulation tools are able to solve many types of problems, such as determining electromagnetic cross coupling from one conductor to another, the radiation of an electromagnetic field by a conductor, and analyzing impedance of a printed circuit board power distribution network. There are problems that arise in both measurement and modeling techniques but the two used together can overcome the weaknesses of either technique.

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INTRODUCTION

Modeling and Simulation tools have become the wave of the future. Corporations are interested in these tools because multiple product iterations can be evaluated and an optimal design can be obtained without devoting resources to building physical hardware. Researchers are drawn to modeling and simulation tools because data can be collected that is outside the capability of current measurement equipment. Today's computer technology resources allow the tools to process complicated mathematics in a reasonable time frame which makes simulation tools increasingly popular as this technology improves.

Typically, one of the first tasks for a simulation tool after being purchased is to produce answers to questions that are already known or can be easily found out through other means. Quite frequently, a simulation tool is asked to reproduce the results of measurements. Measurements are immediately trusted by many as the authority in what a correct answer should look like and have been referred to as "real world" by some to the discredit of simulation methods. Concerns about the validity of a simulation method are usually not unfounded therefore these concerns need to be addressed. When performing this sort of comparison, it should be accepted that there are pitfalls in any simulation or in any test method and in order to arrive at a correct conclusion several methods need to work together.

In the following sections case studies of verification methods are given for an electromagnetic simulation tool. This method is not exhaustive and it is required to continually verify simulations to make sure the accurate answer is given. It is important to determine how a simulation tool will be used then a test case should be designed for each application. In each case study, attempts were made to isolate the conceptual investigation to one or two principles. This avoids confusing the main contributing factors of the results.

ELECTROMAGNETIC CROSS COUPLING

Electromagnetic cross coupling (sometimes referred to as crosstalk) causes signals travelling on a transmission line, such as a wire or printed circuit board (PCB) trace, to induce the signal (now considered noise) onto nearby conductors. Electromagnetic cross coupling is difficult to quantitatively predict especially for electrically long transmission lines. Most electromagnetic simulation tools claim to calculate electromagnetic cross coupling but it is necessary to verify this function of the software in an application in which the tool will be used.

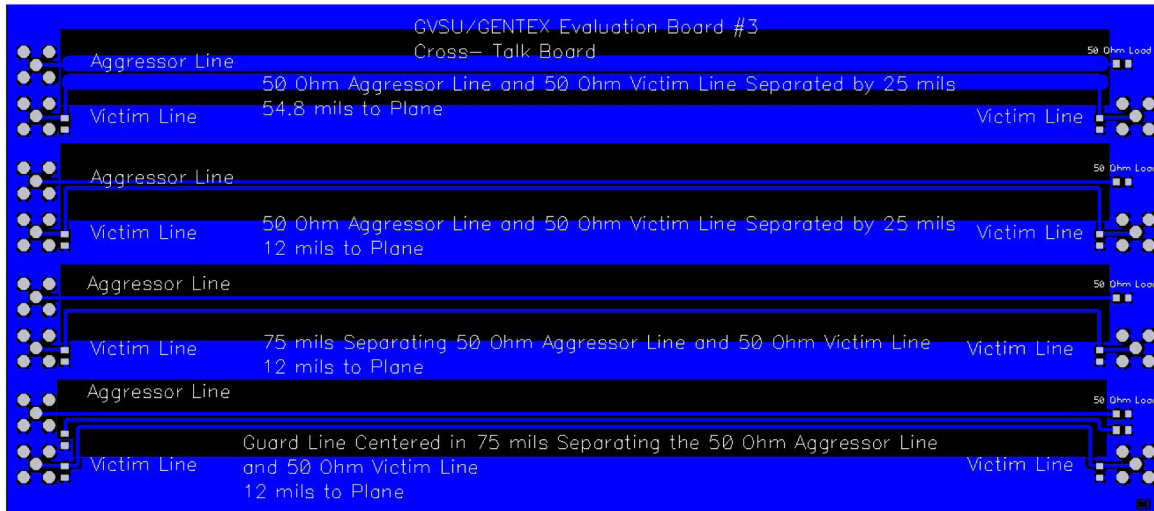


Figure 1. Electromagnetic Cross Coupling Test PCB

TEST METHODOLOGY

A simple PCB will be designed for the purposes of demonstrating electromagnetic cross coupling (see [figure 1](#)). This PCB would include examples of PCB trace configurations. In each of these examples, one of the traces (aggressor line) will be excited with a signal and the signal induced into the adjacent trace (victim line) will be measured. The frequency range of interest is 10 MHz to 1 GHz.

MEASUREMENT SETUP

The PCB was manufactured and a vector network analyzer was used to excite the aggressor trace and measure the signal on the adjacent victim trace (see [figure 2](#)). The network analyzer was set to measure S_{21} from 10 MHz to 1 GHz. The ends of the trace not connected to the network analyzer were terminated with 50Ω resistors.

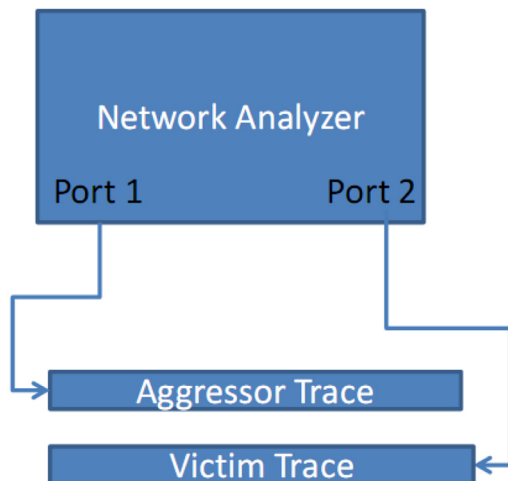


Figure 2. Electromagnetic Cross Coupling Measurement Setup

SIMULATION SETUP

A model was constructed of the test PCB (see [figure 3](#)). During the creation of this model, valuable experience in using the software tool was gained that would not have happened if the tool immediately went into use after purchase. 50Ω excitation and measurement ports were added to the model to replicate the function of the network analyzer

RESULTS

Measured and modeled results were collected for the first pair of traces and the final results are shown in [Figure 4](#). Initially the simulated results were significantly different from the measured results. After an investigation in both measured and simulated methods, it was found that there was more detail required in the model in order to achieve the correlation shown in [Figure 4](#). The results of this test showed the tool's ability to accurately model electromagnetic cross coupling in addition to providing information on the required modeling tool settings to provide an accurate representation of this phenomenon.

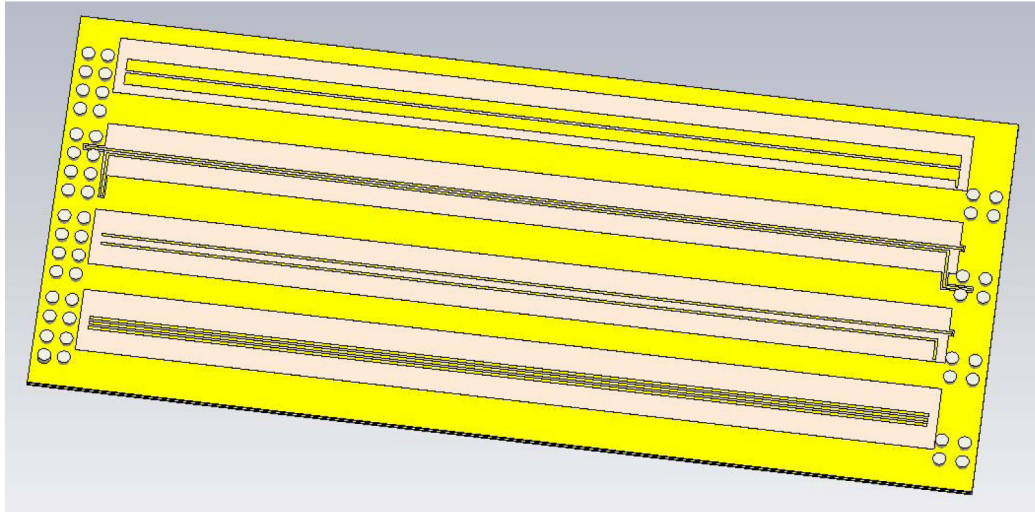


Figure 3. Electromagnetic Cross Coupling Model

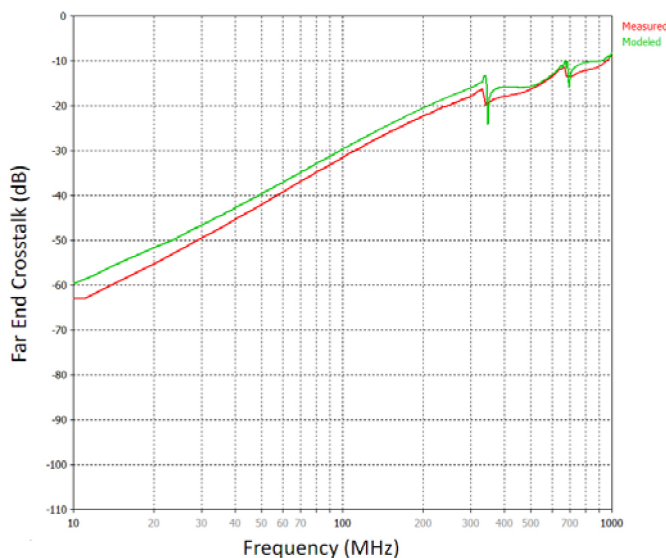


Figure 4. Electromagnetic Cross Coupling Results (top pair of traces)

ELECTROMAGNETIC RADIATION FROM A WIRE

When dealing with a large platform such as a vehicle, long wires are necessary to carry power and signals from one module to another to support various functions. Long wires pose a risk for electromagnetic emissions or immunity problems because these wires act as antennas to broadcast noise generated by a module or receive noise that may disrupt the module's functions. The behavior of long wires is difficult to predict therefore a modeling is needed to quantify the wire's effects.

The goal of this exercise is to determine the modeling tool's ability to calculate radiated electromagnetic fields when a wire is excited with a high frequency signal.

TEST METHODOLOGY

A wire will be located 5 centimeters above a copper sheet. This sheet will be connected to another conductive plane 90 centimeters below the surface of the sheet. The wire will be connected to a signal source on one end, and terminated to the sheet on the other end. The electric field at a point 1 meter away from the wire will be determined. See Figure 5 for a block drawing of the setup.

The wire would be approximately 5 meters in length. The wire was placed in a serpentine pattern to mimic a typical setup found in MIL-STD-461E test standard. In this scenario, if a straight piece of wire was used to prove out the accuracy of the model then it would be unknown if a typical test configuration (serpentine) would also correlate therefore a serpentine pattern was chosen.

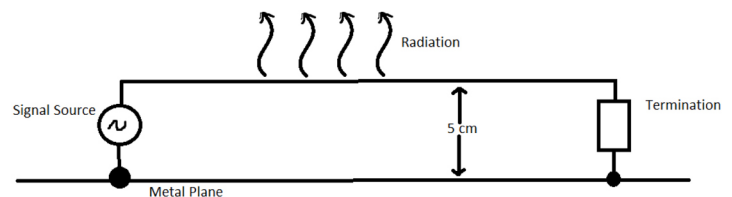


Figure 5. Electromagnetic Radiation from a Wire Setup

MEASUREMENT SETUP

The great challenge in an experiment such as this is to control the amount of variables present. A known signal needs to be applied to the wire in such a way as to not introduce high complexity to the scenario. The signal source cannot be located in the test chamber without causing additional emissions from complicated signal generating

equipment, this requires the signal source to be located outside the test chamber and the signal to be fed to the wire using cables. The cables feeding the wire should not be allowed to interact with the wire other than providing the signal to excite the wire.

A shielded coaxial cable was used to make a connection between the signal source outside the test chamber and the wire. The coaxial cable shield was directly connected to the metal plane at the point the wire was connected to the inner coax conductor (see [Figure 6](#))

Two antennas were used to measure the electric field from the wire. A 41-inch active monopole antenna was used from 1 MHz to 30 MHz and a biconical antenna was used from 30 MHz to 100 MHz. When using the monopole antenna, measurement test standards often require an electrical connection between the metal plane and the antenna counterpoise.

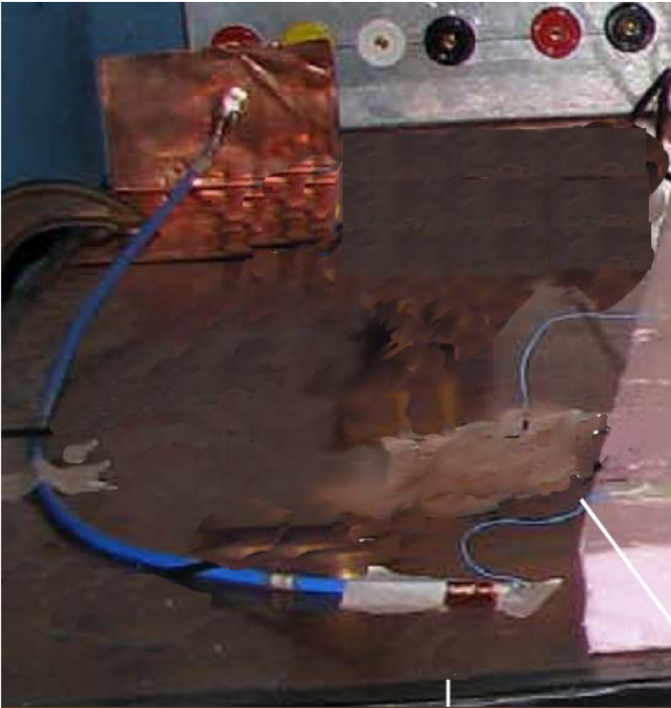


Figure 6. Wire Excitation Measurement Setup

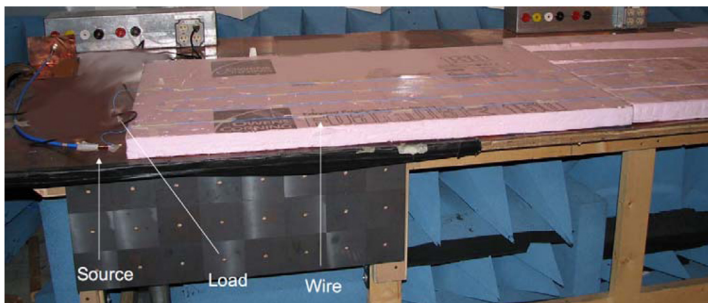


Figure 6. Wire Measurement Setup

SIMULATION SETUP

The simulation was design to mimic the measurement setup as much as possible. The wire was placed above the metal plane similar to the measurement setup (see [Figure 7](#)). An advantage of using simulation for this purpose is that sources do not take up space or cause extra emissions therefore the source can be located immediately at the point the wire starts.

The simulation tool vendor recommended to physically represent the antenna geometry in the simulation for greater accuracy. However the software also had a single point electric field monitor that will measure the field from the wire. Because the point monitor was much easier to manage than an antenna model, the point monitor was used to see if an accurate answer could be given without the extra detail. A sheet was added underneath the monitor point to mimic the counterpoise for the active monopole antenna (see [Figure 8](#)). This counterpoise was connected to the metal plane that was underneath the wire.

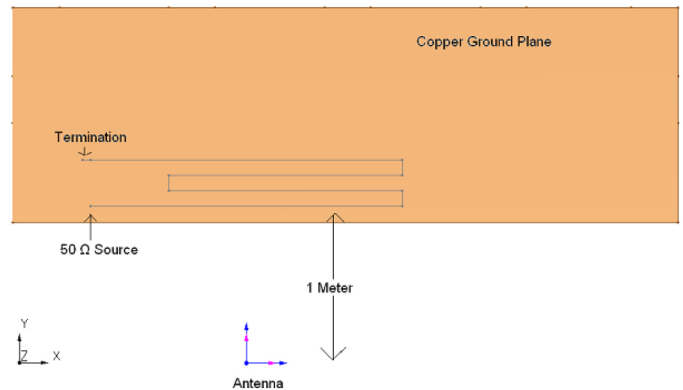


Figure 7. Wire Simulation Setup (30 MHz - 100 MHz)

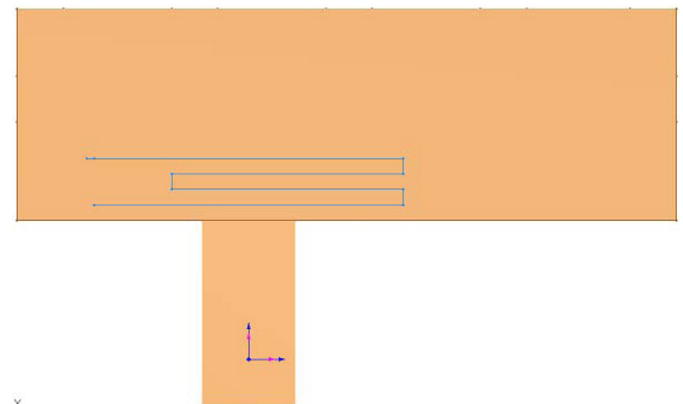


Figure 8. Wire Simulation Setup (1 MHz - 30 MHz)

RESULTS

Initial measured and simulated results are shown in [Figure 9](#). There are many frequencies that correlate well between the