A Fundamental Study on Estimation Method of 10 m Test-range Electric Field Strengeth by Near-field Measurment

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Abstract ***In this paper, we have fundamentally studied the estimation of 10 m test-range electric field strength height pattern by means of measuring the tangential electromagnetic fields on the cubic surface surrounding Bi-conical and Log-periodic antennas placed above the ground plane by using the differential electric and magnetic probe. The analysis frequency range is from 30 MHz to 1GHz, and the polarization is both horizontal and vertical. The 10 m test-range electric field strength is calculated according to Field Equivalent Principle through replacing the electromagnetic fields with the equivalent surface currents. And also, the ground plane is hypothesized the infinite conductive plane, and the image receiving point is formed against the real receiving point above the ground plane. The 10 m test-range electric field strength is calculated by adding the each estimated electric field both the real and image receiving point. As the results, the estimation of 10 m test-rang electric field strength height patterns at each polarization are in agreement with NEC2-calculation. There are within ±1 dB, except null points. The estimation results with the condition of ground plane demonstrated the effectiveness of the proposed method.***

Keywords; Near-field Measurement, Far-field Estimation, Field Equivalent Principle, Differental electromagnetic Probe, Electric Field Strength, 10 m Test-range, Ground Plane.

I. INTRODUCTION

The emission radiated from EUT is evaluated through Open Area Test Site (OATS). Recently, it is not fully prepared the environment for OATS because of a variety of communication sources. The semi anechoic chambers for emission test are therefore becoming more and more important by means of a change for the worse of OATS environment. The 3 m and 10 m semi anechoic chambers, abbreviated as test site, are in widespread use for EMC. By the way, these test sites are required the ground plane for EUT emission tests at lower frequency range below 1GHz, and also, there are required to satisfy the conditions stipulated in ANSI C63.4, CISPR22 or EN50147 in the frequency range of 30MHz to 1GHz, at which the normalized site attenuation shall be within ±4dB to a theoretical one [1][2][3].

However, the 3 m and 10 m semi anechoic chambers are necessary the large space and high construction expenses. It is therefore demanded the compact and low expenses evaluation systems. In recent year, several compact evaluation systems have been developed, such as a measurement system of reactive near-field for the print circuit board (PCB). These systems are useful for EMC countermeasure, but there are not come to be estimated the 3 m and 10 m test-range electric field strength yet. And also, there are not considered the location requirements for EUT, such as the ground plane.

We have already studied the estimation of 3 m test-range site attenuation height pattern by means of measuring the tangential electromagnetic fields on the cubic surface surrounding Dipole antenna placed above the ground plane in the narrow frequency range [4]. The object of this study is to present the estimation method of 10 m test-range electric field strength by measuring the near-field in the wide frequency range from 30 MHz to 1 GHz. We have fundamentally studied the estimation of 10 m test-range electric field strength height pattern by means of measuring the tangential electromagnetic fields on the cubic surface surrounding Bi-conical and Log-periodic antennas placed 1.0 m above the ground plane by using the differential electric and magnetic probe. Figure 1 shows the summary of condition between the near-field and the 10 m test-range. We propose the estimation method which is considered the ground plane for EUT emission tests.

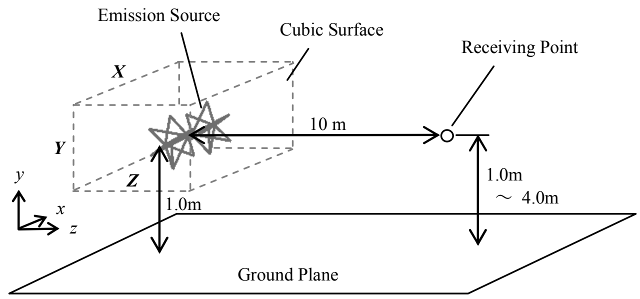


Fig. 1. Summary of Condition between Near-field and 10 m Test-range.

II. ESTIMATION METHOD

A. Field Equivalent Principle

The 10 m test-range electric field strength can be calculated according to *Field Equivalent Principle* through replacing the tangential electromagnetic fields E and H on the surface surrounding the radiation source with the equivalent surface currents J and M, as shown in Fig.1. The equivalent surface current J and M are related to the tangential electromagnetic fields E and H by

$$J = \hat{n} \times H \quad , \quad M = -\hat{n} \times E \tag{1}$$

where $\hat{n}$ is a normal vector.

The electric field strength $\boldsymbol{E}(r)$ can be represented by the equivalent surface currents $\boldsymbol{J}$ and $\boldsymbol{M}$ [5].

$$\boldsymbol{E}(r)=\oint_S\left(-jk\eta\left(\boldsymbol{J}G+\frac{1}{k^2}\boldsymbol{J}\cdot\nabla\nabla G\right)-\boldsymbol{M}\times\nabla G\right)dS \tag{2}$$

where k is the wavenumber $2\pi/\lambda$, η is the intrinsic impedance. On the other hand, Green's function G, ∇G, and $\boldsymbol{J}\cdot\nabla\nabla G$ can be represented by

$$\begin{aligned} &G=\frac{e^{-jkr}}{4\pi r}\ ,\ \ \nabla G=\left(-\frac{1+jkr}{r}\right)G\hat{r} \\ &\boldsymbol{J}\cdot\nabla\nabla G=(\boldsymbol{J}\cdot\hat{r})\left(-k^2-\frac{2k^2}{jkr}-\frac{2k^2}{(jkr)^2}\right)G\hat{r} \end{aligned} \tag{3}$$

where r is the distance from the surface point to the receiving point, $\hat{r}$ is a unit vector.

B. Ground plane Reflection

The ground plane can be regarded as a reflector for the electromagnetic wave. Figure 2 shows the summary of the ground plane reflection. In Fig.2, the ground plane is hypothesized the infinite conductive plane, and the image receiving point P' is formed against the real receiving point P above the ground plane. Then, the 10 m test-range electric field strength $\boldsymbol{E}(r)$ is calculated by adding the each estimated electric field $\boldsymbol{Ep}'(r')$ and $\boldsymbol{Ep}(r)$ both the each receiving point.

$$\begin{aligned} &\boldsymbol{E}(r)=\Gamma\cdot\boldsymbol{Ep}'(r')+\boldsymbol{Ep}(r) \\ &\begin{cases}\Gamma=-1 & (Horizontal\ :\ TE\ \ wave) \\ \Gamma=+1 & (Vertical\ :\ TM\ \ wave)\end{cases} \end{aligned} \tag{4}$$

where Γ is the reflection coefficient of the ground plane.

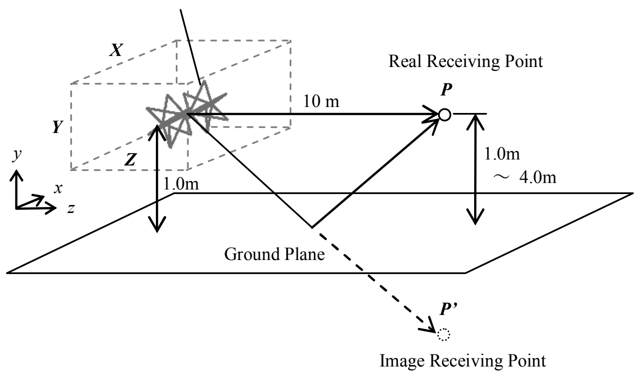


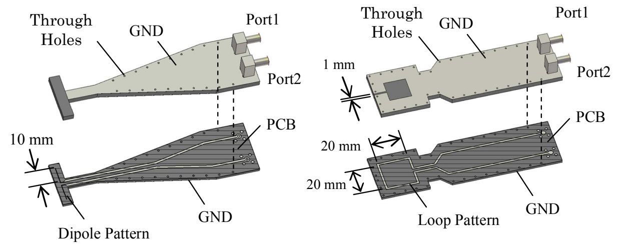
Fig. 2. Summary of Ground Plane Reflection.

III. Near-field Measurement

A. Electric and Magnetic Probes

In the near-field measurement, we have used the differential electric and magnetic probe of the shield structure having the two ports [6]. Figure 3 shows the differential electric and magnetic probe structure.

The electric probe is the dipole structure, it is constituted of two monopoles which each element length is fixed 10 mm. On the other hand, the magnetic probe is the shielded loop structure having 1 mm gap on tip, it is constituted of square element which one side is fixed 20 mm. The core plate of electric and magnetic probe is constituted of PCB which the dipole and loop shape are patterned on the dielectric board. And also, the each probe is the shielded structure of which the core plate is sandwiched between two GND plates having the many through holes together.



(a) Electric Probe (b) Magnetic Probe

Fig. 3. Differential Electric and Magnetic Probe Structure.

B. Probe Factors

The each probe is fixed to the height of 1 m from the ground plane same as Bi-conical and Log-periodic antennas height, as shown in Fig. 4. And the electromagnetic fields $\boldsymbol{E}_x^{meas}$ and $\boldsymbol{H}_y^{meas}$ have measured by changing the distance between the each antenna and the each probe from 30 cm to 100 cm in the pitch of 10 cm. The electromagnetic fields are obtained by a differential method which is subtracted the port 2 vector *S31* from the port 1 vector *S21*. Then, we have obtained the probe factor $\boldsymbol{PF}_E$ and $\boldsymbol{PF}_H$ by dividing the measured electromagnetic field $\boldsymbol{E}_x^{meas}$ and $\boldsymbol{H}_y^{meas}$ from NEC2-calculated $\boldsymbol{E}_x^{NEC}$ and $\boldsymbol{H}_y^{NEC}$, as follows the equation (5). The element structure of Bi-conical and Log-periodic antennas is modeled by the conductive wire. The model of each antenna is divided into small segments, then $\boldsymbol{E}_x^{NEC}$ and $\boldsymbol{H}_y^{NEC}$ are calculated by supplying with 1 [V] to those antennas.

$$\boldsymbol{PF}_E=\boldsymbol{E}_x^{NEC}/\boldsymbol{E}_x^{meas},\ \ \boldsymbol{PF}_H=\boldsymbol{H}_y^{NEC}/\boldsymbol{H}_y^{meas} \tag{5}$$

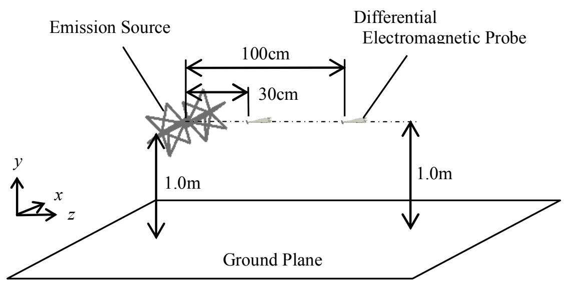


Fig. 4. Summary of Probe Factor Measurement.

Figure 5 shows the magnitude factor of each probe, and also Figure 6 shows the phase factor of each probe. It is ascertained that the magnitude factor and the phase factor at each measurement point converge to the constant value, respectively.

In Fig.5, it is found that the each magnitude factor indicates inversely proportional to the frequency, respectively. And also, it is found that the magnitude ratio between the electric probe magnitude factor and the magnetic probe one indicates constant value. On the other hand, in Fig.6, it is found that the each phase factor indicates linearity to the frequency, respectively. And also, it is found that the phase deviation by subtracting between the electric probe phase factor and the magnetic probe one decreases with increasing the frequency.

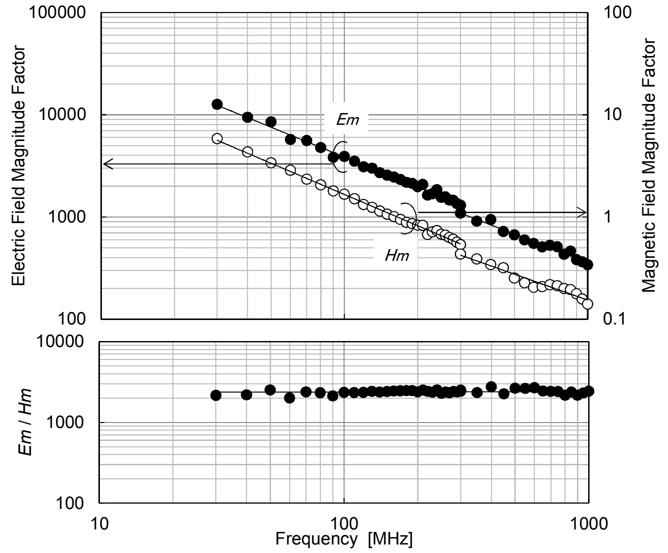


Fig. 5. Magnitude Factors.

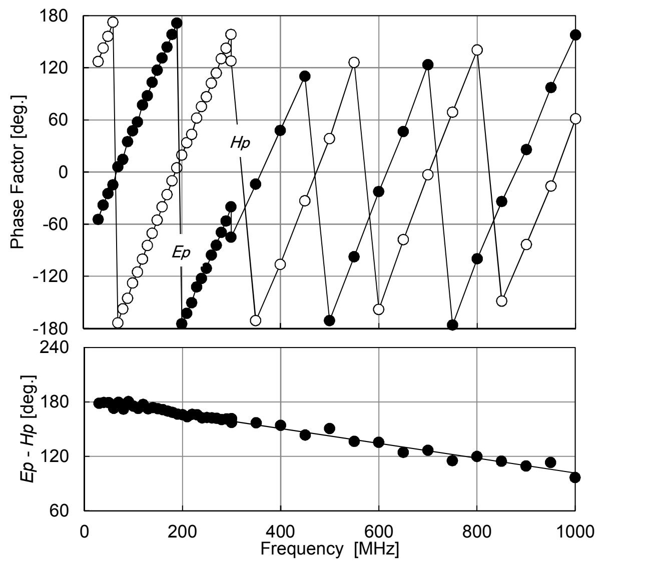
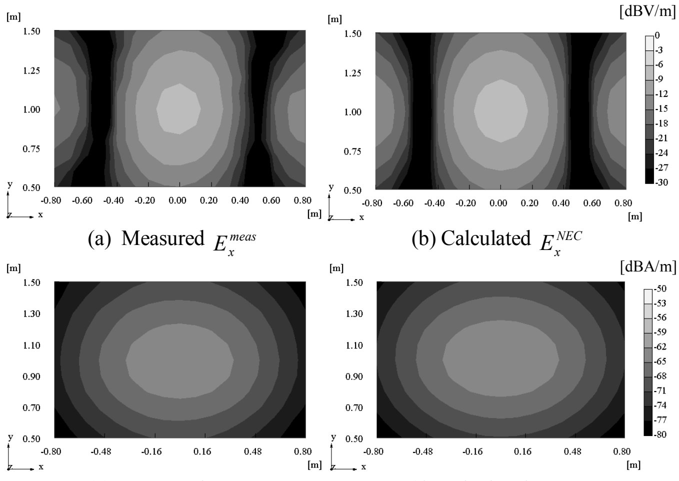


Fig. 6. Phase Factors.

C. Near-field Measurement

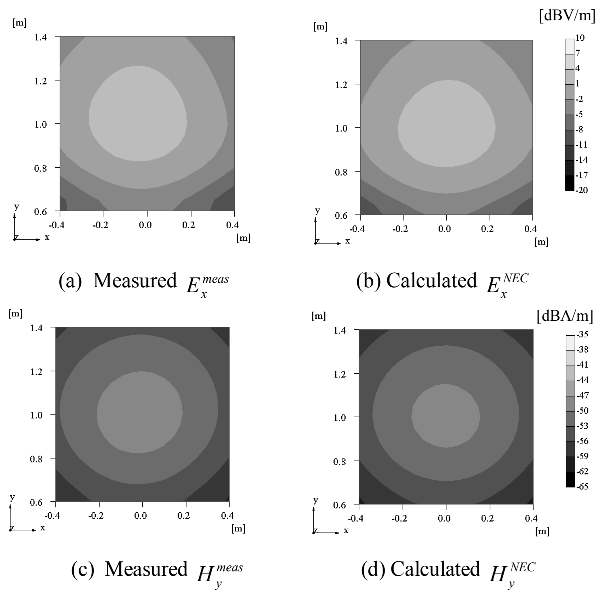
The electric and the magnetic probes are scanned from left to right and bottom to top, or back to front on the cubic surface surrounding Bi-conical and Log-periodic antenna placed above the ground plane, and the tangential electromagnetic fields are measured, as shown in Fig.1. Then, the numerical tangential electromagnetic fields E and H are determined using the probe factor PF_E and PF_H. In Fig.1, the cubic size of Bi-conical antenna is fixed X=100 cm, Y=160 cm, and Z=100 cm at horizontal polarization, and X=100 cm, Y=100 cm, and Z=160 cm at vertical polarization. And also, the measurement pitch is 10 cm length. On the other hand, Log-periodic antenna is fixed X=Y=Z=80 cm at both polarization. And also, the measurement pitch is 5 cm length. The each cubic size is determined the reception of each probe into consideration.

For example, figure 7, 8 show the magnitude distributions of tangential electromagnetic fields on *xy*-plane at 30 MHz and 300 MHz, horizontal polarization. And also, NEC2-calculation results at the near-field are shown in these figures. It is found that the each measured results agree well with NEC2-calculated results.



(a) Measured E_x^{meas} (b) Calculated E_x^{NEC}
(c) Measured H_y^{meas} (d) Calculated H_y^{NEC}

Fig. 7. Magnitude Distributions of Tangential Electromagnetic Fields on *xy*-Plane at 30 MHz (Horizontal Polarizaiotn, Bi-conical).



(a) Measured E_x^{meas} (b) Calculated E_x^{NEC}
(c) Measured H_y^{meas} (d) Calculated H_y^{NEC}

Fig. 8. Magnitude Distributions of Tangential Electromagnetic Fields on *xy*-Plane at 300 MHz (Horizontal Polarizaiotn, Log-periodic).

IV. Estimation of Electric Field Strangeth

As mentioned above, we have studied the estimation of 10 m test-range electric field strength height pattern from the measured tangential electromagnetic fields.

Figure 9 shows the estimation results of horizontal polarization at 30, 50, 100, 300, 500, and 1000 MHz, and Figure 10 shows the estimation results of vertical polarization. And also, NEC2-calculation results at 10 m distance are shown in these figures.

As the results, the estimation of 10 m test-rang electric field strength height patterns at each polarization are in agreement with NEC2-calculation. There are within ±1 dB, except null points. These estimation results with the condition of ground plane demonstrated the effectiveness of the proposed method.

V. Conclution

In this paper, we have fundamentally studied the estimation of 10 m test-range electric field strength height pattern by measuring the near-field in the wide frequency range from 30 MHz to 1GHz using Bi-conical and Log-periodic antennas which is clear as an emission source.

As the results, we have ascertained that the estimation of 10 m test-rang electric field strength height patterns with the condition of ground plane are in agreement with NEC2-calculation. We could be confirmed the validity of this estimation method.

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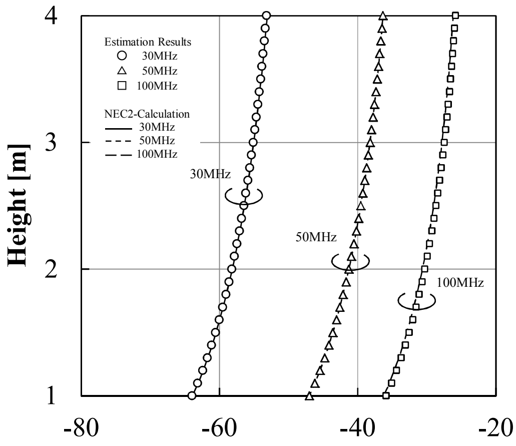
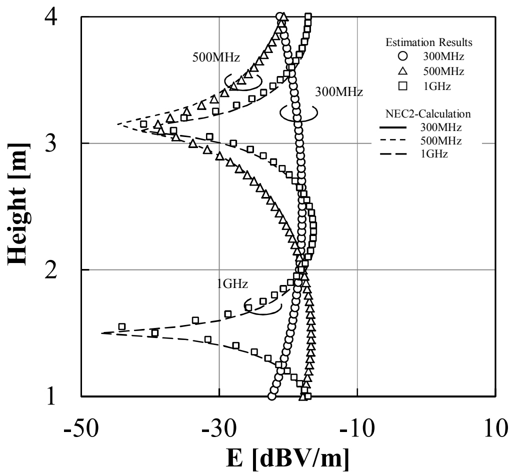
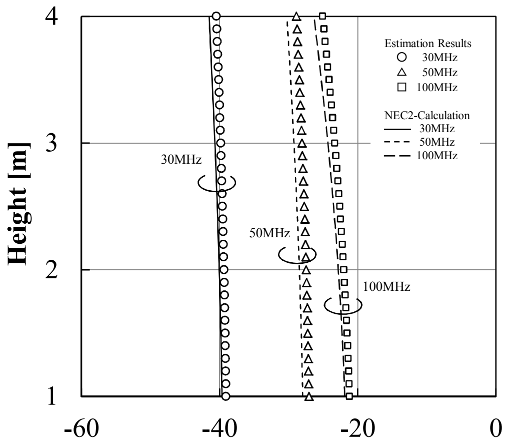


(a) Bi-conical Antenna

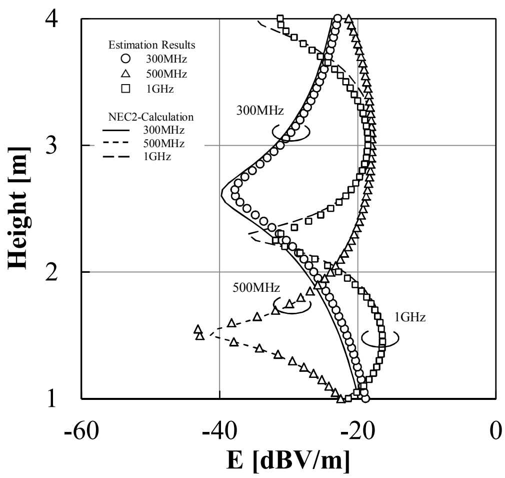


(b) Log-periodic Antenna

Fig. 9. Estimation Results at Horizontal Polarization.



(a) Bi-conical Antenna



(b) Log-periodic Antenna

Fig. 10. Estimation Results at Vertical Polarization.