Using a LISN as an Electronic System EMC Diagnostic Tool

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Most EMC engineers consider a Line Impedance Stabilization Network (LISN) to be a device that presents the ac power line of the equipment under test (EUT) with a precise impedance over a designated frequency range. This is the required function of a LISN. A LISN can also be used as a diagnostic tool to evaluate an electronic system electromagnetic emission (EME) design, especially in the area of grounding.

When a LISN is connected to an electronic system it becomes a window through which many EMC problems of the system can be examined. Every electronic system has natural resonances that occur in the conducted emission profile. These resonances are broadband in nature when observed with a spectrum analyzer and occur between 2 and 100 MHz. Since the upper frequency range of these resonances is 100 MHz, a LISN with an upper frequency limit of 100 MHz and a 50 Ω impedance should be used. Refer to Fig. 1 for the impedance curve of the EMCO Model 3825 LISN. The resonances are caused by the data rates of circuit boards, impedances mismatches, internal harnesses and poor grounding practices.

Using a 100 MHz LISN to monitor conducted emissions is important because conducted emission testing is more consistent and repeatable than radiated emission testing. This takes one more variable out of the design troubleshooting cycle. When these resonances are reduced in the conducted emission profile, the corresponding frequencies in the radiated profile will also be reduced. These resonances are like a fingerprint of an electronic system; that is, they occur at the same frequency and look the same for a particular electronic system.

The test setup was in accordance with FCC OST/MP-4 for measuring conducted and radiated emissions. The test equipment used was a Hewlett-Packard Model 8568A spectrum analyzer, an Electro-Mechanics Co. (EMCO) Model 3825 LISN and a personal computer (uncertified FCC Class B) with a keyboard, monochrome monitor, 5 1/4 inch double-sided floppy disk, a 10 MB hard disk drive and 256 kB of RAM. The personal computer served as the EUT.

The data in Fig. 2 shows what the natural resonances look like in the RF spectrum for the personal computer used in this test. Also, Fig. 2 shows the conducted emission scan of the fully configured, uncertified, Class B personal computer.

There are two ways of troubleshooting an electronic system. One way is to start with a fully configured system and try to eliminate the emissions that are above the specification, and the other is to start with a minimum configuration and try to solve each problem as each piece of hardware is added. The latter approach is the one used here. Instead of looking at the emissions in general that are over specification, emphasis is placed on eliminating the resonances when each piece of hardware is added.

The test was started with the frame and cover set, the processor circuit board and the switching power supply. Figure 3 shows the initial scan plot for the conducted emission profile. Notice that there are resonances at 14.35 MHz and 71.38 MHz. The 14.35 MHz resonance was caused by a resistor connected from the top of the 14.35 MHz crystal package and to one leg of the crystal. This resistor was added after the fact. The 14.35 MHz clock may have had trouble starting on power-up. Since the crystal package was connected to the dc ground of the processor motherboard, the resistor was connected to the dc ground at another location, away from the crystal. This eliminated the resonance. The 71.38 MHz resonance was caused by the motherboard ground plane not be-

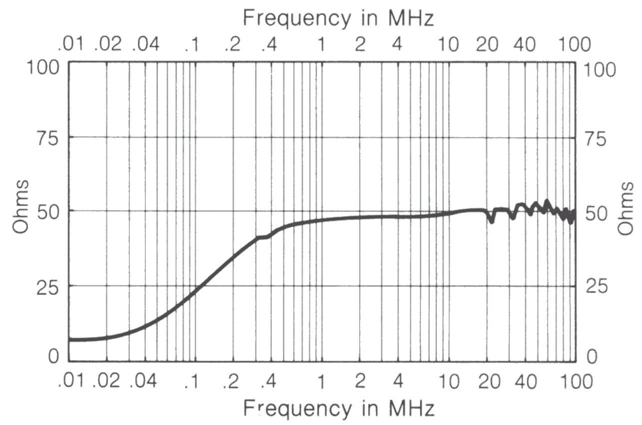

Figure 1—Characteristic Impedance of LISN Model 3825/2R Serial #1165 Line #1

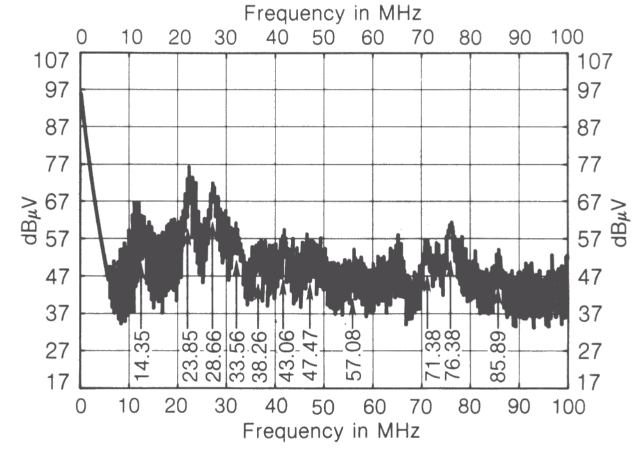

Figure 2—Conducted Emissions of the Fully Configured, Class B Personal Computer

ing connected to the chassis frame. A screw was placed through a plated-through circuit board mounting hole to chassis ground. This connection tied the motherboard dc ground plane directly to chassis ground, eliminating the resonance. Figure 4 shows the removal of the 14.35 and 71.38 MHz resonances.

Next, a floppy disk drive, hard disk drive and the disk drive controller circuit board were added to the system. The controller circuit board had a ground plane that was capacitively coupled to the chassis at the connector plate. No resonances were added because of these subassemblies.

A memory circuit board was added to one of the expansion slots of the motherboard, which included an RS-232-C ribbon cable to an external port. This circuit board caused resonances at 14.35 MHz and 85.89 MHz. This circuit board had no ground plane and no capacitive reference from circuit board dc ground to chassis ground. These resonances were removed by adding a 0.1 μF capacitor between circuit board dc ground and chassis ground and by shielding the RS-232-C ribbon cable internal to the EUT.

A video circuit board was added to one of the expansion slots, but without a monitor. This video board had no dc ground plane. The dc ground was referenced directly to chassis ground via the connector plate. Resonances appeared at 14.35 MHz, 71.38 MHz and 85.89 MHz. It seems like these same resonances are easily excited. Providing a ground plane for the video board eliminated the resonances.

Next, a monochrome CRT (monitor) was connected to the video board, and a keyboard was connected to the system. For the keyboard, the resonances were removed from the RF spectrum by connecting the keyboard cable shield in a low-impedance manner at both ends (without pigtails). This was done by disconnecting the shield drain wire and connecting the braid shield 360° in a metal connector shell on the processor end and using an aluminum p-clamp on the keyboard end. Also, dc ground and keyboard chassis ground were referenced through a 0.1 μF capacitor. The CRT cable shield was terminated in the same way as the keyboard cable. Also, a ferrite block was used in the CRT video circuit wire harness internal to the CRT. Again, a 0.1 μF capacitor was used to reference CRT dc ground to CRT chassis ground. This eliminated the resonances excited by connecting the CRT. The process of removing the resonances is called RF stabilization.[1]

The final check to verify removal of the resonances was to perform radiated emission scans. The site attenuation data for this site was on file with the FCC. Since this EUT was a Class B device, the radiated testing was done at 3 m. Horizontal scans from 2 to 100 MHz showed no significant emissions. Even raising the antenna from 1 to 4 m in height showed no significant emissions. A vertical polarization of 1 m appeared to be the worst case for the radiated emissions for this EUT. Even though the test setup was in accordance with FCC OST/MP-4, the actual testing was not. The bandwidth and detector functions were changed to allow observation of broadband resonances in the frequency range from 2 to 100 MHz. The purpose of this testing was to perform relative diagnostic testing to verify removal of resonances that were found in the conducted and radiated emission profile. Figure 5 shows the radiated emission scan for the fully configured EUT **with** emission solutions. The emissions were identified by rotating the EUT and turning the power of the EUT on and off. It can be seen in the radiated emission profile of the EUT **without** emission solutions in Fig. 6 that the resonances that are present and the frequencies of those resonances correspond to the frequencies of the resonances found in the conducted emission profile of Fig. 2, with the exception of 38.26 MHz and 76.38 MHz. These two frequencies were present and stronger on the opposite side of the personal computer. As in any open-field site radiated testing, ambients were a problem; this is obvious in Figs. 5 and 6. Masking of the radiated emissions by ambients occurred at 14.35 MHz, 23.85 MHz, 71.38 MHz and 85.89 MHz, as shown in Fig. 6.

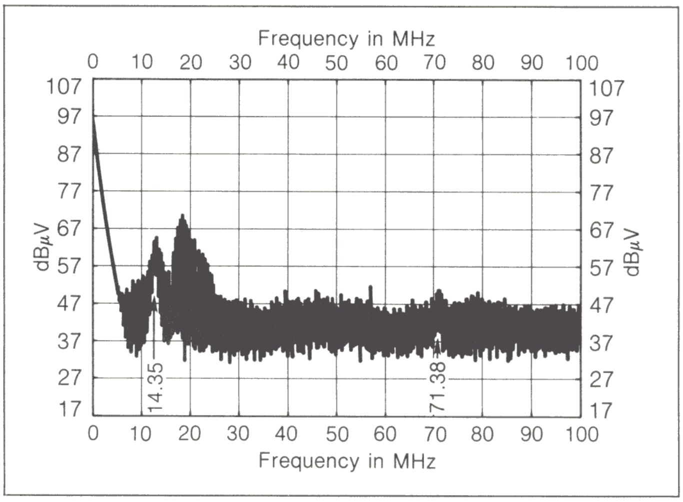

Figure 3—Initial Scan Plot for the Conducted Emission Profile

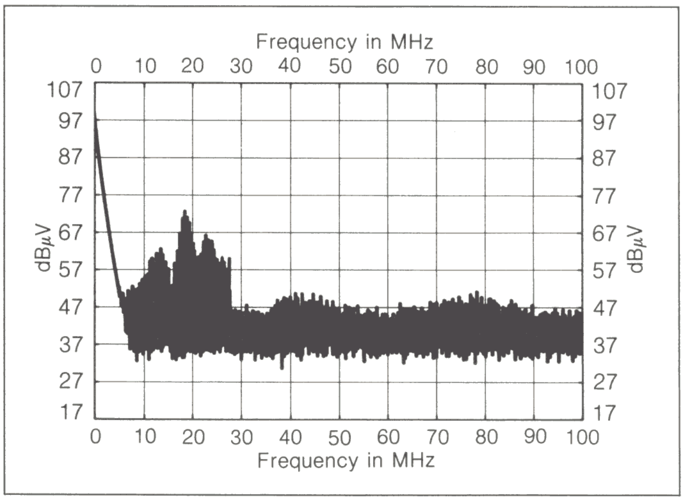

Figure 4—Conducted Emissions after the Removal of the 14.35 and 71.38 MHz Resonances

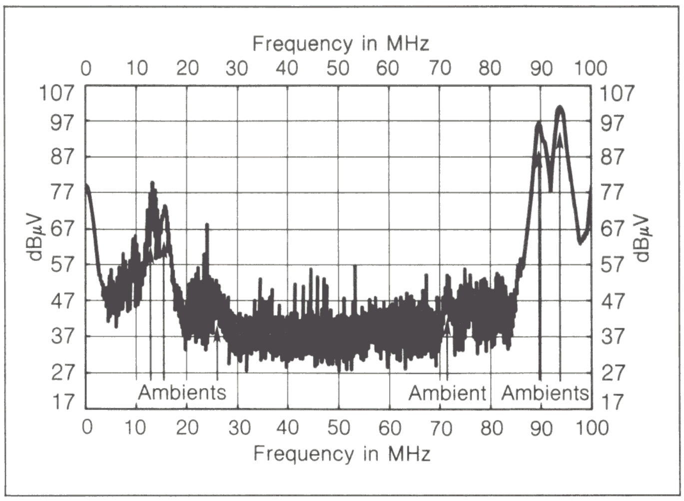

Figure 5—Radiated Emissions of EUT with Emission Solutions (20 dB Preamp Used)

Two frequencies were present in the radiated emission scan of Fig. 6 that were not present in the conducted emission scan of Fig. 2. These two new frequencies were due to keyboard and CRT external cable placement.

Different combinations of hardware will cause resonances at different frequencies. To determine which resonances are caused by which hardware combinations, careful testing must be done. By providing emission solutions for the three resonant frequencies, the other eight resonant frequencies were not formed. Final certification testing showed the EUT to pass FCC Class B radiated and conducted emission limits with an 8 to 10 dB margin.

References

1. D. Staggs, "RF Stabilization," *1986 EMC Symposium Record*, 1986, pp. 383-86.

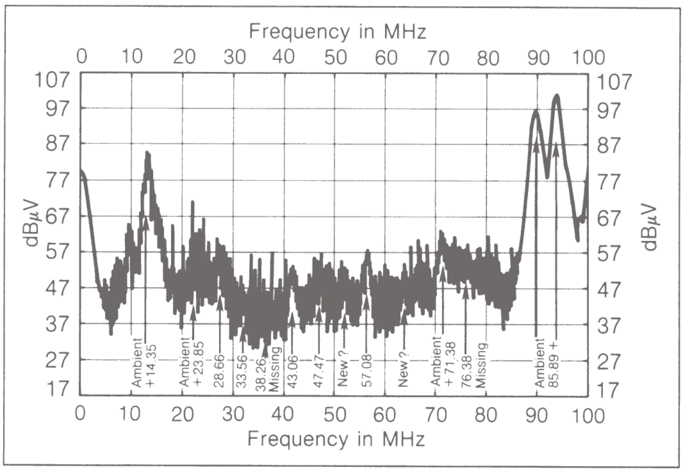

Figure 6—Radiated Emissions of EUT without Emission Solutions (20 dB Preamp Used)

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