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Radiation Efficiency Measurement with Partial Spherical Scanning by Using a Reflector

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Abstract

A simplified experimental system using a reflector based on the pattern integration method has been developed to evaluate the radiation efficiency of small antennas. The proposed method employs a reflector to reform the radiation pattern of the sample antenna, and reduce the scanning area by concentrating the power radiated from the antenna into the upper hemispherical area. This paper presents the basic concept and some experimental results to confirm the validity of the proposed method.

1. Introduction

Several methods have been proposed so far as for measuring the small antenna efficiency, i.e. Wheeler cap method[1][2], the random field method[3], the direct calorimetric measurement method[4], and the pattern integration method[5] etc.

In radiation efficiency measurement based on the pattern integration method, the scanning area of probe antenna and the feeding line connected to AUT may cause measurement errors. For such problems, a system composed of a side-supported rotator and a formed material and an AUT incorporating a self oscillator are employed in actual systems. They are useful to avoid the interferences from the supporting devices; however, they have a difficulty in fabrication and time- and cost-consuming problems. In this paper, a simplified method to evaluate the radiation efficiency of small antennas is proposed. The proposed method employs a large reflector to reshape the radiation pattern of the sample antenna, and reduce the scanning area by concentrating the power radiated from the antenna into the upper hemispherical area. This paper presents a basic concept and some experimental results to confirm the validity of the proposed method.

2. System Configuration

Fig.1 shows the configuration of a measurement system. The spherical scanning system is composed of an azimuthally rotating table and a spherically movable probing antenna. The probing antenna is placed at the radius r.

AUT is placed with the distance of d above a reflector and the offset with s from the plate centre, which is rotating azimuthally with the step $\Delta\phi$. The probe antenna is scanning over the sphere with the radius r and θ=0~θ_m and the increment of $\Delta\theta$. The radiated power is calculated by integrating the detected power by probing antenna. In this study, a standard dipole antenna is employed as the probing device, and $\Delta\phi$ and $\Delta\theta$ are chosen as 3° and 5°, respectively. In this paper, the parameter r/λ=4.0 is employed.

3. Effect of a Reflector

The effect of a reflector on the AUT is evaluated experimentally. The antenna employed here is a standard dipole antenna placed along the reflector so that the supporting conductive rod incorporating an impedance transformer and ballun circuits affects on the radiation pattern of dipole element. VSWR ranges from 1.2 to 1.8 in the presence of the reflector. Fig.2 shows the vertical radiation pattern cut at ϕ=0° and 90°, and each pattern is normalized by its maximum value. The pattern is sampled up to θ_m=165° because a foamed cylinder supporting the AUT exists. It has inheritably asymmetric pattern in the E-plane due to the supporting conductive rod. As the reflector radius become large, the radiation leaked into the bottom sphere become small.

Assuming that the reflector concentrates the power into the upper hemisphere, the calculated results may be independent on the vertical scanning area when the θ_m is greater than $\pi/2$. Fig.3 shows the radiation efficiency for the AUT position d, where the maximum scanning angle θ_m is chosen as a parameter. Fig.3(a) shows the results for the reflector with a=1.33λ, the difference between θ_m=90° and θ_m=160° become small when the AUT is in the range of $d \leqq 0.7$. It indicates that the power leakage into the bottom sphere become small because the antenna is cloth to the reflector. On

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the other hand, in the case with a=0.67λ as shown in Fig.3(b), the power leakage to the bottom hemisphere can not be suppressed by antenna position, the measured value does not converge for the parameter θ_m. Therefore, it is not available for evaluating the radiation efficiency. The results are summarized in table 1. Table 1 indicated that radiated power concentrates into the upper hemisphere when using a reflector and larger reflector is more effective.

4. Examination of Reflector Size, Antenna Position, Maximum Scan Angle and Comparison with Improved Wheeler Method

In this section, a precise examination of the effect of reflector is described using numerical simulation in terms of the reflector size, the antenna position, and the maximum scan angle θ_m. Evaluated antenna efficiency is the calculated ratio of the power radiated in $0<\theta<\theta_m$ to the one in overall sphere. AUT is a half-wave dipole antenna, and its field is calculated using an FDTD method.

Figure 4 shows the efficiency of a horizontally installed antenna as a function of the maximum scan angle θ_m, where the reflector size a/λ is chosen as a parameter. Each figure in Fig.4 describes the effect from antenna position such as d/λ =0.3 in the figure (a) and d/λ=0.6 in the figure (b). The minimum spacing d is determined here so that the standard dipole antenna with a supporting rod may be installed vertically on the reflector. The evaluated sizes of the reflector are a/λ=0.7, 1.3, 2.3, where the maximum size is limited only by the space for the experimental setup.

As shown in the Fig.4(a), each efficiency for a/λ=0.7, 1.3, 2.3 is 96%, 99%, 99%, respectively when θ_m =90°. According to this result, the reflector size should be larger than a/λ=1.3 when the error with 5%, which is due to the power leakage to the backside of a reflector, is acceptable. On the other hand in the experiment, each efficiency for a/λ=0.7, 1.3, 2.3 is 82%, 81%, 84%, respectively when θ_m =90°. They have an error of more than 15% for the simulated one. It may be caused mainly by the power dissipation in an EM absorbers installed on the feeding cable, which is not considered in the simulation. Conductive loss of the antenna itself is not also considered on the simulation, however, which may be smaller than the power loss in the absorber.

As shown in the Fig.4(b), each efficiency for a/λ=0.7, 1.3, 2.3 is 75%, 90%, 97%, respectively when θ_m =90°. According to this result, the reflector size should be larger than a/λ=1.3 when the error with 10%, which is due to the power leakage to the backside of a reflector, is acceptable. On the other hand in the experiment, each efficiency for a/λ=0.7, 1.3, 2.3 is 69%, 82%, 87%, respectively when θ_m =90°. They have an error of about 10% for the simulated one.

This result indicates that the proposed method is less effective to the antenna including the vertical polarization component in the radiated field. It indicates that the placing the AUT close to the reflector reduces the error due to the power leakage to the reflector's backside when the small reflector is employed.

In Fig.5, asymmetry in antenna installation is evaluated, where the parameter s from the origin in the xy-plane is chosen as a parameter while the reflector radius a/λ=1.33. It indicates that the offset in positioning does not affects on the simulated efficiency when the error of less than 10% can be accepted.

Fig.6 shows an examination on the polarization of AUT, where the result of a vertically placed dipole antenna is included in addition to that of the horizontal dipole antenna. A dipole antenna without reflector is also presented as a reference. When θ_m =90°, a simulated efficiency of the vertical dipole antenna on a reflector is 79% which is 18% smaller than that of horizontal one. Looking at the dipole with not reflector, it gives the efficiency of 53%, which is reasonable value even though small error is included. As a consequence, the reflector is effective to concentrate the power from the antenna into the upper hemisphere within the error of 20%. When the error within about 10% is required, the maximum scanning angle should be 100°. When the error within about 5% is required, the maximum scanning angle should be 120° from the calculated result.

Next we apply the proposed method to several surface mountable chip antennas, and present their results with the ones by improved wheeler method using a short circuited waveguide[6]. In the partial spherical scanning method, the radiation efficient of the chip antenna No.1,2,3 are around 60%, which has a similar tendency with the waveguide method. For the dipole antenna, the efficiency of 70% and 80% are obtained respectively. The difference of 10% is observed between the methods. The efficiency reduction observed in the proposed method may be also caused by the power loss on the absorption materials wrapped around the feeding coaxial cable; however, a further discussion will be remained as a future study.

Conclusions

A partial spherical scanning radiation efficiency measurement method with a reflector was presented in this paper, and its validity was confirmed experimentally. It was also confirmed that the antenna position and the reflector size affect mainly on the measurement results. Further discussion on the difference against other measurement method will be studied in next step.

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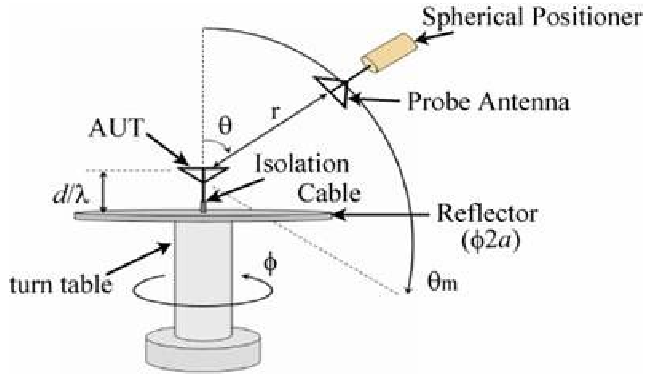


Fig.1: measurement system

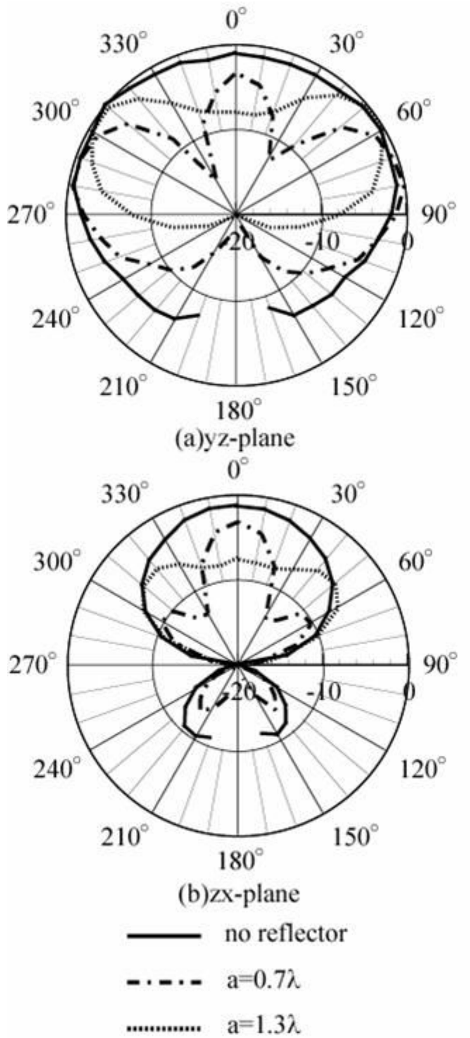
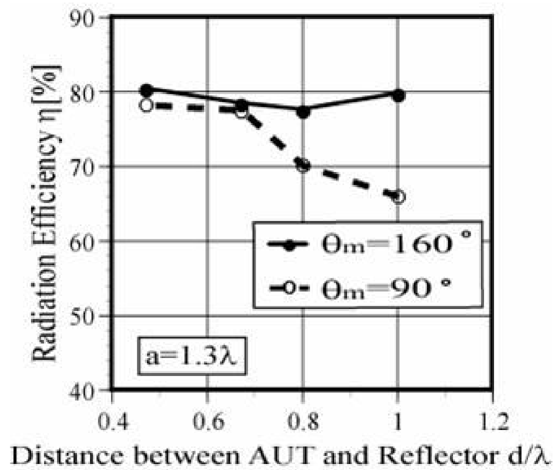
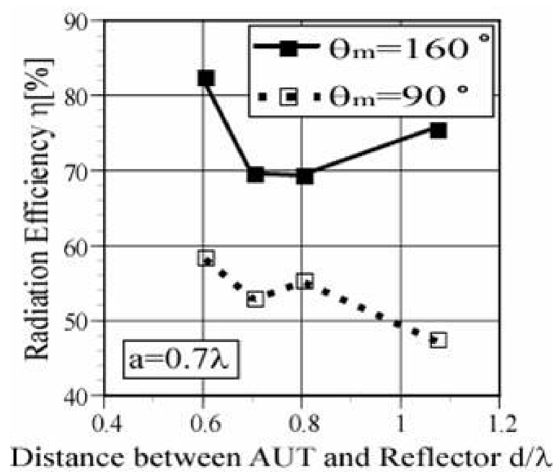


Fig. 2: Radiation pattern of a standard dipole antenna



(a) a=1.3λ

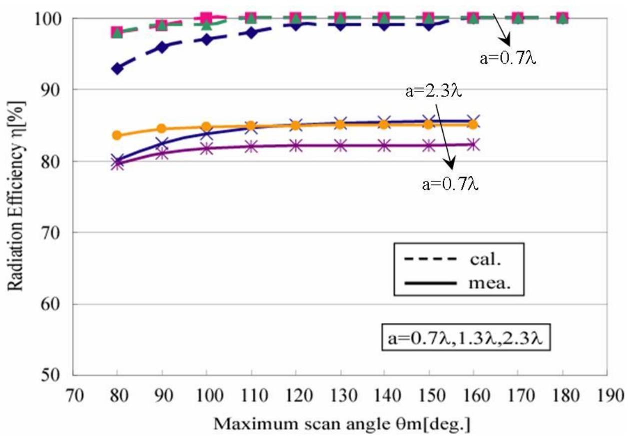


(b) a=0.7λ

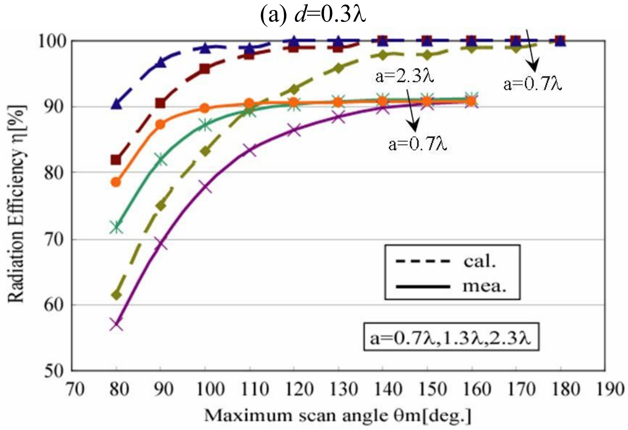
Fig.3: Radiation efficiency measurement for a half-wave dipole antenna placed parallel to a circular reflector.

Table 1: Radiation efficiencies of a half wave dipole antenna with and without the reflector when the maximum scan angle θ_m is chosen as a parameter

θ_m	no reflector	with reflector	
		a/λ=0.7	a/λ=1.3
90°	48%	58%	78%
160°	60%	82%	80%



(a) d=0.3λ



(b) d=0.6λ

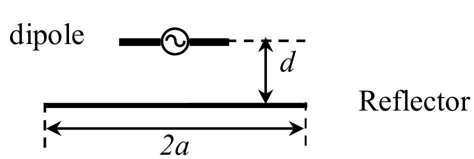


Fig. 4: Calculated and measured efficiencies versus maximum scan angle θ m

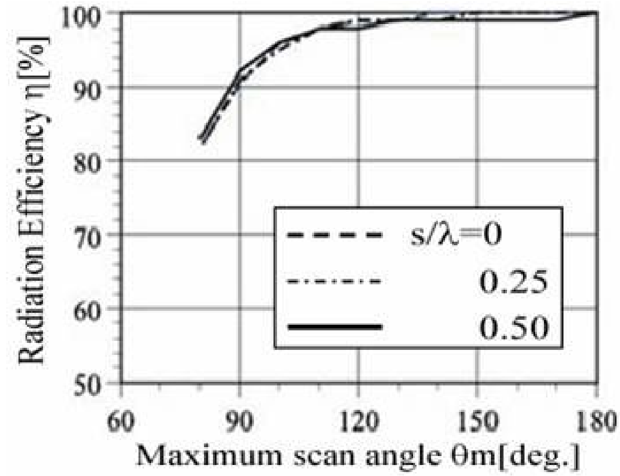


Fig. 5 Calculated efficiency versus AUT position s/λ

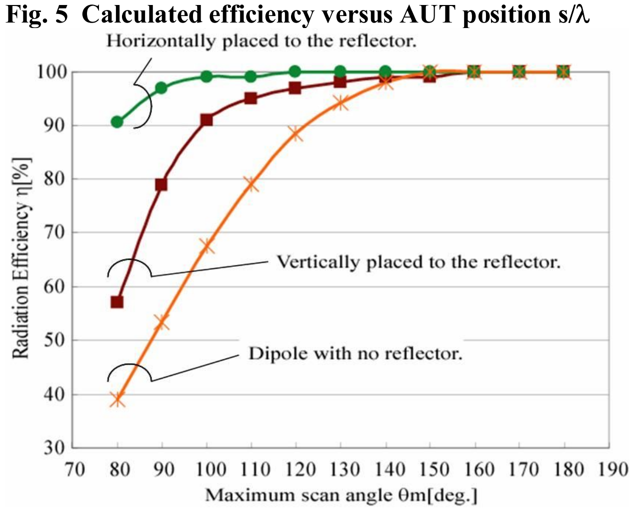


Fig.6: Evaluation of antenna polarization (*d*=0.6λ,*a*=2.3λ)

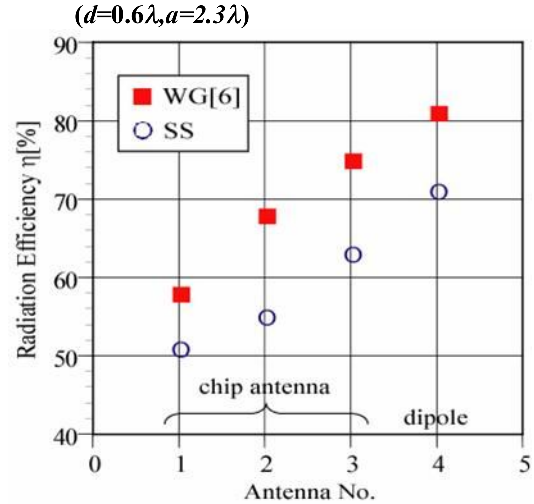


Fig. 7: Radiation efficiency evaluated using the proposed method. The result by improved wheeler method using a shorted waveguide is also presented as a reference.