LIMITATIONS OF NEAR-FIELD BACK PROJECTION FOR PHASED ARRAY TUNING APPLICATIONS

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Abstract

Simulated data is presented for a planar array to demonstrate the limitations of planar near-field back projections. It is well known that the result obtained in this way is of limited resolution and accuracy and these limitations are further illustrated through the data presented here. The impact of probe to AUT separation distance is shown as well as the correspondence between array excitation perturbations and that detected through the back projection technique. Results are shown for a simple iterative array excitation adjustment process. The purpose of this paper is to provide guidelines for the application of the planar near-field back projection technique.

Keywords: Back projection, Phased arrays, Planar near-field.

1. Introduction

The calibration of phased array antennas require the determination of the aperture distribution of the antenna for a given set of excitation coefficients. A common approach taken in this process is to measure the radiating near-field of the antenna and to then mathematically back project to the aperture surface of the array to form an estimate of the aperture distribution. It is well known that the result obtained in this way is of limited resolution and accuracy and these limitations may at times render the result of little use for successful adjustment of the feed distribution.

In this paper numerical results are presented for a simulated array antenna. These results demonstrate the limitations of this back projection technique. The impact of antenna to probe distance is investigated as well as the correspondence between array excitation perturbations and the amplitude change detected through the back projection technique. Results are also shown for a simple iterative array excitation adjustment (tuning) process.

2. Simulated Array Data

The antenna array considered here is a planar array containing 21 x 13 surface current densities of uniform amplitude and phase distribution as shown in Figure 1. Each single surface current density radiator is 0.4λ x 0.4λ and contains a y-directed (vertical) current density only.

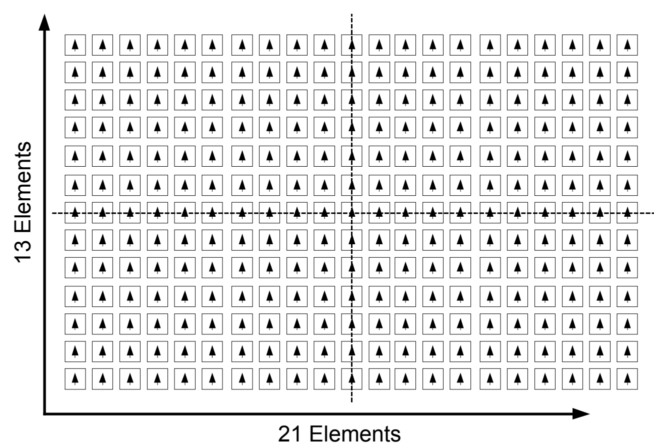

Figure 1: Schematic diagram of the simulated array radiators.

The elements are spaced 0.5λ apart as shown in Figure 2 and all are excited by uniform phase and amplitude. This array renders near-field distributions (orthogonal centered cuts) as shown in Figure 3. The data shown were calculated at a distance of 0.025λ above the surface of the array. By importing the computed planar near-field data into the NSI 2000 software [1], far-field radiation patterns can be computed as shown in Figure 4. Note that the data shown is for a probe to antenna separation of 3λ and in this case the probe used is an infinitesimal point source. No probe correction is therefore performed.

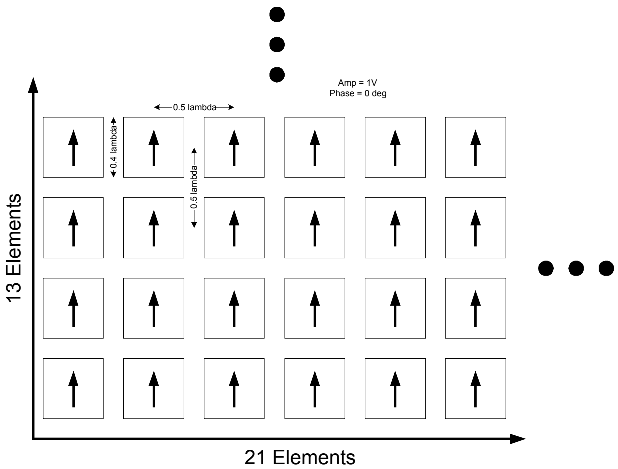

Figure 2: Enlarged section of Figure 1 showing array element size and spacing.

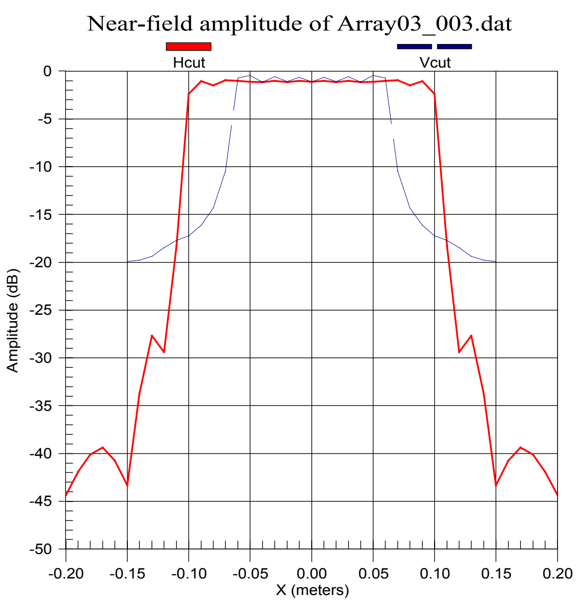

Figure 3: Orthogonal near-field pattern cuts close to the surface of the array.

Using this model as a baseline, various element excitation anomalies were introduced to generate the data as presented below. As a first case the phase of the element as indicated in Figure 5 (5'th from the top & 5'th from the right) was reversed. The impact of this on the near-field data is as shown in Figure 6. (The data shown were calculated at a distance of 0.025λ above the surface of the array.)

3. Probe to AUT Separation Impact

An important parameter when making back projections is the distance from the probe to the plane where the hologram is computed.

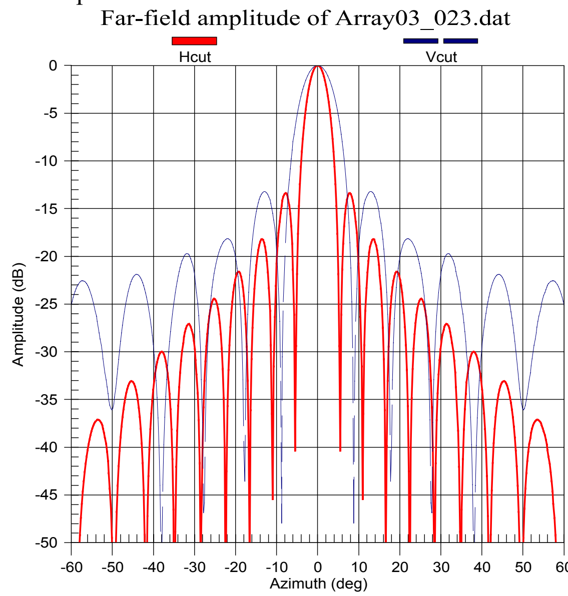

Figure 4: Principal plane pattern cuts for the uniform array distribution shown in Figures 1 & 2.

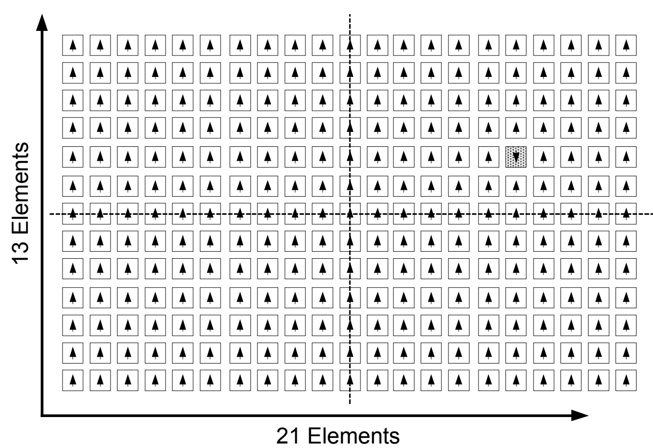

Figure 5: The location is shown of the single element with reversed phase.

It is known that this distance should be kept as small as possible, but the effect of the near-field probe on the antenna under test (AUT) limits this. (This can also be limited by the profile of the AUT.) In the results presented here the ideal nature of the probe avoids the latter problem and we can therefore investigate the issue of back projection distance without having the interference effect of the probe present.

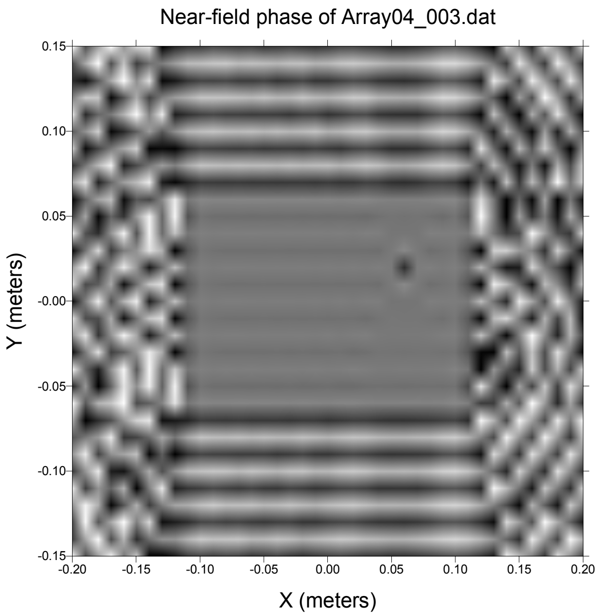

Figure 6: Near-field phase distribution for the array shown in Figure 5.

Figures 7 & 8 show amplitude and phase patterns extracted from the back projected data sets for cases where the probe to AUT distance was set to 0.025λ, 1λ, 2λ, 3λ & 5λ. These patterns demonstrate the loss of "focus" of the back projected image as this distance increases. Note that the element width in this case is 8mm (0.4λ at 15 GHz).

It is also worthwhile to note in Figure 8 that the actual 180° phase change of the element can not be detected, regardless of the probe to AUT distance. This limited capability of the back projected image is explored further in the following section.

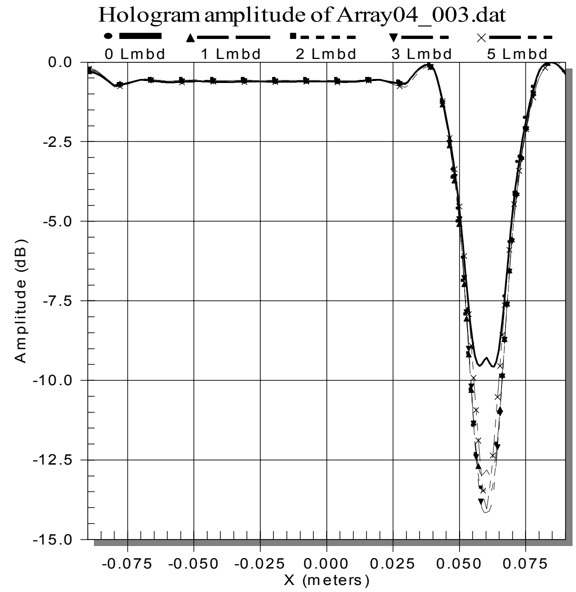

Figure 7: Amplitude of the back projected data for different probe to AUT separation distances.

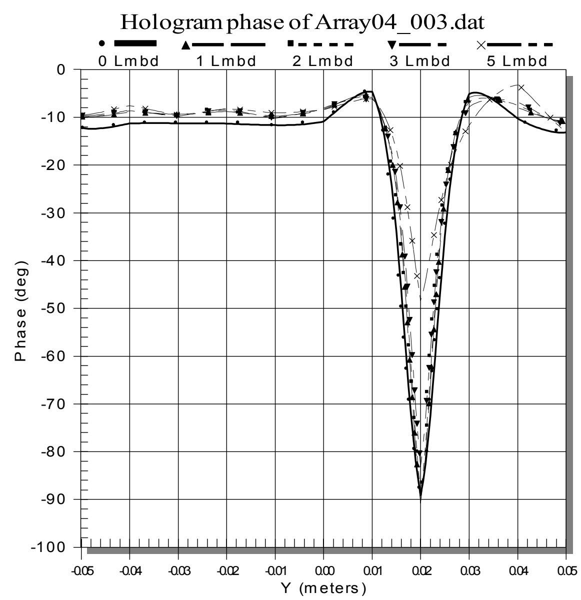

Figure 8: Phase of the back projected data for different probe to AUT separation distances.

4. Amplitude Resolution

In order to establish the sensitivity of the back projected data on small amplitude changes in the excitation of the array, the amplitude of the element as indicated in Figure 5 (5'th from the top & 5'th from the right) was attenuated to 0.5dB , 1dB, 3dB and 10dB below the unity excitation of the reference case (phase reversal was removed for this second test case). The resulting back projected amplitude data is shown in Figure 9 (all generated for a probe to AUT separation distance of 3λ). From these curves it is clear that the back projected amplitude change at the array element location (60mm) does not correspond to the actual array excitation change. This fact therefore prevents one from extracting the array excitation coefficients from a single measurement and hologram.

This phenomenon is due to the fact that the back-projected result at each x-y point is a weighted sum of all the measured data, and the highest weights are assigned to the data in the immediate vicinity of a given back-projected point [2]. The larger excitation amplitudes of the adjacent array elements therefore limit ones ability to resolve the lower amplitude values in the back projection. (It is significant to note that in Figure 9 even the 0.5dB amplitude change of the single element can be detected in the back projected data, even though the detected change does not correspond to the absolute change.)

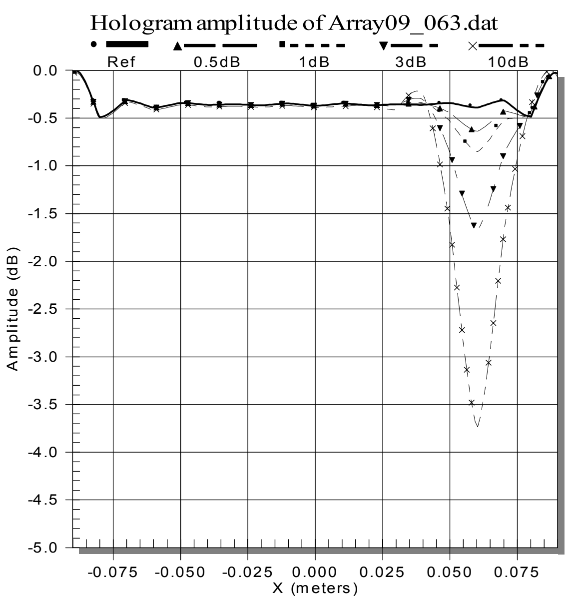

Figure 9: Amplitude change in the back projected field for excitation amplitude change of a single array element.

5. Iterative Excitation Adjustment

The data presented in Figure 9 above show that for adjacent array elements with large excitation differences, one can not obtain accurate amplitude (and phase) data of the excitation from a single back projected image. In order to explore this limitation further a case was simulated where a linear amplitude taper was imposed on an entire row of the array shown in Figure 1. For the row of elements 5'th from the top, the excitation amplitude was linearly (as a function of distance) attenuated from the original 1V (on the right hand side) to 0V on the left hand side of the array. For this excitation distribution, the near-field data as shown in Figure 10 was generated and the back projected data as shown in Figure 11 was computed. The sharpening due to the back projection is clear and the linear amplitude taper of the array elements is evident in Figure 11.

A single near-field pattern cut extracted at point y=20mm in Figure 11, renders the distribution indicated as "Iteration 1" in Figure 12. The field taper due to the excitation function is evident. Even though the field values do not represent the array excitation function, an estimate of the linear attenuation function can be made and compensated for in the simulation. After this compensation the data denoted as "Iteration 2" in Figure 12 is obtained. This distribution, although not perfect, is closer to the desired uniform array excitation. Another two repetitions of this process provide the desired result as shown in Figure 12.

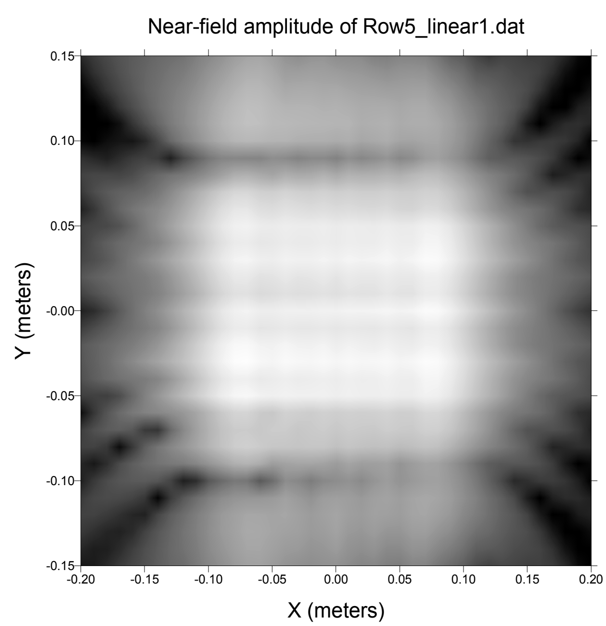

Figure 10: Raw near-field amplitude (3λ) for the array shown in Figure 1 with a linear attenuation factor introduced for the excitation of row 5.

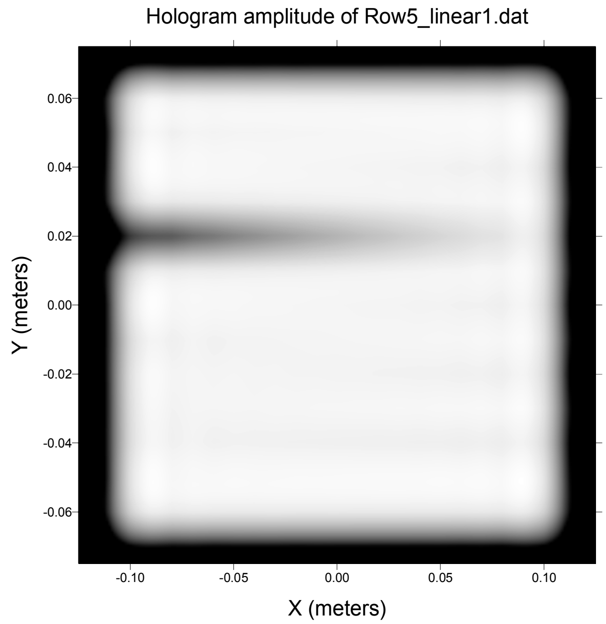

Figure 11: Field amplitude of the back projected data for the array shown in Figure 1 with a linear attenuation factor introduced for the excitation of row 5.

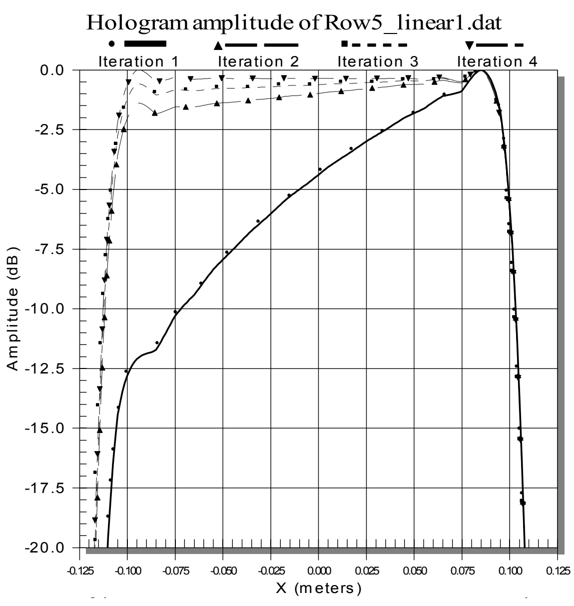

Figure 12: Iterative array excitation correction and extraction of the back projected field amplitude.

This simple array excitation adjustment process demonstrates it's iterative nature and shows how this can be used as a way of circumventing the limited accuracy of the back projection image.

6. Conclusion

The findings presented in this paper serve to demonstrate the limitations encountered when an estimate of an antenna array excitation is obtained using the planar near-field back projection technique. It is shown how the back projected image "loses focus" when probe to AUT distance is increased. The results presented also show how small changes in the array excitation vector can be detected using this technique. However, determining the magnitude of such a change is usually not possible and an iterative approach has to be taken to the array tuning process. The latter point is illustrated through a simple example. Examples of actual array tuning procedures applied in industry are described in [3].

The data presented here relies on the use of an infinitesimal point "probe" and the effect of the probe, as would be present in an actual measurement environment, is absent. Probe correction is not required in this case and the findings presented here should be considered with this assumption in mind. Future investigations should include a study of the effect of probe correction and also the advantages to be gained through higher sampling density in the near-field.

Acknowledgement

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References

[1] *NSI2000 Software Users Manual*, Nearfield Systems Inc, Carson, CA, USA, 2001.

[2] A. C. Newell, "Holographic Back Projection in Planar Near-Field Measurements", *Private communication*.

[3] D. Garneski, *CSUN Antenna Measurement Course Notes*, Northridge, CA, June 2001.

[4] C. A. Rose, "Accuracy estimation of microwave holography from planar near-field measurements*", AMTA Proceedings 2000*, p. 12, Philadelphia, PA, Oct 2001.

[5] M. H. A. Paquay, "Locating Defective Array Modules Using Planar Near-Field Measurements*", AMTA Proceedings 1998*, Montreal, QC, Canada, Oct 1998.