2010 Asia-Pacific International Symposium on Electromagnetic Compatibility, April 12 - 16, 2010, Beijing, China

Near Field Probe for Detecting Resonances in EMC Application

Jiang Xiao#1, Dazhao Liu#2, David Pommerenke#3, Wei Huang#4, Peng Shao #5, Xiang Li#6, Jin Min*7, Giorgi Muchaidze*8

EMC Lab, Missouri University of Science and Technology, Rolla, MO, 65401 USA
1 Xiaoj@mst.edu, 2 dlhbf@mst.edu, 3 davidjp@ mst.edu, 4 wh57f@ mst.edu, 5 psrg8@ mst.edu, 6 xlcn3@ mst.edu

* Amber Precision Instruments, Santa Clara, CA 95054 USA
7 Jinmin@amberpi.com, 8 giorgi@amberpi.com

***Abstract*— Resonances degrade the product's EMI or immunity performance at resonance frequencies. Near field scanning techniques, like EMI scanning or susceptibility scanning determine the local behaviour, but fail to connect the local behaviour to the system level behaviour. Resonating structures form part of the coupling paths, i.e., identifying them will aid in understanding system level behaviour of products. In this article, a near field probe (patent pending) is proposed to detecting the resonances frequencies, locations or resonating structures and their Q-factors. The probe is suitable for integration into an automatic scanning system for analysing resonances of PCBs, cables, structural elements etc. The mechanism of the probe has been verified with full wave tools (CST MWS and Ansoft HFSS). Two samples of application are presented.**

I. Introduction

Resonances in products are caused by the circuit topology and by the geometry of structural elements, cables, etc. They can form lumped (L-C) element resonators or they can be of distributed nature. Resonances may be caused by IC interconnect, traces, cable placement and structural elements of a system [1][2]. It has been observed that radiated immunity failures usually occur in relatively narrow frequency bands. This cannot be explained with broadband, simple (like inductive) coupling mechanisms. Instead coupling from resonances must be considered. The resonating structures can also form antennas and couple to the far field, consequently increase the EMI.

Some methods for detecting resonances are known. Firstly, a S11 measurement method injects RF energy to a probe and measures the signal reflected returning from the probe. If the probe is able to couple to a resonating structure, a dip in the S11 will be observed at the resonance frequencies. This method has been known for at least 90 years (grid dipper). The depth of the dip is sensitive to the coupling to the resonating object, and making it difficult to implement this method in an automated scanner. The second method uses two orthogonal probes. They are decoupled from each other. A VNA (Vector Network Analyzer) measures S21 which expresses the coupling between the two probes [3]. The third method uses a far field antenna driven by a VNA to illuminate the DUT (Device Under Testing) and measures the excited local magnetic (or electric) field using probes [1][2]. This method will only excite the resonances that can be excited by the far field. The near field excitation will also excite resonances that are locally excitable. Besides these three methods, a newly designed resonance detection probe that integrates an electrically small cone structure with a shielded magnetic field loop is proposed in this paper. Full wave simulation based on CST MWS [6] and Ansoft HFSS [7] and measurement results are shown and results of resonance scanning are presented.

II. Description of the Probe Geometry

Two probes have been designed that differ in the plane the loop is mounted, shown in Figure 1 and Figure 2.

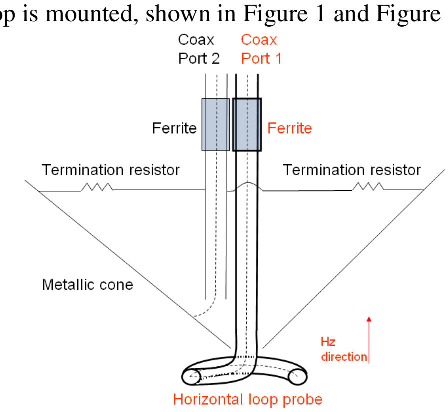

Figure 1: Proposed structure 1 of the resonance probe

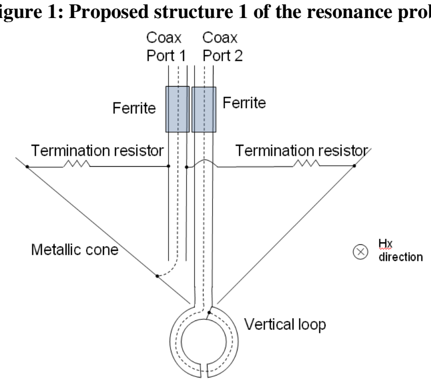

Figure 2: Proposed structure 2 of the resonance probe

Figure 1 shows the main parts of the probes: The small shielded horizontal loop and the cone. The coax cables are connected to the VNA . Figure 2 shows the second design and it uses a vertically mounted shielded loop.

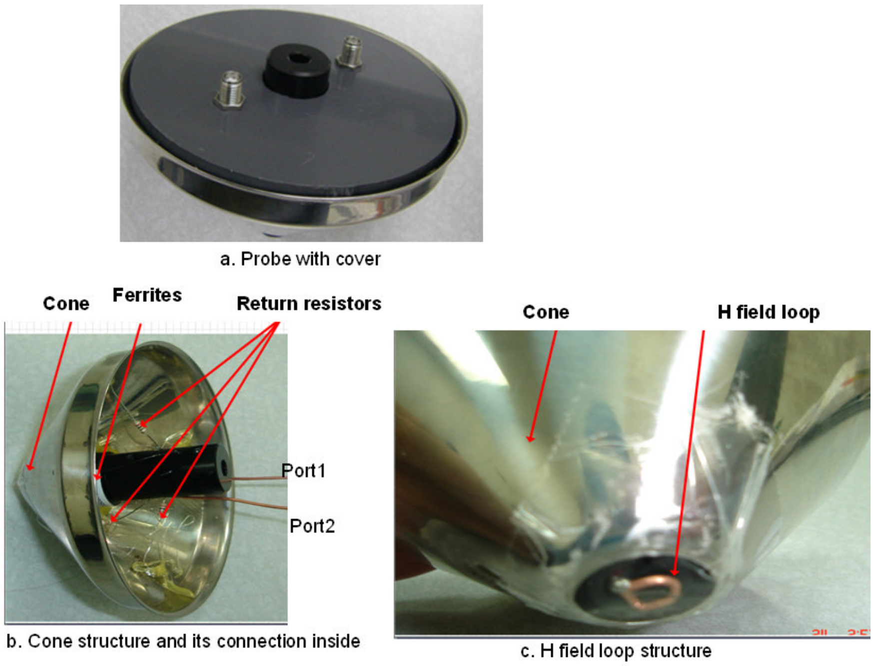

Figure 3: Detailed structure of a real resonance probe (structure 1)

Details are shown in Figure 3. A semi-rigid cable forms the shielded loop. A gap in the shield allows the magnetic field to couple. The inner conductor of the second coaxial cable connects to the lower part of the cone structure. This excites the cone in its inner side.

III. MECHANISM OF RESONANCE DETECTION

The loop forms an H-field sensor. The cone structure is more complex. It is excited on its inside. To better understand its functions, full wave simulation was used in CST MWS. Field probes are placed underneath the cone, while the cone is placed above a large ground plane. Figure 4 shows the geometry. Results of the E-field divided by 377 and the magnetic field are shown in Figure 5. The E-field dominates the coupling.

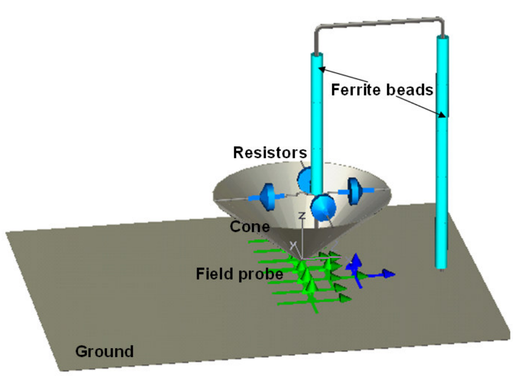

Figure 4: Cone structure above PEC in CST

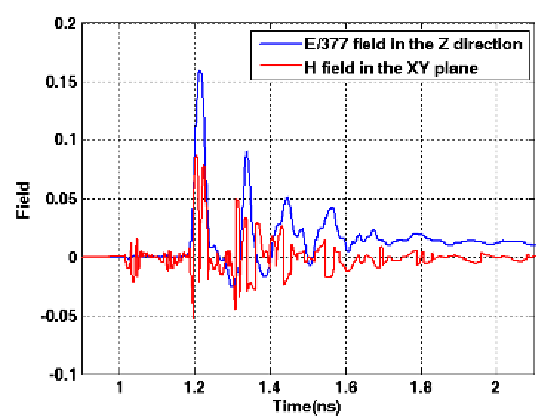

Figure 5: Comparison of the E-field (divided by 377) and the H field underneath the cone

The resonance scanning probe contains both the cone and the loop sensor. An S21 measurement is used to identify resonances. If no resonating structure is present the S21 value needs to be as low as possible, allowing the S21 to rise if resonating structures are detected. Figure 6 shows the full wave model in HFSS. Simulation and measurement results are compared in Figure 7. They match well.

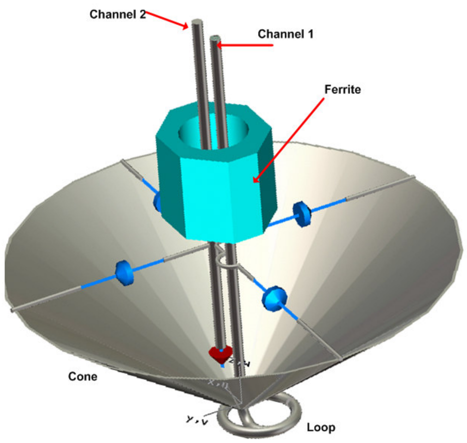

Figure 6: Full wave simulation model of the complete probe

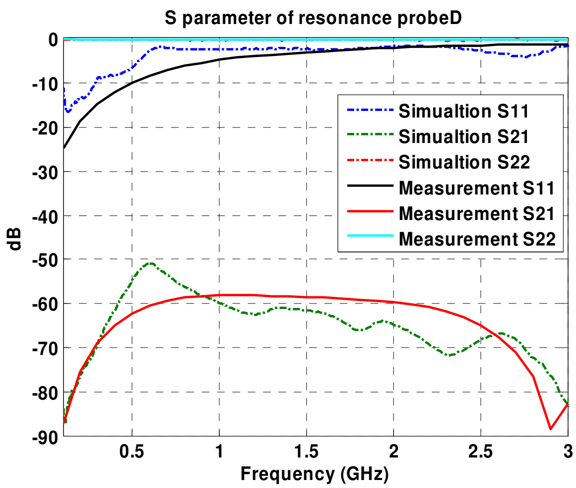

Figure 7: S parameter comparison

IV. SAMPLES OF RESONANCE DETECTION

Test samples have been scanned to identify resonant structures, frequencies and Q-factors. Two sample structures are shown below. Sample 1 is a test structure containing a ring structure with microstrip traces. Sample 2 is the commercial product.

Sample 1: Simple Resonance Structure

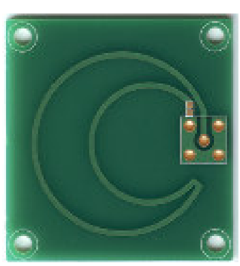

Figure 8: Ring structure with microstrip traces

Figure 8 shows the ring structure with microstrip traces. In Figure 9, scan results are overlaid with a photo of the test sample. This data presentation does not distinguish between different resonant frequencies. The color indicates the magnitude S21 of the resonances. The resonance shows strongly at the first resonance frequency is around 240 MHz.

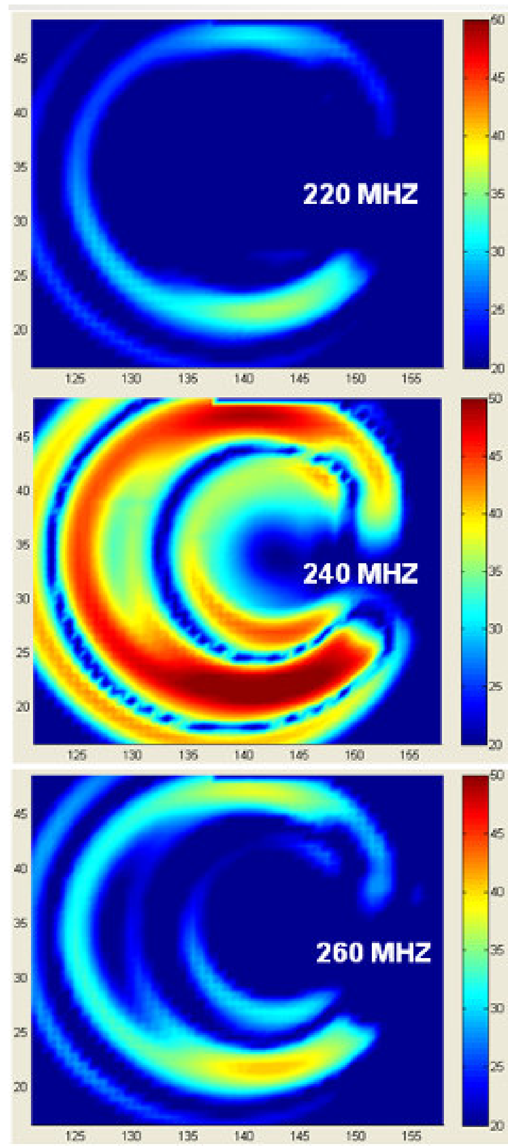

Figure 9: Resonance scanning result of the first test structure

The results show that the resonance is correctly detected. Also the probe doesn't need to rotate by 90 degree to measure the H-field over the DUT due to its symmetry. One disadvantage is that right over the middle of the trace the field component detected (Hy) has a null. However this disadvantage can be solved by applying a deconvolution algorithm in data post-processing.

Sample2: Electronics product: computer

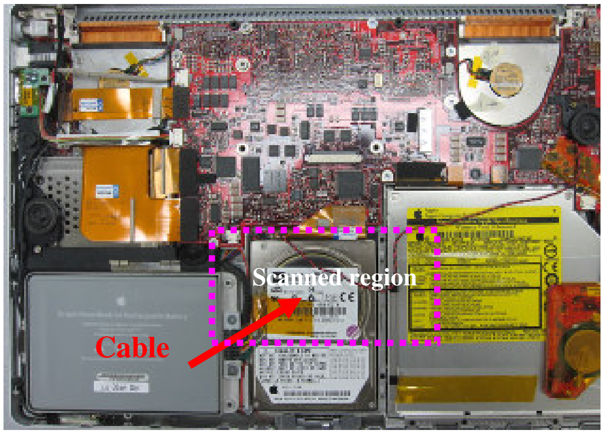

Figure 10: Resonance detection sample for the electronics product

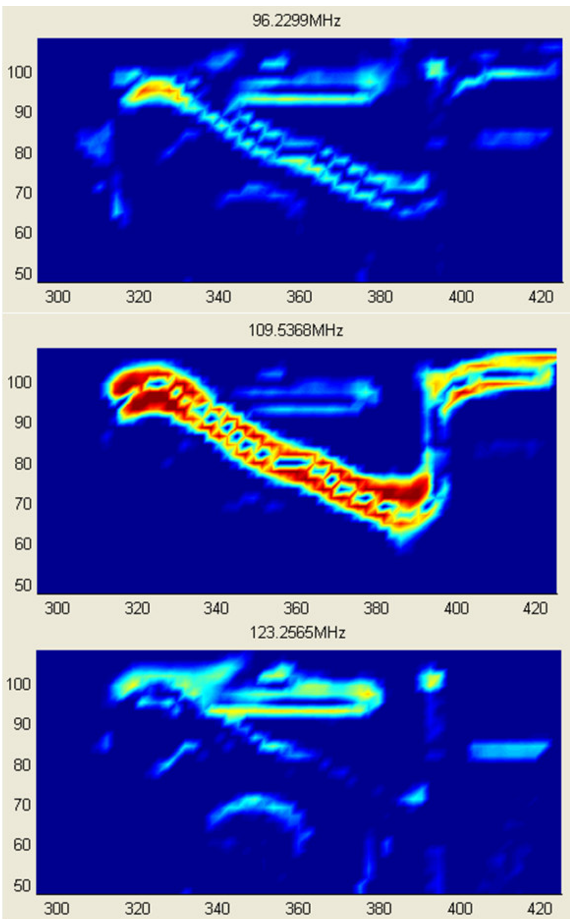

Figure 11: Scan magnitude results for the DUT at 96.2, 109.5 and 123.2 MHz showing the resonance of the cable

The methodology was applied to scan the motherboard of a computer, shown in Figure 10. It clearly reveals the cable resonance around 109 MHz shown in Figure 11.

V. CONCLUSIONS

Resonances increase the coupling from the field to the circuits, then cause decrease the immunity and enhance the emission of system. They are often the "missing link" between system level performance and local level. Therefore, identifying resonances is an important step in understanding immunity sensitivities or emission maxima. This paper presents a method for detecting resonance in the PCBs, ICs, and components. The product is scanned by an auto-scanning system (Smartscan) [8] and resonances are detected via S21 measurement.

VI. REFERENCES

[1] D. Liu, J. Xiao, W. Huang, G. Muchaidze, J. Min, P. Shao, J. Drewniak and D. Pommerenke, “Near field resonance scanning as a method for analyzing coupling for ESD and radiated immunity”. EMC Compo 2009, France (accepted).

[2] G. Muchaidze, W. Huang, J. Min, P. Shao, J. Drewniak and D. Pommerenke, “Automated Near-Field Scanning to Identify Resonances, ” *Electromagnetic Compatibility - EMC Europe, 2008 International Symposium on,* pp. 1-5, Sept. 2008.

[3] Tun Li, Yong Cheh Ho, David Pommerenke, “Orthogonal loops probe design and characterization for near-field measurement,” IEEE EMC Symp. Detroit , PP:1 – 4, 18-22 Aug. 2008.

[4] J. Koo, Q. Cai, K. Wang, J. Mass, M. Hirata, A. Martwick, D. Pommerenke “Correlation between EUT failure levels and ESD Generator paramters,” *IEEE Trans. Electromagn. Compat*., vol.50, no.4, pp. 794–801,Nov. 2008

[5] G. Muchaidze, J. Koo, Q. Cai, T. Li, L. Han, A. Martwick, K. Wang, J. Min, J. Drewniak, D. Pommerenke, “Susceptibility Scanning as a Failure Analysis Tool for System-Level Electrostatic Discharge (ESD) Problems,” *IEEE Trans. Electromagn. Compat*., vol.50, no.2, pp. 268–281, May. 2008.

[6] CST MWS software. MWS created by CST Software. CST Software, Darmstadt, Germany. [Online]. Available: www. CST.com

[7] HFSS software. HFSS created by Ansoft Software. Ansoft Software, Pittsburgh, PA. [Online]. Available: www. Ansoft.com

[8]Smartscan www.amberpi.com. Amber Precision Instruments, jinmin@amberpi.com