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Radiated emissions measurements by using conducted emissions measuring method

Sang-Wook Yoon*, Cheon-Hee Lee**, Kae-Dal Kwack*

Dept. of Electronic Engineering, Graduate school of engineering, Hanyang University,
17 Haengdang-dong, Seongdong-gu, Seoul 133-791, Korea*
Dept. of Electron and Information Engineering, Cheongju University,
Cheongju, Chungbook, 360-764, Korea**

Abstract

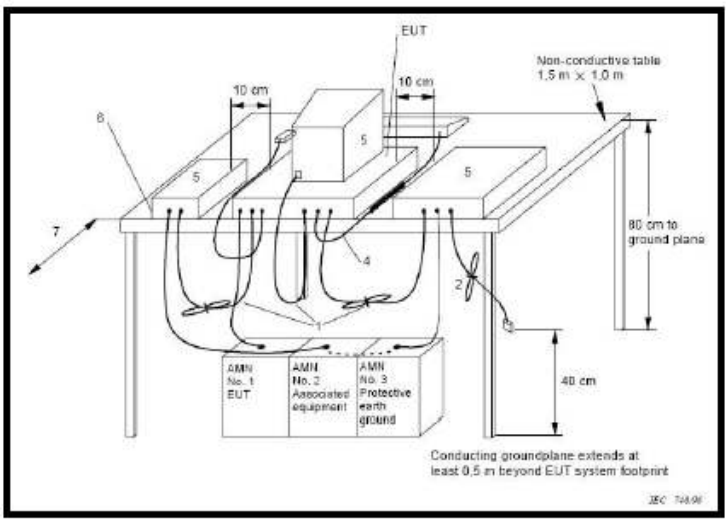
The measure of common-mode current on a cable can be closely correlate to the radiated emissions from the cable. This paper describes that to use the conducted emissions measurement method for calculating radiated emissions and compares them the measured radiated measurement results. For that the LISN which cover the radiated emissions frequency was developed.

Keyword : radiated emissions, conducted emissions measuring method

1. INTRODUCTION

The manufacturer should design and test a product to the EMC standard that would be acceptable a country or worldwide. Electromagnetic interference (EMI) has become a major problem for the manufacturer. Methods of measurement of disturbances consist of conduction method and radiation method.

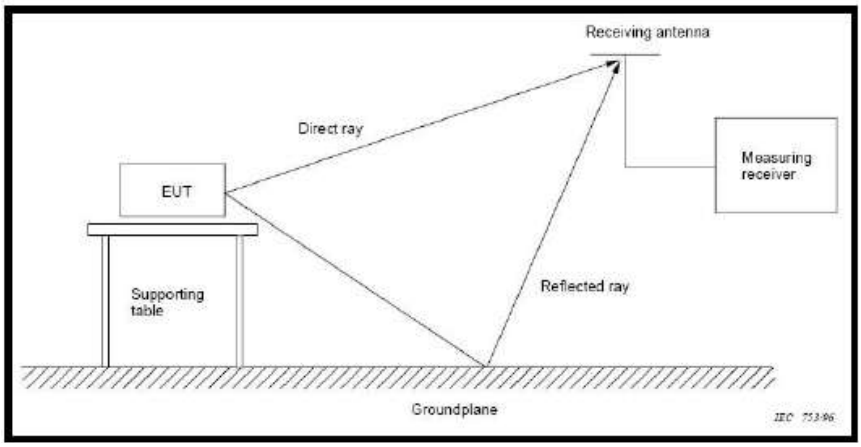
Conducted disturbance measuring method is described in the international standard CISPR 16-2-1. The equipment under test(EUT) is connected to the LISN to measure the conducted disturbances along the power cable. Generally the measuring frequency is from 150 kHz to 30 MHz.



<Figure 1> Table-top equipment for conducted disturbance measurements on power mains

Radiated disturbance measuring method is described in the standard CISPR 16-2-3.

Normally measurements should be made of both the horizontal and vertical components of the disturbance with respect to the reference ground plane. The electric component of the disturbance is normally measured at frequencies from 30 MHz ~ 1GHz.



<Figure 2> Radiated emissions measurements made on an open area test site at the receiving antenna

The EUT is set up at a specified height above the ground plane and the antenna is positioned at the specified separation distance. The EUT is rotated in the horizontal plane and the maximum reading noted. The open area test site shall conform with the relevant specifications of CISPR 16-1-4 and CISPR 16-1-5 for its physical and electrical properties and for its validation.

2. DIGITAL DEVICE RADIATION

Differential-mode (DM) radiation can be modeled as occurring from a small loop antenna.

For a small loop of area A carrying current I, the magnitude of the electric field E measured in free space at a distance r, in the far field is equal to

$$E = 131.6 \times 10^{-16} (f^2 A I)(\frac{1}{r}) \sin\theta \qquad (1)$$

where E is in volts/meter, f is in hertz, A is in square meters, I is amperes, and r is in meters.

However, most measurements of radiation from electronic products are made in an open field over a ground plane, not in free space. The extra ground reflection

can increase the measured emission by a factor of two. Correcting for the ground reflection and assuming an orientation that maximizes emission.

$$E = 263 \times 10^{-16} (f^2 AI)(\frac{1}{r}) \quad (2)$$

Equation (2) shows that the radiation is proportional to the current I, the loop area A, and the square of the frequency f. Common-mode (CM) radiation emanates from the cables in the system. The radiated frequencies are determined by the common-mode potential. The frequencies radiated are not the same as differential-mode signals in the cable.

Common-mode (CM) emission can be modeled as a short monopole antenna, driven by a voltage. For a short monopole antenna of length l over a ground plane, the magnitude of the electric field strength, measured at a distance r in the far field is

$$E = \frac{4\pi \times 10^{-7} (fIl)\sin\theta}{r} \quad (3)$$

where E is in volts/meter, f is in hertz, I is the common-mode current on the cable in amperes, and l and r are in meters.

Equation (3) is valid for an ideal antenna with a uniform current distribution. For a real antenna the current goes to zero at the open end of the wire. In practice, a uniform current distribution can be achieved if the antenna is capacitively loaded with a metal plate at the open end. This configuration is approximated when the antenna when the antenna connects to another piece of equipment that is either grounded or, if it is not grounded, has sufficient capacitance to ground. The capacitor-plate antenna then closely approximates the ideal uniform current antenna model.

Assuming an orientation that maximizes the emission ($\theta = 90^\circ$), Eq.(3) can be rewritten as

$$E = 12.6 \times 10^{-7} (flI)(\frac{1}{r}) \quad (4)$$

Equation (4) shows that the radiation is proportional to the frequency, the length of the antenna, and the magnitude of the common-mode current on the antenna.

3. LINE IMPEDANCE STABILIZATION NETWORK(LISN)

LISN is required to provide defined impedance at radio frequencies at the terminals of the EUT, to isolate the test circuit from unwanted radio-frequency signals on the supply mains, and to couple the disturbance voltage to the measuring receiver.

To measure the radiated emissions by using the conducted emissions measuring method, the LISN which can cover the radiated disturbances measuring frequency range is needed.

In this paper, the LISN which is valid from the frequency 150kHz ~ 300MHz is made.

It is because most of radiated disturbances were found below the frequency 300 MHz.

<Figure 3> LISN made for the test

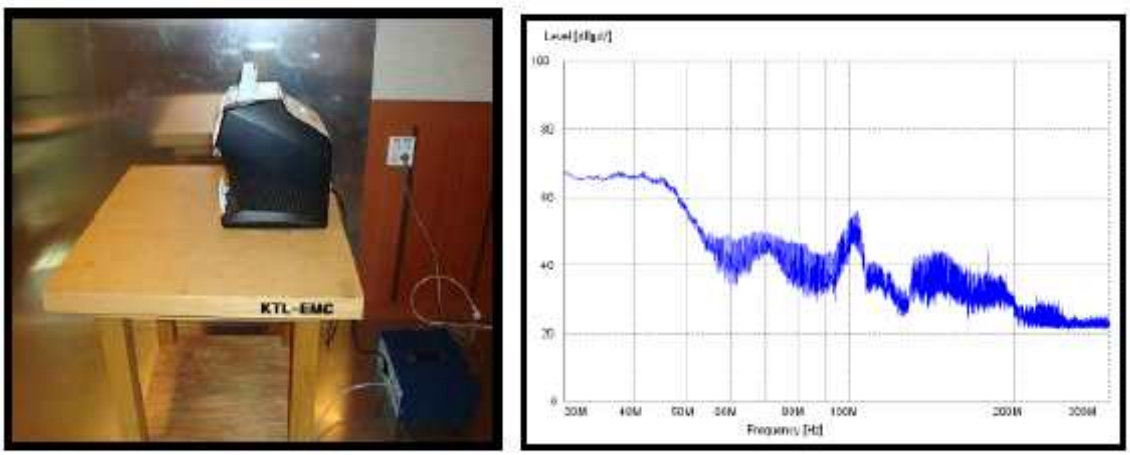
<Table 1> Specifications for LISN made

	Specifications
Frequency range	150 kHz ~ 300 MHz
Supply line	2
Network impedance	50 Ω/5 μH
Max. current	16 A
Max. voltage	AC 250 V / DC 600 V
Power frequency	DC ~ 60 Hz
RF output	50 Ω N type
Tolerance limits impedance	± 20 %
Rated temperature range	0 ~ 50 ℃

4. MEASUREMENT RESULTS AND ANALYSIS

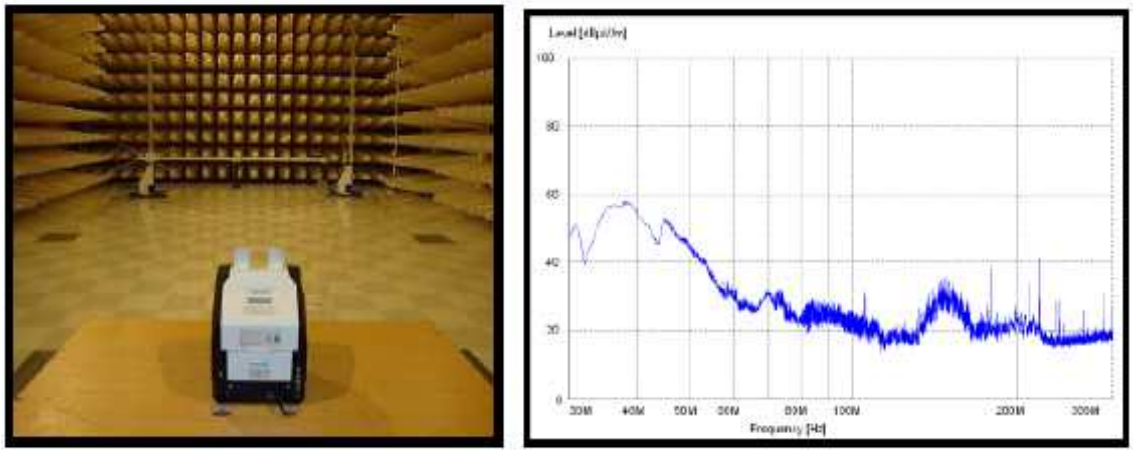
The money counter is chosen as the reference EUT, because it has enough radiation sources and only one in and out cable.

The conducted emission measurement was performed in the shielded room. The measuring unit is $dB\mu V$.

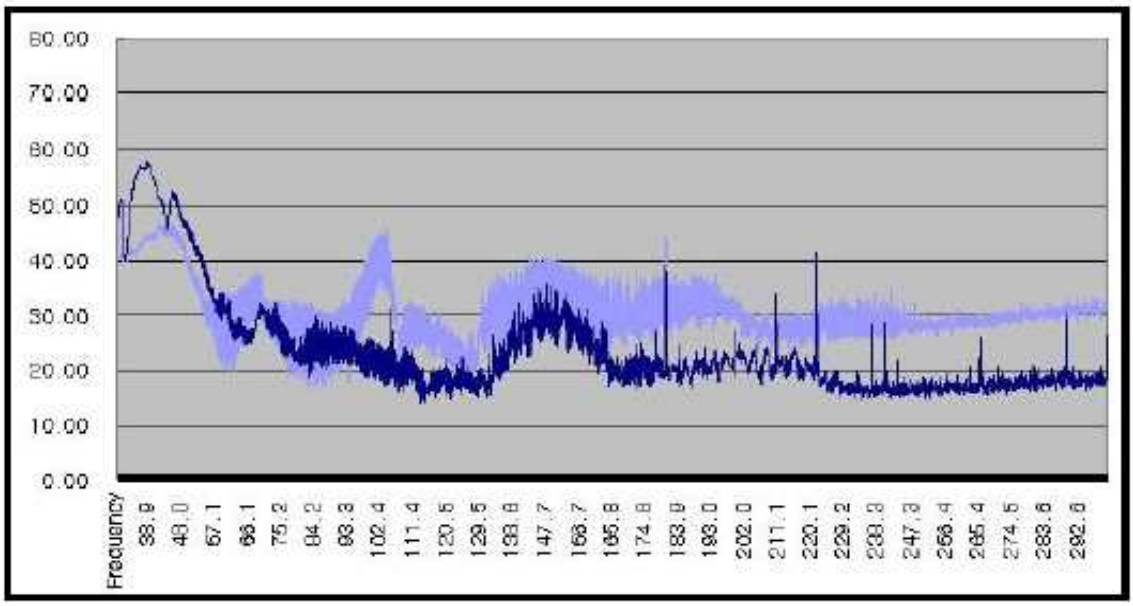


<Figure 4> Conduced emission measurement and the result

The radiated emission measurement was performed in the 10m semi-anechoic chamber. The measuring unit is $dB\mu V/m$.



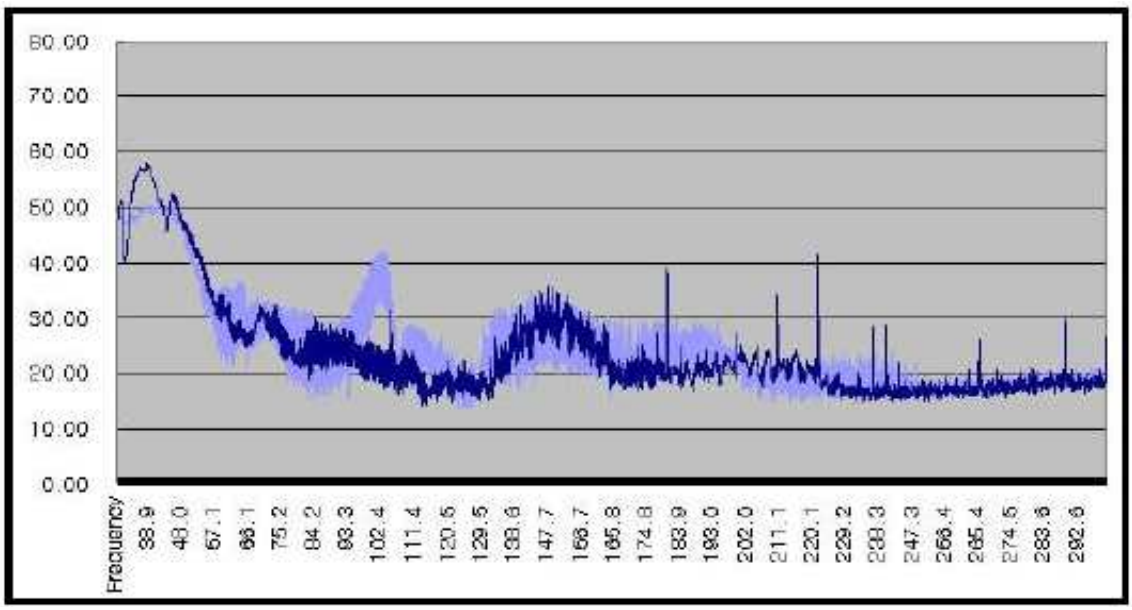
<Figure 5> Radiated emission measurement and the result



<Figure 6> Calculation result (differential-mode current)

Assume that radiated disturbance of the EUT is mainly from differential-mode current, it can be calculated using equation (3). The dark blue line is the radiated emissions result and the light blue line is the calculated results from conducted emissions results.

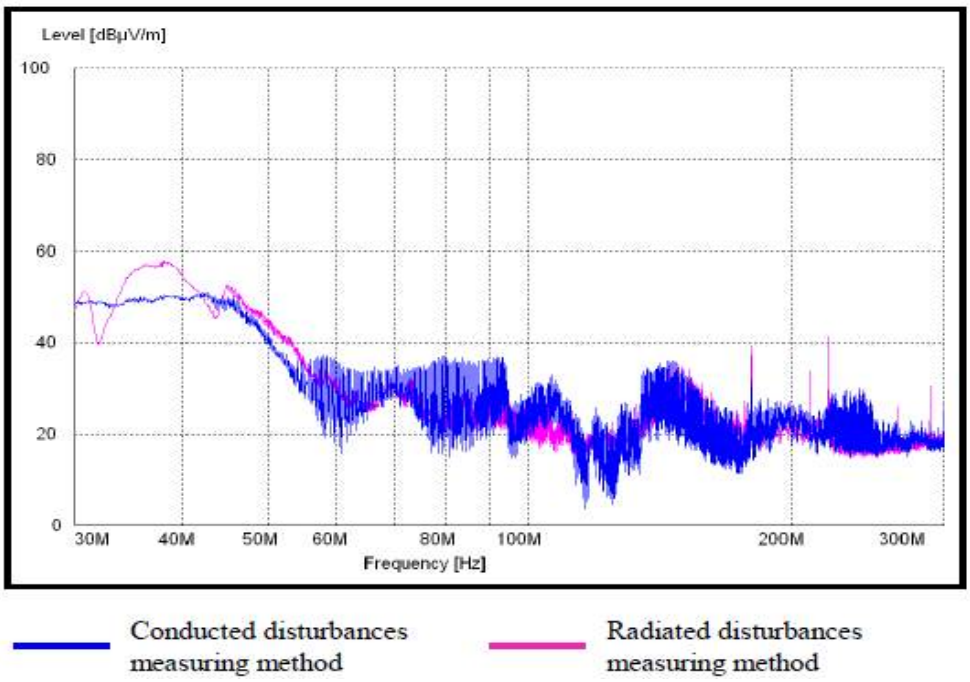
Assume that radiated disturbance of the EUT is mainly from common-mode current, it can be calculated using equation (4).



<Figure 7> Calculation result (Common-mode current)

As a result, the common-mode current on a cable can be closely correlated to the radiated emissions measurement results.

Using equation (4), the transfer factors for LISN were produced.



<Figure 8> Comparison of measurement results

<Figure 8> shows that the radiated emission measurement results in the frequency from 30 MHz to 300 MHz by using conducted emissions measuring method (blue line) are closely correlated to the results by using radiated emissions measuring method.

6. CONCLUSIONS

Conventional radiated emissions measurement method according to the standard is not readily applicable due to the cost of facilities and spaces for test sites. This paper has described that common-mode current is main source of radiated emissions. Using the LISN which cover the radiated emissions measurement frequency, the radiated emissions result can be predicted approximately by conducted emissions measurement method.

It will save the testing time and cost for the manufacturers who want to get the certification, because it can predict the test results approximately before apply the product to the testing house.

ACKNOWLEDGEMENT

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