How Far is Good Enough for the Far-Field Pattern?

K. Hirasawa, T. Arima, T. Uno and *H. Morishita
Tokyo University of Agriculture and Technology
Koganei, Tokyo 184-8588, Japan
*National Defense Academy
Yokosuka, Kanagawa 239-8686, Japan
hirasawa@ieee.org

1. Introduction

In the measurement of far-field patterns it is important to keep the enough distance r between a test antenna and a probe antenna [1]-[3]. As the far-field condition it is well known that r should be greater than r_f $(= 2D^2/\lambda)$ where D is the largest dimension of the physical aperture of a test antenna as shown in Fig. 1 and changes with the location of the rotation center of the test antenna.

In this paper we show how the pattern changes with r for two kinds of antennas by using a moment method computer program [4]. One is with the minimum D larger than λ (an eight element linear array). The other is with the minimum D smaller than λ (a monopole antenna on a rectangular conducting plate that is a model of a portable radio). Patterns are calculated for two different rotation centers of each antenna and the necessary r for the far-field pattern is investigated.

2. Results and Discussions

Fig. 2 shows the configuration of an eight element equally spaced linear array consisting of a center-fed half-wavelength dipole antenna with the radius of 0.001λ. The dipole element is directed in the z-axis and the inter-element spacing is $\lambda/2$. The feed terminal is located on the x-axis and the feed voltages are the same for all of the dipoles. The probe antenna is the same as the array element, is directed in the z-axis and the receiving terminal is in the x-y plane. The probe antenna is rotated from $\phi = 0$ to 360 (deg.) with the constant r in the x-y plane. In Fig. 2 (a) the probe is rotated around the array center and in Fig. 2 (b) it is rotated around element #8. Note that the origin is the rotation center of the probe antenna and dimension D in Fig. 2 (b) is twice that in Fig. 2 (a).

Fig. 3 shows array patterns for three different r for Fig. 2(a) where $D = 3.5\lambda$ and $r_f = 24.5\lambda$. When $r = 245\lambda$, the far-field pattern is obtained. When $r = 24.5\lambda$, the pattern is almost converged to the far-field pattern except the first sidelobe slightly higher and the null not deep enough. Fig. 4 shows array patterns for Fig. 2 (b) where $D = 7\lambda$ and $r_f = 98\lambda$. The satisfactory far-field pattern is obtained when $r \geq 2r_f$ from our calculation. When $r = 24.5\lambda$, the whole pattern is shifted about 5 degrees from the far-field pattern. From these figures we see that it is important to rotate a probe antenna with respect to the center of a test antenna and not to destroy the symmetry of the array pattern whenever possible.

Fig. 5 shows the configuration of a monopole on a conducting plate (0.5λ x $0.2\ \lambda$) located in the *y-z* plane. The monopole (the length is $0.27\ \lambda$ and the radius is 0.002λ) is directed in the *z*-axis and the feed point is at the bottom of the monopole. It is assumed that the plate is infinitely thin. The probe antenna is 0.1λ long with the radius 0.001λ and is chosen to be small enough to avoid the mutual coupling effects between the test and the probe antenna. The probe is rotated with a constant r in the *y-z* plane and is always perpendicular to radius vector r as shown in Fig. 5. The rotation center is at the center of the antenna in Fig. 5 (a) and is at the bottom of the antenna in Fig. 5 (b).

Fig. 6 shows the *y-z* plane pattern for the location of the test and the probe antenna in Fig. 5 (a) where $D = 2\lambda\sqrt{0.385^2 + 0.1^2} = 0.80\lambda$ and $r_f = 1.27\lambda$. The satisfactory far-field pattern is obtained when $r = 2.54\lambda$ and the difference between the patterns for $r = 1.27\lambda$ and 2.54λ is quite small. Fig. 7 shows the *y-z* plane pattern for the antenna locations in Fig. 5 (b) where $D = 1.55\lambda$ and $r_f = 4.82\lambda$. The satisfactory far-field pattern is obtained when $r \geq 2r_f$ from our calculation. The patterns for $r = 1.27\lambda$ and 2.54λ are quite different from the far-field pattern and the necessary r is much larger compared with the one in Fig. 6 due to the increase of D.

4. Conclusions

We showed that higher sidelobes, filled nulls and pattern shape changes may occur when r is not large enough, but satisfactory far-field patterns may be obtained when $r \geq 2r_f$. Also the better far-field pattern with less distance r will be obtained when the center of the test antenna is chosen as the rotation center of the probe.

References

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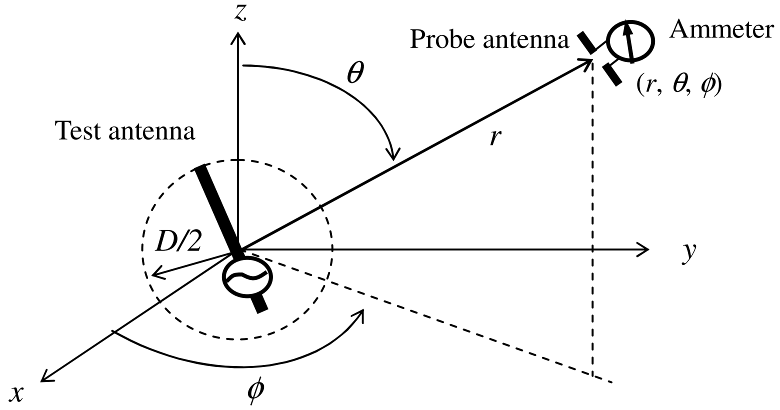


Fig.1 Test antenna and a probe antenna

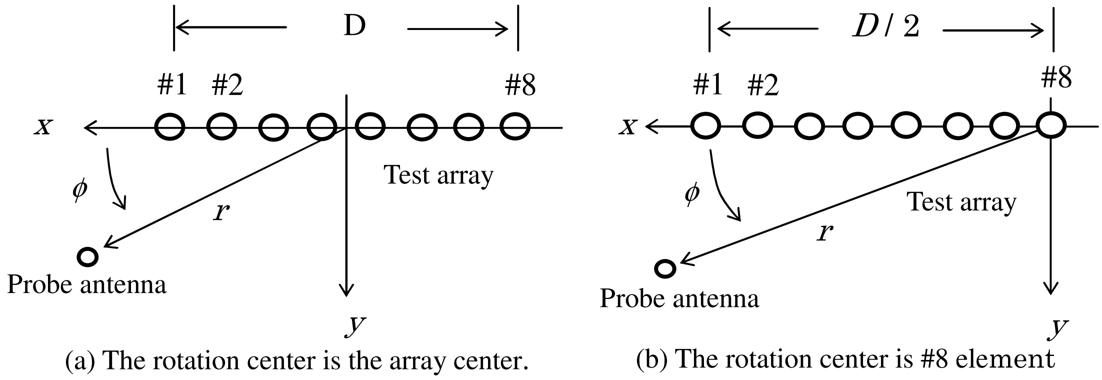


Fig.2 A probe antenna is rotated with a constant r in the x-y plane.

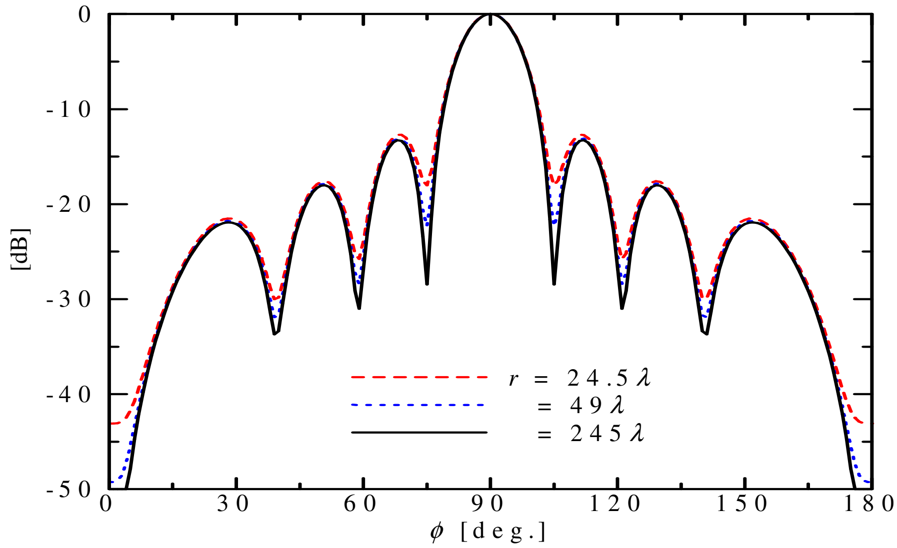


Fig. 3 The horizontal pattern when the probe is rotated around the origin.

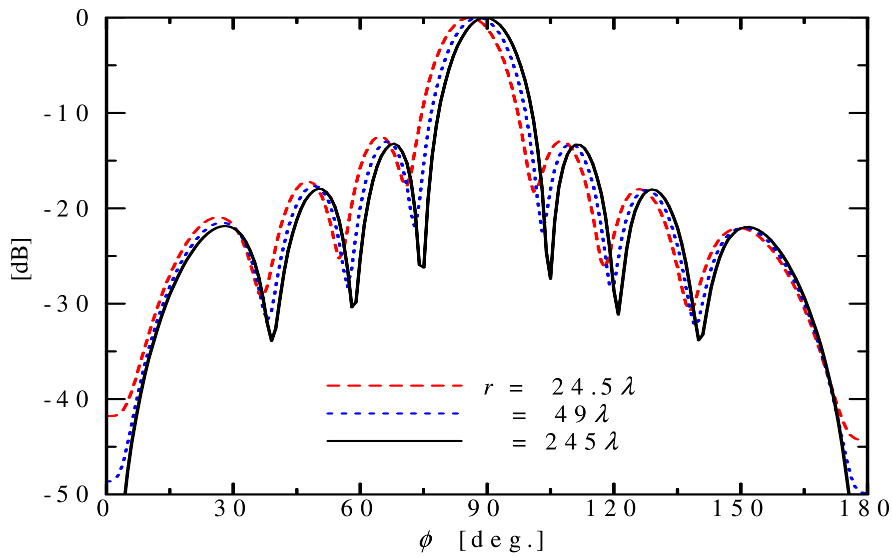
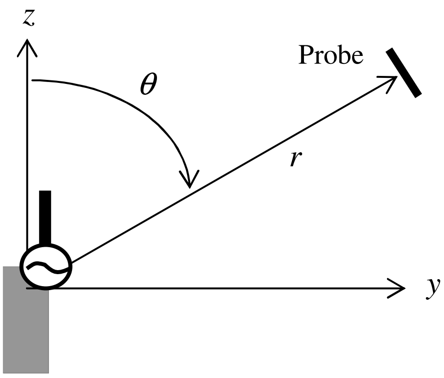
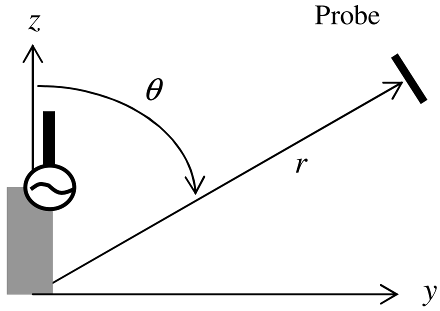


Fig. 4 The horizontal pattern when the probe is rotated around element #8



(a) The origin is the antenna center



(b) The origin is the bottom of the plate

Fig.5 The probe is rotated with respect to the origin in the *y*-*z* plane

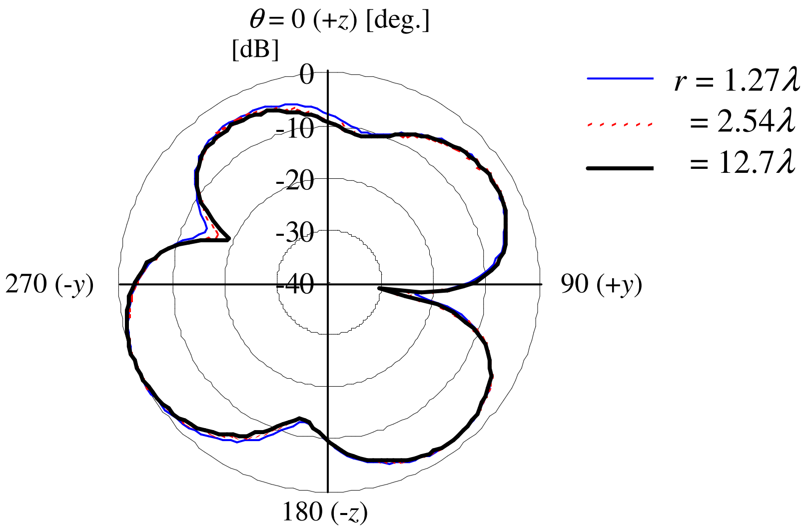


Fig.6 *y*-*z* plane E_θ pattern (rotation center : antenna center)

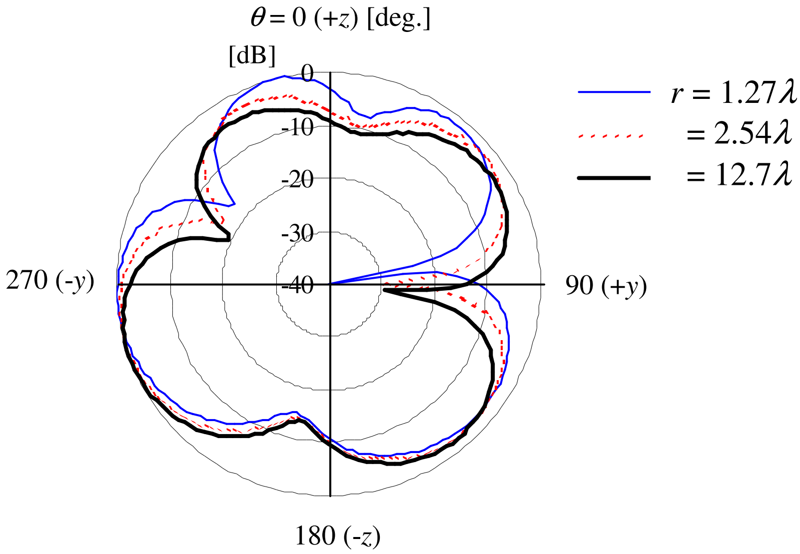


Fig.7 *y*-*z* plane E_θ pattern (rotation center : bottom of the antenna)