PHASED-ARRAY SIMULATION FOR ANTENNA TEST RANGE DESIGN

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ABSTRACT

A simulation tool used during the design of near-field ranges for phased array antenna testing is presented. This tool allows the accurate determination of scanner size for testing phased array antennas under steered beam conditions. Estimates can be formed of measured antenna pointing accuracy, side lobe levels, polarization purity, and pattern performance for a chosen rectangular phased array of specified size and aperture distribution. This tool further allows for the accurate testing of software holographic capabilities.
Keywords: Antenna Measurements, Phased arrays, Planar near-field ranges, Error Simulation.

1. INTRODUCTION

Planar near-field antenna test facilities are increasingly being used for the testing and calibration [1] of agile phased array antennas. The complexity of these antennas does not only require high speed antenna interfaces, but also presents the antenna range designer with new challenges. One such aspect is that antenna beams may be steered to acute angles for planar near-field testing and such a condition requires careful assessment of the impact of known existing measurement imperfections on the overall range performance.

In this paper a software simulation tool is presented which allows the range designer to study the impact of mechanical and electrical errors in a planar near-field facility when a phased array is tested under steered beam conditions. The approach taken is to estimate measurement errors via computer simulation for a particular hardware configuration and error parameter set. This allows the generation of parametric curves which show the impact of particular measurement errors. In this way, specific facility specifications may be justified and over specification may be avoided to reduce system cost.

The theory supporting the simulation tool will be described, results will be shown for a typical array, and the impact of scanner design on the measured pattern performance will be demonstrated through examples.

2. ERROR ESTIMATION TECHNIQUE

In any near-field measurement system, errors arise due to RF instrumentation inaccuracy, instrumentation drift, chamber reflection, mechanical inaccuracies, poor alignment and numerical processing effects. Experience has shown that numerical processing and RF equipment imperfections do not contribute significantly to the overall error budget. For the other items it is desirable to be able to determine accuracy levels required apriori since this can lead to system cost reductions. It is for this reason that a software error simulator is used to study their impact [2, 3, 4].

The approach taken is to simulate near-field data for a phased array antenna and to introduce specific mechanical and electrical inaccuracies and to study the impact that these will have on the far-field measurement result through comparison to the perfect case (no introduced inaccuracies). The software presented allows modeling of mechanical and electrical errors.

3. THE SOFTWARE ERROR SIMULATOR

In the formulation of this error simulator the phased array antenna is specified by its aperture size, number of Herzian dipole radiators, side lobe level and cross-polarization figure. It is then modeled as a planar array over an infinite groundplane. The array scan angle can also be specified. For the array, a Taylor aperture distribution is assumed in the horizontal direction and a constant distribution in the vertical direction. For the cross-polar generated component, an orthogonal co-located set of dipoles is used with a constant aperture distribution. The amplitude of the cross-polar component is specified as a fraction of the normalized amplitude of the co-polar distribution. The electric and magnetic field components are computed exterior to the source region for all positions of the planar scanned probe.

Considering a planar scanning configuration where the probe is moved in a plane parallel to the array face at a fixed distance, a number of mechanical errors may be introduced in the scanner simulation. The following mechanical error sources are modeled:

- Array angular offset w.r.t. the scan plane.
- Constant probe position error in x, y & z.
- Random probe position error on x, y & z[1].

The following electrical errors are modeled:

- Probe channel isolation (for dual polarized probes).
- Receiver amplitude & phase non-linearity.

A near-field data set may now be generated for the ideal case (where the above error terms are all set to zero) and for a perturbed case and these two data sets may be used to estimate the impact of the error. Parametric curves may be generated by recursive modeling of a single error term.

4. SIMULATION DATA

To demonstrate the process described above, data was generated for a phased array antenna with an aperture of 0.5m x 0.5m. The array contains 17 x 17 elements and the frequency of operation is 9 GHz. The aperture distribution simulates a –22 dB side lobe level and no cross-polar currents are incorporated. The near-field scan is simulated for a probe at a distance of 0.1m away from the array face and covering a scan area of 1.9m x 1.9m to allow far-field angular coverage from –80 to +80 degrees in both azimuth and elevation. Using the NSI97 near-field to far-field processing package, the far-field azimuth pattern for the array can be computed and is shown in Figure 1.

If the array is scanned to an angle 20 degrees off boresight in azimuth the pattern shown in Figure 2 results. Due to the large antenna element spacing a grating lobe is introduced at –55 degrees.

To investigate the effect of probe x-position (horizontal) error a random number between –1mm and +1mm is added to the probe position during the simulation process and far-field patterns are compared. This comparison is shown in Figure 3 as an error pattern. As can be seen the random probe x error does not impact the radiation pattern accuracy significantly for this particular case. Note that this may also be due to the absolute random nature of the error and for more systematic errors this may not be the case.

To investigate the effect of scan plane truncation on scanned beam antennas the following experiment was conducted: For the pattern of Figure 1 (no beam steering) the scan plane was truncated to 0.74m x 0.74m. This scan area should provide reliable far-field data in the region from –50 to +50 degrees in both azimuth and elevation. Using the reference pattern of Figure 1 and that obtained with the truncated scan simulation the error pattern as shown in Figure 4 was obtained.

For the pattern of Figure 2 (beam steered to 20 degrees & grating lobe present) the scan plane was truncated in a similar manner and using the reference pattern of Figure 2 and that obtained with the truncated scan simulation the error pattern as shown in Figure 5 was obtained. When comparing Figure 4 and Figure 5 it is clear that the scan area truncation has a greater impact on the steered beam case and this data will influence the scanner design for such an AUT. This result is significant for scanner design where the intent is to measure phased arrays with beams steered to acute angles.

To demonstrate how the simulator may be used to determine the feasibility of using an existing facility for testing a particular phased array antenna, an example is shown of the impact of probe z-position

[1] Since these mechanical parameters are typically available from the NSI laser optics alignment system they can also be imported into the simulation to assess the suitability of an existing facility for testing a particular type of phased array antenna.

error on far-field pattern accuracy. If the planarity data of the scanner is known (either through theodolite measurements or a laser monitoring system) this data can be incorporated into the simulation to determine far-field pattern perturbation. For illustration here the effect of a 2mm peak to peak random planarity error (exaggerated to demonstrate the simulation capability) is shown. Figure 6 shows the perturbed pattern and the reference radiation pattern as shown in Figure 1.

To further illustrate the applicability of this software simulator the holographic image shown in Figure 7 is presented. This image was obtained through a back projection to the array face from the simulated near-field data. The individual radiators can be identified. This example shows the imaging capability of the software and will allow testing of the imaging accuracy to determine to what level of accuracy phased array antenna calibration can be performed in this way.

5. CONCLUSION

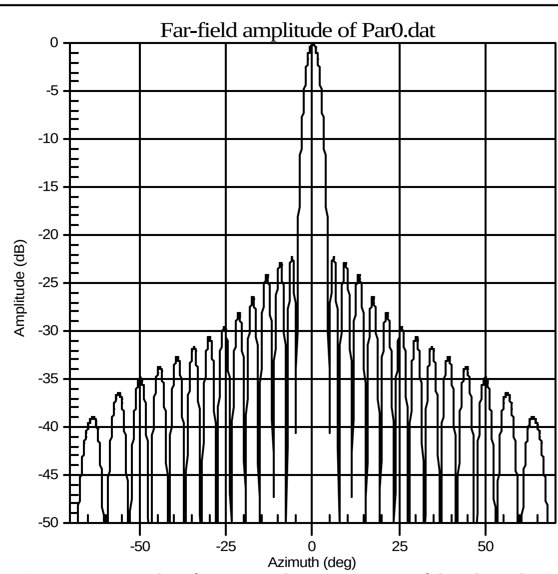

Figure 1 *Azimuth reference radiation pattern of the phased array.*

In this paper a software error simulator has been introduced that allows modeling of phased array antennas in a planar near-field test facility. The antenna simulator allows side lobe level and cross-polarization adjustment so that the impact of measurement errors on both these parameters can be studied in detail. Various mechanical and electrical measurement errors may be introduced in the simulation and examples were shown for probe random x and z positional error. The impact of scan area size for beams steered to acute angles may also be studied and an example of this has been presented. This example demonstrated that scan plane truncation may have a greater accuracy impact on steered beam antennas and should therefore be studied carefully when a near-field scanner is designed for this purpose.

The tool allows NSI to assess antenna test range specifications and to demonstrate to what extent specific error sources will limit measurement accuracy. It also allows the testing of holographic back projection techniques and can show if the required accuracy for phased array antenna calibration can be achieved using such techniques. Existing planar near-field scanners can also be evaluated using this simulator and measured mechanical performance parameters of the system.

The simulator currently provides a platform for modeling specific mechanical and electrical errors in planar near-field facilities and the error models will be refined in future.

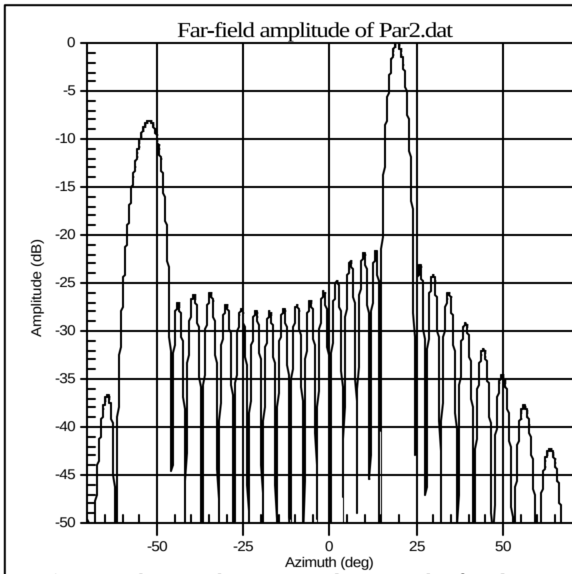

Figure 2 *The m ain beam scanned to an angle of 20 degrees off boresight.*

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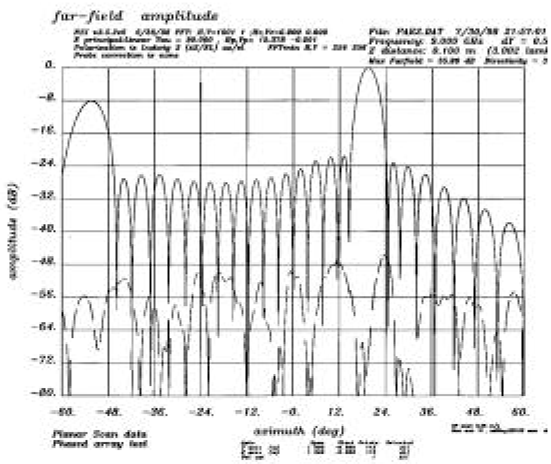

Figure 3 *The effect of a 2mm peak to peak random error in the probe x-position is shown. A reference pattern and an error pattern are shown.*

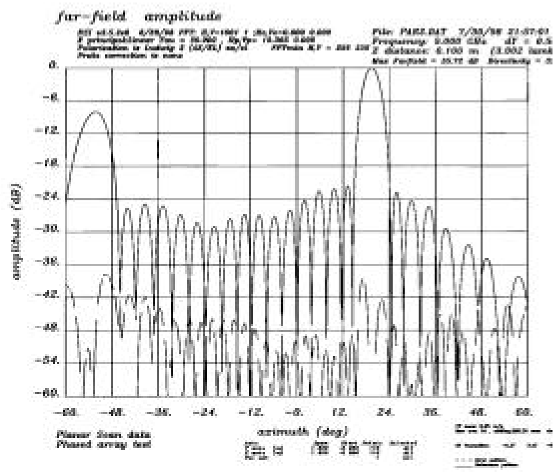

Figure 5 *The effect of scan aperture truncation is shown for the steered beam case. The reference radiation pattern and the error pattern are shown.*

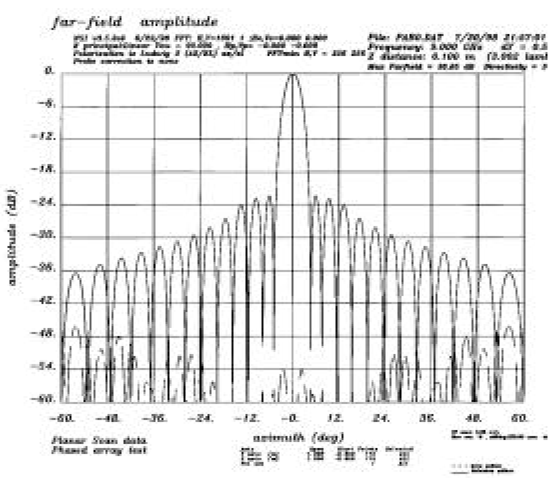

Figure 4 *The effect of scan aperture truncation is shown for the case where there is no beam steering. The reference radiation pattern and the error pattern are shown.*

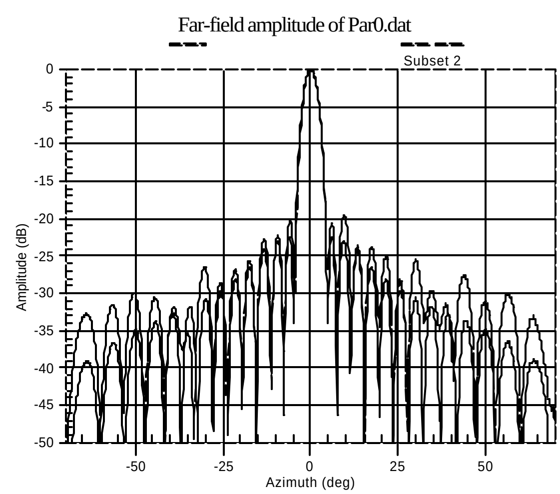

Figure 6 *The effect of a 2mm peak to peak random error in the probe z-position is shown. The reference pattern and the perturbed pattern are shown.*

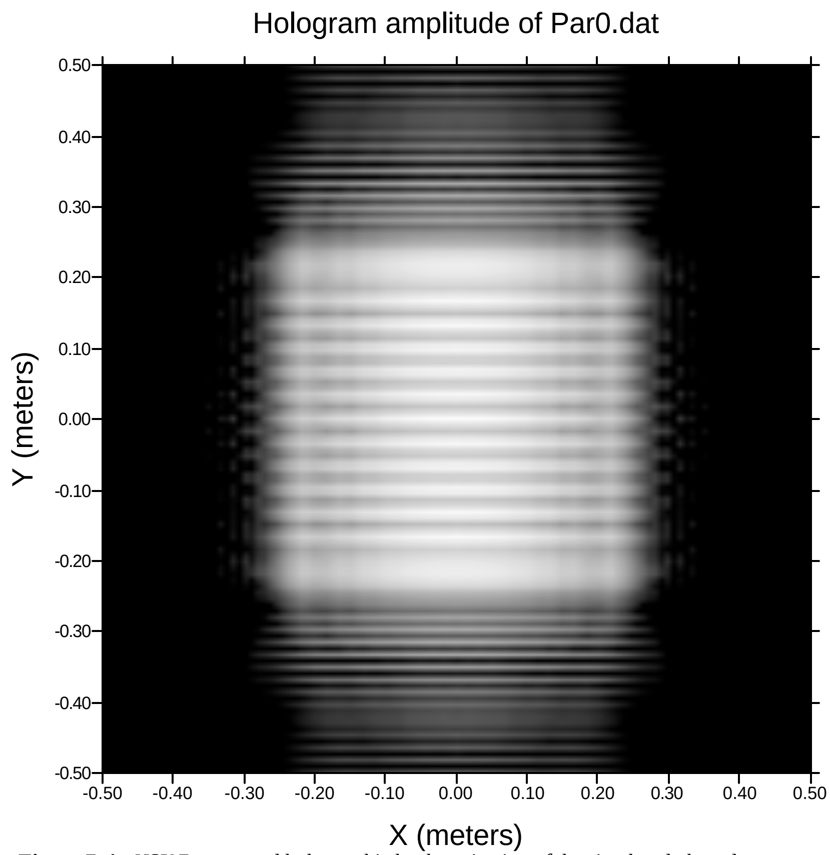

Figure 7 *An NSI97 generated holographic back projection of the simulated phased array aperture.*