Simulating the ESD Measurement for High Value Feedback

ESD Abstract

Simulating EMC performance using 3D EM modelling software in the time domain has advantages over frequency domain modelling because a wide frequency band is simulated in one run. However some phenomena like ESD, lightning strikes, EMP or other transient phenomena can only be simulated in the time domain. The TLM-TD method can be used to simulate a model of an ESD gun for analysing induced currents on wires and visualising the discharge current path on electronic equipment. The main benefit of performing an ESD simulation is that it gives results which could otherwise be difficult or even impossible to measure. It is also a very quick simulation to perform. In this paper examples of using the ESD gun simulator to mimic measurement setups and address real design problems at an early stage are presented.

Ett föredrag från E³ 2007

Introduction

Simulating EMC performance using 3D EM modelling software in the time domain has advantages over frequency domain modelling because a wide frequency band is simulated in one run. However some phenomena like ESD, lightning strikes, EMP or other transient phenomena can only be simulated in the time domain. The TLM-TD method can be used to simulate a model of an ESD gun for analysing induced currents on wires and visualising the discharge current path on electronic equipment. The main benefit of performing an ESD simulation is that it gives results which could otherwise be difficult or even impossible to measure. It is also a very quick simulation to perform. In this paper examples of using the ESD gun simulator to mimic measurement setups and address real design problems at an early stage are presented.

ESD Standards

Many different ESD standards exist. These relate to the testing of electronic products and also ensure that in ESD sensitive areas, there are safe handling procedures in place. Examples include the Human Body Model of MIL-STD-883, the Machine Model (or 'Japanese' model) of EIAJ-ED-4701-1 and, the contact and air discharges of EN 61000-4-2. In this paper, we will be concentrating on the contact discharge aspects of EN 61000-4-2.

The basic test setup for the contact discharge method in EN 61000-4-2 [1] is shown in figure 1. Here it can be seen that the equipment under test (EUT), along with any auxiliary equipment, is placed on a wooden table which is 0.8 m in height above a ground reference plane. A horizontal coupling plane of 1.6 x 0.8 m is placed on top of the table and this is connected to the ground reference plane by means of a ground strap, at both ends of which is a 470 kΩ resistor. An insulating layer is then placed on top of the horizontal coupling plane on top of which is placed the EUT. Contact discharges are then applied to the user accessible metallic parts of the EUT along with the horizontal coupling plane and the vertical coupling plane (0.5 x 0.5 m in size and connected to the ground reference plane in the same way as the horizontal reference plane).

One of the problems with the ESD standards is that while the discharge current is specified, as is the parameter which is measured when the gun is calibrated, there is no equivalent specification for the fields which are generated by the discharge. Indeed, these fields may even vary depending on the ESD gun used and how the gun is orientated to the device under test – in other words, two different test engineers performing an ESD test on the same EUT with the same ESD gun could get different results. Let us take the following real situation as an example of the impact the radiated field from the ESD event can have on the performance of the EUT. While performing ESD testing on a PC style item, discharges were being applied to the lower left of the rear panel and it was found that the presence of the cable to the auxiliary device impacted on the results. There was no noticeable impact on the EUT performance when the cable was disconnected, but with it in place, it was found that the operation of the EUT would be disturbed. By changing the cable from a standard unscreened to screened version, it was found that performance of the EUT could be maintained. As this degradation in performance would only occur with the cable present (tests were also done with the auxiliary device disconnected from the cable to ensure the device was not the cause of failure) it became clear that the field radiated from the discharge was the cause.

ESD Gun Model

Figure 2 shows a schematic representation of the ESD gun. In this, we can see that there is a mechanism for charging up a capacitor from a power source which, through the flip of a switch can then be discharged to the equipment under test.

In order to simulate the ESD event, you need to model the discharge, either by: directly enforcing the ESD current onto the structure, using a simplified model, or by using a detailed model of the ESD gun. The first of these approaches, enforcing the current, is a good method for early simple simulations. However, this approach is an approximation as it is only looking at the injected current and not the associated field. As discussed earlier, as the field generated by the gun is integral to how the ESD event couples to the EUT, this approach is therefore best used when the accuracy of the result is not the prime driver for the simulation. The third approach, that of using a detailed model of the gun, would give the best quality simulation but at the expense of having to create and include a detailed representation of

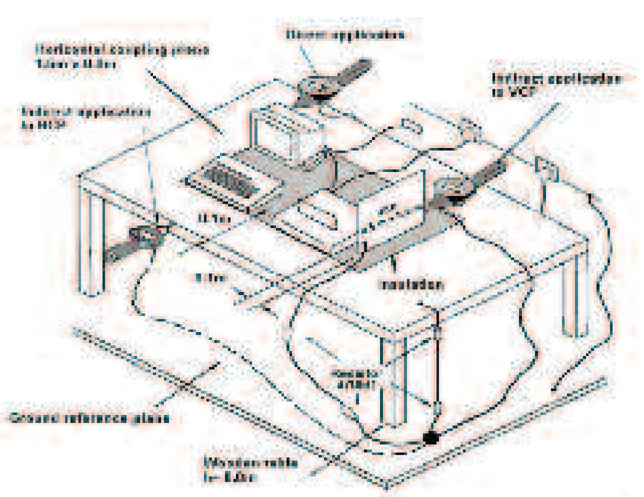

Figure 1. Typical Test Setup for ESD Testing EN 61000-4-2 Contact Discharge.

the ESD gun within the model. Hence, within the modelling environment, the second option is typically used.

It is also important to note that, as the ESD event is transitory in nature, within the modelling environment it is necessary to use a time domain based simulation algorithm such as FDTD or FIT (as used in CST MICROWAVE STUDIO®) or, as in the case of this paper, the Transmission Line Matrix (TLM) method [2] as used in the CST MICROSTRIPES 3D electromagnetic modelling tool[3].

The gun model used in this paper is derived from that in [4] in which it was shown how a fully detailed model of the ESD gun, using time dependant materials, could be developed within the FDTD method. However, the downside of this is that many time steps are required to stabilize the static field and also many cells are required to achieve the accuracy needed. Both of these lead to increased computation times. With the method used here, typical simulations can be computed within a much shorter period of time.

Within an ESD gun, there is a discharge network and, the full network and geometry can be found in [4] for the EM-Test Dito ESD gun. Figures 3 and 4 show the network and gun geometry as used in the simplified model. A step function (of approx 1ns rise time), rising from zero to the desired discharge voltage is applied to the excitation port. It is this step function, mimicking fast charging (rather than the slow charging, switching and rapidly discharging sequence in [4]) in conjunction with the discharge networks in figure 4 which allows the simplified model to be accurately used.

Examples

Once the model of the gun had been developed, a series of test and validation cases were simulated. These ranged from applying discharges to large metallic surfaces (to test the discharge waveform) through to looking at the coupling into a representative electronics enclosure. The major benefits of simulating the ESD event are that it allows designers to gain enhanced insight into how the discharge is distributed throughout the system through visualisation of the current paths and fields. At the same time, voltages and currents induced on traces and cables can also be calculated along with the fields at different points within the system. Figure 5 shows a model of a PCB board consisting of two traces. One trace stays on the top side of the PCB along it entire length, whereas the second trace switches to the bottom side and then back to the top side. The discharge is then applied to a metal face (representing the wall of an electronics enclosure) in front of the PCB. The voltages induced onto the two traces are then calculated (see figure 6) and, it can be seen that the peak voltages induced onto the trace which changes layers (0.3 V) is roughly double that of the trace which stays on the single layer (0.18 V). It is also clear that the voltage on this trace is taking longer to decay and is 'ringing' at a slightly higher frequency.

Metal Surface for Calculating the Induced Voltages on PCB Traces

As previously mentioned, one of the other key benefits is the ability to visualise the distribution of the surface current at different moments in time following the ESD event. Figure 7 shows the surface current distribution on a chassis for a server system 1, 2 and 3 ns after the ESD event. As can be seen, the distribution of current varies with time and, in this case, the standoffs for the PCB show significant current which could couple to the associated PCB boards causing disturbance of the system.

Summary

In this paper, it has been shown how it is possible to consider ESD much earlier in the electronics design process through the use of time domain based computational modelling. A model of a simplified ESD gun has been presented along with some examples of ESD modelling. One of the key benefits of modelling for ESD is the added insight gained by the designer into the distributions of field, current and induced voltages and currents due to the ESD event.

Paul Duxbury
Senior EM Engineer,
CST GmbH
paul.duxbury@cst.com

Acknowledgements

The author gratefully acknowledges the contributions from his colleague Federico Centola.

References

[1] EN 61000-4-2; Electrostatic Discharge Immunity Test
[2] "The Transmission-Line Modeling Method"; C Christopoulos; IEEE Press 1995
[3] "CST MICROSTRIPES"; CST GmbH; www.cst.com
[4] "Numerical modeling of ESD-Simulator"; Kai Wang, D Pommerenke, R Chundru; 2002 IEEE International Symposium on EMC

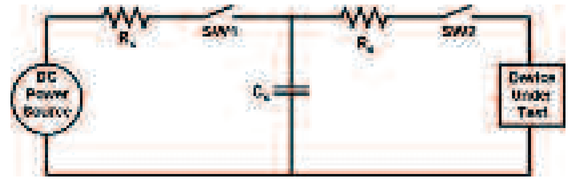

Figure 2. Schematic Representation for EN 61000-4-2 Contact Discharge.

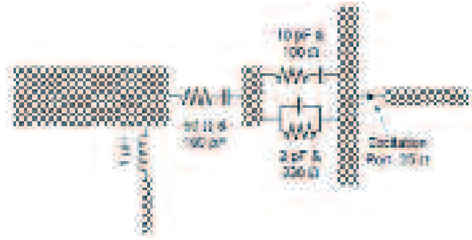

Figure 3. Discharge Network for the ESD Gun Model.

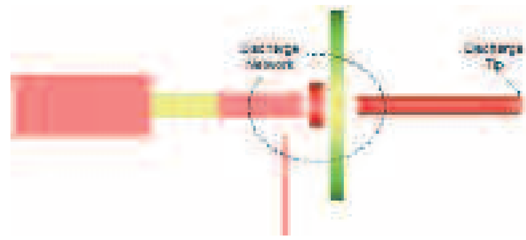

Figure 4. Geometric Representation of the ESD Gun Model.

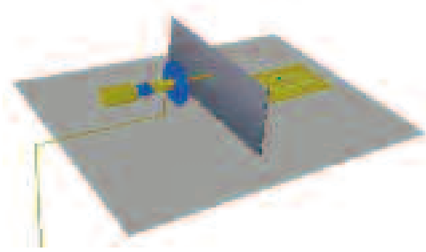

Figure 5. Model of Discharge to a Metal Surface for Calculating the Induced Voltages on PCB Traces.

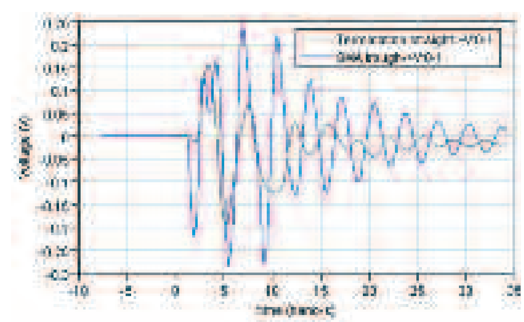

Figure 6. Induced Voltages into the Two Traces.

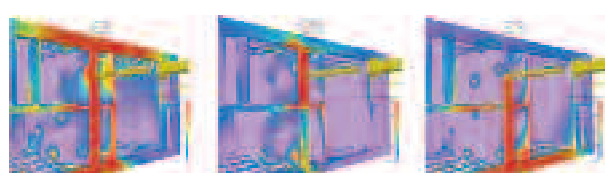

Figure 7. Surface Current Distribution on a Server Chassis 1, 2 and 3 nS After the ESD Event.