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Further Evaluation of the Constrained Least Squares Electromagnetic Compensation Method

by

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Technologies exist for construction of antennas with adaptive surfaces that can compensate for many of the larger distortions caused by thermal and gravitational forces. However, as the frequency and size of reflectors increase, the subtle surface errors become significant and degrade the overall electromagnetic performance. Electromagnetic (EM) compensation through an adaptive feed array offers a means for mitigation of surface distortion effects.

This study looked into implementation of EM compensation with the measured surface errors of the NASA 15 meter hoop/column reflector antenna. There are two parts to the study. The first looked into a hybrid EM compensation technique. The second evaluated the performance of a given EM compensation method when implemented with discretized weights. Both parts were computer simulations.

Hybrid Compensation Bailey [1,2] developed a compensation technique in which an array feed is used to reduce the radiation pattern effects of the distorted surface for the NASA hoop/column reflector antenna. The method uses a constrained least squares (CSL) algorithm to derive excitation coefficients for the feed elements such that the aperture field of the reflector is approximated at specified match points. It is a global algorithm that attempts to correct for irregularities over a significant portion of the radiation pattern. Smith and Stutzman [3] proposed a pattern synthesis compensation (PSC) algorithm that works on localized portions of the radiation pattern. The thrust of the hybrid compensation study was to determine if the side lobe performance of the CSL method could be improved by superposing PSC corrections with the CLS feed excitations.

The hybrid compensation was implemented at 6 GHz. The results of the study showed that the CLS method works very well and that superposing the PSC excitations provided very little improvement in the resulting pattern. Further investigations will be performed at higher frequencies where the surface errors appear more severe and the CLS compensation side lobe levels are slightly higher.

Discretized Weights for the CLS Compensation Technique Most compensation algorithms determine the excitations of the feed elements assuming continuous values of the amplitudes and phases are available. In practice, discretized amplitude and phase weights will probably be used to implement the algorithms. This study evaluated the effects of the quantized excitations on the radiation performance of a compensated distorted reflector. Again, measured surface data from the hoop/column antenna were used.

The quantization study was performed for a frequency of 6 GHz. The exact compensation coefficients were modified by a program which quantizes the amplitudes and phases of the weights. The amplitude was quantized into 1 dB, 2 dB, 3 dB, and 4 dB bins. The phase was quantized into bins corresponding to the number of bits for digital phase shifters: 3 bits (45° bins), 4 bits (22.5° bins), ..., 8 bits (1.41° bins).

The effects of the discretization were judged using contour plots of the radiation patterns. Figure 1 shows the compensated radiation pattern for the distorted hoop/column reflector with a hexagonal 169 element feed array before quantization. The CLS algorithm was shown to be quite insensitive to amplitude quantization. The first sign of pattern degradation occurred for the somewhat coarse 3 dB amplitude bins. Figure 2 shows the pattern for the 3 dB bins where some new side lobes appear above the 30 dB contour. The CLS method was found to be fairly insensitive to phase quantization, also. Slight pattern degradation first appeared when the number of bits was down to 4 (22.5° bins). Figure 3 shows the pattern for the 4 bit phase shifters.

The results of the analysis at 6 GHz showed that CLS compensation can be implemented with discretized weights and can withstand a reasonable amount of quantization error. The analysis is just at the one frequency, however. Work is in progress to evaluate the quantization effects at higher frequencies where the surface errors appear to be more severe.

References

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2. M. C. Bailey, "Determination of Array Feed Excitation to Improve Performance of Distorted or Scanned Reflector Antennas," 1991 Antennas and Propagation Society Symposium Digest, London, Ontario, pp. 175-178, June, 1991.

3. W. T. Smith, W. L. Stutzman, "A Pattern Synthesis Technique for Array Feeds to Improve Radiation Performance of Large Distorted Reflector Antennas," to be published in the IEEE Trans. on Ant. and Prop..

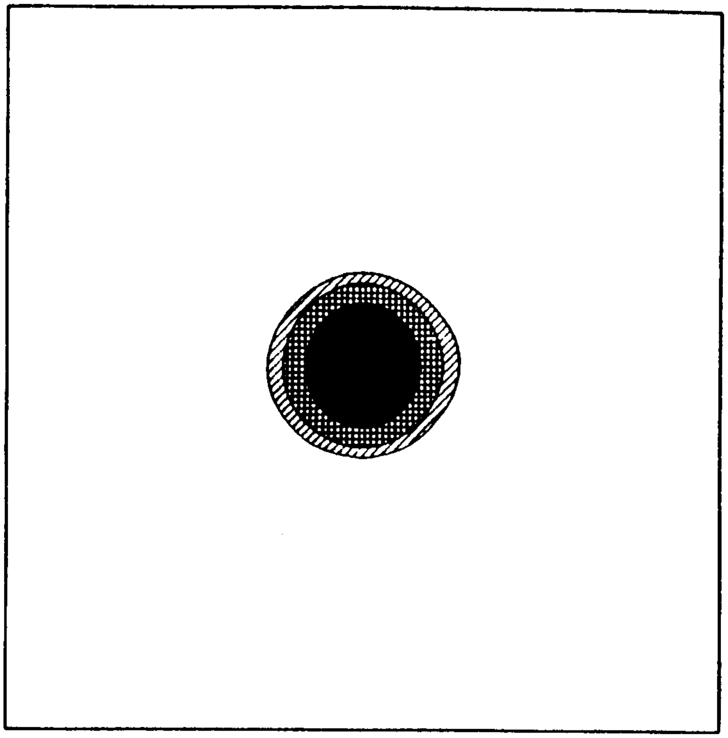

Figure 1 Compensated radiation pattern for the hoop/column reflector antenna without quantization (10 dB - solid; 20 db - crossed; 30 dB - slanted lines). The feed array has 169 elements.

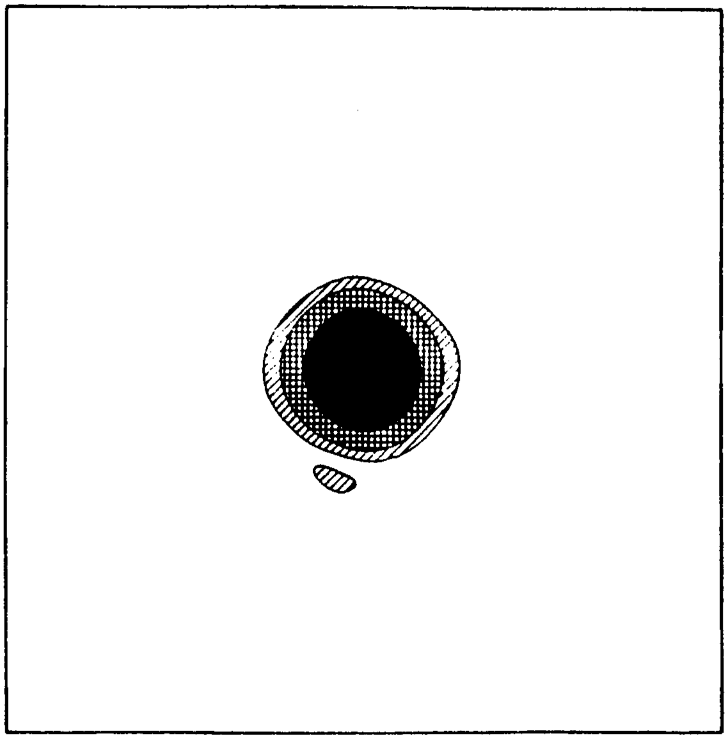

Figure 2 Compensated radiation pattern with 3 dB amplitude quantization (10 dB - solid; 20 dB - crossed; 30 dB - slanted lines).

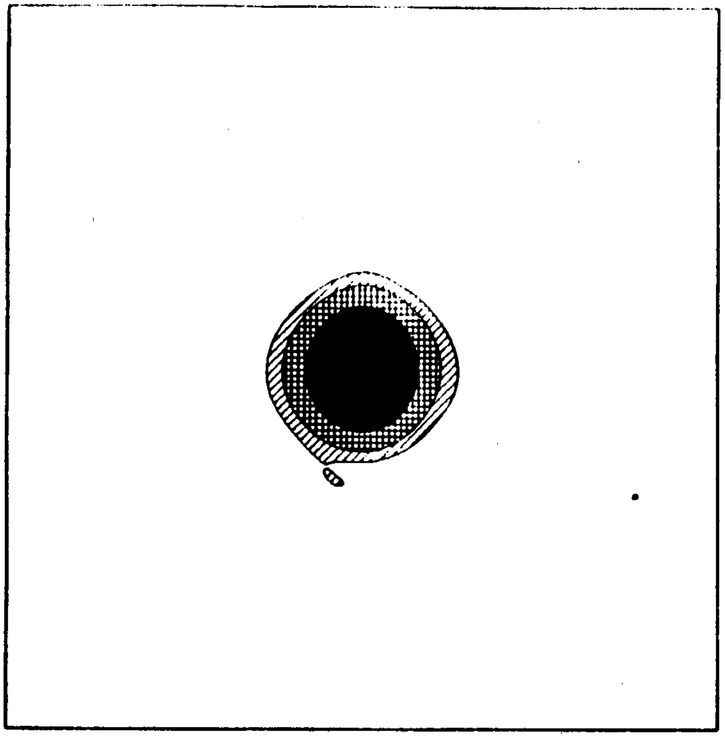

Figure 3 Compensated radiation pattern with phase quantization of 4 bits (22.5° bins) (10 dB - solid; 20 dB - crossed; 30 dB - slanted lines).