A Proposal for an Efficient EMI Measurement Method in a Fully Anechoic Room

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***Abstract*—In a Fully Anechoic Room (FAR), height pattern variation rarely occurs since there are no reflected waves from the floor. Since the height of an antenna does not need to be changed to obtain an accurate peak value, measurement time can be drastically reduced. However, if the directivity of a noise source is very sharp, there is a concern that an accurate peak value may not be obtained when using a fixed-height antenna. In this report, we investigated how to change an antenna height in an FAR. We calculated the narrowest radiated-wave directivity based on EUT size and investigated the optimal step increment for changing the antenna height using the narrowest directivity. As a result, we verified that the difference between measurement results using our proposed and conventional method was within about ± 3 dB. This allowed us to shorten the measurement time to 22 % of that needed for the conventional method.**

Key words: FAR, OATS, SAC, EMI, EMC, CISPR

I. INTRODUCTION

Based on EMC standards, we use an open area test site (OATS) or a semi-anechoic chamber (SAC) to obtain EMC certification. In this case, the received wave is the vector-synthesized-wave, which is composed of a direct wave radiated from the EUT and a reflected wave from the floor. Therefore, the height pattern of the received wave fluctuates significantly. The need to change the antenna height to obtain an accurate peak value at each measuring frequency results in a very long measurement time. On the other hand, the use of an FAR and a new EMC standard is now being discussed [1]. Ideally, since there are no reflected waves from the floor in an FAR, the variation in the height pattern is very small. We therefore don't need to change the antenna height, so we can drastically reduce the measurement time compared with that of a conventional method using an OATS or an SAC.

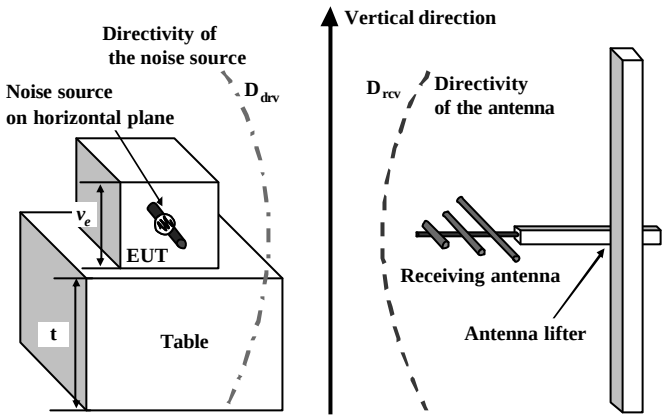
Previously, we evaluated the relationship between a fixed antenna height and the measurement result of the radiated emission in an FAR by using a comb generator and a digital consumer electronics system consisting of a liquid crystal display and a hard disk drive recorder as an EUT. As a result, we verified that the measurement time was shortened and the measurement accuracy was equivalent to the conventional method. However, if a noise source is not assumed to be a point source and it has sharp vertical directivity, we believe that the height pattern may fluctuates significantly, so we may not be able to obtain an accurate peak value by this method using a fixed-height antenna.

In this study, we investigated how to change the antenna height in an FAR. In our proposed method, we first calculated the narrowest vertical directivity of a noise source based on the EUT's size. Second, we decided the step increment for changing the antenna height using calculated directional characteristic. We evaluated the feasibility of this method by using a notebook computer as an EUT, and verified that the difference of the measurement results in our proposed and conventional method was within ± 3 dB and the measurement time was about 22 % of the needed for the conventional method.

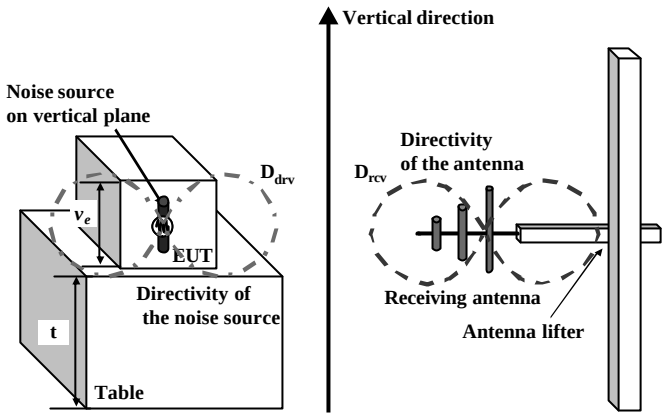
II. PROPOSAL OF AN EFFICIENT MEASUREMENT METHOD

A. Horizontal polarization

Figure 1-(a) illustrates measurement of horizontal



(a) Horizontal polarization



(b) Vertical polarization

Fig. 1 Measuring an EMI levels

polarization. If we assume that the noise source in the EUT is a small dipole antenna that emits a horizontal polarized wave, the vertical directivity of the radiated wave from the noise source is omnidirectional, as shown by the red line in Fig. 1. The vertical directivity of the antenna is omnidirectional too, so the variation in the received-wave height pattern depends solely on the spatial attenuation between the noise source and the antenna. If we assume that the EUT size v_e is 2 m and the table height t is 0.8 m, the noise source in the EUT is present from 0.8 m to 2.8 m. So, if the movable range of the antenna height is from 1 m to 3 m, the difference in the spatial attenuation is a maximum of 2 dB. Therefore, in this case, we regard setting the antenna at the same height as the center of the EUT as an efficient measurement method.

B. Vertical polarization

Figure 1-(b) shows measurement of vertical polarization. If we assume that the noise source in the EUT is a small dipole antenna that emits a vertical polarized wave, the vertical directivity of the radiated wave from the noise source has figure-eight directivity, as shown by the red line in Fig. 1-(b). As the beam width (BW) in the vertical directivity becomes narrower, the variation of the received-wave height pattern becomes greater. Therefore, we may not be able to get an accurate peak value by a method using a fixed-height antenna. In this case, therefore, we need to carry out measurements at different antenna heights. In this study, we investigated how to change the antenna height by using the minimum BW of the radiated-wave directivity. The minimum BW is calculated by using the EUT size. We aimed to achieve a difference of within ± 3 dB between the measurement results in our proposed method and the conventional method.

The details of our proposed method are described below. The BW of the radiated wave from the noise source depends on these structures and the number of antenna elements in the EUT. If the array antenna consists of the small dipole antenna illustrated in Fig. 2, the BW become narrower in proportion to the number of antenna elements. Consequently, to calculate the worst case, i.e., where the BW is at a minimum, we estimate the maximum number of antenna elements by using the EUT size. If we define the distance between each antenna as a half-wavelength at which the grating lobe reaches a

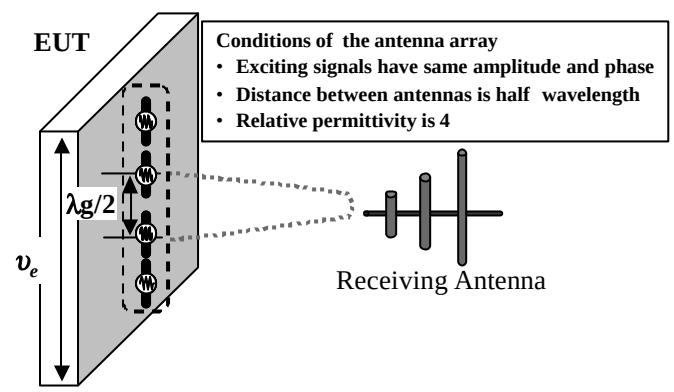


Fig. 2 Conditions of antenna array in an EUT

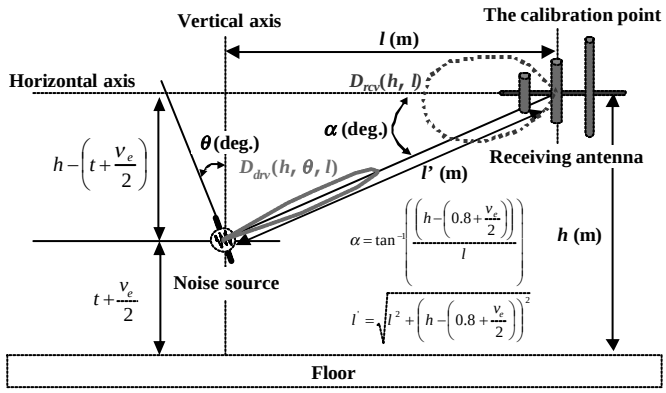


Fig. 3 Positional correlation between a noise source in the EUT and the receiving antenna

minimum, the maximum array number of the antenna element V_A is indicated in Eq. (1), where λ_g denotes the wave length.

$$V_A = v_e \Big/ \left(\frac{\lambda_g}{2}\right) \tag{1}$$

Figure 3 shows the positional correlation between the noise source in the EUT and the receiving antenna. The antenna height is h, the inclination of the small dipole antenna to the vertical axis is θ, the angle between the horizontal axis and the line connecting the noise source and the receiving antenna is a, and the distance between the center of the noise source and the receiving antenna[1] is l'. Equation (2) indicates the vertical directivity of the radiated wave from the noise source D_{drv}, where the first term denotes the array factor and the second term denotes the radiated pattern from the small dipole antenna.

$$D_{drv}(h,\theta,l) = \frac{\sin\left(\frac{V_A\pi}{2}\cos\left(\alpha-\theta+\frac{\pi}{2}\right)\right)}{V_A\sin\left(\frac{\pi}{2}\cos\left(\alpha-\theta+\frac{\pi}{2}\right)\right)} \times \sin\left(\alpha-\theta+\frac{\pi}{2}\right) \tag{2}$$

$$\alpha = \tan^{-1}\left(\frac{\left(h-\left(t+\frac{v_e}{2}\right)\right)}{l}\right)$$

Equation (3) indicates the vertical directivity of the received wave M, where the first term denotes the vertical directivity of a noise source D_{drv} and the second term denotes the vertical directivity of the receiving antenna D_{rcv} and the third term denotes the correction of the spatial attenuation.

$$M(h,\theta,l) = D_{drv}(h,\theta,l) \times D_{rcv}(h,l) \times l \Big/ l' \tag{3}$$

$$l' = \sqrt{l^2+\left(h-\left(t+\frac{v_e}{2}\right)\right)^2}$$

Equation (3) is formed under the far-field conditions. We set the conditions that θ = 0 to 90°, l = 3 m, and h = 1 to 3 m,

[1] This indicates the feeding point for the biconical antenna and the calibration point for the logarithmic periodic broadband antenna.

and calculated all the vertical directivities of the received wave. We defined h_{max} and h_{3dB} as the antenna height at the maximum value in the narrowest directivity and the antenna height at –3 dB compared with the maximum value, respectively; and defined the step increment K_i for changing the antenna height as indicated in Eq. (4). Therefore, by using the step increment, we obtained the height-pattern variation with a measurement accuracy of within ± 3 dB.

$$K_i = |h_{\max} - h_{3dB}| \quad (4)$$

$$20\log\left(M(h_{3dB},\theta,l) \big/ M(h_{\max},\theta,l) \right) = -3 \text{ (dB)}$$

III. Evaluation of Our Proposed Method

We measured the EMI level using our proposed method and the conventional method, then compared the peak levels and the measurement times for both techniques.

A. Measurement setup

We used a 3-m FAR for our evaluations [2]. The size of its electromagnetic shielding enclosure was 11 m (W) x 6 m (D) x 6 m (H).

Figure 4 shows the measurement setup, and Table I shows the specifications of the measurement instruments. The distance between the center of the EUT and the antenna l in Fig. 4 is 3 m, and the table height t in Fig. 4 is 0.8 m. We used a notebook computer as an EUT. The EUT height v_e in Fig. 4 is 26 cm. To avoid measurement errors due to different screen images affecting the internal processor, we placed a still picture on the screen to obtain stable measurement conditions.

Table II shows the step increments for changing the antenna height in our proposed method and in the conventional method. The step increment for changing antenna height in the conventional method was 5 cm. This value is the minimum step increment usable in this measurement system. We calculated the step increment for each frequency range in our proposed method. First, we set the frequency at 300 MHz in Range 1, 1 GHz in Range 2, and 6 GHz in Range 3, and calculated the maximum array numbers in each range using Eq. (1). Second, under the conditions of θ = 0 to 90° in 5-degree increments, l = 3 m, and h = 1 to 3 m in 5-cm increments, we calculated the narrowest directivity of the antenna array for each range using Eq. (2). Next, we calculated the vertical directivities of the

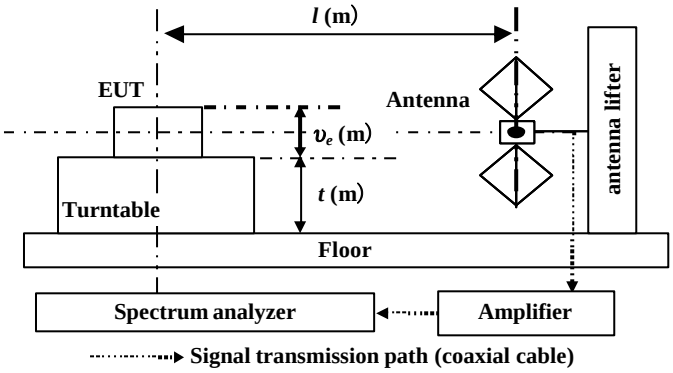


Fig. 4 Measurement setup

TABLE I Specifications of the Measurement Instruments

Instrument		Model	Specifications.
Antenna	30 MHz to 300 MHz	Biconical antenna (Schwarzbeck) BBA9106+VHA9103	Range: 30 MHz to 300 MHz
	300 MHz to 1 GHz	Logarithmic periodic broadband antenna (Schwarzbeck) UHALP9108A	Range: 250 MHz to 2.2 GHz
	1 GHz to 6 GHz	Horn antenna (Schwarzbeck) BBHA9120B	Range: 1 GHz to 10 GHz
Detector		Spectrum Analyzer (Agilent) E4464A	Range: 3 Hz to 44 GHz
Amplifier	30 MHz to 1 GHz	Microwave amplifier (Sonoma) 310N	Range: 700 Hz to 4.2 GHz Gain: 30 dB
	1 GHz to 6 GHz	Microwave amplifier (TOYO) TPA0108	Range: 1 GHz to 8 GHz Gain: 40 dB

TABLE II Antenna Height Step Increment

Polarization	Proposal	Conventional
Horizontal	Fixed (1 m)	0.05 m
Vertical	-Range 1: 30 MHz to 300MHz K_1 = 1.2 m (at 300 MHz) -Range 2: 300 MHz to 1 GHz K_2 = 0.6 m (at 1 GHz) -Range 3: 1GHz to 6 GHz K_3 = 0.1 m (at 6 GHz)	0.05 m

TABLE III Measurement Conditions of Our Proposed Method and the Conventional Method

Method	Condition
Proposal	(Under horizontal polarization) Range : 30 MHz to 6 GHz - Antenna height : 1 m - Rotation speed of table : 0.56 rpm - Number of rotations : 3 (Under vertical polarization) Range 1: 30 MHz to 300MHz (K_1 = 1.2 m) - Antenna height : 1, 2, 3 m - Rotation speed of table : 0.56 rpm - Number of rotations : 3 Range 2: 300 MHz to 1 GHz (K_2 = 0.6 m) - Antenna height : 1, 1.6, 2.2, 2.8 m - Rotation speed of table : 0.56 rpm - Number of rotations : 3 Range 3: 1 GHz to 6 GHz (K_3 = 0.1 m) - Antenna height : 10-cm increments (from 1 m to 3 m) - Rotation speed of table : 0.56 rpm - Number of rotations : 1
Conventional	At horizontal and vertical polarization Range : 1GHz to 6 GHz - Antenna height: 5-cm increments (from 1 m to 3 m) - Rotation speed of table: 0.56 rpm - Number of rotations: 1

received wave at 300 MHz, 1 GHz, and 6 GHz using Eq. (3). Lastly, using the antenna height h_{max} at the maximum value in the directivity and h_{3dB} at –3 dB compared with the maximum value, we calculated the step increments K_1, K_2, and K_3 to change the antenna height for each range using Eq. (4). Table III shows the details of the measurement conditions of the proposed and conventional methods.

B. Measurement results

To confirm the measurement errors of this measurement system, we measured the EMI levels at horizontal and vertical polarizations twice using the conventional method. Fig. 5 shows the differences between the measurement results. We therefore confirmed that the measurement error was within ± 3 dB.

Figure 6 shows the measurement results using our proposed method. Fig. 7 shows the difference between the measurement result for our proposed method and those for the conventional method. As shown in Fig. 7, the difference in the measurement results in the two methods at each peak frequency was within ± 3 dB, equivalent to the measurement error of this measurement system. It took about 950 minutes for the conventional method, but only 210 minutes, which is about 22 % of that needed using the conventional method. We thus conclude that our proposed method is practical.

IV. CONCLUSION

In this paper, we investigated how to change the antenna height in an FAR. In our proposed method, we first assumed a condition under which the vertical directivity of a noise source in an EUT fell to a minimum by using the size of the EUT. We then set the step increment for changing the antenna height based on the assumed directional characteristic. We investigated the feasibility of this method using a notebook as an EUT, and verified that the difference in the measurement results between our proposed and the conventional method was within ± 3 dB. This allowed us to shorten the measurement time to 22 % of that needed for the conventional method.

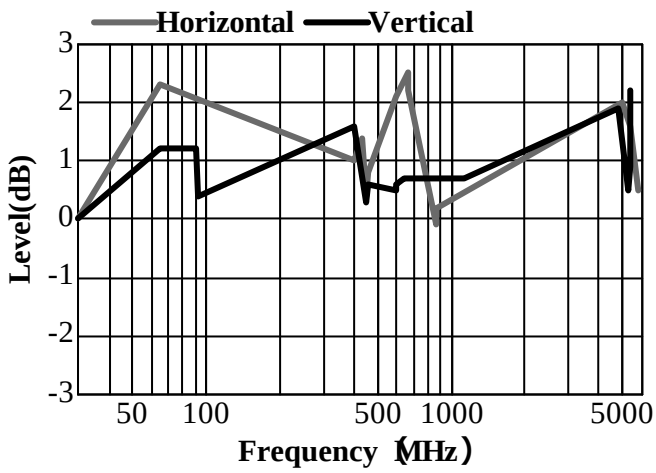


Fig. 5 MEASUREMENT ERRORS

V. REFERENCES

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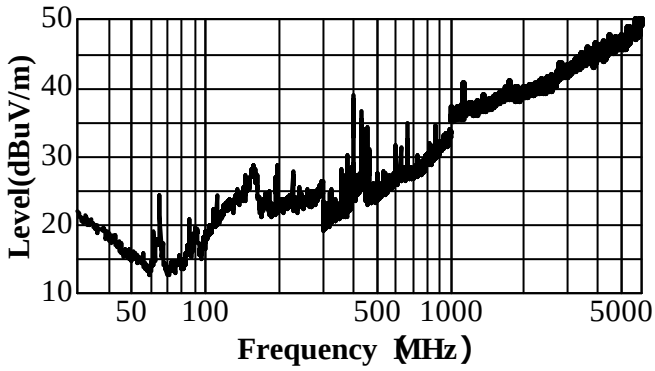
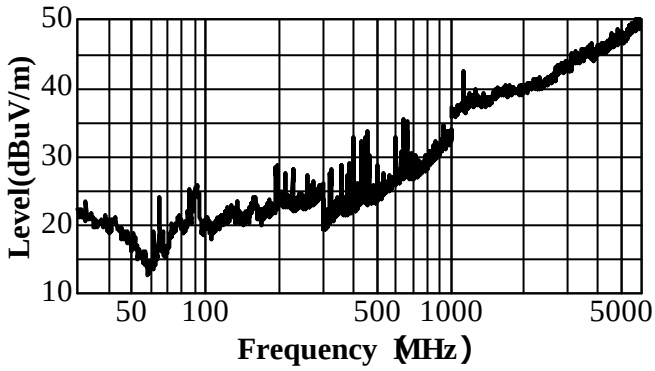
[2] "Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – ancillary equipment – Radiated disturbances," CISPR16-1-4 Ed.2.0, February 2007.



(a) Horizontal polarization



(b) Vertical polarization

Fig. 6 Measurement results of the proposal method

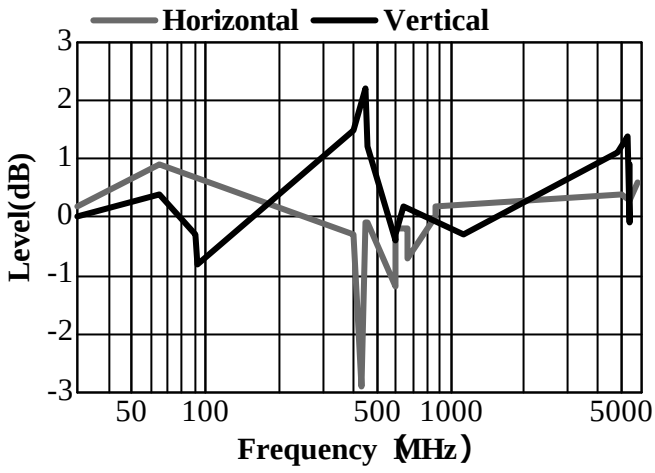


Fig. 7 Differences between the proposal and conventional method