MEASUREMENT ERROR OF THE ROTATING ELEMENT-FIELD VECTOR METHOD DUE TO ERRORS OF PHASE SHIFTERS

Rumiko YONEZAWA, Shin-ichi SATO and Takashi KATAGI
Mitsubishi Electric Corporation
5-1-1, Ofuna, Kamakura-shi, 247 Japan

1 Introduction

The Rotating Element-field Vector(REV) method is effective in measuring amplitude and phase of each element of phased array antenna under the condition of all elements being excited [1] . In this method, the relative amplitude and phase can be obtained by only measuring the received power while the phase of a phase shifter connected to an element is varied. In this paper, the effects of phase shifters' random errors on the measurement error of the phase of each array element measured by the REV method are analyzed. It is shown that the effect of the phase errors of phase shifters is similar to that of the amplitude errors of phase shifters. The result was verified to be a reasonable one by an experiment.

2 Analysis

The antenna configuration used in the REV method is shown in Figure 1. Phase shifters are individually connected to array elements. When the phase of the phase shifter is varied, the received power is varied along the cosine curve as shown in Fig. 2. The relative phase $X = \phi_n - \phi_0$ of each element is given as follows:

$$\tan X = \frac{\sin \Delta_0}{\cos \Delta_0 + \Gamma} \tag{1}$$

where $-\Delta_0$ is the phase of phase shifter in the case of the maximum received power, and when the ratio of the maximum and minimum power is represented by r^2, Γ is equal to $(r-1)/(r+1)$. Δ_0 and r are functions of α, c and s given as follows:

$$\tan \Delta_0 = -\frac{s}{c} \tag{2}$$

$$r^2 = \frac{\alpha + 2\sqrt{c^2+s^2}}{\alpha - 2\sqrt{c^2+s^2}} \tag{3}$$

$$\alpha = \sum_{i=1}^{N} f_i \tag{4}$$

$$c = \sum_{i=1}^{N} f_i \cos \Delta_i \tag{5}$$

$$s = \sum_{i=1}^{N} f_i \sin \Delta_i \tag{6}$$

where f_i is the received level, Δ_i is the phase of the phase shifter and N is the number of setting phase of phase shifter (for example, N is 32 in the case of 5 bits phase shifter). When the phase shifters are independent of each other, σ_f and σ_ϕ being the standard deviations of the received level and the phase of the phase shifter, the standard deviation of the measurement error of each array element is given as follows:

$$\sigma_X^2 = \sigma_1^2 + \sigma_2^2 \tag{7}$$

$$\sigma_1^2 = \frac{\sigma_\phi^2}{2N\Gamma^2} \tag{8}$$

$$\sigma_2^2 = \frac{\sigma_f^2}{2N\Gamma^2} \tag{9}$$

Where $\Gamma \ll 1$. It is shown that the equations (8) and (9) are in the same form.

3 Experiment

It is possible to find the direction of an incident wave by applying the REV method to two elements and calculating the direction using the phase difference. Fig. 3 shows the array antenna configuration for measuring the direction of an incident wave using two elements. The phase shifter is 5 bits and has the error of 2.84° rms. r is 0.8dB and σ_f is 0.0082 which are measured values. When the direction of the incident wave was 8° from the broadside, the phases of two elements were measured using the REV method and the direction was calculated using the difference of the phases of two elements. Table 1 shows the measured average angle of the incident wave and the standard deviation applying the REV method for two elements having the distances of $1\lambda, 2\lambda$ and 3λ in the azimuth plane, and the calculated results using equations (7)-(9). It is shown that the measured standard deviation approximates the calculated standard deviation.

4 Conclusion

The equations which give the relations between the phase shifter's random error and the measurement error of the phase of each array element by the REV method were shown. The direction angles of an incident wave derived by using two elements were measured in order to compare with the values given by these equations. Measured standard deviation approximates the calculated standard deviation, and the equations shown in this paper were ascertained to be effective for estimating the measurement error of each array element.

References

[1] S.Mano and T.Katagi:"A Method for Measuring Amplitude and Phase of Each Radiating Element of a Phased Array Antenna", Trans. IECE Jpn., J65-B, 5, pp.555-560, May 1982.

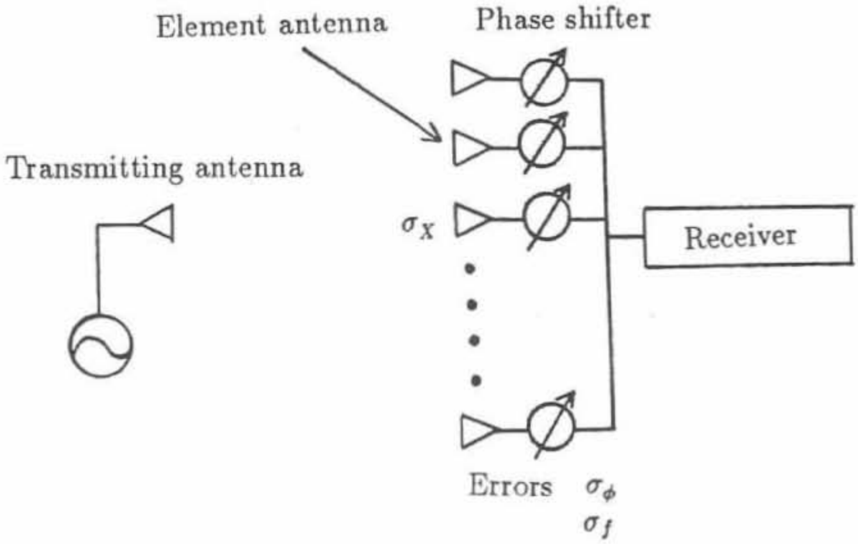

Figure 1 Antenna configuration

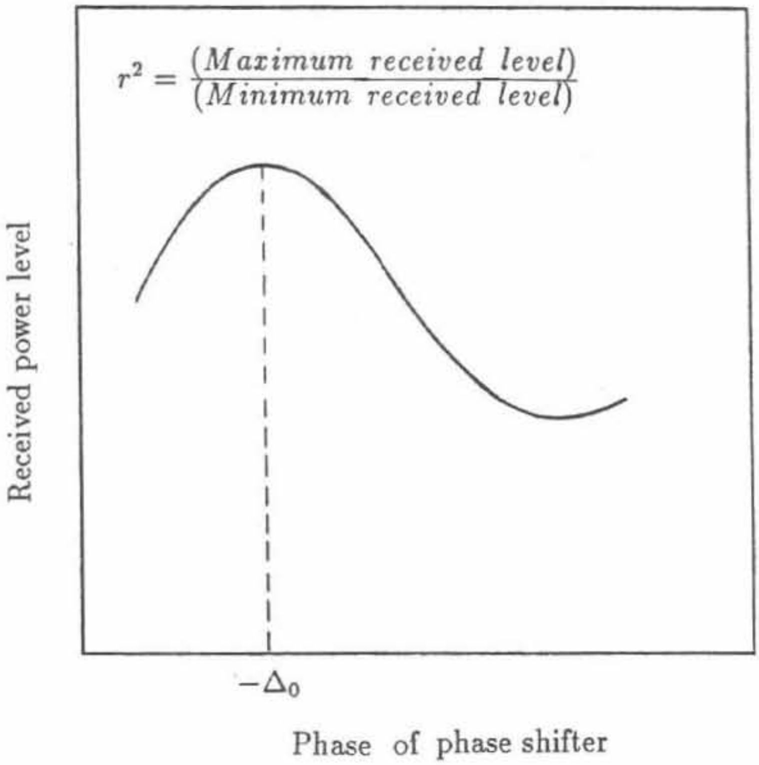

Figure 2 Cosine curve in the rotating element-field vector method

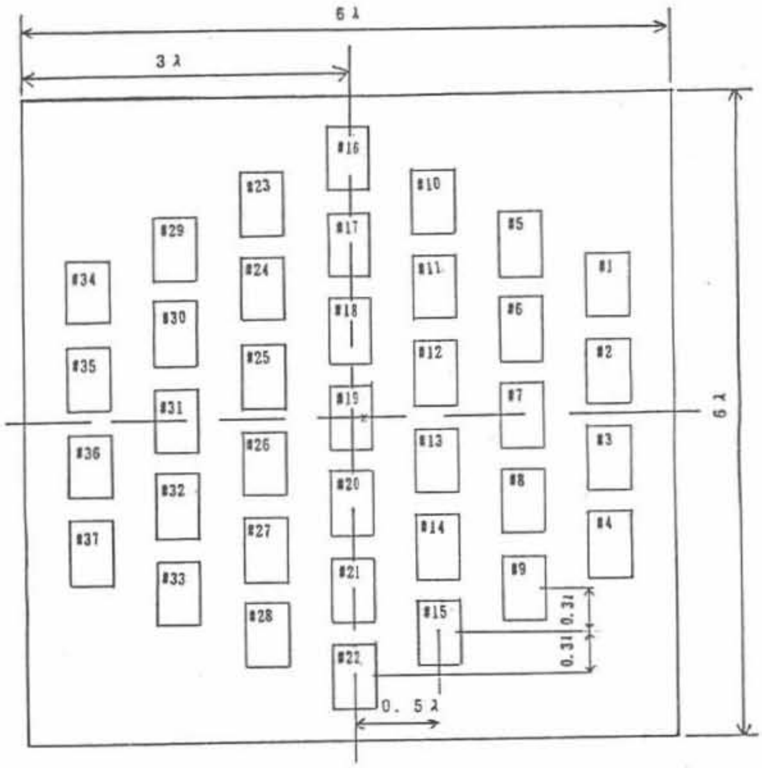

Figure 3 Patch array antenna

Table 1 Direction of incident wave and standard deviation

Distance	Measured number of two elements	Average direction angle (Measured)	Standard deviation	
			(Measured)	(Calculated)
3λ	4	7.2°	0.24°	0.59°
2λ	13	7.6°	1.05°	0.88°
1λ	24	7.8°	1.45°	1.76°
Total	41	7.5°	1.29°	1.45°