A Correlation Test among Measurement Sites for Radiated EMI Using an Actual Machine and a Stabilized Power Line Impedance

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Abstract:

In measurements of radiated emission at frequencies up to 200 MHz, correlation for different test sites has been difficult to obtain. A major reason, we believe, may be that the common-mode impedance of the power source for the EUT (equipment under test) is not stable at the various test sites. To check this hypothesis, we performed a correlation test of the radiated emission at 14 EMI test sites, using a VHF Line Impedance Stabilized Network (VHF LISN) and an actual machine. The results showed that the correlation among test sites can be improved by controlling the common-mode impedance of the EUT power source at each test site. This paper presents the results of the correlation test and our proposal to use the VHF LISN to measure the radiated emission.

1. Introduction

We measured the actual common-mode impedance of the power source for the EUT at some test sites before starting the correlation test. The measured values varied from several ohms to 1 kilo-ohm and the average value of the impedance was about 50 ohms. For the inter-site correlation test, therefore, we decided to make a line impedance stabilized network with an impedance of 50 ohms at frequencies from 30 to 200 MHz. In the earlier measurements made with a comb-generator[1], we found that the deviation of measured data among test sites was caused in part by the routing construction difference of the EUT power source cable under the ground plane of each test site. The deviation was larger at certain frequencies. We also found that the routing difference of the EUT power cord on the ground plane was another cause of the deviation. This difference comes from the different position of the ac power source outlet for the EUT on the turntable. We then performed the correlation experiments again, using an actual machine. This time we inserted a 50-ohm line impedance stabilized network between the EUT power cord and the power source outlet at the center of the turntable. The results of the experiments are described here.

2. Common-mode impedance of the power lines

2.1 Measurement method

The common-mode impedance was measured with a network analyzer at 18 sites. The basic layout is shown in Fig. 1. During the measurement, the power source was switched off as far as possible from the ac outlet for the EUT.

We measured the common-mode impedance between the live and neutral lines of the power source and the reference ground plane at frequencies from 100 kHz to 500 MHz.

The adapter shown in Fig. 2 was used for this measurement. This adapter has a special structure chosen, so that the stray-capacitance and inductance have minimum influence on the measurement. Because calibrating the network analyzer with the adapter was difficult, the network analyzer was calibrated at the end of the coaxial cable, where the cable was connected to the adapter.

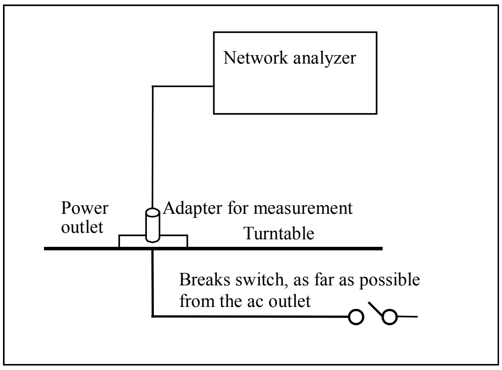

Fig. 1. Layout of the measurement

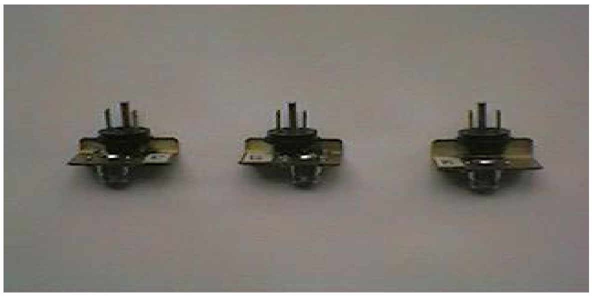

Fig. 2. Adapters of the type used for measuring common-mode impedance

2.2 Results

The results of the measurements of the common-mode impedance of the EUT power source at each site are shown in Fig. 3. The values observed ranged from several ohms to about 1 kilo-ohm, depending on frequency. From this result we guess that, even if the same EUT were tested under the same operating conditions, the value of radiated emission would be different at each test site. The reason is that each test site has a different frequency characteristic of the common-mode impedance for the EUT power source, depending on the routing construction of the power cable under the ground plane.

To reduce the influence of the common-mode impedance of the EUT power source, we propose here that each test site should have the same, stable common-mode impedance at the outlet point of the EUT power source. Also, we suggest that it is reasonable to stabilize the impedance at 50 ohms for the radiated emission measurement, because the central value of the common-mode impedance in the frequency range from 30 to 200 MHz is about 50 ohms, as Fig. 3 shows. Further, we usually use an Artificial Mains Network (AMN) with 50-ohm impedance in measuring the conducted interference voltage at an ac power port of the EUT. For our measurements of correlation between sites, therefore, we fixed the common-mode impedance of the power source at 50 ohms, using the line impedance stabilized network for the VHF frequency range (VHF LISN). The structure and specifications of the VHF LISN are described in the next section.

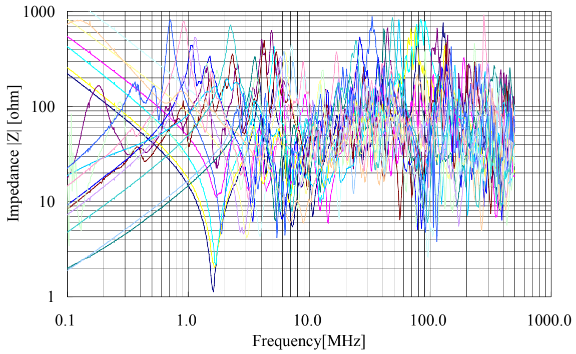

Fig. 3. Measurements of the common-mode impedance of the power source

3. 50-ohm Line Impedance Stabilized Network (VHF LISN)

The basic structure and the equivalent circuit of the VHF LISN used in our measurements are shown in Fig. 4. A feed-through capacitor in the VHF LISN has a capacitance of 5000 pF; its impedance can be disregarded at frequencies over 30 MHz. [2]

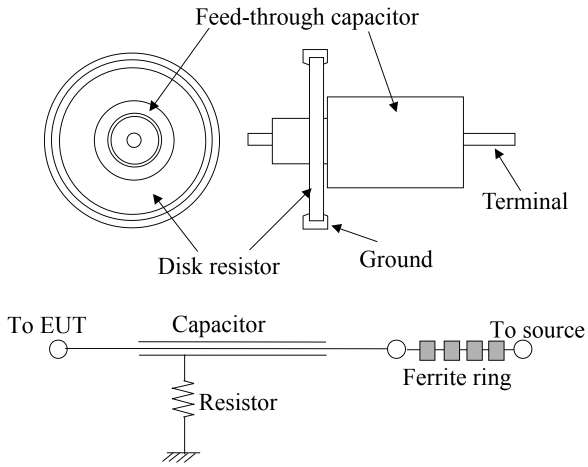

Fig. 4. Structure and equivalent circuit of the 50-ohm VHF LISN

In the correlation measurements, this VHF LISN was connected to the EUT power source of each test site, and the ac outlet to the EUT was placed at the center of the turntable.

A photograph of the VHF LISN used in this correlation experiment is shown in Fig. 5.

The measurements of the common-mode impedance with and without the VHF LISN at the outlet from the power source are compared in Fig. 6.

When the VHF LISN is used, the impedance is stabilized at around 50 ohms at frequencies from 10 to about 200 MHz, as Fig. 6 shows.

These data were obtained at one test site where the correlation measurement was performed. We assume that similar data would be obtained at other sites, if we used the same VHF LISN.

Next, we performed the inter-site correlation measurements described in the following section.

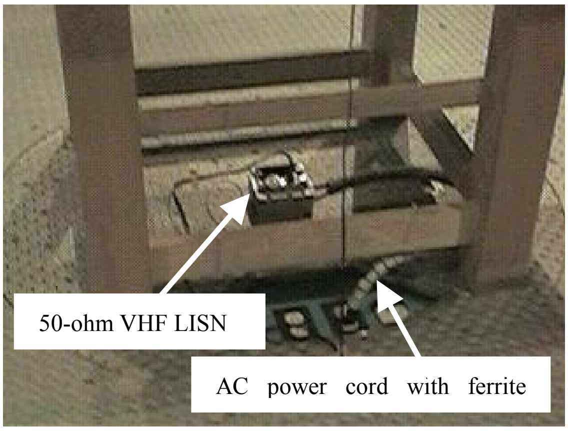

Fig. 5. Photograph of the 50-ohm VHF LISN

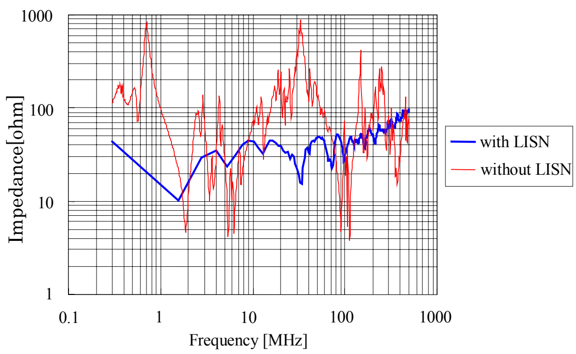

Fig. 6. Impedance with and without the VHF LISN

4. Inter-site correlation measurement with an actual machine

In this measurement, we used an old-model PC that has no I/O cables except the power cord, to limit the radiated emission to that from the power cord, as much as possible. Measurements were performed at 14 test sites, at 2 open area test sites (OATS), and in 12 semi-anechoic chambers (SAC).

4.1 Measurement method

To compare the deviation of the data, we used the following two conditions in the measurement:

1) The EUT power cord was draped to the ground plane and routed to the outlet of the power source for which the common-mode impedance was not specified, in accordance with CISPR22 (Fig. 7).

2) The EUT power cord was draped to the ground plane and routed to the 50-ohm VHF LISN, which is positioned at the center of the turntable (Fig. 8).

At each site, the measurement was performed under the following conditions:

(1) The measurement distance was 3m.

(2) Measurements were taken at 12 frequencies: 42.9, 57.3, 61.3, 62.6, 71.6, 85.9, 100.2, 104.5, 114.5, 118.6, 128.9, and 143.2 MHz.

(3) The measurement polarization was vertical.

(4) To obtain the maximum radiated electric field at each frequency, the turntable was rotated 360 degrees, and the antenna height was scanned from 1 to 4 meters.

(5) The electric field was measured at the maximum quasi-peak (QP) value.

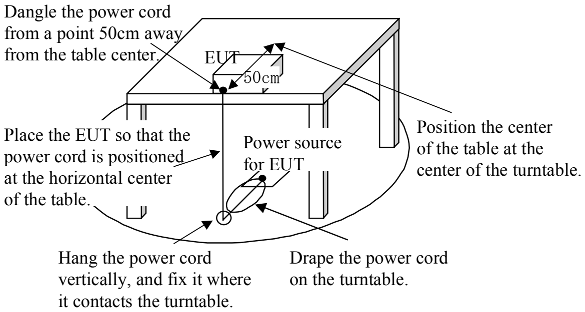

Fig. 7. Setup for measuring the emission for direct connection of EUT power lines, in accordance with CISPR22

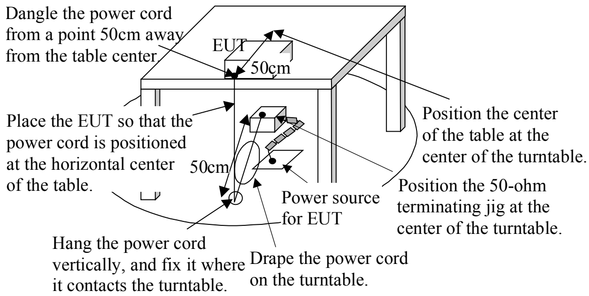

Fig. 8. Measurement setup for 50-ohm termination

4.2 Measurement results

The maximum electric fields measured at each test site for each condition are shown in Fig. 9 and Fig. 10.

Figure 11 shows the standard deviations of the maximum electric field as measured at all of the test sites, for both conditions of section 4.1.

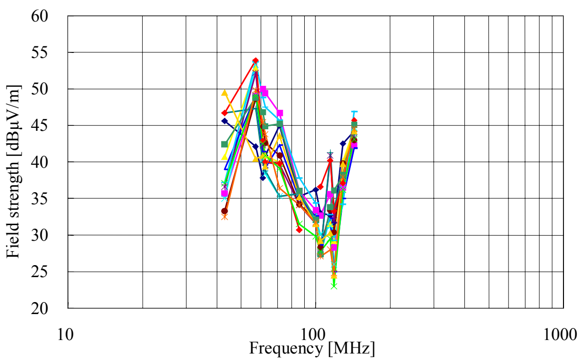

Fig. 9. Maximum emission data for each site with a direct connection in accordance with CISPR22

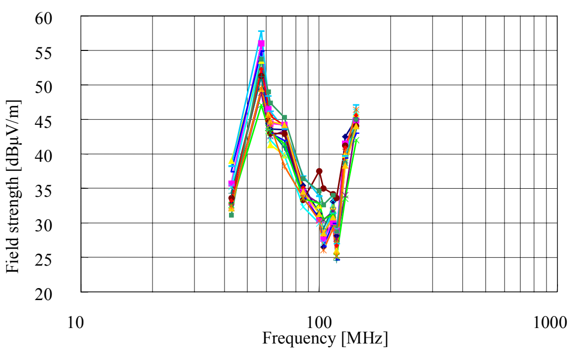

Fig 10. Maximum emission data for each site with 50-ohm VHF LISN termination

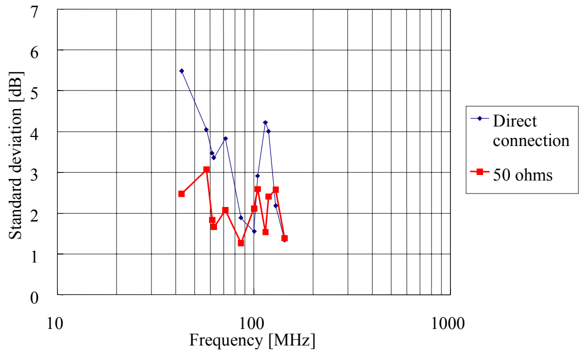

Fig. 11. Standard deviation of the emission level

When the termination with the 50-ohm VHF LISN was used, the standard deviation among 14 sites was almost within 3 dB— much better than with the direct connection recommended in CISPR22.

This result confirms that stabilizing the common-mode impedance of the EUT power source can improve the data correlation among test sites.

A member of CISPR has proposed mounting ferrite clamps on the power cord and the communication cables while measuring of the radiated disturbance, to improve the data correlation among test sites. An Amendment to CISPR22, including this proposal, was published recently. But one report made during the reviewing phase, CISPR/G/WG1 (Frankfurt-Suzuki) 98-1[3], shows that the radiation level changed when the ferrite clamps were mounted. At 30 MHz, in particular, the level was 15 dB lower than that observed in correlation measurements among eight sites taken with a comb-generator and without ferrite clamps (Fig. 12).

From this data, we can guess that the ferrite clamps proposed by CISPR shifted the resonant length of the power cord, and this shift had a strong influence on the emission level, especially around 30 MHz.

On the other hand, the average values of the maximum electric field strength of two conditions in our experiment showed almost no difference, as Fig. 13 shows. The maximum difference of the average values of 14 test sites was 5.6 dB at 42.9MHz, and the average difference between the averages at all other frequencies, at which measurements were made, was 1.7 dB.

From this comparison, we can say that the termination with the 50-ohm VHF LISN connected at the outlet of EUT power source has less effect than the ferrite clamp method recommended in the CISPR22 Amendment. Also, our measurement condition is closer to an actual customer environment. Moreover, our layout does not modify anything on the power cord that is defined as a part of the enclosure port of the EUT, and that is supposed not to be changed in the measurement.

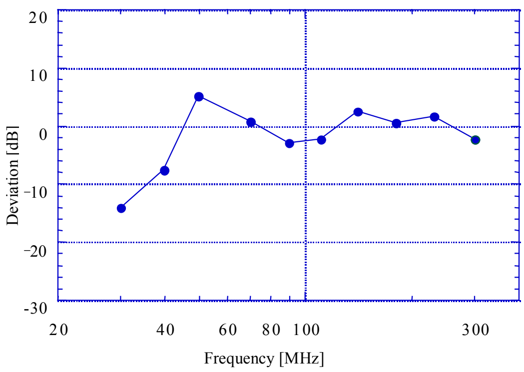

Fig. 12 Deviation of average values of maximum emission with ferrite clamps mounted.
Standard: without ferrite clamps.

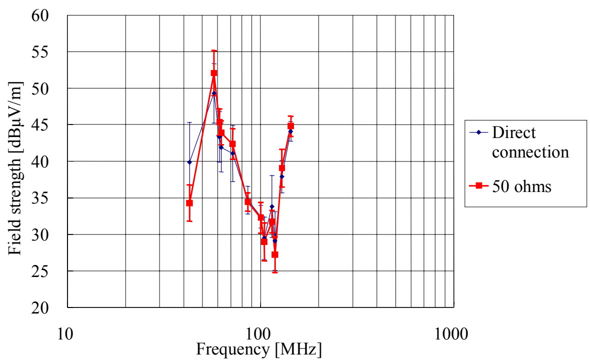

Fig. 13. Average values of maximum emission among test sites, for a direct connection and for a 50-ohm termination

5. **Conclusions**

We performed correlation measurements among 14 test sites with an actual machine, and found that stabilizing the common- mode impedance of the power source at each site gave better correlation among test sites than the previous CISPR method gave. With our instrumentation, also, the values measured varied less than those obtained by the amended CISPR method. Therefore, our instrumentation yields better correlation among test sites.

Our results still show as much as 10 dB deviation in the inter-site correlation, even when the factor of the common-mode impedance of the power source is eliminated. In further studies to eliminate uncertain elements from the radiated emission measurement, the characteristics of the measurement facilities such as OATS and SAC, the calibration of antenna factors, the temperature characteristics of cable losses, and any error introduced by the measurement instrument should be clarified.

6. Acknowledgment

All experiments in this paper were conducted and reported with the cooperation of members of VCCI technical subcommittee. We would like to express special thanks for their effort.

7. References

[1] K. Osabe et al., "Correlation Test Among EMI Measuring Sites Using a Comb Generator," IEEE symposium 2000, Washington, DC.

[2] A. Maeda, "Stabilization of Power Line Impedance for Radiated EMI Level Measurement," IECIC Trans. Commun. Vol.E75-B, No.3 March 1992, pp.148-156.

[3] CISPR/G/WG1 (Frankfurt-Suzuki) 98-1.