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ELECTRIC FIELD STRENGTH SPECIFICATION METHOD UNDER 80 CM FOR RF IMMUNITY TESTING

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Abstract

Electric field distribution below 80cm should be specified to test the rf immunity of the floor-standing equipment. To determine this specification, we used a model in which the equipment is set on the infinite ground plane. Calculations using the moment method show that the height pattern of the field below 80 cm is independent of frequency, and the height pattern measured in a room is close to the calculated pattern. This paper therefor proposes that the electric field below 80 cm is specified based on the height pattern in this model.

Experimental result show that both the electric field distribution specified by IEC and this paper can be generated in a semi-anechoic chamber.

1. Introduction

Information technology equipment (ITE) should be tested its immunity to electromagnetic disturbances such as those due to illegal CB radio stations or TV broadcasting stations. The International Electrotechnical Commission (IEC) has therefore discussed methods for testing this immunity [1],[2]. Immunity from the effects of electric fields, which is called rf immunity, is tested in a uniform electromagnetic field and at frequencies ranging from 80 MHz to 1 GHz [1][2]. The configuration of the rf immunity testing is illustrated in Fig.1. The IEC Technical Committee (TC) 65 regulates that the electromagnetic field deviation should be from 0 to +6dB in the defined points which are 16 points at 0.5 m steps in 1.5 m x 1.5 m vertical plane above 80 cm.

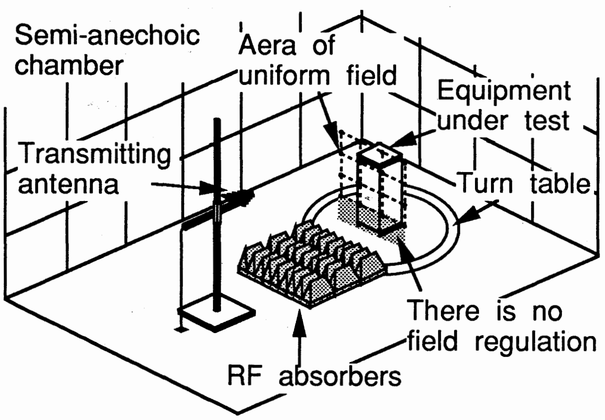


Fig. 1. The configuration of the rf immunity testing

As shown in Fig. 1, the immunity of floor-standing equipment is usually tested by placing it on a conductive ground plane, but the electric field strength below 80 cm has not yet been specified. This specification is needed because the horizontal electric field strength decreases sharply near the ground plane, and this makes it is difficult to apply the regulation of the electric field uniformity above 80 cm to the regulation below 80 cm.

This paper therefore proposes an electric field strength specification method for rf immunity testing below 80 cm. The specified electric field is compared with the actual electric field, and the method for generating the proposed electric field in a semi-anechoic chamber is described.

2. Electric field specification method below 80 cm

The electric field distribution for RF immunity testing should be independent of frequency to simplify the test and should simulate the environment in which the ITE is actually installed. The electric field specification method which meets above requirements is described in this paragraph.

A model to consider the specification below 80 cm is illustrated in Fig. 2. When an interference source is far from the ITE and neglect the influence of the building where the equipment is installed, the electric field applied to the equipment is expressed as a plane wave (Fig. 2). The floor on which the equipment is

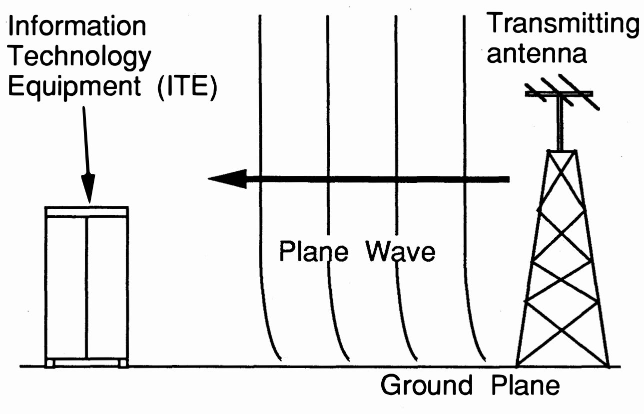


Fig.2. The electromagnetic field model

installed is usually the metallic plate (free access floor) or the reinforced concrete. Therefore, the ground plane is assumed to be perfectly conducting because the conductivity of these materials is very high.

The electric field applied to the equipment in Fig. 2 is represented the model shown in Fig. 3, where Ant. 1 is the transmitting antenna and Ant. 2 is the image of the Ant. 1. According to antenna theory [3], the electric field strength at point O is given by Eq. (1).

$$E(h_2,d)=E_1(h_1,d)+R\cdot E_2(h_1,d) \qquad (1)$$

where, E_1 is the electric field generated by Ant. 1, E_2 is the field generated by Ant. 2, h_1 is the height of Ant. 1, h_2 is the height of point O, d is the distance between Ant. 1 and point O, and R is the reflection coefficient of the ground plane.

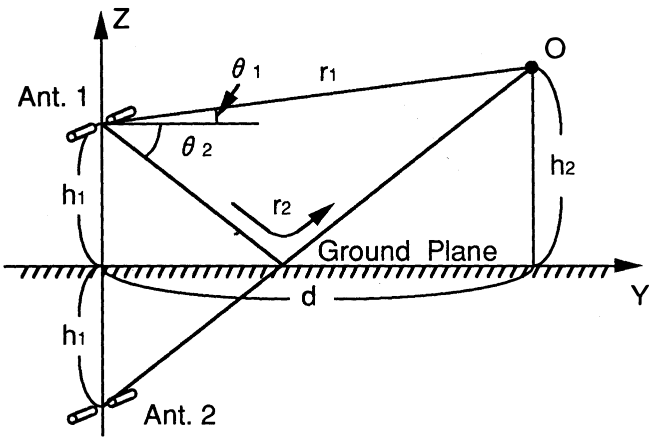


Fig. 3 The calculation model

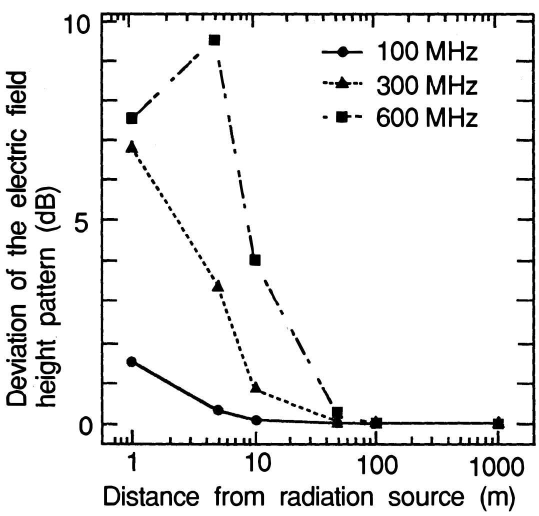


Fig. 4. The dependance on the distance of the electric field height pattern deviation below 80 cm (horizontal)

In order to confirm that the electric field distribution is independent of the frequency, each electric field strength is calculated by using the moment method [4]. For all frequencies, electric field height patterns below 80 cm are calculated for horizontal polarization. The height pattern deviation normalized by that at 80 MHz decreases with distance from transmitting antenna. The deviation is almost 0 at distances over 100 m.

Therefore, the height pattern below 80 cm is independent of frequency if the source is placed very far from a observation point. This means that the electric field specified by this model is independent of frequency and is useful for rf immunity testing.

3. Comparison with an actual environment around ITE

The electric field distribution below 80 cm was measured in a room to confirm whether the specified electric field simulates an actual environment. An active dipole antenna with element 420 mm long was used in order to reduce the variation of the antenna factor caused by the influence of the ground plane. The height pattern was measured at 11 frequencies between 80 MHz and 1 GHz, and the measured height was from 0.18 m to 2.0 m for horizontal polarization and 0.26 m to 2.0 m for vertical polarization. Figure 5 shows an example of results for horizontal polarization. The perpendicular horizontal components E_X and E_Y were measured for horizontal as shown in Fig. 5. The total electric field strength E was given by Eq. (2).

$$E=\sqrt{E_X{}^2+E_Y{}^2} \qquad (2)$$

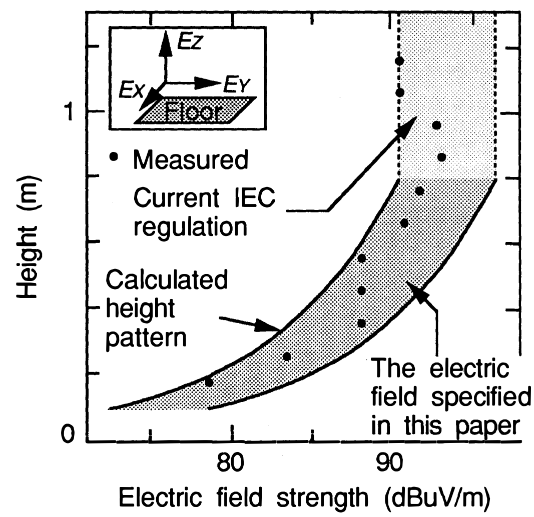


Fig. 5. An example of the electric field measured in a room (103.2 MHz horizontal)

In this figure, • indicates measured values, the left curve below 80 cm indicates calculated values, and the right curve is +6 dB from the calculated value. The dotted lines border the field specified in IEC field uniformity regulation [1]: the left line indicates a test level and the right line indicates the maximum permissible variation of the field. Table 1 lists conditions for calculating the electric field. The measured values are within these two lines. This means that the electric field tolerance above 80 cm can be applied below 80 cm [1].

Table 1. Conditions for the calculation

Diameter of the elements	2 mm
Element length	λ/2 (λ:wave length)
Distance from the source	1 km
The number of partitions on the elements	61
The number of matrix components	29×29
Basis function	sine

There is another way to specify electric field below 80 cm, which is that the usual IEC's regulation above 80 cm is extended to below 80 cm. To confirm the advantage the specification proposed in this paper, the deviation both between measured electric fields and the values specified as proposed here, and between measured values and the values specified by simply extending the usual IEC regulation. These deviations were calculated according to the Eq. (3).

$$\Delta\overline{E}=\frac{\sum^{n}|E_{mn}-E_{tn}|}{N} \qquad (3)$$

Where E_{mn} are measured values up to 80 cm, E_{tn} are calculated values, and N is the number of samples. The results of these calculations are shown in Fig. 6, where the solid line shows the deviation between the measured and calculated height pattern using the model shown in Fig. 3, and the dotted line shows the deviation between measured and the values derived by extending the IEC regulation above 80 cm. The deviation between measured and calculated height pattern is within 6 dB, and the deviation is smaller than the deviation from the nominal values. This means that the calculated electric field based on Fig. 3 accurately simulates the actual environment.

Figure 7 shows an example of results for vertical polarization. The left solid line indicates a test level and the right line indicates the maximum permissible variation of the electric field. The dotted lines show the area bounded by the IEC regulation, and the solid lines are extended them below 80 cm. The calculation using the model in Fig. 3 also shows that the IEC regulation can be extended to below 80 cm. The measured values plotted in Fig. 7 are between these lines, and this means the field uniformity regulation above 80 cm can also be applied below 80 cm.

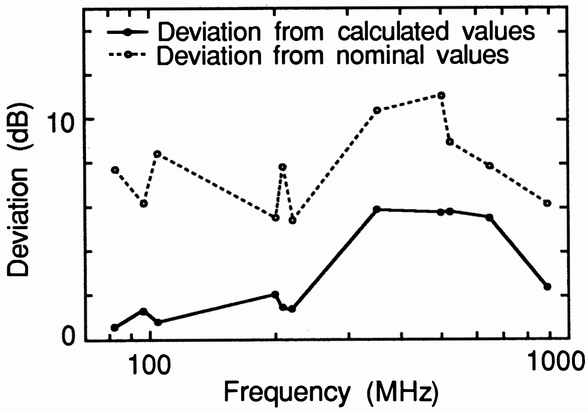


Fig. 6. Deviation of the measured electric field from the calculated height pattern and from nominal values (horizontal)

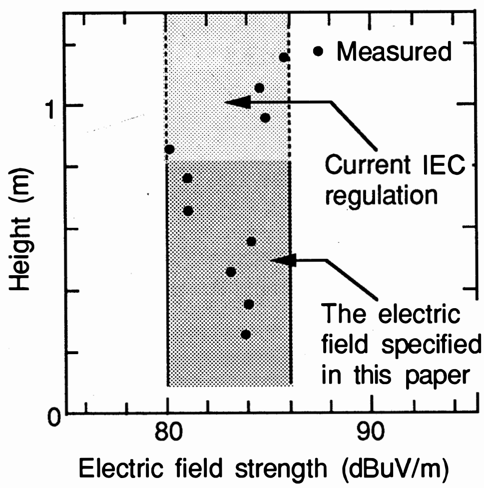


Fig. 7. An example of the electric field distribution measured in a room (103.2MHz vertical)

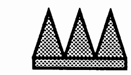
Figures 4, 6, and 7 show that the electric field distribution calculated according to the model shown in Fig. 3 well simulates the actual environment, and that it is independent of frequency. Therefore, the electric field specification method proposed in this paper is useful for rf immunity testing.

4. Generating the specified field in a semi-anechoic chamber

It is examined whether the electric field proposed in this paper can be generated in a semi-anechoic chamber. The electric field above 80 cm whose uniformity meets the usual IEC regulation, [1] can be generated by arranging rf absorbers on the chamber floor. The electric field below 80 cm should be generated under the same conditions. So the conditions that satisfy both above and below 80 cm electric field strength are investigated.

Table 2 shows absorbers used in this experiment. Two types of the absorbers were used in experiment: absorber A is mainly used to get the electric field distributions meeting the usual IEC regulation and the absorber B is mainly used to get the distribution below 80 cm.

Table 2. Absorbers used in this experiment

	Absorber A	Absorber B
Shape (side view)		 (Pyramidal)
Material	Polyurethane with carbon	Polyurethane with carbon
Size (cm)	76×86×60	30×60×60
Reflection coefficient	-40 dB at 1 GHz 50°	-20 dB at 500 MHz

The experimental setup for measuring the electric field distributions are shown in Fig. 8. The electric field sensor using a $LiNbO_3$ optical modulator [5] with 210 mm long dipole element and an optical fiber link, was used for this measurement. The propagation loss between the transmitting antenna and sensor was measured by using a network analyzer, and the electric filed distribution was calculated from the loss. This sensor minimally influence the electric filed distribution, and allowed a short measurement time because its response time is less than 1 ns.

In order to simulate the electric field based on the model in Fig. 3, absorbers arrangement, transmitting antenna height and distance between transmitting and receiving antennas were changed to reduce the influence of the reflected wave. These values were optimized according to the flow chart shown in Fig. 9. Optimum parameter values (table 3) were obtained to satisfy both above and below 80 cm electric field strength.

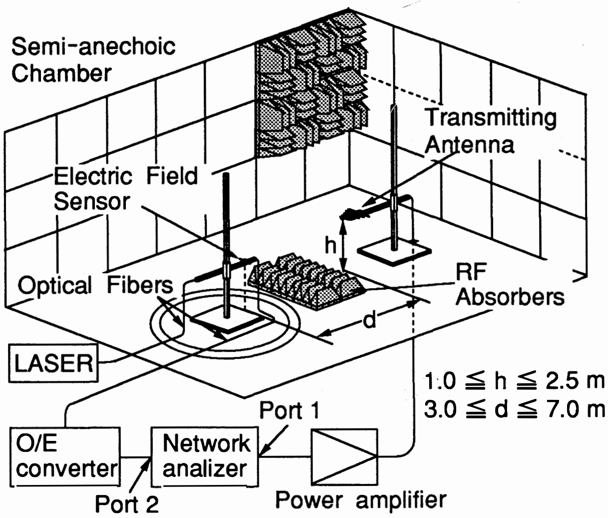


Fig.8. The experimental setup for measuring the electric field distribution in a semi-anechoic chamber

Table 3. Optimum values of test parameters

	Horizontal			Vertical		
Frequency (MHz)	80~ 200	200~ 400	400~1000	80~ 200	200~ 400	400~1000
Absorbers	Absorber A 12 pieces	Absorber A 12 pieces	Absorber A 12 pieces	Abs.A 8 pieces and Abs.B 4 pieces	Absorber B 16 pieces	Absorber B 16 pieces
Transmitting antenna height	2.0 m	1.0 m	2.5 m	1.5 m	1.5 m	1.5 m
Distance between transmitting and receiving antennas	3.0 m	7.0 m	3.0 m	3.0 m	3.0 m	3.0 m

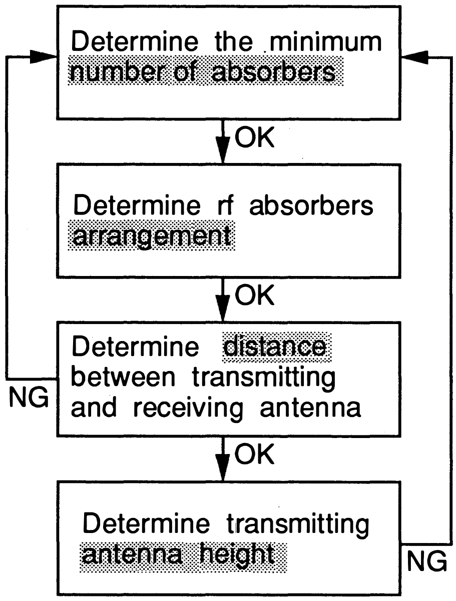


Fig. 9. Flow chart for determining the parameters

Figures 10 and 11 are examples of measurement results for horizontal and vertical polarizations. These figures show that the electric field uniformity for both current IEC regulation and the proposed regulation is within from 0 dB to +6 dB.

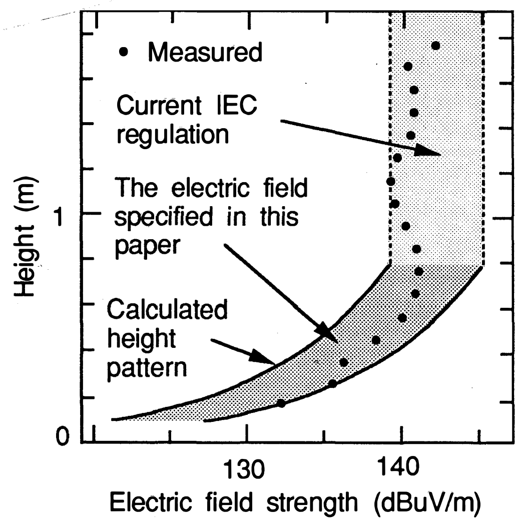


Fig. 10. A result of the electric field distribution in a semi-anechoic chamber (202 MHz horizontal)

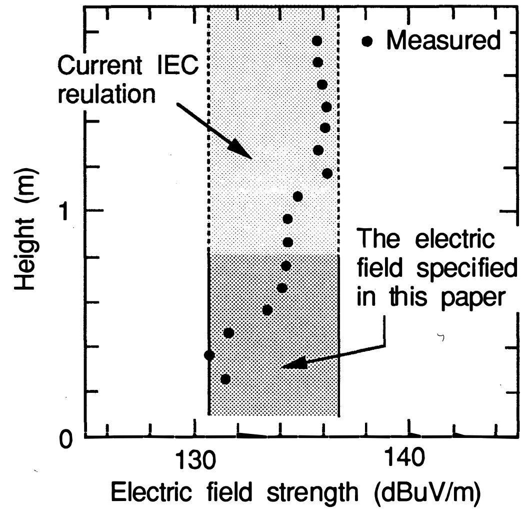


Fig. 11. A result of the electric field distribution in a semi-anechoic chamber (202 MHz vertical)

Figure 12 shows the maximum deviation between measured electric field in a semi-anechoic chamber and the calculated height pattern for horizontal polarization. Figure 13 shows the maximum deviation of measured values for vertical polarization. The electric field strength was measured from 0.2 m to 2.0 m. For horizontal polarization, the electric field strength satisfies required uniformity from 80 MHz to 1 GHz. However, for vertical polarization, the electric field strength did not satisfy the uniformity at some frequency ranges between 100 and 300 MHz. Therefore, more work is needed to determine the parameters for these frequency ranges.

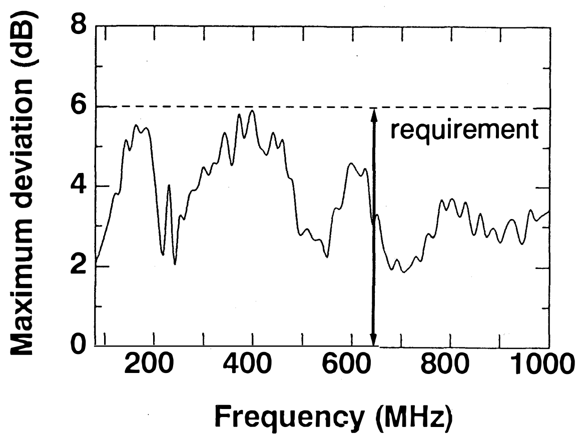


Fig. 12. The maximum deviation between measured and calculated height pattern (horizontal)

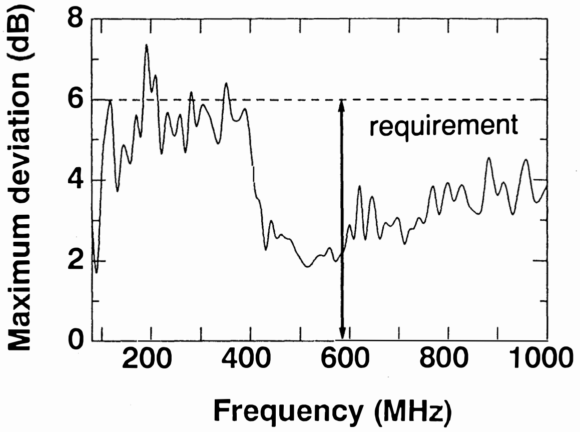


Fig. 13. The maximum deviation between measured and a nominal value (vertical)

5. Conclusion

This paper proposes a method for specifying the electric field at heights below 80 cm. The model used to calculate the electric field environment assumes the disturbance source is far from the equipment, and the electric field strength was calculated by using the plane wave theory. The calculated results show that height pattern of the specified field is independent of the frequency. The measured results in a room show that the specified electric field according to the calculated height pattern well simulates the actual environment around ITE. These results shows that this specification method is useful for the rf immunity testing below 80 cm. Experiments show that a suitable electric field can be almost generated by arranging rf absorbers on the floor a semi-anechoic chamber.

Acknowledgment

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