Improvement of a Tear Drop-Shaped Antenna with an Optical Feeding Using a Dielectric Reinforcement

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***Abstract*— A tear drop-shaped antenna combined spherical and biconical antenna elements had been developed in order to obtain the radiated wideband emission source having directivity specified by CISPR 16-1-4 Ed.2 above 1 GHz. In this paper, an improved tear drop-shaped antenna using a dielectric reinforcement was proposed. The effect of the reinforcement that was made from acrylic fiber (permittivity=3.0) is calculated by the finite integration (FI) method. The calculated result was compared with the measured ones. The upper and lower element of the tear drop-shape antenna is reinforced by a cylindrical acrylic fiber of which thickness is 30 mm. The tear drop-shaped antenna with no reinforcement (conventional model) did not meet the requirement of CISPR standard. In contrast, E-plane radiation patterns obtained by the calculation and measurement were improved at θ=0 and 180 degrees in the case of the tear drop-shaped antenna with the reinforcement mentioned above. The tear drop-shaped antenna with the proposed reinforcement satisfies the directivity specified in CISPR 16-1-4 Ed.2 in a frequency range from 1 GHz to 6 GHz.**

Key words: tear drop-shaped antenna, biconical antenna, optical feeding method, CISPR 16-1-4, finite integration method

I. INTRODUCTION

Recently, electronic and electric equipment including telecommunication equipment is widely used with the incredible advances in technology. However, an electromagnetic interference (EMI) problem arises as the technology advances. The electromagnetic radiation from industrial, scientific and medical (ISM) equipment, home appliances, and information equipment may interfere to other electronic equipment. In international special committee on radio interference (CISPR), a new paragraph (Paragraph 8.2) was added to CISPR 16-1-4 concerning an evaluation method of the EMI measurement site above 1 GHz and the international standard had been published as CISPR 16-1-4 Ed. 2 in February 2007 [1]. The frequency range of the conventional international standard was from 30 MHz to 1 GHz.

The authors had developed a new type of antenna using the optical power feeding that can supply not only an optical signal but also an optical power simultaneously. The antenna has a special O/E conversion element named as uni-travelling-carrier photodiode (UTC-PD). The developed antenna has a shape with combining a hemisphere and a biconical antenna element. It was clarified that the characteristics of the antenna met the requirement of CISPR 16-1-4 the second edition in frequency band from 1 GHz to 6 GHz[2][3]. However, it is difficult to use the antenna actually because there is structural weakness in the feeding part without reinforcement. In this paper, an improved tear drop-shaped antenna using a dielectric reinforcement was proposed. The effect of the reinforcement is calculated by the finite integration (FI) method. The calculated result was compared with the measured ones.

II. CISPR REQUIREMENT FOR MEASUREMENT SITE ABOVE 1 GHZ

To measure an emission from the electric equipment causing EMI, an open area test site (OATS) or an anechoic room that is an alternative site of OATS, in which there are no reflection objects, is required. In this examination an anechoic room was used. The anechoic room has seven sides, and the pyramid-shape microwave absorbers and ferrite tiles are installed for each side. The absorbers are made from ferrite. The evaluation method in 30 MHz to 1 GHz has already stated in CISPR 16-1-4. A new paragraph was added to CISPR 16-1-4 concerning an evaluation method of the EMI measurement site above 1 GHz and CISPR 16-1-4 Ed. 2 was published in February 2007. An ideal EMI examination site below 1 GHz has an infinite volume with an infinite ground plane. The characteristics of the anechoic room were examined by comparing between the site attenuation of the room and that of the ideal site. In contrast, entirely free space or semi-free space with microwave absorbers on the ground plane is used as an ideal site of the EMI examination above 1 GHz. In the case, the directivity of the transmitting antenna is important. A wide directivity in the direction of θ like the dipole antenna and circular symmetry in the direction of φ is required as shown in Figure 1.

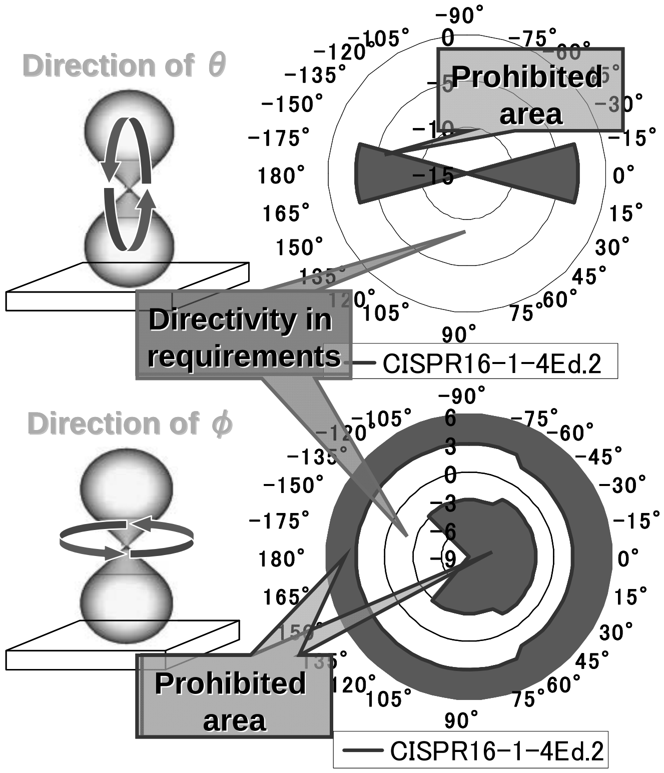

Fig.1 Directivities stated in CISPR16-1-4Ed.2.

III. Simulation Method

In this paper, MW-Studio [4] was used in the numerical simulation of the FI method. The integral forms of the Maxwell equation are used in the method. Figure 2 shows the simulation model of the tear drop-shape antenna. The element of the antenna has a structure of a combination of a spherical element and a biconical antenna element. Generally, an antenna with the biconical-shape elements is known as a broadband antenna. The radius of the spherical part of the antenna is 50mm. The cell sizes of the numerical simulation using the FI method are determined automatically by the code, all boundary conditions are assumed to be free space.

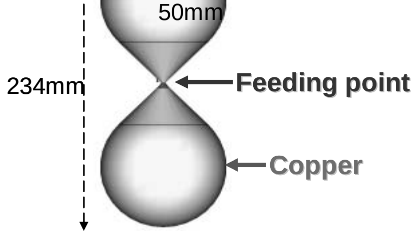

Fig.2 Simulation model with no reinforcement.

IV. Directivity of the Tear drop-shaped Antenna with No Reinforcement)

Figure 3 shows the simulation result of the directivity in θ direction of 1.6 GHz in the tear drop-shaped antenna as shown in Fig. 2 with the element radius of 50 mm. The directivity in θ=0 and 180 degrees at the frequency of 1.6 GHz in does not meet the requirement of CISPR standard. However, the directivity in other θ directions meets the requirement from 1 GHz to 6 GHz except for 1.6 GHz. It is confirmed that the directivity in φ direction also meets the requirement with the frequencies from 1 GHz to 6 GHz.

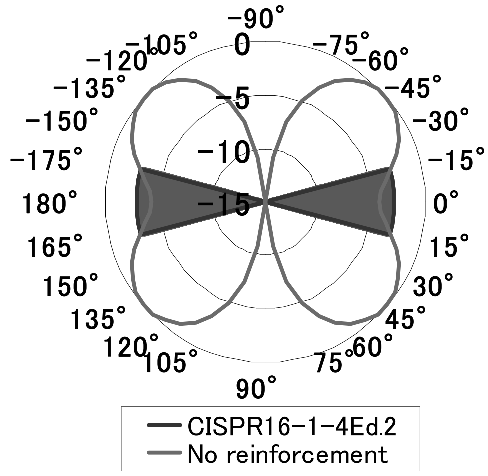

Fig.3 Directivity in θ direction at 1.6 GHz.

V. Reinforcement of Tear drop-shaped Antenna

There is another problem about the conventional antenna as shown in Fig. 2 except for the compliance for the requirement of the CISPR standard. The problem is a strength poverty of the feeding part. In this study, an improvement of the structure of the antenna was examined without degrading the specifications of the antenna.

In the conventional studies, a cylindrical dielectric material (Teflon) with 30 mm in thickness was the best reinforcement material according to the result of the numerical simulation. However, Teflon is costly. Therefore, an acrylic fiber was used as an alternative reinforcement material. The permittivity of the acrylic fiber is not so different with that of Teflon, and the acrylic fiber is not costly.

The antenna with the acrylic-fiber reinforcement was assembled experimentally. Figure 4 shows a model of the antenna with reinforcement material. Since the 5 mm gap exists between the antenna and the reinforcement, the styrene foam with the doughnut shape was used for bridging the gap.

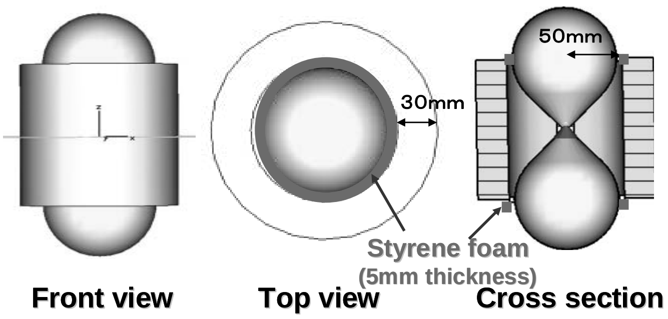

Fig.4 Antenna model with reinforcement that made from acrylic fiber with 30 mm in thickness.

VI. Radiation Patterns

Figure 5 shows the setup for measurement of a radiation pattern of the tear drop-shaped antenna with reinforcement material. The measurement of the radiation pattern was conducted in the anechoic room with seven sides. The antenna is proposed as the transmitting antenna. The feeding power is -2 dBm through the UTC-PD and the optical fiber. The electric field radiated from the antenna was detected with double ridged guide horn antenna. The detected power was measured with a spectrum analyzer. The transmitting antenna is installed on the turntable and the support stand, of which height is 1 m. In addition, a distance between the transmitting antenna and receiving antenna is 1 m. When the radiation pattern is measured, the antenna is rotated by the turntable every 5 degree.

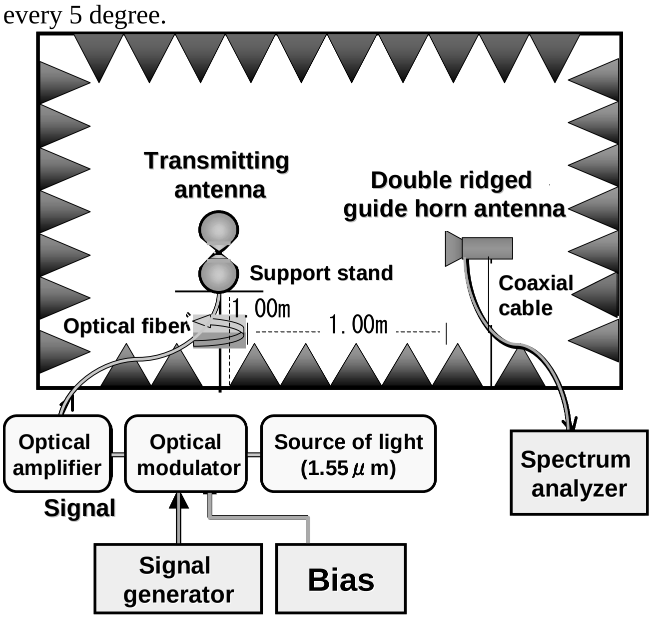

Fig.5 Setup for measurement of radiation patterns.

A. Radiation pattern

The measured radiation patterns are shown in Figs. 6. and 7. The directivity in θ direction (1.6 GHz) by the numerical simulation was compared with the measurement result for the reinforcement antenna model (Acrylic fiber: 30mm thickness) in Fig.6. A result of the numerical simulation was compared with the measurement result in the case of the directivity in φ direction (1.6 GHz). It is confirmed that the both of results meet the requirement of CISPR standard in the cases of the θ and φ directions. Moreover, the result of the numerical simulation agreed well the measured ones. It is also confirmed that the directivities meet the requirement of the CISPR standard at the frequencies from 1 GHz to 6 GHz. Therefore, the proposed antenna can be used for the transmitting antenna of the CISPR EMI measurement.

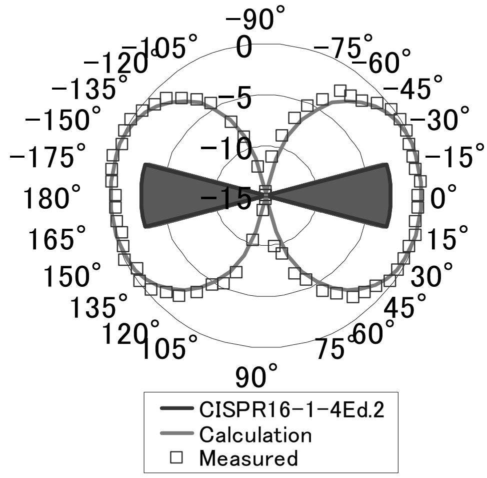

Fig.6 Directivity in θ direction (1.6GHz).

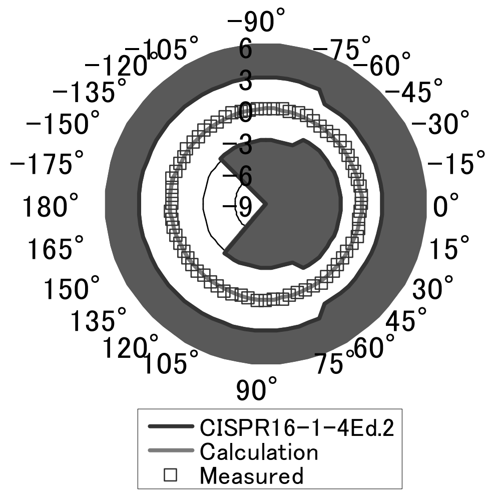

Fig.7 Directivity in ϕ direction (1.6GHz).

B. Frequency characteristics of radiated fields

Figure 8 shows the measurement and calculation results of the frequency characteristics of the radiated fields. As a result, the measured characteristics almost agreed with ones by the numerical simulation except for the vicinity of 2 GHz. It is clarified that the improved tear drop-shape antenna is applicable as a wideband transmitting antenna.

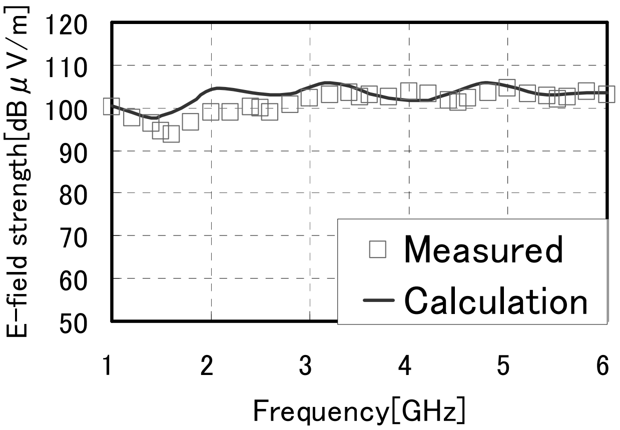

Fig.8 Frequency characteristics of radiated fields

C. VSWR

Figure 9 shows the measurement and calculation results of the VSWR for a comparison. The measured and calculated VSWR responses have almost same qualitative nature. However, the values of VSWR are somewhat different between both of results. The difference may be caused by the "mediocre" machining accuracy of the antenna and by the imperfect treatment of the styrene foam in the simulation model.

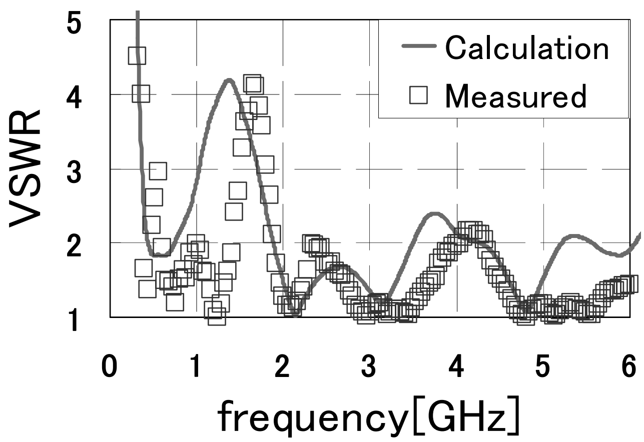

Fig.9 VSWR of the antenna.

VII. CONCLUSION

We have developed a tear drop-shaped antenna combined spherical and biconical antenna elements, in order to obtain the radiated wideband emission source having directivity specified in CISPR 16-1-4 Ed.2 above 1 GHz. In this paper, an improved tear drop-shaped antenna using a dielectric reinforcement was proposed. The effect of the reinforcement that was made from acrylic fiber (permittivity=3.0) is calculated by the finite integration (FI) method. The calculated result was compared with the measured ones. As a result, the followings were clarified.

(1) Both of directivity in θ direction and directivity in φ direction met the requirement of the CISPR standard from 1 GHz to 6 GHz using the cylindrical acrylic reinforcement (30 mm in thickness). These results were confirmed from both of calculation and measurement results.
(2) The measured frequency characteristics almost agreed with ones by the numerical simulation except for the vicinity of 2 GHz. It is clarified that the improved tear drop-shape antenna is applicable as a wideband transmitting antenna.
(3) The measured and calculated VSWR responses have almost same qualitative nature. However, the values of VSWR are somewhat different between both of results. The difference may be caused by the "mediocre" machining accuracy of the antenna and by the imperfect treatment of the styrene foam in the simulation model.

As a result, it is confirmed that the reinforced tear drop-shape antenna has a practical use for the transmitting antenna specified in CISPR16-1-4 Ed.2 in every aspects, which is the directivity, frequency characteristics, and VSWR.

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