# NEAR FIELD MEASUREMENT FOR AN ULTRA-LOW SIDELOBE PHASED ARRAY ANTENNA

Shin-ichi ITOH, Hiroshi YOKOYAMA and Akio TANAKA
NEC Corporation, Tokyo, Japan

## 1. INTRODUCTION

For the phased array radar operated in unwanted signals like interference or heavy clutter, an antenna having ultra-low sidelobe characteristics over a wide angle is indispensable. Although highly accurate aperture distribution is needed in order to achieve an ultra-low sidelobe antenna, improvement of the accuracy of antenna hardware has a limitation from the view point of the cost to performance. Therefore, a near field measurement is necessary for the highly accurate measurement and adjustment of the aperture distribution in place of the far field measurement which is apt to be affected by the measurement environment.

However, in a technique to simulate the far field pattern from the near field distribution of the antenna, the probe position should be set with high accuracy over a large extent of area[1][2], and in a technique to measure the performance of each array element by the probe antenna fixed in the near field, calibrations of the range difference between the probe and each array element, and of the weighting due to the patterns of the probe and each array element are required[3][4].

This paper describes the theory and the experimental results of the near field measurement method in which excitation distribution on the array aperture can be measured with high accuracy without increasing the probe positioning accuracy of the near field scanner as in the conventional method.

## 2. MEASUREMENT ACCURACY OF APERTURE DISTRIBUTION

Factors that raise sidelobes of an array antenna are mainly classified into (a) random error, (b) periodic error and (c) gradual distortion of the aperture. (b) can be reduced by randomization of the array structure and/or the excitation phase. In (c), only the sidelobes near the main beam rise, and there is only a slight effect on the sidelobes in the wide angle region. accordingly, in order to achieve an ultra-low sidelobe pattern over a wide angle, suppression of the random error is important.

Fig.1 shows the results of the computer simulation of the relation between the random error of the aperture distribution of a linear array and the cumulative probability of its maximum sidelobe levels. In order to achive an ultra-low sidelobe of -40 dB, measurement accuracy of 0.1 dB rms in amplitude and 1° rms in phase is required.

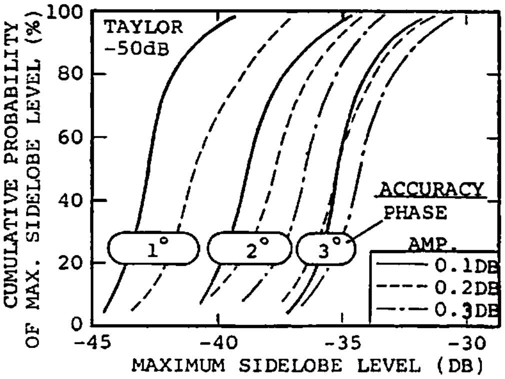

Fig.1 Maximum sidelobe vs aperture distribution accuracy.

## 3. PRINCIPLE OF THE NEAR FIELD MEASUREMENT

The measurement diagram of the developed method is shown in Fig.2. In this method, the probe is positioned in the near field of the array aperture and in the far field of the array element. Here, the probe moves on the plane parallel to the test array aperture, and is positioned in front of the array element to be measured, for example, n-th element in Fig.2. The received electric field by the probe is the vector sum of the radiated electric fields from all array elements, including the weighting by the patterns of the probe and the array elements. However, these vectors are not added in phase in the near field. Therefore the received electric field changes remarkably when the excitation condition of only the n-th element is changed.

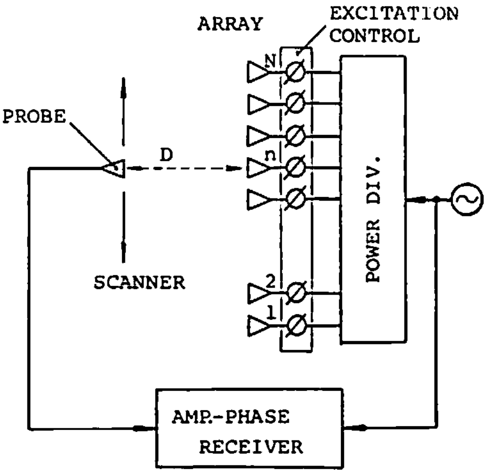

Fig.2 Near field measurement diagram.

A brief illustration of this principle is shown in Fig.3, in which $\dot{E}o$ and $\dot{E}o'$ are the electric fields received by the probe, $\dot{E}a$ is the sum of the electric fields from the elements other than the n-th element, and $\dot{E}n$ and $\dot{E}n'$ are the electric fields from the n-th element. When the excitation condition of the n-th element is changed from $\dot{E}n$ to $\dot{E}n'$, the received electric field changes from $\dot{E}o$ to $\dot{E}o'$. This relation leads to the following equation.

$$\dot{E}n = \frac{\dot{E}o - \dot{E}o'}{1 - \dot{E}n' / \dot{E}n} \qquad (1)$$

From (1), the excitation amplitude and phase of the n-th element can be obtained from the ratio of the excitation condition $\dot{E}n'/\dot{E}n$ given to the n-th element, and the measured values of $\dot{E}o$ and $\dot{E}o'$ correspond to the excitation conditions $\dot{E}n$ and $\dot{E}n'$, respectively. There are three means of changing the excitation condition of each element; amplitude only, phase only and the combination of both amplitude and phase. In addition, the improvement of accuracy can be achieved by increasing the redundancy of the number of measuring samples. The following part of this paper describes an example where only the excitation phase is changed by means of a phase shifter.

This method is theoretically difficult to be affected by the radiation patterns of the probe and the array elements because the probe is always positioned in front of the element to be measured. As a result, the probe can be optionally selected without being limited to the point source. For example, as an antenna having directive pattern such as a horn antenna can be applied, the

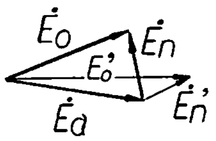

Fig.3 Principle of the measurement.

multipath reflection caused by the measurement environment can be reduced by the weighting effect of the probe pattern.

The major error factor of this method is the distance between the probe and the element to be measured, that is D in Fig.2. Therefore, it is important to maintain the parallelism between the probe scanning plane and the test array aperture. However, even if a slight error exists in the probe transverse position from the front of the element to be measured, the effect of this error on D is small. For example, in case of D=3m, even if the transverse position error is 1 cm, the phase measurement error caused by this error is 0.06° at S-band and 0.2° at X-band.

Accordingly, the summary of the error allocations of the near field test system based on this method becomes, for example, as shown in Table 1. This is an example of the measurement system having the accuracy of 0.1 dB rms in amplitude and 1° rms in phase at S-band. As shown in Table 1, the scanner used in this method requires the same level of the scanning plane accuracy as that of the conventional method, but the probe positioning in the transverse direction does not necessary require high accuracy.

Table 1. Random error allocations of the near field test system at S-band.

| FACTOR | MECH. (RMS) | PHASE (RMS) | AMP. (RMS) |
|---|---|---|---|
| PROBE LONGITUDINAL | 0.1mm | 0.4 DEG | - |
| PROBE TRANSVERSE | 5 mm | 0.03DEG | - |
| MULTIPATH | - | 0.4 DEG | 0.06DB |
| AMP-PHASE RECEIVER | - | 0.5 DEG | 0.03DB |
| RF CABLE | - | 0.5 DEG | 0.07DB |
| MISCELLANEOUS | - | 0.3 DEG | 0.03DB |
| SUM (RSS) | - | 1.0 DEG | 0.1 DB |

4. EXPERIMENTAL RESULTS

For the confirmation of feasibility of an ultra-low sidelobe array antenna by this method, the measurement and adjustment of a linear array antenna were performed using an experimental near field scanner. The near field scanner is a single axis scanner using a horn antenna as a probe. The linear array is a printed circuit dipole array, and analog phase shifters were installed between the elements and the power distribution circuit in order to control the excitation condition of the elements. A conventional network analyzer was used for the amplitude-phase measurement. The experimental target of the sidelobe level of the linear array was less than -35 dB, and because of this, the measurement system was adjusted so that the accuracy becomes within 0.2 dB in amplitude and within 1.5° in phase.

The aperture distribution of the linear array measured and adjusted using this test set is shown in Fig.4. Since these measured values contain the error of the experimental measurement system, the aperture distribution accuracy estimated by excluding the measurement error is 0.3 dB rms in amplitude and 2° rms in phase. This accuracy satisfies the condition to achive the sidelobe of less than -35 dB as shown in Fig.1.

Fig.5 shows the radiation pattern of this linear array measured in the conventional far field antenna range. As a result of the phase adjustment of the array aperture distribution by utilizing this method, sidelobes of less than -36 dB was achieved. Since it is possible to realize the accuracy of the scanner as shown in Table 1 by utilizing calibration techniques of the probe

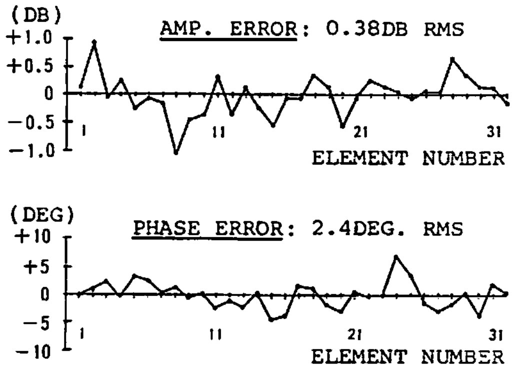

Fig.4 Measured aperture distribution error.

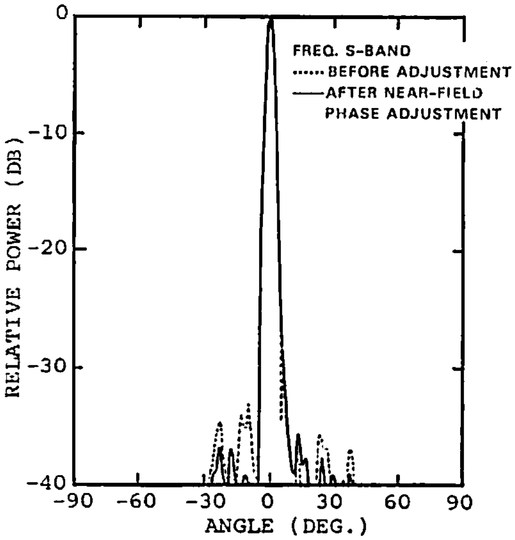

Fig.5 Measured far field patterns.

position, an ultra-low sidelobe antenna of less than -40 dB is promissing.

## 5. CONCLUSION

The near field measurement method of the array aperture distribution suitable for ultra-low sidelobe phased array antennas has been developed. This method has the following advantages compared with the conventional near field measurement method; (a) a scanner with accuracy as high as that of the conventional method is not required, (b) the effect of the measurement environment can be reduced because the probe having directive pattern is available and (c) excitation error of each array element can be directly measured including its array element pattern. The experimental results show that the ultra-low sidelobe antenna of less than -40 dB can be achieved by this method. Moreover, this method is possible to be applied to aperture antennas as well as array antennas.

## REFERENCES

[1] R.C.Johnson et al.,"Determination of far-field antenna patterns from near-field measurements," Proc. IEEE, vol.61, No.12, pp.1668-1694, Dec. 1973.

[2] W.A.Harmening,"A Laser-bssed, near-field probe position measurement system," Microwave J., Oct. 1983, pp.91-102.

[3] J.F.White,"Phased array technology workshop," Microwave J., Feb. 1981, pp.16-28.

[4] K.Shiromatu et al.,"Short range measurement of phased array antennas," 1984 National Conv. Digest, IECE Japan, No.734, March 1984.