Deviations of conducted disturbance voltages measured with AMN due to differences in height of the AMN and its grounding conditions

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Abstract— **This paper describes the results of calculating and measuring deviations of conducted disturbance voltages caused by differences in the arrangement of an artificial mains network (AMN) used to measure the voltage, for example, the height of the (AMN) from a horizontal reference ground plane and the connection between the AMN and the ground plane. The results indicated that the conducted disturbance voltage can be under-estimated when using an arrangement in which the AMN is set on a 40-cm–high non-conductive support as specified in CISPR 16-2-1 edition 2.0. The deviations increased as the frequency increased and the width of the grounding conductor became narrower. The largest deviations were observed when using a cable connection between the AMN and the horizontal reference ground plane. Resonance due to stray capacitances between the AMN and grounding conductor caused larger deviations. To minimize the deviations, these results should be taken into account when using the arrangement in which the AMN is set on a 40-cm-high non-conductive support.**

Keywords—conducted disturbance measurement, artificial mains network (AMN), measurement arrangement

I. INTRODUCTION

Efforts to protect radio services include measuring the conducted disturbance voltages at AC mains ports of information technology equipment (ITE) and other kinds of equipment by using an artificial mains network (AMN). The disturbance voltage between one conductor of the AC mains port and the ground is measured across a terminal impedance of 50 Ω given by the AMN.

Currently, conducted disturbance voltages at AC mains port of ITE have been measured according to the test arrangements specified in the international standard CISPR 22 or CISPR 32 published by the International Special Committee on Radio Interferences (CISPR) [1], [2]. These standards specify that the AMN shall be placed on the reference ground plane 80 cm away from the equipment under test (EUT) when using the horizontal reference ground plane as shown in Fig. 1. We call this "Arrangement A." In contrast, in CISPR 16-2-1 edition 2.0, which specifies basic requirements for methods used to measure conducted disturbances, the AMN shall be placed on a 40-cm-high non-conductive support 80 cm away from the EUT and connected to the horizontal reference ground plane as shown in Fig. 2 [3]. We call this "Arrangement B."

This paper describes deviations of conducted disturbance voltages measured using an AMN that are caused by differences in the height of the AMN from the horizontal reference ground plane and the ground connection of the AMN. These measured deviations were carried out in order to determine whether or not test results obtained by using these two arrangements are equivalent and how to connect the AMN to the reference ground plane.

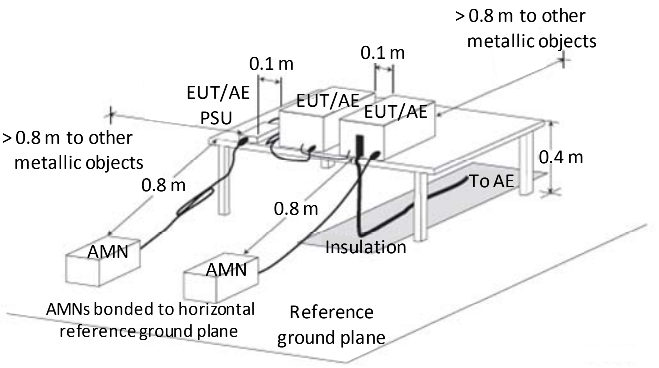


Fig. 1 Arrangement of AMN and EUT in case of using horizontal reference ground plane specified in CISPR 32 edition 1.0. (Arrangement A)

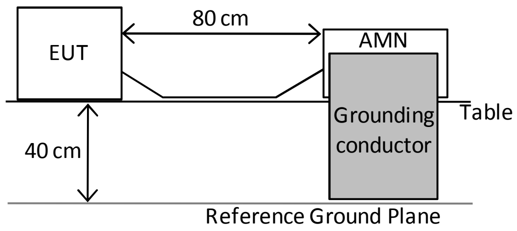


Fig. 2 Arrangement of AMN and EUT in case of using horizontal reference ground plane specified in CISPR 16-2-1 edition 2.0. (Arrangement B)

II. ANALYTICAL APPROACH

A. Circuit model of the measurement arrangements

First, the deviations of the measured voltages were calculated by using a simple circuit model, as shown in Fig. 3.

Voltages between one conductor of the AC mains and the reference ground (unsymmetrical voltage defined in CISPR 16-1-2) across the terminal impedance of 50 Ω given by the AMN were measured [4]. Therefore, EUT can be represented by an unsymmetrical voltage source, $\dot{E}_{us}$, with a nominal source impedance, $\dot{Z}_{us}$. The 50 Ω/50 µH artificial mains V-network specified in CISPR 16-1-2 is generally used to measure the conducted disturbance voltages at the AC mains port of ITE. This type of AMN can be represented by a parallel 50-Ω resistor and 50-µH inductor. The $\dot{Z}_x$ represents the impedance of the ground connection between the AMN and the horizontal reference ground plane.

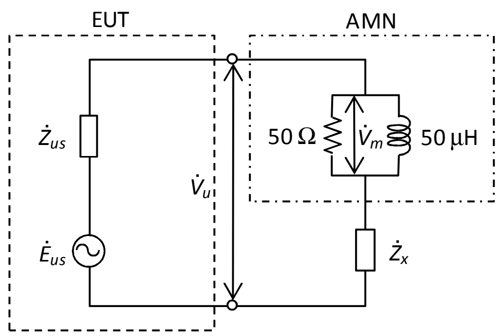


Fig. 3 A circuit model of the test arrangement using AMN.

B. Derivation of the equations

The relation between unsymmetrical conducted disturbance voltage $\dot{V}_u$ and the voltage measured with the AMN, $\dot{V}_m$, is represented by Eq. (1).

$$\dot{V}_m = \frac{\dot{Z}_{para}}{\dot{Z}_{para} + \dot{Z}_x} \dot{V}_u \quad (1)$$

where $\dot{Z}_{para}$ indicates parallel impedance of 50 Ω and 50 µH in Fig. 3.

The impedance $\dot{Z}_x$ can be ignored when using Arrangement A because the AMN is placed directly on the reference ground plane and the metallic bottom surface of the AMN is completely bonded to the reference ground plane. Therefore, the voltage measured using arrangement A, $\dot{V}_{m\_A}$, is given by Eq. (2).

$$\dot{V}_{m\_A} = \dot{V}_u \quad (2)$$

The voltage measured using Arrangement B, $\dot{V}_{m\_B}$, is given by Eq. (1).

Therefore, deviations between the voltages measured using Arrangements A and B are calculated by Eq. (3).

$$\frac{\dot{V}_{m\_B}}{\dot{V}_{m\_A}} = \frac{\dot{Z}_{para}}{\dot{Z}_{para} + \dot{Z}_x} \quad (3)$$

The inductance of the grounding conductor needs to be determined in order to obtain grounding impedance $\dot{Z}_x$ between AMN and the reference ground plane. The inductance can be calculated by Eq. (4) [2].

$$L(nH) = 2 \cdot l \cdot \left(\ln\left(\frac{2 \cdot l}{b+c} \right) + 0.5 + 0.22 \cdot \left(\frac{b+c}{l} \right) \right) \quad (4)$$

where l is the length of the grounding conductor in cm, b is the width in cm, and c is the thickness in cm, as shown in Fig. 4.

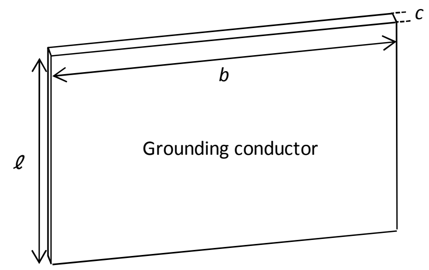


Fig. 4 Shape of the grounding conductor for calculation

To determine the dependence of the deviations on the grounding conductor, deviations of measured voltages were calculated with varying lengths l of the grounding conductors, as indicated in Table I. The width w was the same as that of the most common AMN in Japan.

TABLE I. PARAMETERS OF GROUNDING CONDUCTORS

l (cm)	**w** (cm)	**b (cm)**					**c** (cm)
		b=w	*b= 0.5*w*	*b= 0.3*w*	*b= 0.2*w*	*b= 0.1*w*	
40.0	39.0	39.0	19.5	11.7	7.8	3.9	0.1

C. Calculation results

Calculated voltage deviations are shown in Fig. 5. The maximum deviation was about -6 dB at 30 MHz, and all values of the deviation were negative. This means that conducted disturbance voltages can be underestimated when using Arrangement B. The deviations increased with higher frequencies and as the width of the grounding conductor became narrower. This is because $\dot{Z}_x$ in Eq. (3) increases at higher frequencies and as the inductance of the grounding conductor increases.

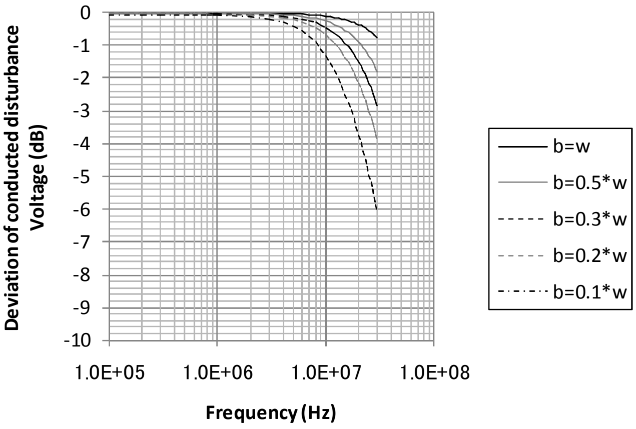


Fig. 5 Calculated voltage deviations

III. EXPERIMENTAL APPROACH

The deviations of voltages measured with arrangements A and B were experimentally evaluated.

A. Experimental arrangement

The experimental setup is shown in Fig. 6. Two typical types of AMN, AMN1 and AMN2, were used. The signal output port—port 1 of the network analyzer—was connected to the EUT port of the AMN. Two conductors of the twisted pair cable were connected to the center conductor of the coaxial cable. At the other end, the conductors of the twisted pair cable were connected to the L_A and L_B terminals of the AMN. The outer mesh of the coaxial cable was connected to the horizontal ground plane. Unsymmetrical voltages were input into the EUT port of the AMN and output to the measuring port of the AMN. The output voltages were input to the receiving port—port 2 of the network analyzer. S_{21} was calibrated according to S_{21} measured using arrangement A. Therefore, S_{21} measured using arrangement B shows deviations between the two measurement arrangements.

In arrangement B, the AMN was connected to the reference ground plane by using a grounding conductor made of a 1-mm-thick copper plate. The dimensions of the grounding conductors are shown in Fig. 7.

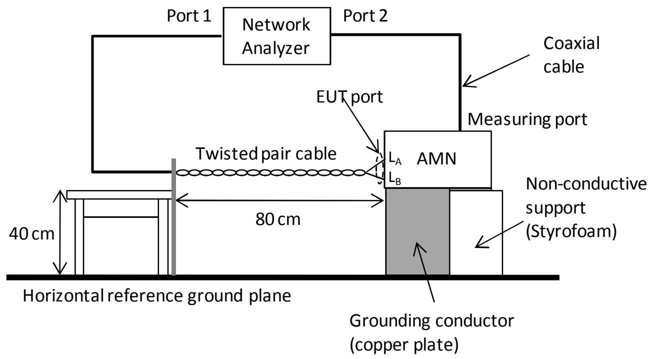
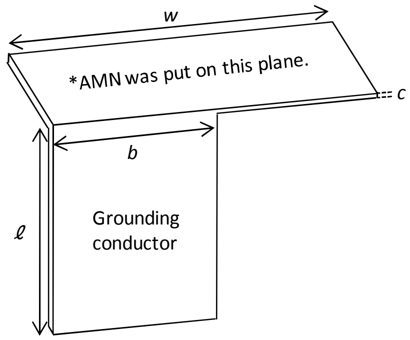


Fig. 6 Experimental setup



AMN	b (cm)					c (cm)	d (cm)
	b=w	b= 0.5*w	b= 0.3*w	b= 0.2*w	b= 0.1*w		
AMN1	39.0	19.5	11.7	7.8	3.9	0.1	20.0
AMN2	60.4	30.2	18.1	12.1	6.0	0.1	49.2

Fig. 7 Dimensions of grounding conductors

B. Experimental results

The experimental results of using AMN1 are shown in Fig. 8. For comparison, the measurement was also done using a cable to connect the AMN to the reference ground plane instead of the grounding conductor. The deviations increased as the frequency increased and the width of the grounding conductor became narrower. These tendencies correspond to those of the calculation results. A maximum deviation of about 3 dB was measured when the cable was used.

The experimental results of using AMN2 are shown in Fig. 9. The deviations increased as the frequency increased and the width of the grounding conductor became narrower. A maximum deviation of about 10 dB was measured at 10.6 MHz when using the cable.

AMN2 was connected to the grounding conductor by using a copper mesh sheet as shown in Fig. 10. As a result, resonance occurred at 10.6 MHz due to stray capacitances between the grounding mesh and the AMN surface. The stray capacitances were inserted into grounding impedance $\dot{Z}_x$ in Eq (3.).

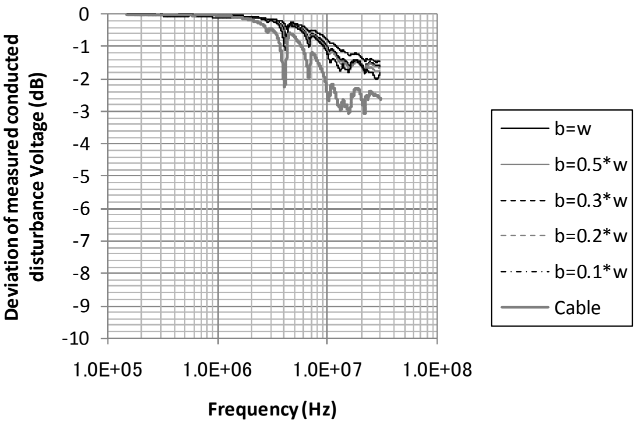


Fig. 8 Measured results of AMN1

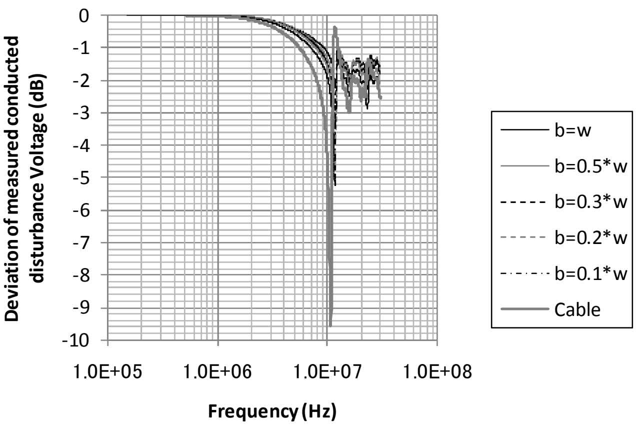


Fig. 9 Measured results of AMN2

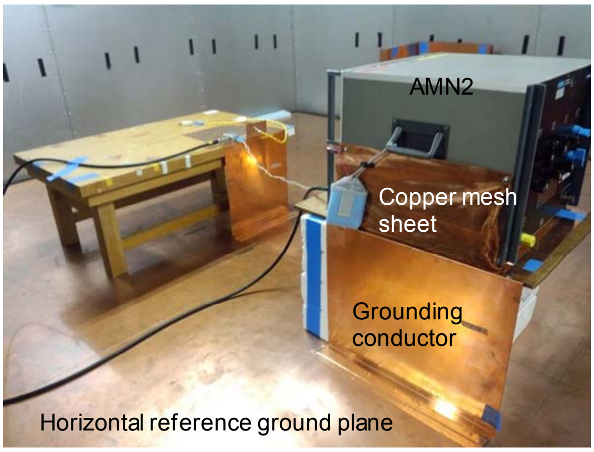


Fig. 10 Ground connection of AMN2 (Arrangement B)

IV. CONCLUSIONS

Conducted disturbance voltages measured using an AMN deviated because of differences in the measurement arrangements of the AMN. We evaluated these deviations analytically and experimentally. One arrangement specified in CISPR 22 and CISPR 32 involved setting the AMN on a horizontal reference ground plane. The other arrangement, specified in CISPR 16-2-1 edition 2.0, involved setting the AMN on a 40-cm-high non-conductive support and connecting it to the horizontal reference ground plane by using a grounding conductor.

Conducted disturbance voltages can be underestimated when using the latter arrangement.

The calculated and measured deviations showed the same tendency in which the deviations increased as the frequency increased and the width of the grounding conductor became narrower. The largest deviation was measured when using a cable instead of grounding conductors.

The resonance due to stray capacitance between the AMN and the grounding conductor was found to affect the deviations.

On the basis of these results, the following points should be taken into account to minimize the deviation when using the measurement arrangement where the AMN is set on a 40-cm-high non-conductive support as specified in CISPR 16-2-1 edition 2.0.

- The width of the grounding conductor should be as wide as possible.
- The use of a cable connection between AMN and the horizontal reference ground plane should be avoided.
- Care should be taken in the connection between the AMN and the grounding conductor to reduce stray capacitance.

REFERENCES

[1] CISPR 22 edition 6.0, "Information technology equipment- Radio disturbance characteristice- Limits and methods of measurement," 2008.

[2] CISPR 32 edition 1.0, "Electromagnetic compatibility of multimedia equipment– Emission requirements," 2012.

[3] CISPR 16-2-1 edition 2.0, "Specification for radio disturbance and immunity measuring apparatus and methods– Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements," 2008.

[4] CISPR 16-1-2 edition 1.2, "Specification for radio disturbance and immunity measuring apparatus and methods– Part 1-2: Radio disturbance and immunity measuring apparatus– Ancillary equipment– Conducted disturbances," 2006.