RESULTS OF PLANAR NEAR FIELD TESTING WITH ULTRALOW SIDELOBE ANTENNAS*

by A. C. Newell**, M. H. Francis**, D. P. Kremer**, and K. R. Grimm***

1.0 INTRODUCTION

An investigation to demonstrate planar near field (PNF) measurement accuracy for ultralow sidelobe antennas is nearing completion at the National Bureau of Standards, Boulder, CO. The existing NBS scanner has been modified to accommodate antennas up to 10 m long and 4 m high. Two antennas will be measured as a part of this research effort. They are the AWACS (U. S. Airborne Warning and Control System) and the ULSA (Ultra Low Sidelobe Antenna), traveling wave antennas which are respectively 8 m X 1.5 m and 6 m X 1 m. Results of tests to introduce controlled NF measurement error confirm predicted far field (FF) sidelobe accuracies at the -60dB level. Additional results show the utility of a new 2-element probe to extend sidelobe measurement accuracy by steering a probe pattern null in the direction of the test antenna's main-beam.

2.0 BACKGROUND

Planar near field testing for directive antennas has been in wide use in the U. S. since the early 1970's when the first NF test with a phased array was performed by researchers at NBS [1]. Many measurement applications followed with landmark analytical and computer simulation error analyses completed by Yaghjian in 1975 [2] and Newell [3]. In 1982, Grimm reevaluated the existing error analyses, and predicted that FF measurement accuracy would be fundamentally limited by three classes of NF error [4]:

1. the form of residual (random) error following compensation of known systematic error, e.g., probe position error.

2. probe/antenna multipath.

3. probe pattern directivity.

** NBS, Electromagnetics Division, Boulder, CO.

*** Technology Service Corporation, Silver Spring, MD.

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Improved FF error bounds were suggested which were based on the statistics of residual NF error and measured multipath effects. An optimum probe pattern was suggested which would minimize the weighted mean square error in the transformed FF. The suggested probe was based on the earlier work of Huddleston [5], but for low sidelobe testing, the new probe was required to have a pattern null which could be costeered with the test antenna's mainbeam [6].

The reason for the improved sidelobe accuracy when using the difference pattern probe can be seen from the results of the analytical error analysis and the equations relating measured data and calculated results. The plane wave spectrum of the antenna under test (AUT) $\underline{t}_{10}$ $(\underline{K})$, is determined from the measured near-field data $\underline{B}_0(x,y)$ and the receiving spectrum of the probe $\underline{s}'_{02}$ $(\underline{K})$. For illustrative purposes let us assume that the main polarization of the AUT and the probe are identical for all values of $\underline{K}$, where $\underline{K} = k_x \underline{e}_x + k_y \underline{e}_y$ is the transverse part of the propagation vector. The calculation of $\underline{t}_{10}$ $(\underline{K})$, is performed in two steps. First the spectrum of the measured data $D(\underline{K})$ is obtained using the FFT. $D(\underline{K}) = \underline{t}_{10}(\underline{K}) \cdot \underline{s}'_{02}$ $(\underline{K})$

$$= \frac{e^{-i\gamma d}}{4\pi^2 F' A'} \int B_0(x,y)\, e^{i\underline{K}\cdot\underline{P}}\, dx\, dy\ , \qquad (1)$$

where F' is an impedance mismatch factor, A' an amplitude normalization constant,

$$\gamma = \pm\, k_z, \text{ and } \underline{P} = x\underline{e}_x + y\underline{e}_y,$$

the probe position vector. The transmitted spectrum of the AUT is then obtained from the second step in the data processing referred to as the probe correction

$$t_{10_m}(\underline{K}) = \frac{D(\underline{K})}{s'_{02_m}(\underline{K})}, \qquad (2)$$

where the "m" subscript notes the main component. Errors in $\underline{t}_{10_m}(\underline{K})$ arise from the errors in the measurement of the probes receiving pattern $s'_{02}(\underline{K})$ and errors in the measured data $B_0(x,y)$ which produce corresponding errors in $D(\underline{K})$. In the analytical error analysis it was found that the relationship between measurement uncertainties and errors in $D(\underline{K})$ in the sidelobe region was of the form

$$\frac{\Delta D(\underline{K})}{D(\underline{K})} = C\ \Delta^n\ \frac{D(\underline{K}_0)}{D(\underline{K})} \qquad (3)$$

for almost all sources of error. In the above equation C is a constant that varies for each error source, Δ is the magnitude of the error in the near-field data, n = 1 or 2, and $\underline{K}_0$ is the wavenumber direction for the maximum of the spectrum. The ratio $D(\underline{K}_0)/D(\underline{K})$ is then the inverse of sidelobe level where the error is being determined. For instance if the error in a 40 dB sidelobe is desired the ratio is 100, and therefore the effect of very small Δ's in the near-field data can be magnified many times for low sidelobes. This magnification arises from the high main beam energy producing artificial sidelobes when there are periodic errors in the near-field measurements.

The effect of the errors can be lowered by reducing either the Δ's or the peak value of the spectrum, $D(\underline{K}_0)$, which is what the difference pattern probe does. The high main beam energy is filtered out leaving only the near-field data corresponding to the sidelobe pattern. The effect of errors is reduced and the sidelobes can be measured more accurately.

Since the main beam has been filtered out, a separate measurement with a standard probe must be used to obtain the patterns near the main beam.

3.0 TEST PLAN

Figure 1 shows the modified NBS scanner and the mounted ULSA array. It is probed in sections and the high resolution FF is computed by merging the transform sections, or by merging the NF data sets before transform. Intentional NF error is induced via:

- o defeating the receiver calibration compensation to corrupt NF data as a function of test signal level in a known way.
- o causing known probe position error offsets.
- o selective deleting of measured NF samples for both truncation and sampling density studies.
- o increasing probe/array multipath.

Both a standard single element probe and the new 2-element probe shown in Figure 2 are used. Scan lengths are typically 11m X 4m and lead to 512 X 256 FFT transforms with probe correction. The frequency is in the 2.9 to 3.3 GHz band and probe/array separation is typically 1m or less. The results of tests yield measured changes in various FF sidelobe levels for selected induced NF measurement error values. Both co- and cross-polarized patterns are investigated.

The tests have shown that the two-element, difference pattern probe does indeed provide more accurate results for very low sidelobe measurements. The results of these tests will be presented in detail.

4.0 CONCLUSIONS AND IMPLICATIONS

These tests have demonstrated that existing error bounds may be used to predict FF measurement accuracy for patterns derived by NF probing 20 dB lower than previous results. Known systematic errors must be compensated including probe position and receiver conversion errors. Existing rules for scan length and sample density appear adequate for low sidelobe testing. The new probe enhances low sidelobe measurement accuracy by spatially filtering the high-energy main beam wave numbers, but only can be used providing an independent test to accurately recover the main beam is also performed.

5.0 REFERENCES

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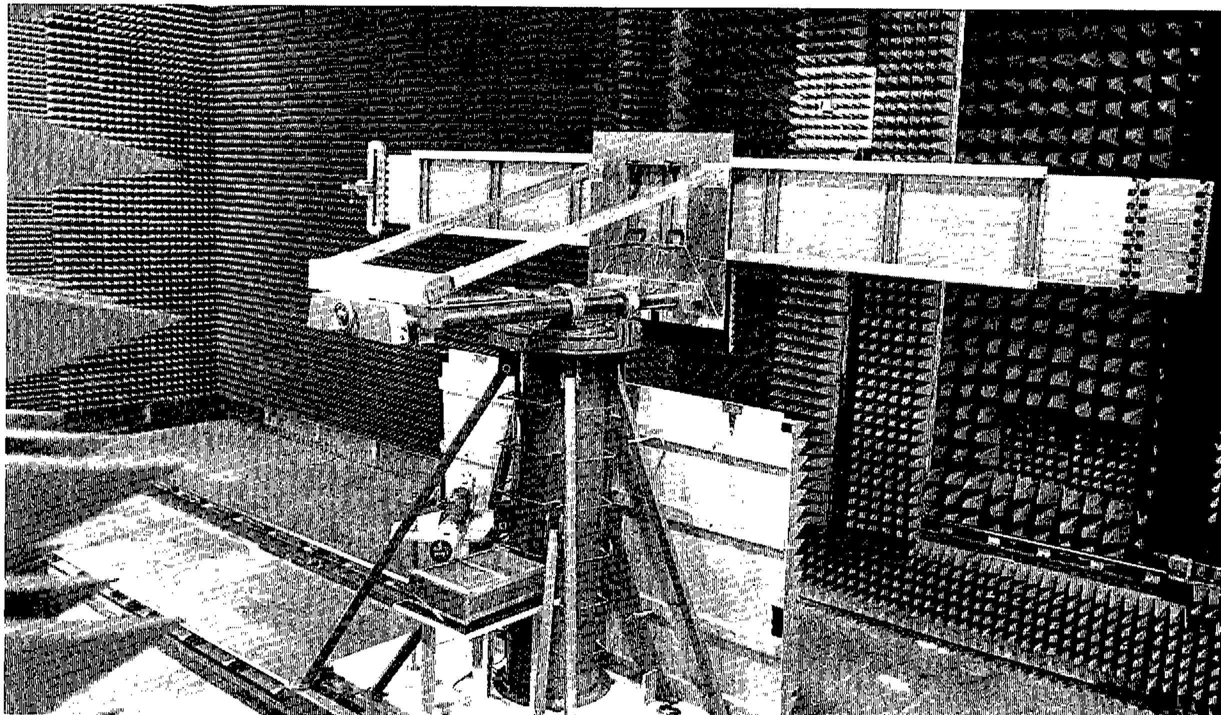

Figure 1. Modified NBS scanner and mounted ULSA array.

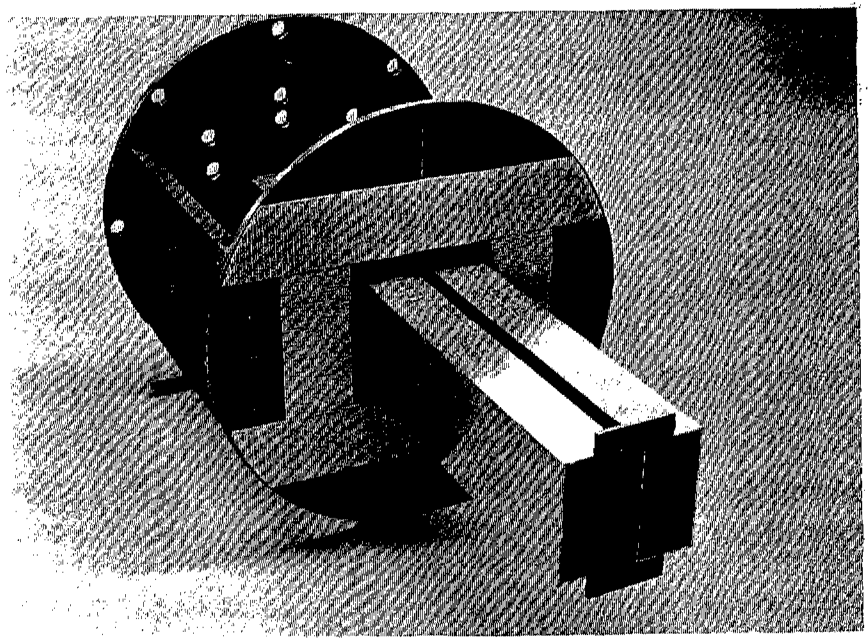

Figure 2. The two-element probe.