REMOTE, NEAR-FIELD MEASUREMENT OF LARGE ANTENNAS[1]

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ABSTRACT

Characterization of many antenna systems is difficult in a laboratory environment. Size is the major consideration, but an increasing number of sophisticated antennas are being placed at remote sites where they are simply inaccessible. Of particular concern is the advent of very large active phased arrays that are projected to have $10^4 - 10^6$ elements. Such arrays not only must be characterized initially, but they must be measured periodically so that their functions can be optimized to offset inevitable degradation with time.

Currently, in situ/remote measurements are often performed using far-field techniques with distant (often extraterrestrial) sources. These methods usually provide incomplete diagnostic information. At NIST we are considering how near-field measurements can be used to obtain more complete information about the status of a remote test antenna.

INTRODUCTION

There are many situations where in situ measurements are desirable. We will focus on one case for which a practical near-field measurement system seems feasible with use of current technology. As shown in Figure 1, we envision an arch which carries a probe on a semicircular path over a test object that can be rotated in azimuth. Standard near-field to far-field transformation algorithms require measurements on an equispaced grid in elevation and azimuth. Because a practical mechanism might be large and unwieldy, positioning the probe at the desired locations may be difficult. A practical near-field measurement method requires (1) the ability to accurately determine the actual probe position for each data point, and (2) an efficient computational technique that does not assume ideal measurement locations.

THEORY

The theory of probe position correction for near-field spherical scanning is similar in principle to that of the planar scanning case [1]. An efficient algorithm was devised to predict probe response at actual measurement points given an estimate for the spherical-mode coefficients that describe the test antenna field. The corresponding linear operator and its Hermitian adjoint are applied in an iterative (conjugate-gradient) solution of the normal equations. Computational complexity is $O(N^{3/2})$ where N is the number of unknowns. By contrast, the computational complexity is $O(N^3)$ for Gaussian elimination. The number of iterations depends on the conditioning and the specified numerical accuracy.

SIMULATIONS

We have successfully tested the algorithm for uniformly distributed position errors as large as 3λ in the radial coordinate and 3Δ in the angular coordinates. (Here, Δ is the maximum angular sample interval allowed by the sampling theorem.) We have found that increasing the number of samples by a modest amount, above that required by the sampling theorem, significantly improves the conditioning (and convergence). In addition, conditioning may often be improved by increasing the measurement radius. Computations (128 x 128 data points using a 2 GHz Pentium PC) have required less than 2 hours for less extreme probe position errors (radial $< 0.5\lambda$ and angular $< 0.5\Delta$).

IMPLEMENTATION CONCEPTS

A scanning arch could be constructed inexpensively as long as mechanical tolerances are modest. Based on laboratory experiments at NIST, we believe that probe position can be measured with good accuracy (±.05 mm at a range of 5 m) using a commercially available laser tracking device following retroreflectors mounted on the probe and turntable. In our experience to date, laser trackers have been free running; however, the essential ability to simultaneously trigger both position and signal measurements has recently become available.

CONCLUSION

We have demonstrated the capability to correct for significant errors in probe position. This will permit the use of simple light-weight scanners for in situ measurements. (These algorithms will also help extend the frequency range of scanners currently used in laboratory environments.) Commercially available laser tracking devices have the potential for collecting probe position data.

REFERENCE

[1] R. C. Wittmann, B. K. Alpert, and M. H. Francis, "Near-field antenna measurements using nonideal measurement locations," *IEEE Trans. Antennas Propagat.*, vol. AP-46, pp. 716 – 722, May 1998.

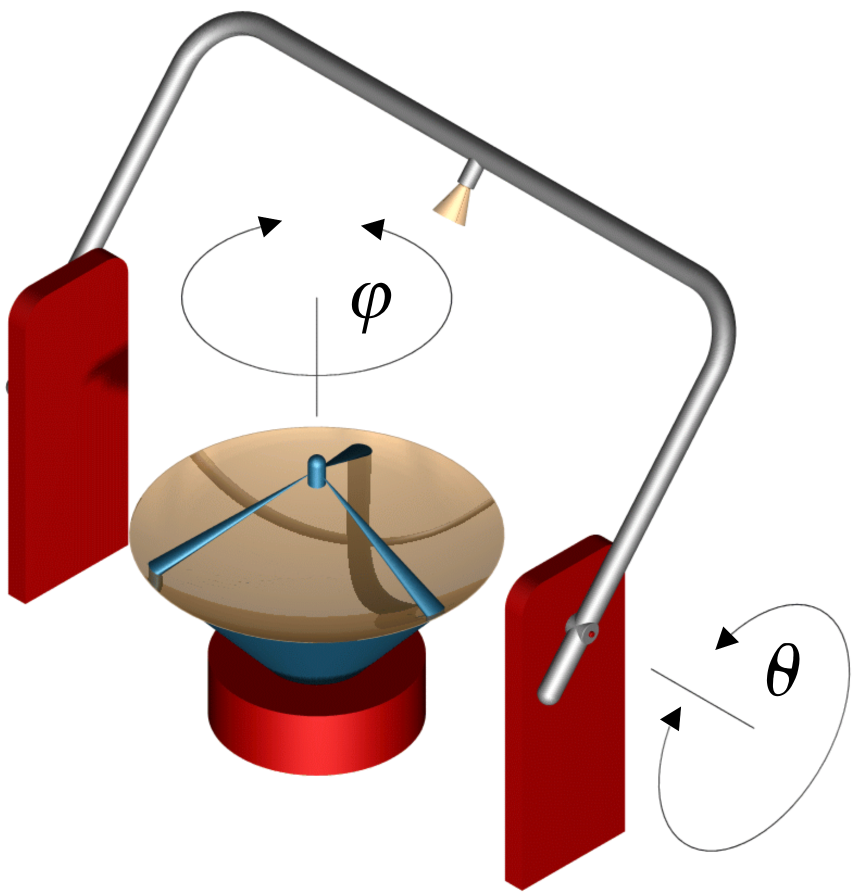

Figure 1. A sketch of a (hemi)spherical scanning system