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A STUDY OF GRANULARITY IN THINNED MONOPULSE PHASED ARRAY ANTENNAS

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1. INTRODUCTION

A monopulse phased array antenna has the advantages of rapid beam scanning and accurate beam direction finding, so that it can be applied not only to a radar system, but also to a mobile communication system. In such applications, the null direction angle in the difference pattern is the most important factor in tracking accuracy[1].

This paper represents a study of the minimum scanning step of the null beam(granularity) in the difference pattern. The resultant equations that estimate the granularity are simple and can be applied to a phased array antenna whose aperture amplitude is tapered by thinning.

2. THEORY

The construction of a monopulse phased array antenna is symmetrical with respect to the YZ plane, as shown in Fig.1. In a thinned monopulse phased array antenna[2], when the beam scanned with ZX plane, the granularity of the beam direction θ_{min} is expressed as[3]

$$\theta_{min} = \frac{A_{k(min)} \cdot \phi_{min}}{\frac{4\pi}{\lambda} \cos\theta_0 \sum_{k=1}^{K} N_k A_k} \cdot \frac{\sum_{m=1}^{M} f(x_m)}{\sum_{m=1}^{M} x_m f(x_m)} \qquad (1)$$

where

- A_k : the amplitude of definite number
- $A_{k(min)}$: the minimum value of A_k
- N_k : the number of elements whose excitation amplitudes are A_k
- λ : the wavelength
- x_m : the m-th element position
- θ_0 : the set null direction angle
- ϕ_{min} : the minimum phase shift realized by the phase shifters
- $f(x_m)$: the function describing the amplitude distribution on the antenna aperture, as shown in Fig.2

When $f(x_m)$ is approximated by the quadric function as

$$f(x_m)=1-A\left(\frac{x_m}{D/2}\right)^2 \qquad (2)$$

where D is the aperture length, the granularity is expressed as

$$\theta_{min}=\frac{1-\dfrac{A}{3}}{\dfrac{\pi D}{\lambda}\cos\theta_0\left(1-\dfrac{A}{2}\right)\sum_{k=1}^{K}N_kA_k}A_{k(min)}\cdot\phi_{min} \qquad (3)$$

If the number of bits used for calculating the phase value is M_b, the beam scanning step θ_b realized in this system becomes

$$\theta_b=\frac{\lambda}{2^{Mb}\cdot D} \qquad (4)$$

Then M_b for realizing the granularity θ_{min} in Equation(3) is as follows.

$$M_b> \log_2\left(\frac{\lambda}{D'\cdot\theta_{min}}\right) \qquad (5)$$

3. NUMERICAL RESULTS

As an example, we have calculated and measured the granularity in the difference pattern of the thinned phased array antenna. The set amplitude taper is -28dB(n=6) Taylor distribution; 112 elements remain after thinning, and 5-bit phase shifters are employed. From Equation(3), the granularity of this antenna is 0.01degrees and, to realize this granularity from Equation(5), M_b should be larger than 10.

The relation between the null direction angles, set and actual, are shown in Fig.3. The solid and dotted lines show the results for an 8-bit calculator and a 16-bit calculator, respectively. From these results, the 8-bit calculation step is insufficient to attain the granularity determined by the antenna hardware. By using the 16-bit calculator, however, the expected granularity is attained because M_b is larger than 10.

4.CONCLUSION

The analysis for the granularity in a monopulse difference pattern has been presented. The equations derived here have a simple form and are useful for accurately predicting the granularity of a phased array antenna whose aperture amplitude is tapered for application to a communication or radar system.

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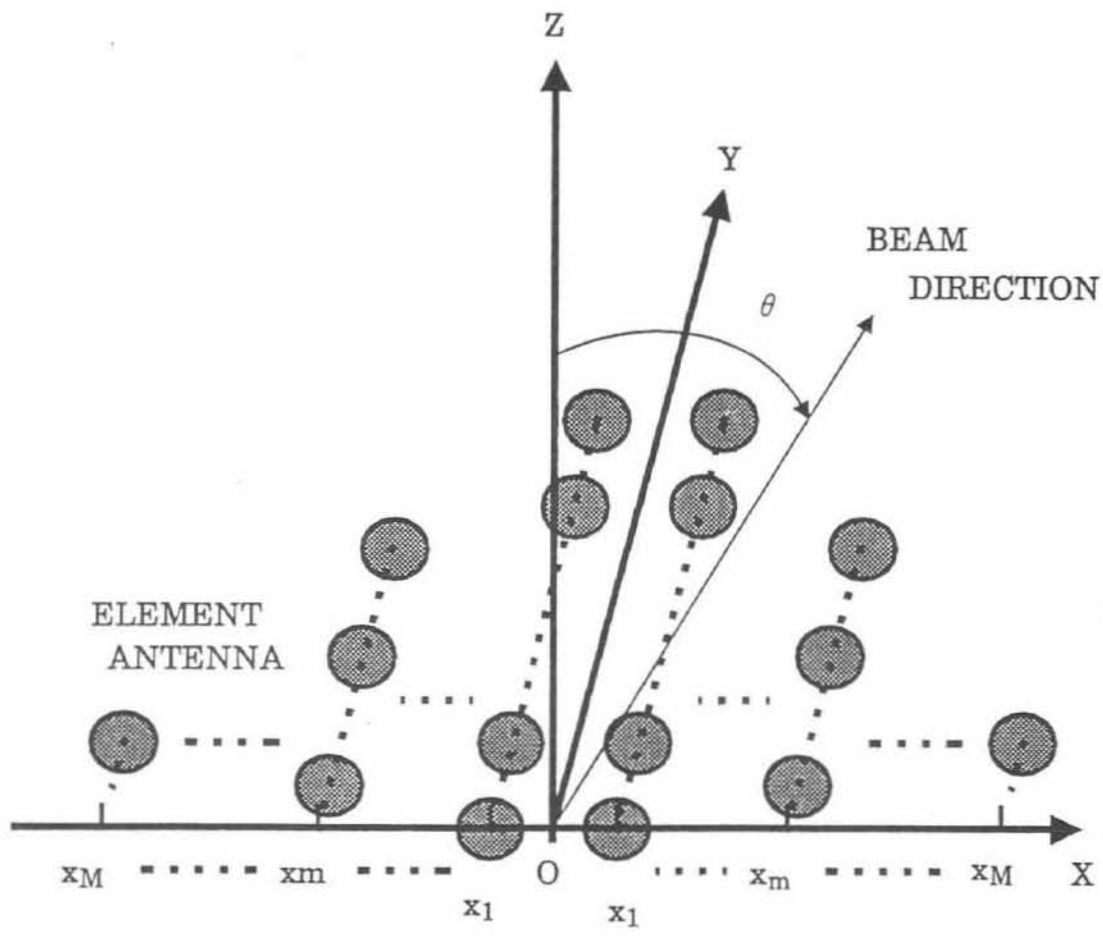

Fig.1. Construction of monopulse phased array antenna.

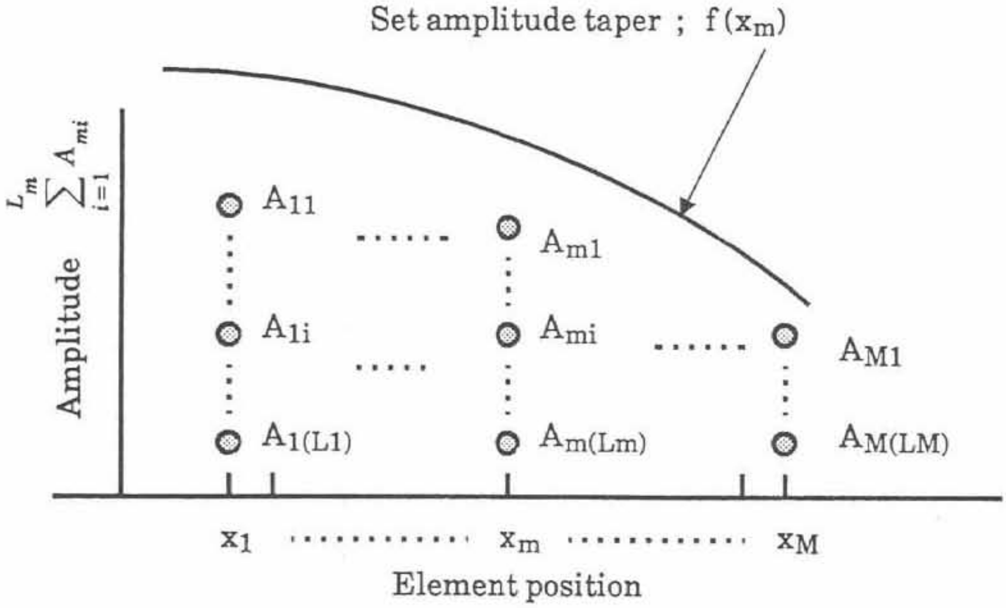

Fig.2. Aperture amplitude taper.

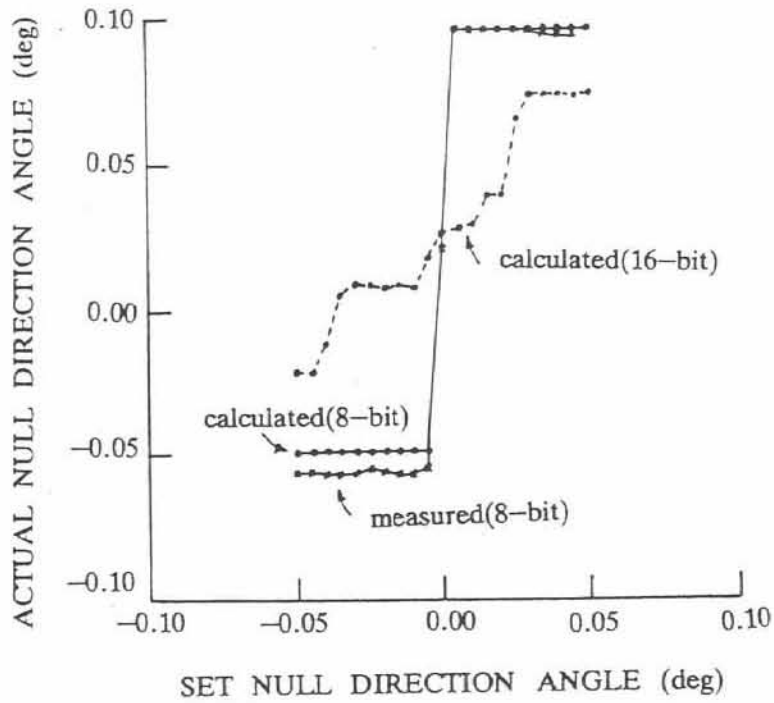

Fig.3. Null direction angle in the difference pattern.