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ESD Current Spread Measurement Using Mesh Structure

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Abstract— **If a PCB is struck by an ESD the injected current spreads throughout the PCB and returns via attached cables. During the current spread a variety of effects occur: The current spreads on the main ground and power planes, couples into traces and IC lead-frames and bond wires. Further, the PCB and the attached cables can form resonators causing ringing at their natural resonance frequencies.**

Understanding the current spread onto a PCB, best, also onto the traces is of great importance for gaining insight into ESD related problems on products.

A test setup has been created that allows capturing and quantifying the spreading current. It is a mesh like structure above a ground plane. The current in each trace of the mesh can be measured via the magnetic field allowing to analyze the magnitude of the current for complete mesh or slotted mesh structures.

Additionally, Current-probe was designed though the process of measuring the current waveform.

I. INTRODUCTION

The structure of PCBs is complex, making it difficult to predict either by measurement or simulation how the current spreads after an ESD event. If there is only a single trace close to the probe the measurement is greatly simplified. Instead of using a full plane, the propagation (amplitude and timing) of current can be analyzed by substituting the plane by a mesh structure. The complexity of the mesh is such that a numerical analysis is relatively simple. To understand how the ESD waveform alters when the structure of the PCB is changed, a slot was placed in the middle of the mesh-structure. The slot will reduce the currents in areas behind it, thus provide a "shield" against the spreading current.

The novelty of this paper is the current spread analysis using a mesh structure and the design of probes to capture the trace current while suppressing the ground plane's common mode current's magnetic field.

II. CURRENT-WAVE MEASUREMENT

When an ESD pulse is injected into the mesh, the current propagates along the mesh causing magnetic fields around the mesh traces. Those can be captured using a loop like current probe. This measured data can be then translated into the current wave form through integration and scaling by the mutual-inductance between the trace and the probe. This measurement setting is shown in Fig. 1.
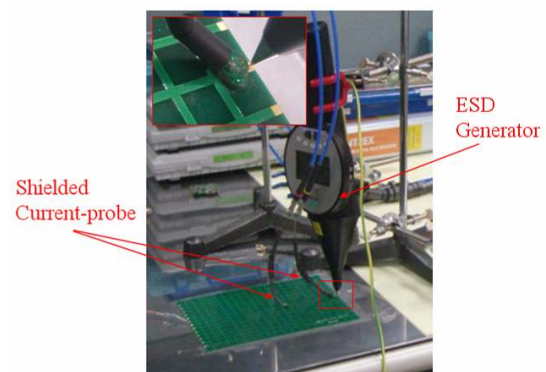

Fig. 1. Set-up for current measurement

The oscilloscope captures the voltage induced in the probe Fig. 2 through integration the current waveform shown in Fig. 3 is obtained.
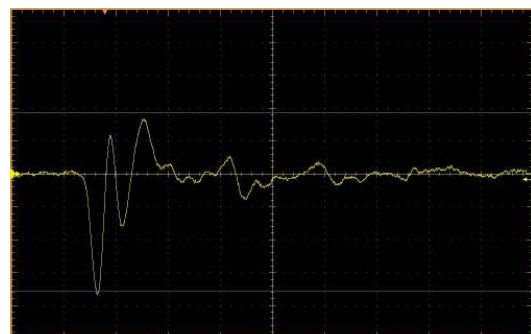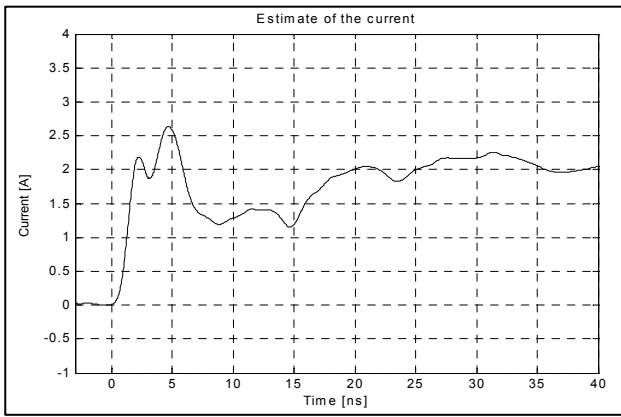

Fig. 2. Waveform through current-probe

Fig. 3. Estimate of the current from the measured waveform

The setting of ESD generator is 1000V. Current is only 2.5A and somewhat differ from IEC waveform. A partial distortion of the ESD current can be seen. This distortion is a result of reflections in the mesh structure and the finite size board.

Measuring S-Parameter that characterized the coupling between the current-probe and the trace allows obtaining the mutual inductance. C is the parasitic-capacitance and M is the mutual-inductance. Fig. 4 shows the measurement setting for the S-Parameter and Fig. 5 presents the result.

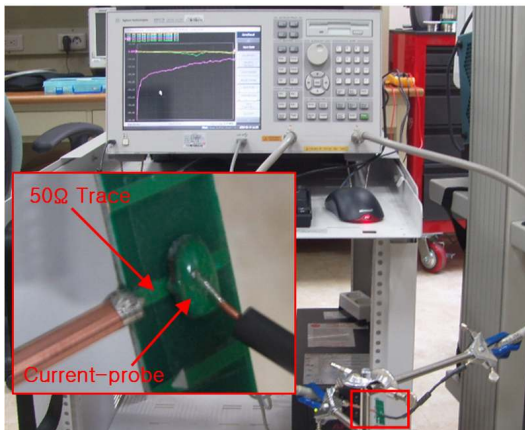$$\left|S_{21}\right| = 40 \cdot \log_{10}(2\pi \cdot f \cdot \sqrt{MC})$$

Fig. 4. S-Parameter measurement between Trace and Current-probe

Capacitance is approximately 2pF, and mutual-inductance is about 2nH. It was also simulated using CST-MWS. Fig. 6 displays the 3D-model of Current-probe and Fig. 7 is result.
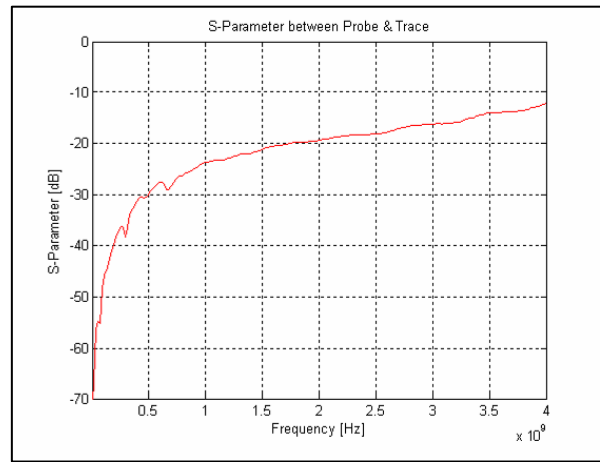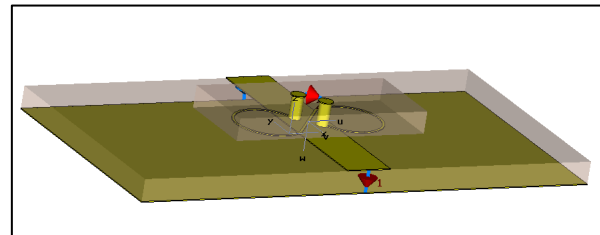

Fig. 5. S-Parameter plot

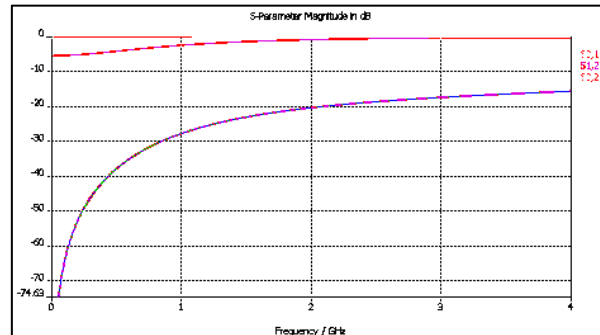Fig. 6. Model of the trace and current-probe

Fig. 7. The result of simulation

III. ESD ANALYSIS THROUGH CURRENT-WAVE

Injecting an ESD to the mesh structure, the current-wave can be plotted as shown below:
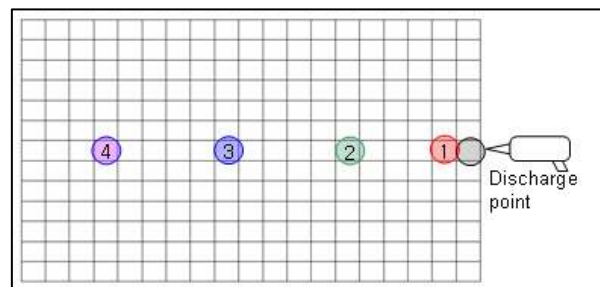

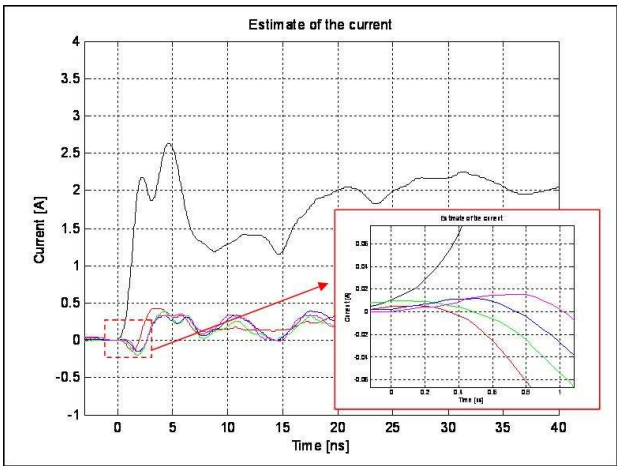Fig. 8. The current measurement location for mesh structure

Fig. 9. Current estimation plot at every measurement point

Fig. 8 shows the measurement points and Fig. 9 plots the captured current-wave at the indicted positions. Through this measurement setting specific image that ESD flows like echo, timing and peak-current can be seen.

IV. CURRENT PLOT IN EVERY LOCATION OF THE MESH

The current measurement on the mesh is one of many indicators for the ESD stress a device experiences. For example the magnetic field caused by the current density will induced, via its time derivative, voltages into traces, leadframs and bond wires. Thus, knowing the current density distribution provides insight into the likelihood of an ESD problem for different PCB locations. Fig. 10 displays peak-current distribution in the basic mesh structure. Fig. 11 and Fig. 12 display the peak-current distribution for the modified mesh having a slot. If a slot is added the over all peak-current in the mesh with slot are higher than the peak currents in the basic mesh. Especially, relatively high current sections are found nearby the slots.
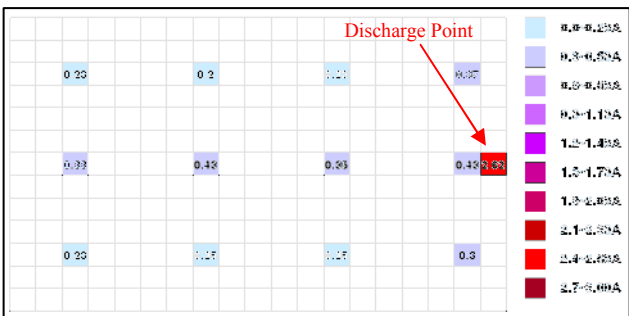

Fig. 10. Peak-current plot for relevant mesh-plane
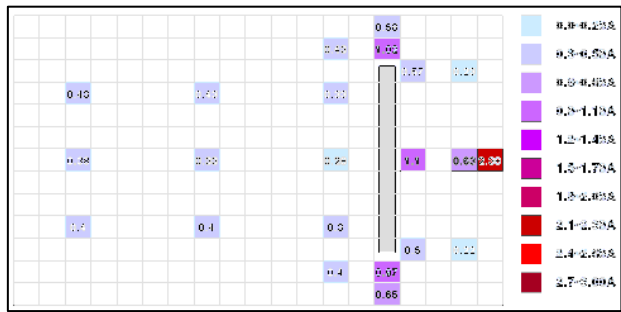

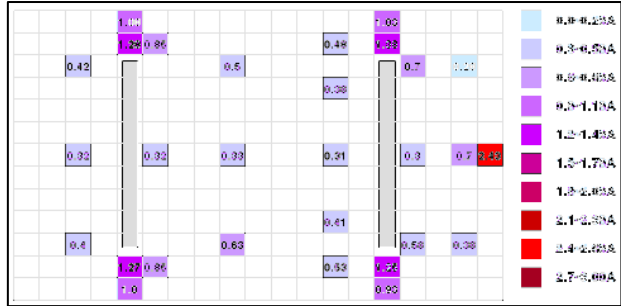Fig. 11. Peak-current-map for mesh with additional one slot

Fig. 12. Peak-current-map for additional two slot

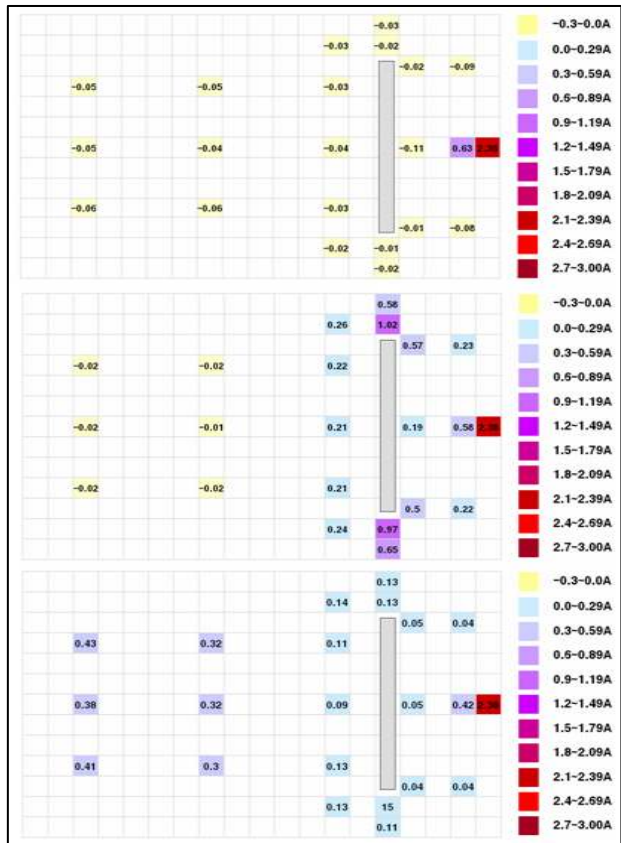To see the distribution of H-Field magnitude of current has been plotted at 1nsec, 3nsec, 5nsec.

Fig. 13. Current plot: 1nsec, 3nsec, 5nsec

To further verify the measurement method a simulation has been performed with ESD-Generator through CST-MWS [4], [6]. The result of the simulation for the mesh with additional one slot is shown in Fig. 14. It expresses the distribution of H-Field and timing.
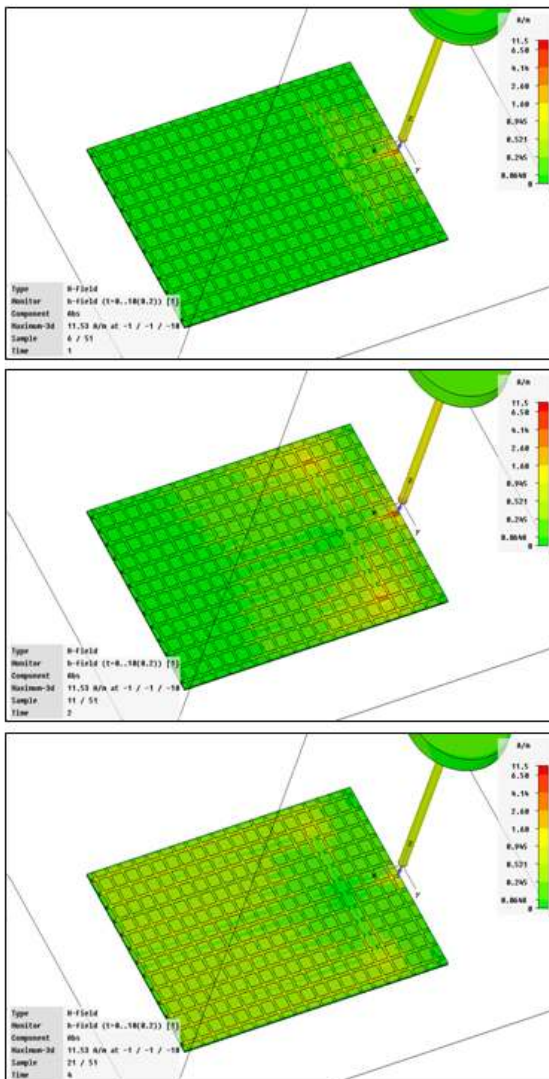

Fig. 14. Simulation using CST-MWS

V. CONCLUSION

The mesh structure is used as a tool for better understanding phenomena of the spreading of ESD currents throughout a PCB. And, a probe to measure the current flowing on traces in the mesh is designed. Using this probe, the current map can be plotted at specific time. So far the data has been analyzed by the peak current value at different locations. These can be used to analyze the effects of different structure of PCB. The method will be further extended to analyze the timing and spectral components at different locations.

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