Radiation properties of a spherical dipole antenna

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ABSTRACT

This paper describes an an advanced spherical dipole antenna for use as a standard electromagnetic field emission source. Its radiated field is easily calculated, and its radiated frequency and amplitude are controlled over a wide frequency range by an outside signal generator through an optical fiber. The radiated field is calculated by the mode-matching method, and also measured for comparison. The theoretical and experimental values differ by less than 1 dB in the frequency range 30 MHz-1000 MHz.

1. INTRODUCTION

A standard electromagnetic field emission source is used to calibrate antenna properties, to check test sites, and to evaluate the shielding factor of materials. Half wave length dipole antennas have been used as emission sources. However, these antennas suffer from capacitive coupling between the emission source and receiving devices which cause measurement errors as well as metallic cable reflections.

A spherical dipole antenna[1][2][3], which is small and does not have a metallic cable, has been proposed as an emission source. However, it is difficult to analyze the precise radiation properties of the antenna, because the electric circuit in the antenna should be considered as the boundary condition.

This paper describes a new advanced spherical dipole antenna, whose theoretical radiated field can be easily calculated and whose radiated field is controlled by an outside signal generator through an optical fiber.

2. Configuration of an spherical dipole antenna

The configuration and coordinate system of the spherical dipole antenna is shown in Fig. 1. The upper part of the antenna is a hollow hemisphere to decrease the capacitance of driving point O, and to provide a wide frequency of operation. The lower part is a case to contain the optical-electrical(O/E) converter and its battery. A spacer, made of a dielectric ring, separates the upper and lower hemispheres.

Since the O/E converter and its battery are contained in the lower hemisphere, the boundary condition is simple. Therefore, it is easy to analyze the antenna radiation properties.

3. Numerical analysis

The electric field $\mathbb{E}^i(P)$ can be represented by a finite series of the vector modal functions $\mathbb{e}_n(P)$, which is given by

$$E^i(P) = -V\sum_{n=1}^{N} b^i_n\, e_n(P) \quad . \qquad (1)$$

where the superscript "i (i=I,II)" represents the index number of the region S_I and S_{II} shown in Fig. 1, $b^i_n(n=1,2,...,N)$ is an expansion coefficient, V is the output voltage of the O/E converter, and en(P) is an eigen function of the Maxwell equation. $P(r, \theta, \varphi)$ is a point in the region S_I or S_{II}.

Since the spherical dipole antenna is symmetrical about the Z axis, the electric field does not depend on the parameter φ. Then, the components of vector function $e_n(P)$ are given by

$$e_{nr}(P) = n(n+1)\frac{Zn(kr)}{kr}Pn(\cos\theta) \qquad (2)$$

$$e_{n\theta}(P) = \frac{d}{dr}(rZn(kr))\frac{d}{d\theta}Pn(\cos\theta) \qquad (3)$$

$$e_{n\varphi}(P) = 0 \qquad (4)$$

here

$$Z_n(P) = \begin{cases} B_n(kr) & (r \in S_I) \\ H_n(kr) & (r \in S_{II}) \end{cases} \qquad (5)$$

where, k is a wave number. The functions $B_n(kr)$ and $H_n(kr)$ are the Bessel function of the order (n+1/2) and the first order Hankel function of the order (n+1/2), respectively. The function $P_n(\cos\theta)$ is a Lugendle function.

Using the mode matching method, the expansion coefficients b^i_n in Eq. (1) are determined for the radiated field of the antenna to satisfy the boundary condition.

When the antenna is set over a metallic plane, the total electric field $E^T(P)$ is given by

$$E^T(P) = E(P) + \rho E'(P) \quad . \qquad (5)$$

where E'(P) is the radiated electric field of the image emission source, and ρ is the reflection coefficient of the metallic plane.

4. Measurement and discussion

The electric field radiated from the spherical dipole antenna was measured to evaluate the validity of the numerical calculations. The dimensions of the antenna used in experiments are shown in Fig. 1. These values had been analytically determined to radiate efficiently in the frequency range 30 MHz-1000 MHz. An Avalanche Photo Diode with Lithium battery (DC33V) was used as the O/E converter.

The measurement configuration is shown in Fig. 2. The spherical dipole antenna is set at a height of 1 m above a metallic plane. The receiving antenna(a half wave length dipole antenna) is set 3 m away from the spherical dipole antenna. The height pattern is measured at heights from 1m to 4m.

An example of height pattern is shown in Fig. 3. In this experiment, the radiation frequency is 600 MHz, the output voltage V is 79.2 dBuV, and the electric field is parallel to the metallic plane. In Fig. 3, the horizontal and longitudinal axes are the electric field strength and the receiving antenna height, respectively. The solid line represents the theoretical values and the solid circles are experimental results. The measured values agree well with the theoretical values.

The mean deviation of the height pattern between the theoretical and experimental results over frequency range 30 MHz-1000 MHz is less than 1 dB as shown in Fig. 4. This result shows that the radiated field is accurately given by numerical calculations.

5. Conclusion

A spherical dipole antenna, whose radiation properties can be numerically calculated, has a good performance of an electric field emission source. The mean deviation between the theoretical and calculated height patterns are less than 1 dB in the frequency range 30 MHz-1000 MHz.

In the future, the spherical dipole antenna will be improved to radiate at higher power, and its application as a receiving antenna will be investigated.

7. Acknowledgment

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8. References

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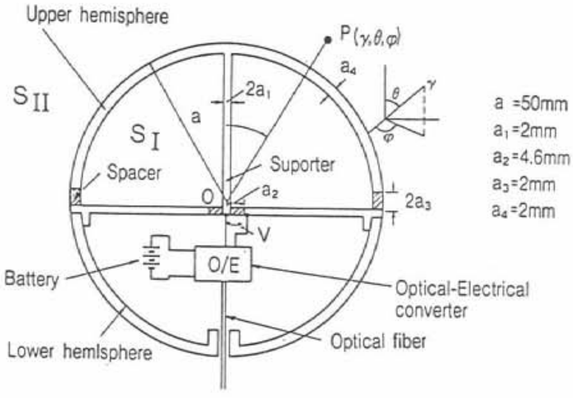

Fig.1 Configuration of spherical dipole antenna

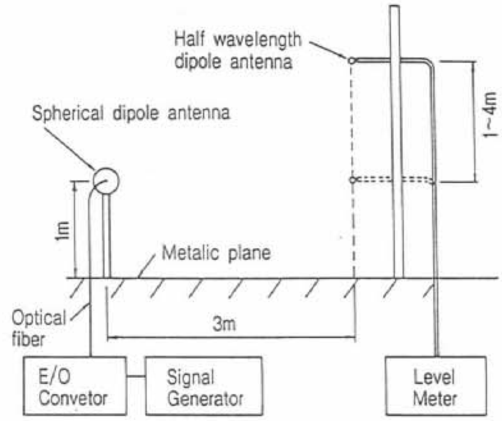

Fig.2 Measurement configuration of height pattern

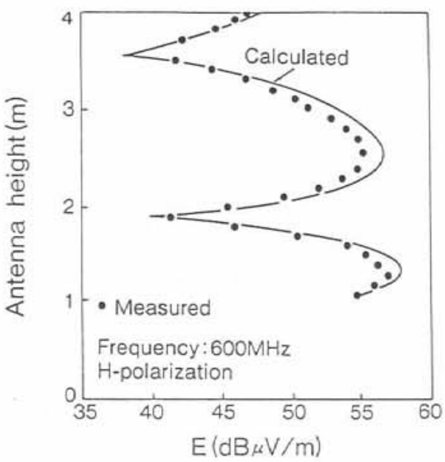

Fig.3 Height pattern of spherical dipole antenna

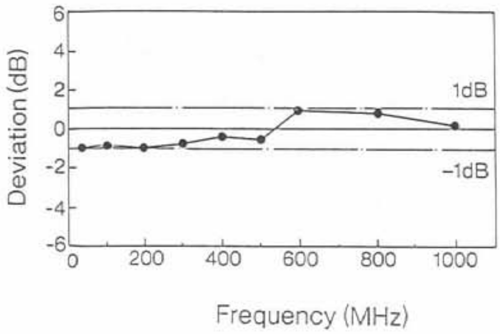

Fig.4 Deviation of height pattern between measurement and calculated values