Prediction of Electric Field Strength at 10m Distance Using Emission Source Finding Method

Noburo Aoki* Masato Kawabata Yasuhiro Ishida*** Nobuo Kuwabara***

*Department of Electrical Engineering, Kyushu Institute of Technology, Kitakyushu, Japan
**Fukuoka Industrial Technology Center, Kitakyushu, Japan
***ADOX Fukuoka, Nogata, Japan
E-mail: aoki@buddy.elcs.kyutech.ac.jp

Abstract: The equipment under test (EUT) was modeled by current sources. The current positions were estimated using the finding method of radiated emission source by electric field strength data alone. The current vectors were determined by the conditions, where *Norm* (deviation between the calculated electric field and the measured one) was minimized. Using estimated current sources model, the electric filed strength at 10m distance was predicted. The predicted results were compared with the measured data for an imitated equipment and a personal computer. The results indicate that the radiation patterns were similar to the measured ones, and the maximum electric field strength at 10m distance was comparable to the measured value and the calculated value on the assumption where electric field decreases in proportion to distance.

Key words: Finding method of radiated emission source. Prediction electric field strength. EUT modeling.

1. Introduction

In recent years, the influence of electromagnetic disturbance has enlarged as one of the social problems. The electromagnetic disturbance generated from electrical equipment may disturb the operation of the surrounding radio wave apparatus. In order to prevent this problem, the measurement method and the limit for radiated emission are internationally specified, and its measurement distance is generally 10m. In many cases, however, pre-measurement is performed at 3m distance. In this case, the electric field strength at 10m distance should be estimated from the pre-measurement data.

In the previous, the electric field strength at 10m distance has been estimated on the assumption, where electric field strength decreases in proportion to distance. However, the calculated value was sometimes different from the measured one because the directivity of emission source influenced to the distance dependence.

This paper presents a new method to predict the electric field strength from the pre-measurement data. The equipment under test (EUT) was modeled by current sources, and the electric field strength was predicted by this modeling. The predicted field strength was compared with the measured results to evaluate the validity of this method.

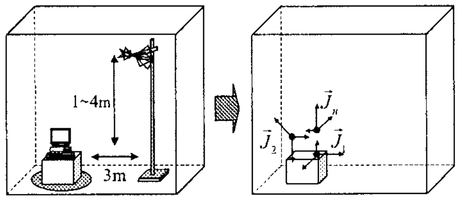
2. Prediction procedure

2.1 Basic concept of prediction

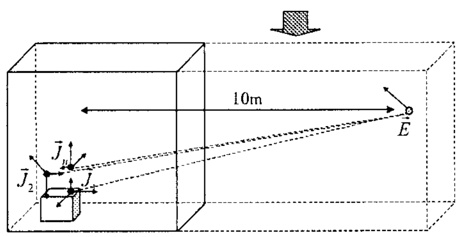
Figure 1 shows the procedure to predict the electric field strength at 10m distance.

Firstly, the electric field strength at 3m distance is measured as shown in Fig.1(a). Secondly, the EUT is modeled by the current sources as shown in Fig. 1(b). Finally, the electric field strength at 10m distance is calculated from the modeled sources by using the following relation.

$$\vec{E}^{(0)} = \sum_{n=1}^{N} \left\{ \frac{\vec{J}_n^{(0)} e^{-jkr_n}}{r_n} + \frac{\vec{J}_n^{(0)\prime} e^{-jkr_n'}}{r_n'} \right\} \tag{1}$$



(a) Measurement at 3m distance. (b) Modeling of current sources.



(c) Calculation at 10m distance using modeled sources.

Fig.1 Prediction procedure of electric field at 10m distance.

Where, $\bar{E}^{(0)}$ is the electric field at observation point, N is the number of current sources presenting EUT, $\bar{J}_n^{(0)}$ is the current source vector, r_n is the distance between the source position and the observation position, and k is wave number. The second term in Eq. (1) presents the emissions from image sources.

The method has an advantage to consider the directivity of electric filed from EUT because the EUT is modeled by some current sources.

2.2 Modeling of EUT

To predict the electric field at 10m distance, the EUT should be presented by the current sources. This means that we should determine the positions and vector values of the current sources.

The emission source finding method using only amplitude data [1], [2] is applied to determine the current source position. This method can determine the position where the contribution to the measured values is the maximum.

This method is effective to determine the current source position. However, this method cannot identify the current vector value. Then, the similar method is applied to determine the vector value.

The deviation of measured and calculated values is evaluated by the *Norm*, which is given by

$$Norm_i = \frac{\sum_{m=1}^{M_p} \left| E_{im}^{(0)} - E_{im}^{M} \right|^2}{\sum_{m=1}^{M_p} \left| E_{im}^{M} \right|^2} \quad (i = x, y, z) \quad (2)$$

Where M_p is the number of total observation points, E_{im}^{M} is the measured electric field strength, $E_{im}^{(0)}$ is the calculated one at the same position. Each current vector component $\bar{J}_n$ is compensated by the conditions given by

$$\frac{\partial Norm_i}{\partial \bar{J}_i} = 0 \qquad (3)$$

Repeating the process presenting in Eq. (2) and Eq. (3), we can obtain the optimum current vector value.

3. Verification using an imitated equipment

3.1 Verification method

The proposed method was experimentally verified in a large semi-anechoic chamber (L=24m, W=15m, H=10m). Figure 2 shows the imitated equipment used for an EUT in this verification. It has an O/E converter and a battery in a shielded box (0.48m x 0.36m x 0.1m). And the loop antenna (0.2m x 0.05m) on the shielded box emits the signal transmitted through the optical fiber. In this verification, the focused frequency was 300 to 700MHz. In this range, the number of the observation points was 384points, according with the presenting paper [1].

3.2 Evaluation result

Figure 3 shows the radiation patterns at 3m distance, 3m height. The solid lines indicate the measured value and the dotted lines indicate the calculated one.

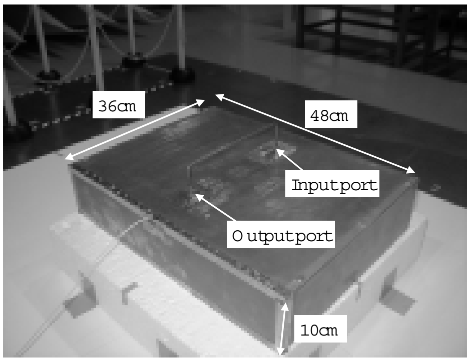
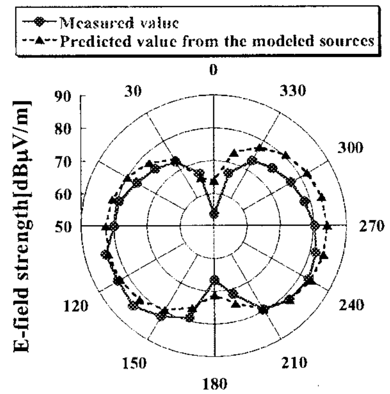
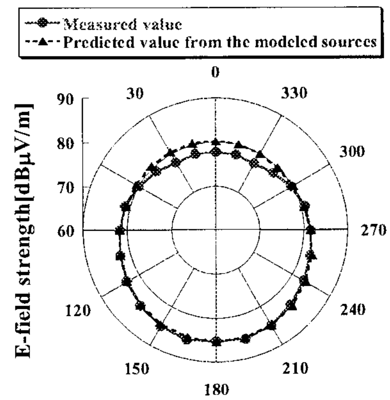


Fig.2 Appearance of imitated equipment



(a) Horizontal polarization



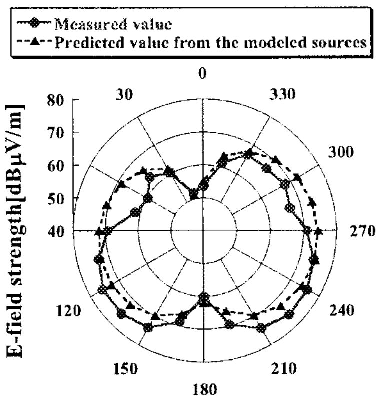
(b) Vertical polarization

Fig.3 Radiation patterns of imitated equipment at 300MHz, 3m distance, 3m height.

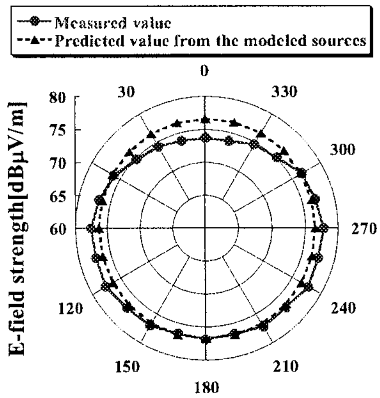
On the calculation, the EUT was presented by three current sources, and their positions and vector values were determined by the method presenting section 2.2. These figures show that the predicted patterns agree well with the measured ones.

These results mean that the identified current sources modeled the EUT in sufficient accuracy.

By using the above-mentioned modeling, the radiation patterns at 10m distance were predicted, as shown in Fig.4. The deviation between the measured and predicted value at 10m distance is 10dB in horizontal polarization and 3dB in vertical polarization respectively, and the predicted patterns are similar to the measured ones.



(a) Horizontal polarization

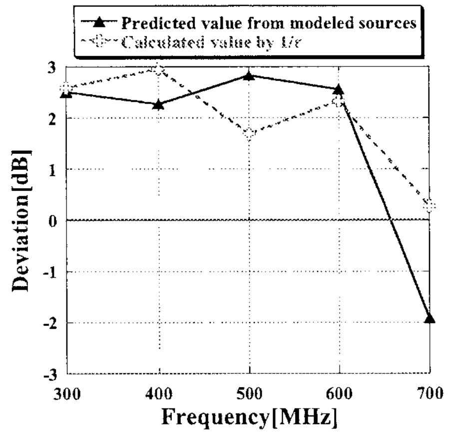


(b) Vertical polarization

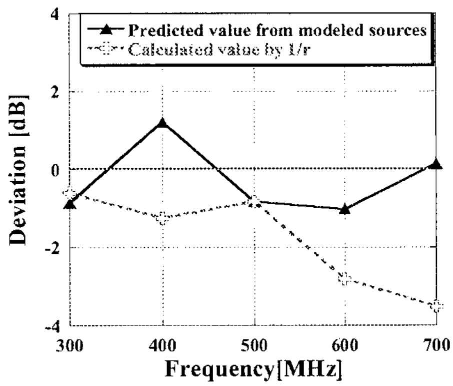
Fig.4 Radiation patterns of imitated equipment at 300MHz, 10m distance, 3m height.

Figure 5 shows the deviation from the measured value. The maximum electric filed strength at 10m distance was selected as reference. The triangles indicate the deviation of the predicted value by using the proposed method, where the maximum value in all the observation points is picked up. The crosses indicate the deviation of the maximum electric field at 10m distance calculated from the assumption, where the electric field strength decreases in proportion to distance (= by 1/r, r: distance). These figures indicate that the predicted values are almost the same as the values calculated by the assumption.

It has been reported that the maximum electric field strength of the imitated equipment decreases in proportion to the distance [4]. This is similar to the results obtained by the proposed method.



(a) Horizontal polarization



(b) Vertical polarization

Fig.5 Frequency vs. deviation from maximum vertical electric field strength measured at 10m distance.

4. Verification with a PC

The method was applied to an actual equipment. Figure 6 shows the EUT used in this experiment. The focused frequency was selected to 189.5MHz because the radiation level was sufficient large and steady to model the PC. A large semi-anechoic chamber (L=24m, W=15m, H=10m) was used for the experiment.

The PC was modeled by three current sources, where the positions and the values were determined by the proposed method using the measured data at 3m distance. The electric field strength at 10m distance was predicted by this modeling, and the maximum value was picked up.

The maximum electric field strength was also measured at 10m distance, and it was compared with the predicted one.

Fig.6 PC used in this measurement

Table 1 shows the maximum electric field strength and the deviation from the measured value. The calculated value was derived from the measured value at 3m distance based on the assumption, where the electric field decreases in proportion to distance.

Table 1 Maximum value of electric field strength (upper berth: [dBμV/m]) and deviation from measured value (lower berth: [dB]).

	Distance[m]	Measured value	Predicted value from modeld sources	Calculated value by 1/r
Horizontal polarization	3	59.44	59.57	
			0.13	
	10	50.13	50.20	48.98
			0.06	-1.15
Vertical polarization	3	59.62	58.84	
			-0.78	
	10	51.26	55.12	49.16
			3.86	-2.10

In horizontal polarization, the electric field strength was predicted in sufficient accuracy whose deviation from the measured value was within 1dB. In vertical polarization, however, the deviation from the measured value was more than 3dB. The similar results were also obtained in the calculation considering with the distance dependence.

These results indicate that prediction accuracy might be more than 3dB. The raising accuracy is future problem.

5. Conclusion

In this paper, we proposed a new modeling method of equipment under test (EUT). This method estimates the current position and the current value through the optimization process by using electric field strength data at 3m distance. With this modeling method, the electric field strength at 10m distance was predicted. It was experimentally verified by using an imitated equipment and a PC in a large semi-anechoic chamber. As the results for the imitated equipment, the predicted radiation patterns agreed well with the measured ones. In case of the PC, the maximum predicted electric field strength was comparable to the results assuming that the electric field decreases in proportion to distance. These results mean that the basic applicability of the proposed method has been revealed. In the future work, we plan to improve the modeling process in order to raise the prediction accuracy.

References

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