SESSION 6C

UNSPECIFIED LISN PARAMETERS CAN CAUSE EMISSIONS TO APPEAR GREATER THAN 10dB HIGH

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Abstract

The purpose of this paper is to summarize our findings when testing two different products using FCC/VDE LISNs from several manufacturers. The initial problem, inconsistent measurement of emissions, was noted on one UUT; while measurement of emissions on another UUT were consistent. Modifying the grounding of LISN VA #2 allowed us to achieve more reproducible measurements compared to LISNs VC or VD which meet the impedance specifications and had a low internal ground impedance.

The vendor numbering scheme is used to maintain anonymity.

Introduction

In the past several months one of our products has demonstrated **marginal conducted emissions performance** when tested in the **VDE table top configuration** at another test site. The initial evaluation used a reference UUT that was tested at one site and sent to the other site, the **site-to-site variability was 10 to 20 dB** in the 5 to 30 MHz region of the band tested.

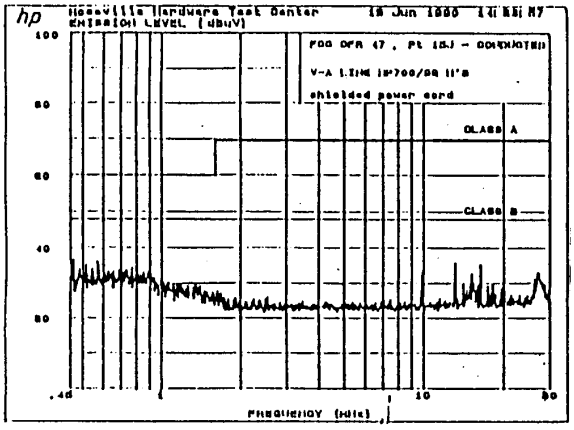


Figure 1a Emissions noted using Vendor A LISN

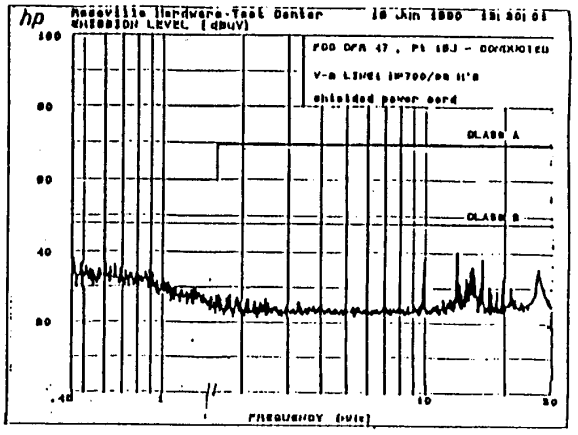


Figure 1b Emissions noted using Vendor B LISN

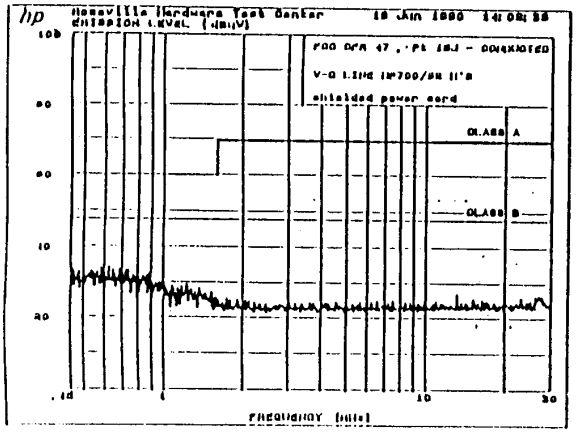


Figure 1c Emissions noted using Vendor C LISN

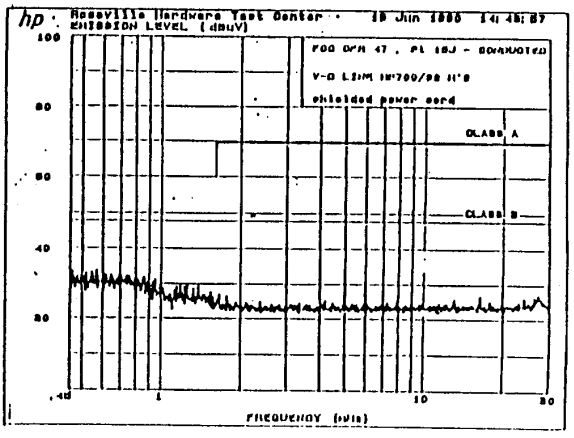


Figure 1d Emissions noted using Vendor D LISN

In addition to the differences in measurement equipment, ground plane, and location different LISN vendors were also used. One site used a LISN made by Vendor B, while the other used a LISN made by Vendor A.

After obtaining different vendor LISNs the reference UUTs were tested in our screen room. Notice the differences in the emission measurements on Figures 1a-d when the inconsistent UUT was tested using four LISNs. On Figures 2a-d notice the similar emission measurements when the consistent UUT was tested using the four LISNs. The shielded power cord was used to reduce the variability noted when using unshielded power cords.

The ensuing investigation identified three areas that contributed to the variations noted. They are as follows:

1. Of the six LISNs tested:
   a. Three meet the 40 to 60 ohm impedance requirement.
   b. Five meet the <1 dB insertion loss requirement.
   c. One meets the >40 dB isolation requirement.[1]

2. Accuracy is a function of the receptacle ground to the LISN ground connection impedance.[2]

   VDE 0876 PART 1/9.78 states that a LISN is used to "high frequency terminate the power lines from the RFI source with reference to ground and with a defined resistance." [4]

3. Repeatability/reproducibility, on a given LISN, is a function of the power cord and UUT resonant frequency.

[1] No longer considered a specification by FCC--some vendors specify.

[2] Implied as high quality ground connection but unspecified in standards.

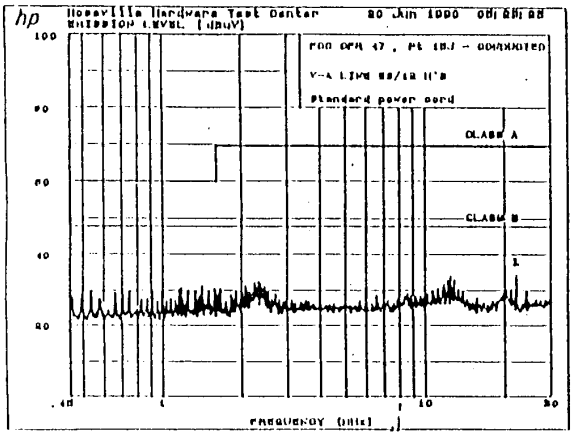


Figure 2a Emissions noted using Vendor A LISN

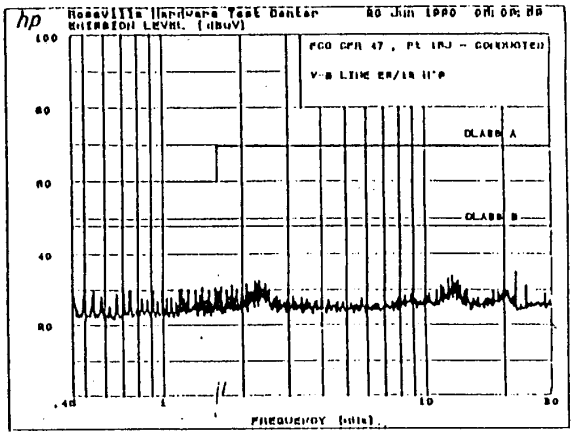


Figure 2b Emissions noted using Vendor B LISN

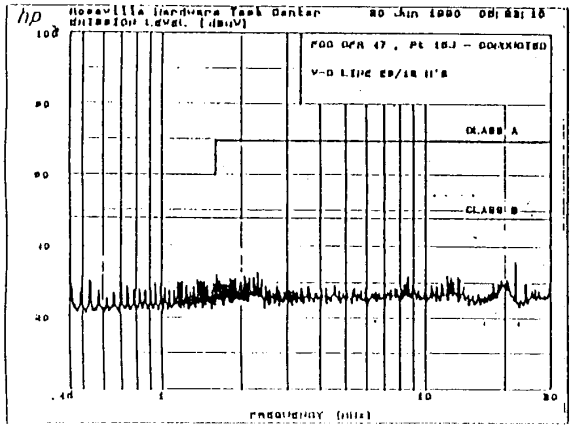


Figure 2c Emissions noted using Vendor C LISN

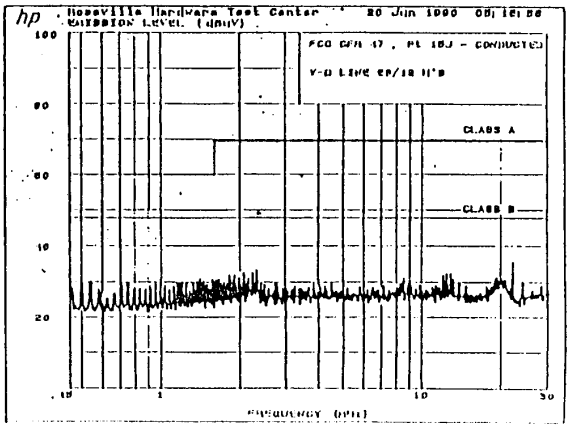


Figure 2d Emissions noted using Vendor D LISN

Investigation Summary

The first step in understanding the variations was to check the specifications of each of the LISNs. By this time we had acquired another Vendor A LISN (a loan from the manufacturer), two from another vendor, and one built locally.

Figure 3 is a photograph of the LISNs evaluated. Test connectors, (see Figure 4), were made to plug into the standard AC receptacle of the LISNs. The impedance was measured using an HP4193A Vector Impedance Meter, insertion loss and isolation (crosstalk) an HP 3577A Network Analyzer, or HP 8590 Spectrum Analyzer with an HP8444 Tracking Generator. Figure 5a, 5b, and 5c are the test configurations used. Below is a worst case summary of the 1 to 30 MHz test data.

Vendor-Unit-Phase	Impedance 50 +/- 20%	Insertion Loss ≤ 2 dB	Isolation >40 dB[1]	Internal Ground Z[2]
VA-#1-N	69.3*	1.3	33.6*	38 ohms
VA-#1-L	71.2*	1.4	33.9*	
VA-#2-N	140.1*	4.5*	23.5*	39 ohms
VA-#2-L	141.3*	4.7*	23.2*	
VB-#1-N	65.2*	1.3	28.0*	70 ohms
VB-#1-L	71.8*	2.5*	29.2*	
VB-#2-N **	60.7*	1.9	31.3*	37 ohms
VB-#2-L **	57.4	1.8	32.8*	
VB-#2-N	52.0	1.9	31.3*	
VB-#2-L	51.2	1.8	32.8*	
VC-#1-N	55.5	1.3	33.3*	11 ohms
VC-#1-L	55.6	1.3	27.6*	
VD-#1-N	49.1	1.5	47.0	24 ohms
VD-#1-N	48.4	1.6	45.0	

* indicates does not meet specification
** indicates U.S. to European adapter used

Figure 6 is a composite of the neutral to ground impedance of the six LISNs. Figure 7 is a composite of the neutral insertion loss and isolation of the six LISNs. Figure 8a and 8b indicate a composite of the internal impedance.

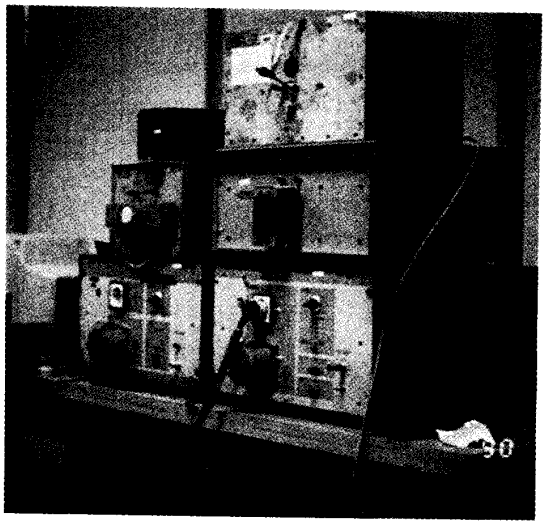


Figure 3

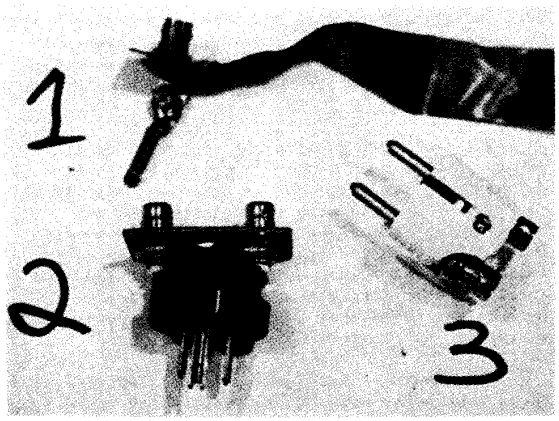


Figure 4

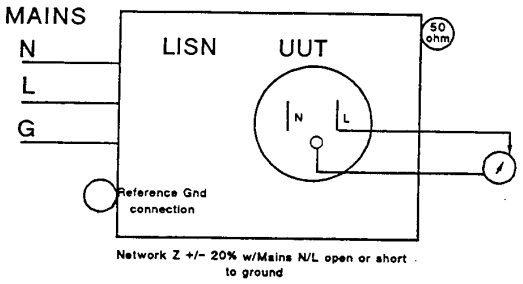


Figure 5a LISN Impedance

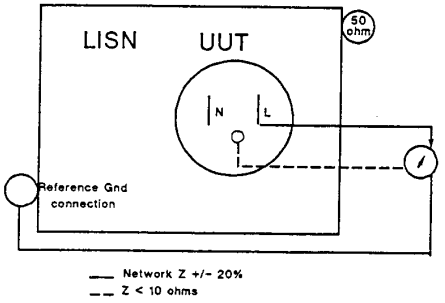


Figure 5b LISN Internal Ground Z

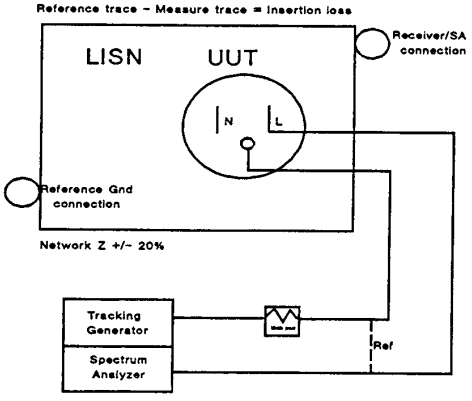


Figure 5c Insertion Loss

LISN Impedance

The impedance of Vendor A and B-#1 was unacceptable due to internal design and mating adapter requirements.

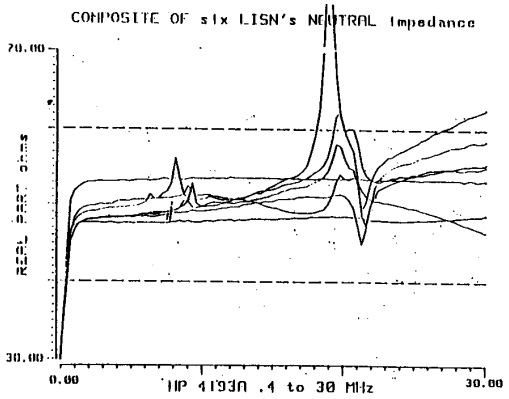


Figure 6

LISN Insertion Loss

The >2 dB insertion loss was caused by worn recepticles.

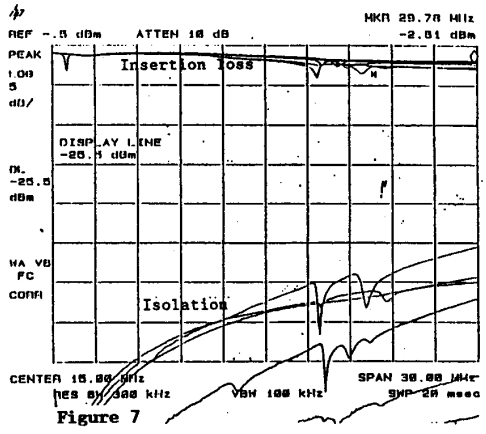


Figure 7

LISN Isolation

Not considered a problem if >20 dB.

Receptacle Ground-to-Ground Connection Impedance

The internal ground real impedance (Figure 8A) of Vendor A and B LISN's was not as good as Vendor C or D. Vendor A's worst case was 39 ohms, Vendor B's 70 ohms, Vendor C's 11 ohms, and Vendor D's 24 ohms.

The internal ground real and imaginary impedance indicate a more severe problem for all LISNs tested. The imaginary impedance is caused by relatively long internal ground wires which can be reduced by using large braided wire or adding copper bus bars.

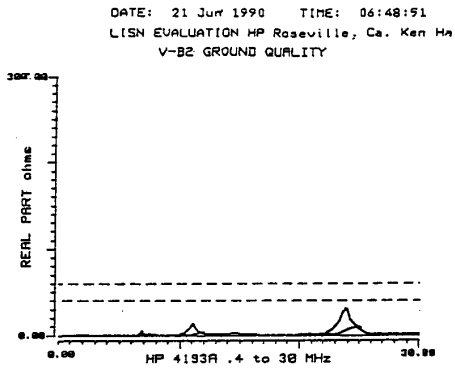


Figure 8a Composite Impedance

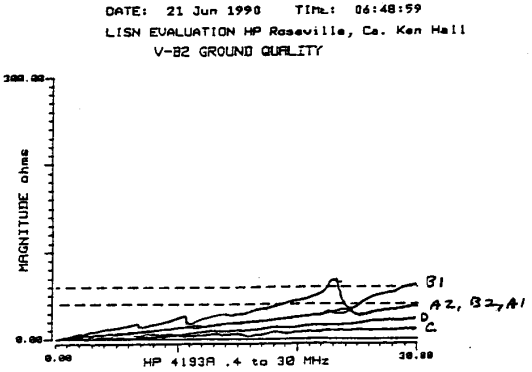


Figure 8b Composite Impedance

The internal grounding of LISN A2 was modified, Figure 9 displays the internal ground impedance of the modified unit.

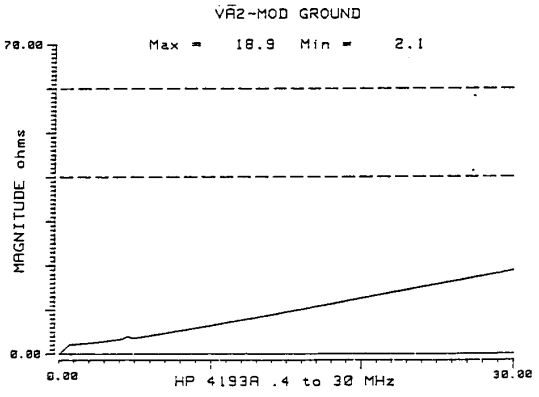


Figure 9

Figure 10 a, b, c, and d display emissions measured on four LISNs. Figure 10d is the modified LISN. Note the similarity with Figure 10c, one of the LISNs with low internal ground impedance.

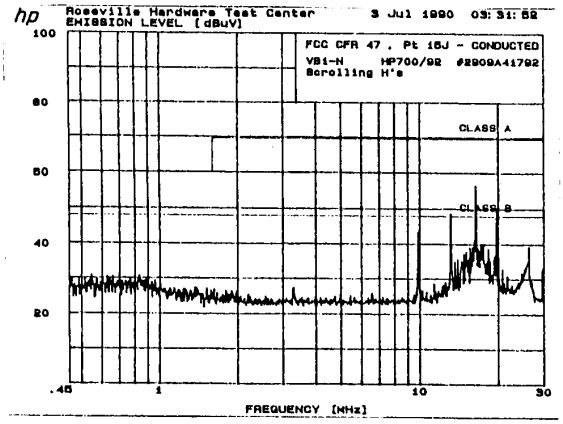


Figure 10a

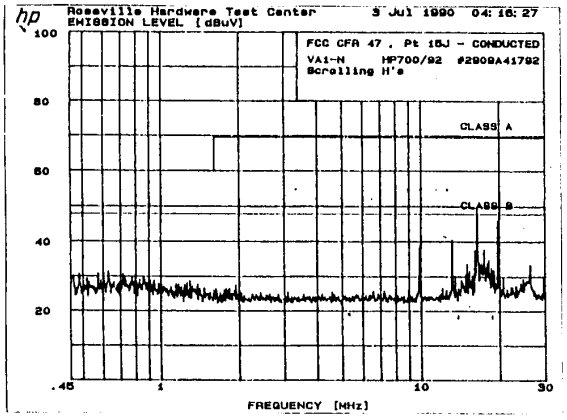


Figure 10b

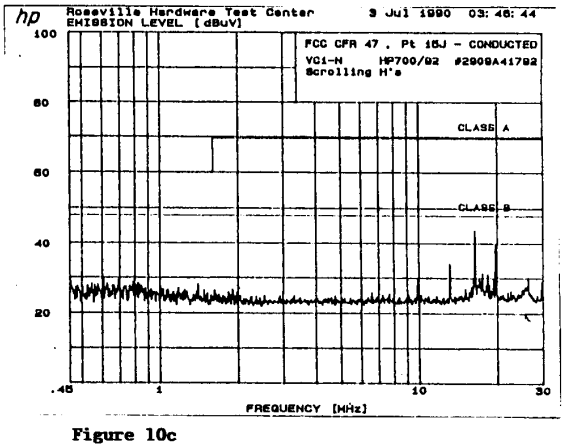


Figure 10c

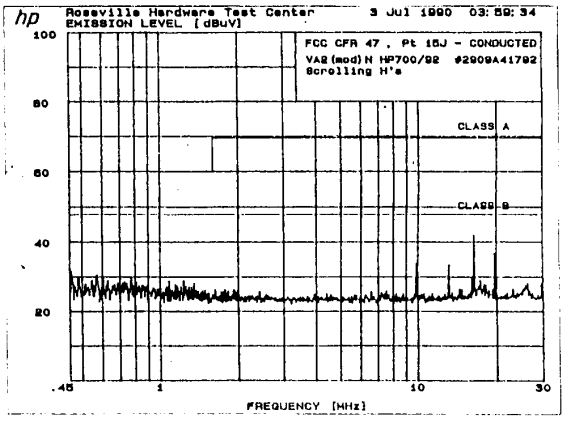
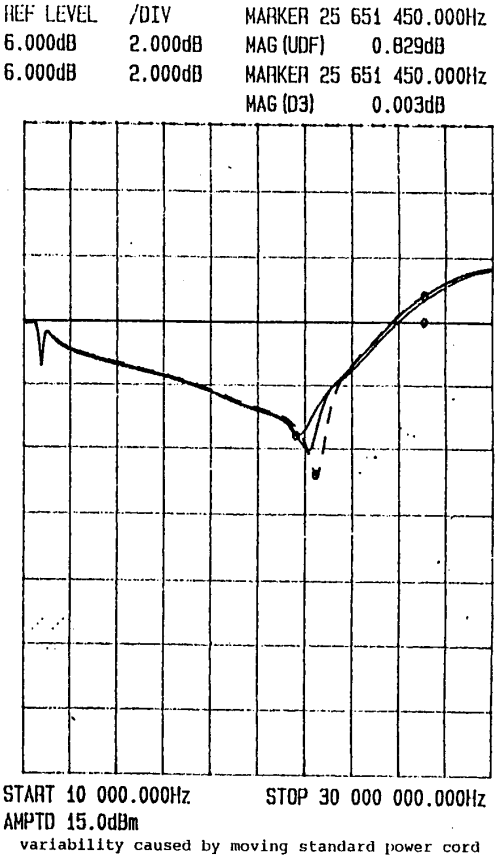


Figure 10d

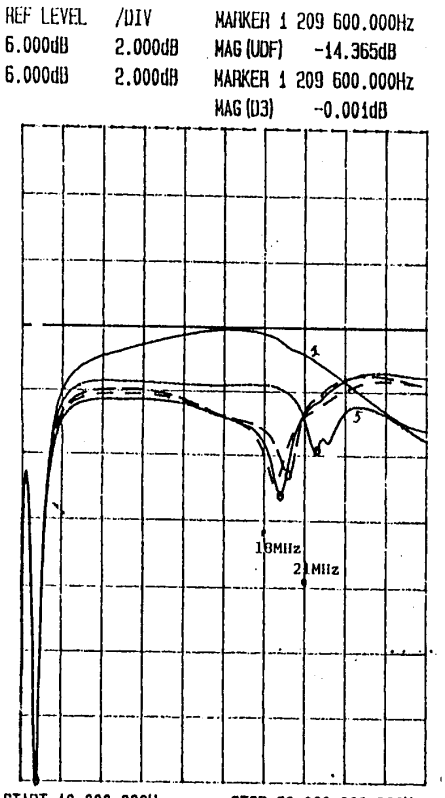
Power Cord Variations

It was noted that moving the unshielded power or source cable caused considerable frequency shift and slew of a resonant point (Figure 11a) and different power cords different resonances (Figure 11b) in the test configuration shown in Figure 12. Figure 13 indicates the difference changing the UUT has on the resonant condition. The terminal (HP 700/92) test configuration resonance was reduced to an insignificant value by adding four ferrites to the source cable or by using a shielded power cable.



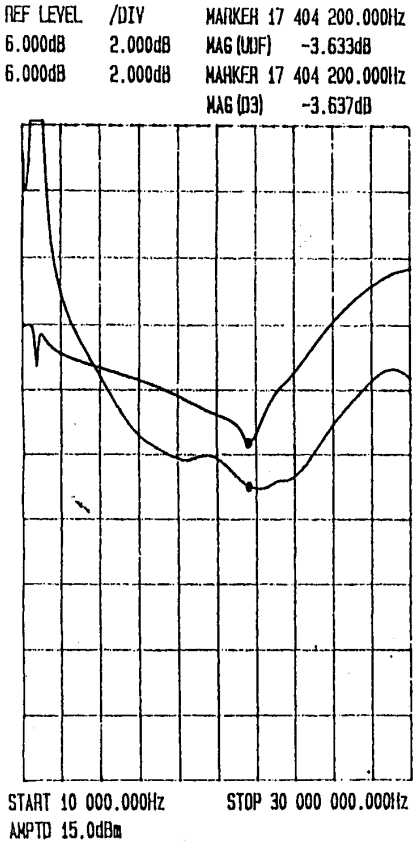
variability caused by moving standard power cord

Figure 11a



1 - shielded power cord
2, 3 & 4 - standard HP cords
5 - 80 cm standard cord

Figure 11b



relative difference between two UUTs

Figure 13

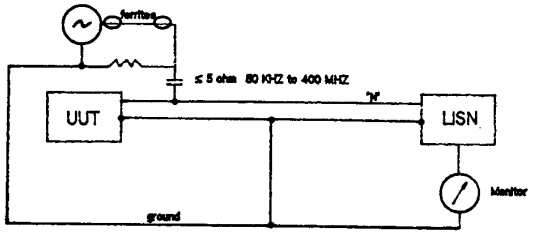


Figure 12 Power Cord Test Configuration

The variations due to power cords was identified in the next step of the evaluation. Figure 14 displays the variations noted when comparing unshielded power cords. Figure 15 displays the variations noted when comparing shielded power cords. **The cord to cord variation was <5 dB for unshielded and <2 dB for the shielded versions.**

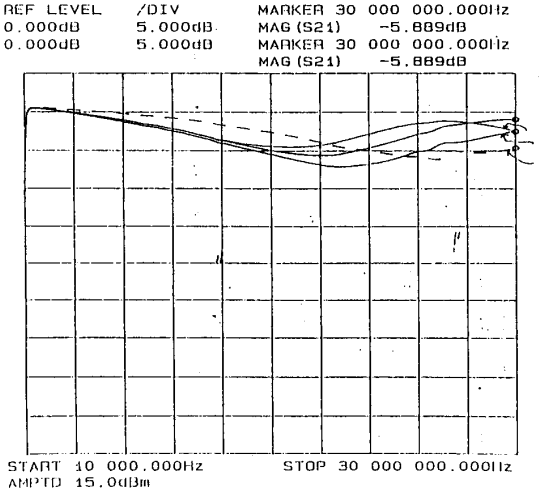


Figure 14 Unshielded Power Cord Variations

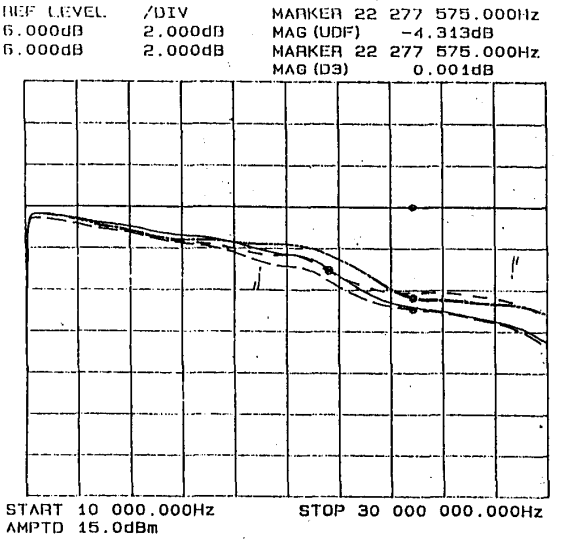


Figure 15 Shielded Power Cord Variation

Recommendations

1. Understand the contribution the power cord has to your specific product emissions. It is part of your product.

2. Reduce the **receptacle ground to LISN tie point ground** impedance.

3. Verify the impedance and insertion loss of line and neutral regularly; isolation does not appear as critical.

4. LISN builders and manufacturers should add another critical specification to the test specifications; **internal ground impedance.**

5. Do not use power cord adapters.

6. Maintain a low impedance between the LISN and ground plane/wall.

Conclusion

When testing certain products to FCC specifications you could realize a 10 dB improvement in emissions if the LISN used meets the normally specified impedance and insertion loss specifications and **has a low receptacle to ground tie point impedance.**

Comment

The test data and recommendations have been sent to the LISN vendors. It is expected that they will improve their design where necessary.

References

[1] "FCC Procedure for Measuring Radio Frequency Emissions from Computing Devices." FCC/OET MP-4 (1987).

Proposed "FCC Methods of Measurement of Radio Noise Emissions from Digital Devices." FCC/OET TP-5 (1988).

[2] Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment." CISPR Publication 22.

[3] "The Measurement of Radio Frequency Interference (RFI). Part 1: The Measurement of RFI Voltages." VDE 0877. Part 1.

[4] "Radio Frequency Interference Measurement Equipment. Part 1: RFI Measurement Set with Quasi-Peak Detector and Accessory Equipment." VDE 0876 Teil 1/9.78.