DEMONSTRATION OF AN ACTIVE ELECTRONICALLY SCANNED ARRAY ON A CONIC SURFACE

Donna Owens, R. F. Systems Branch
Naval Air Warfare Center Weapons Division, China Lake, CA 93555-6001
and
Dr. H. Schuman, Technical Director
ARC Professional Services Group, Rome, NY 13440

Abstract

Previous work on RF conformal array design has been limited to synthesizing arrays without benefit of individual radiating element phase and amplitude control. With recent advances in transmit/receive (T/R) module technology, the need for validated analysis tools to evaluate conformal designs using active electronically scanned arrays (AESAs) becomes more pressing. Potential applications for this type of technology are numerous. The work discussed here focuses on conformal missile seekers for SDIO (Strategic Defense Initiative Organization), but the analysis tools under development have the capability to analyze a variety of conformal surfaces.

The program has two phases. In phase one the analysis/synthesis capability is developed. In phase two, hardware tests to validate the analysis efforts are conducted. A funding cut terminated this work at the end of fiscal year 1992 (FY 92). Work completed on both phases is summarized in this document.

Background

This work was sponsored by SDIO under the Millimeter Wave Seeker Program at the Naval Air Warfare Center Weapons Division (NAWCWPNS), China Lake. The program focused on technology development for Endo Atmospheric Interceptors.

The seeker for an endo-atmospheric hit-to-kill interceptor missile must meet extreme requirements to fulfill its mission. The need for low weight, small volume, and high accuracy in adverse weather capability make the seeker design problem difficult. The weather requirement rules out the sole use of highly accurate and lightweight optical sensors; therefore, a RF sensor is required. The angular accuracy requirement approximately 0.2 milliradians forces the use of millimeter wave frequencies, with associated unique problems. Many technologies that are relatively well developed at X-Band (e.g.,T/R modules) are virtually nonexistent at Ka- or W-Band. The use of a conformal active RF array becomes attractive when considering how best to utilize the limited available space.

Dual-mode seekers containing both IR and RF modes may offer advantages. Dual-mode seekers are especially attractive when considering the combined requirements of adverse weather operation and high angular accuracy. This might also allow the RF array to be designed at lower frequencies because the higher accuracy IR sensor would take over the guidance in the terminal phase.

The RF conformal array also lends itself to the dual-mode seeker configuration. A dual mode seeker, however, would be heavier and more costly than a single-mode RF seeker.

The above tradeoff issues must be explored to determine the performance of different designs relative to cost. In addition, the potential difficulties associated with implementing these different configurations should be examined in a demonstration.

Objective

This project has two objectives; (1) to provide a validated tool to analyze and predict the performance of conformal arrays first on conic and then on other types of curved surfaces, such as, paraboloids, ellipsoids, and hyperboloids; and (2) to demonstrate the ability to form polarization

4620

compensated monopulse sum and difference beams with a conformal AESA. The development of this analysis tool will significantly aid in evaluation of different seeker configurations. A successful conformal array demonstration will greatly heighten the feasibility of implementing this type of seeker configuration.

Approach

A joint contractor/Government effort is planned over a 4 year period from FY 92 through 95. NAWCWPNS Code C2156 heads the government effort. The contractor for this program is ARC Professional Services Group.

A computer code for determining the optimum element orientation and complex excitations for realizing desired sum and difference radiation patterns is under development by ARC. This analysis/synthesis code is to be implemented on an IBM-compatible 386 class personal computer. The code has been modified from pre-existing FORTRAN code hosted on a VAX. The conformal radiating assembly (cone structure and radiating elements) was developed by NAWCWPNS Code C2952.

The radiating assembly will be driven by a breadboard AESA developed by NAWCWPNS Code C2156. This AESA uses Westinghouse developed wideband T/R modules (2-18 GHz). They have 6 bits of phase control and 6 bits of amplitude control. The testing will take place in NAWCWPNS Code C2156's active array laboratory using either a compact range or a near-field range.

With the assistance of ARC, NAWCWPNS Code C2156 will demonstrate the ability to form both sum and difference beams with the conformal radiating assembly in FY 94 using the NAWCWPNS breadboard wideband active array controller. The individual element excitations and orientations to produce a given pattern will be output from the ARC code. This code will be integrated into the wideband array controller program. The code will also be used to predict pattern degradations that arise from random amplitude and phase errors, phase shifter and amplifier quantization errors, element position errors, and limited amplifier dynamic range.

The demonstration also will serve to ascertain validity of the code. The Government team will work closely with the contractor in this development. The results of testing will be fed back to ARC for use in developing mutual coupling models as well. ARC will provide guidance as to the types of tests (and data) that will be the most useful for the code development.

Results

Before termination of this project, progress was made in three principal areas:

1. The conformal radiating assembly was developed during FY 92.
2. Integration of the breadboard AESA was completed and planar beamforming was demonstrated. This occurred in early FY 93 under separate funding.
3. ARC completed the initial version of the analysis/synthesis code in January 1993.

More detail on no. 1 and no. 3 is provided below.

The conformal radiating surface is a cone with a half angle of 15 degree, base radius of 13.4", and height of 25". The material is 0.125" thick aluminum. The surface contains two triangular lattice array ("Aperture 1-84 elements and Aperture 2-56 elements") configurations on opposite sides of the cone. The bottom row of each aperture begins 2" from the base of the cone. See Figure 1 for a drawing of the aperture configurations.

Brass sleeves are mounted into circular openings with conductive epoxy such that the elements can be flush with the surface. The array is fully conformal, unlike that of previous work that concentrated on endfire type arrays (Homer antenna). Each radiating element is a dual polarized dielectrically loaded circular waveguide. Performance is optimized for 15.5 GHz. The elements are easily mounted and removed from the sleeves by hand and the individual polarization can be oriented in any direction. The element symmetry, isolation, ease of construction, and reusability were the driving reasons for choosing this radiating element. In an actual application, the element choice would be driven by performance and producibility, rather than experimental utility.

Other aperture configurations and surface shapes could be explored at nominal cost. Future configurations will include doubly curved surfaces.

Early results of the ARC code have been obtained. The ability to perform all the basic functions on the VAX (including graphics) exist. The code now runs on a PC as well, but without full graphics capability.

Accession Number: 4620

Publication Date: Jun 06, 1993

Title: Demonstration of an Active Electronically Scanned Array on a Conic Surface

Personal Author: Owens, D.; Schuman, H.

Corporate Author Or Publisher: U.S. Naval Air Warfare Center, China Lake, CA; ARC Prof. Services Grou Report Number: AIAA 93-2649

Comments on Document: 2nd Annual AIAA SDIO Interceptor Technology Conference, June 6-9, 1993 at Albuquerque, NM

Descriptors, Keywords: Demonstration Active Electronics Scan Array Conic Surface Sensor Discrimination

Pages: 00013

Cataloged Date: Aug 05, 1993

Document Type: HC

Number of Copies In Library: 000001

Record ID: 28001

Source of Document: AIAA

Examples illustrating the applicability of the ARC code to conformal array synthesis and analysis include: (1) a parabolic surface with an offset (with respect to the surface axis) conformal array of circular (in the projection plane) rim; (2) a 95-element rectangular rim array on a 15 degree, half angle cone; and (3) a 53-element rectangular rim array on the same cone. Examples 2 and 3 pertain to the experimental arrays developed by NAWCWPNS.

Figure 2 shows the geometry of the parabolic surface array and the orientation of the elements. The array lattice is square in the projection plane. The elements are dual orthogonal linearly polarized and initially excited parallel to their orientation. A 20 dB nbar = 4 Taylor weighted sum pattern is requested, and the principal and cross polarization patterns resulting from the synthesis process are shown in Figures 3 and 4. The peak gain value, location, and polarization, and nearest lobe location and gain, with respect to the peak gain are stated in Figures 3 and 4 as well.

Patterns synthesized from a 20 dB nbar = 4 Bayliss difference pattern specification are shown in Figures 5 and 6. The effects of phase quantization with 6 bit phase shifters is shown in Figure 7. Pattern bandwidth limitations are shown in Figure 8. Note the slight shift in null location. Patterns arising from exciting the orthogonal polarization of the elements are shown in Figure 9.

The geometry for the 95 element cone array (approximately "Aperture 1") is shown in Figure 10. The synthesized array pattern pertaining to a pattern specification of uniform weighting taken 15 degree from the cone axis beam direction is shown in Figure 11. The choice of element (for reasons given previously) required a greater than half lambda spacing. For this reason the grating lobe seen in the sum pattern is expected.

The geometry for the 53 element cone array (approximately "Aperture 2") is shown in Figure 12. The synthesized array pattern resulting from specifying a 30 dB nbar = 5 Bayliss difference pattern with null at 45 degree from the cone axis is shown in Figure 13. The cross polarization portion of the pattern should be low enough to prevent seeker problems associated with its intended use as an air-to-air interceptor.

The full scale array testing is scheduled for November and December 1993, pending new sponsorship. These tests were originally scheduled for April and May of 1993, but were postponed due to SDIO funding cuts.

Conclusion

Conformal arrays offer many potential benefits. For a missile, the ability to implement a multi-purpose dual mode seeker without creating holes or blockage in the RF aperture is especially appealing. Other benefits for missiles include more efficient use of available space and virtual elimination of radome induced errors.

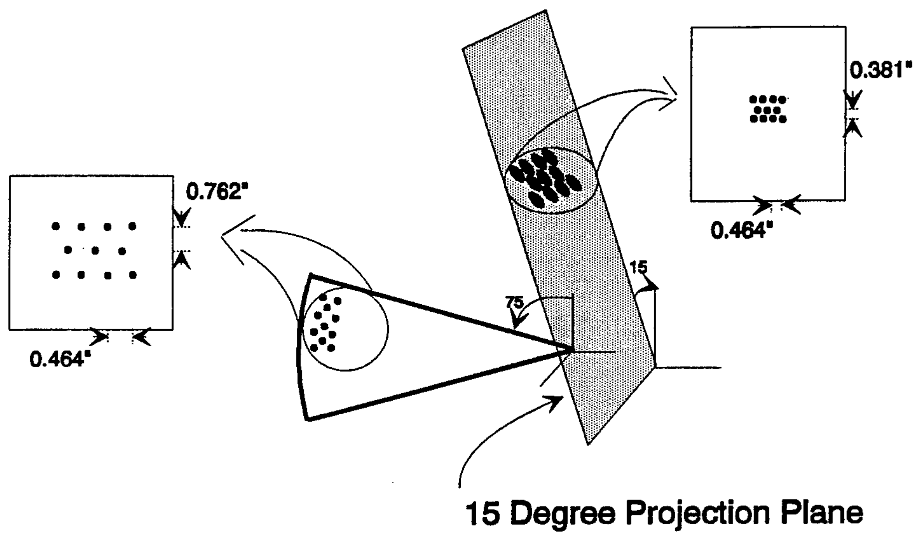
Possible uses of conformal arrays also include conformal aircraft sensors. This type of antenna could potentially decrease the number of apertures on the aircraft. In addition, the available aircraft volume could be used in a more efficient manner, because an array of this type requires less space and cooling. Because the array requires less volume, apertures could be added in locations that would otherwise be prohibitive.

Further development of analysis/synthesis software is needed. A hardware proof-of-principal demonstration is also needed.

This project has developed a conformal radiating assembly. A wideband AESA to drive the conformal radiating assembly exists from a previous project. Initial software algorithms for synthesis (beamforming) and analysis (prediction) have also been developed. Potential sponsors for completion of this work are being sought.

Frequency = 15.5 GHz Element Diameter = .41"
The center of each array is on a radial line. The elements are spaced as shown. The varying element spacing due to the cone curvature is not shown.

Aperture One (11 X 8) Total Elements = 84



Aperture Two (4 X 16) Total Elements = 56

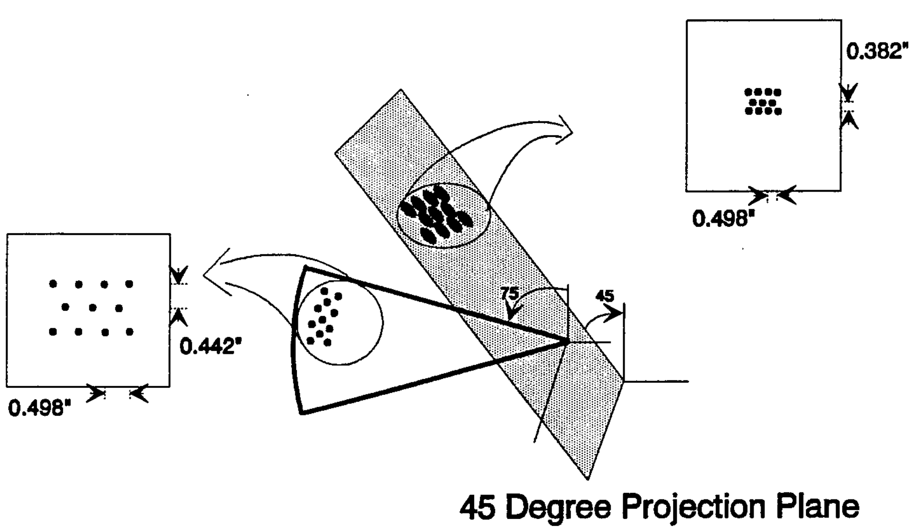


FIGURE 1.

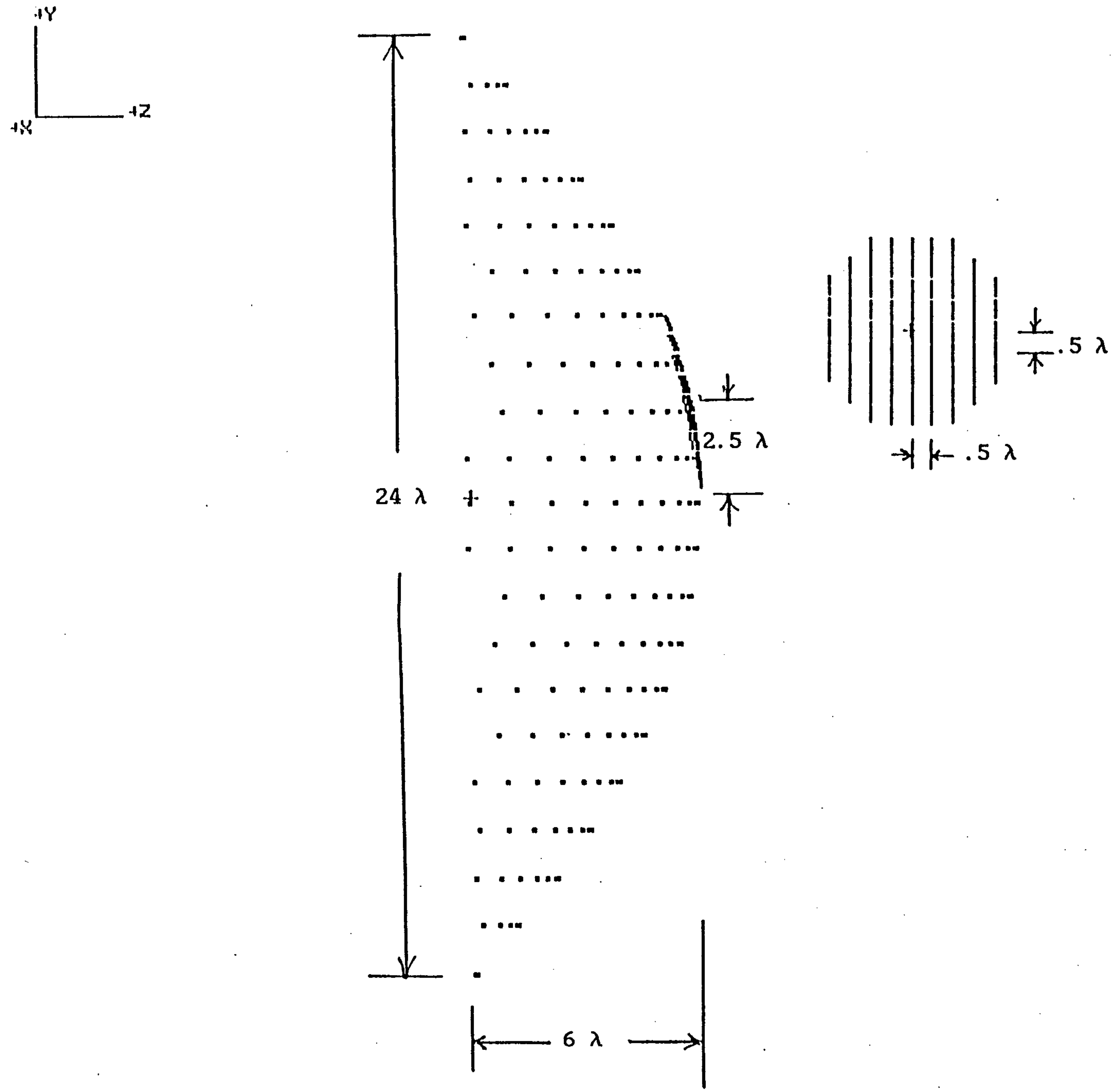


Figure 2. Parabolic Surface, Circular Aperture Array of Linear Polarized Elements - Offset from Surface Axis

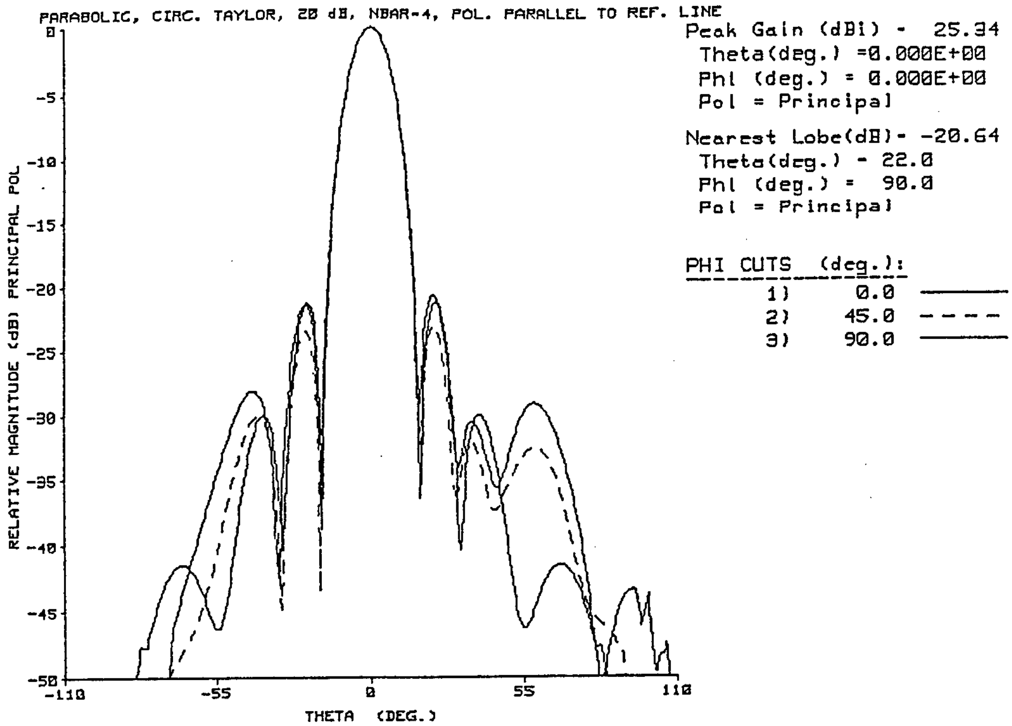


Figure 3. Conformal Array Principal Polarization Sum Patterns

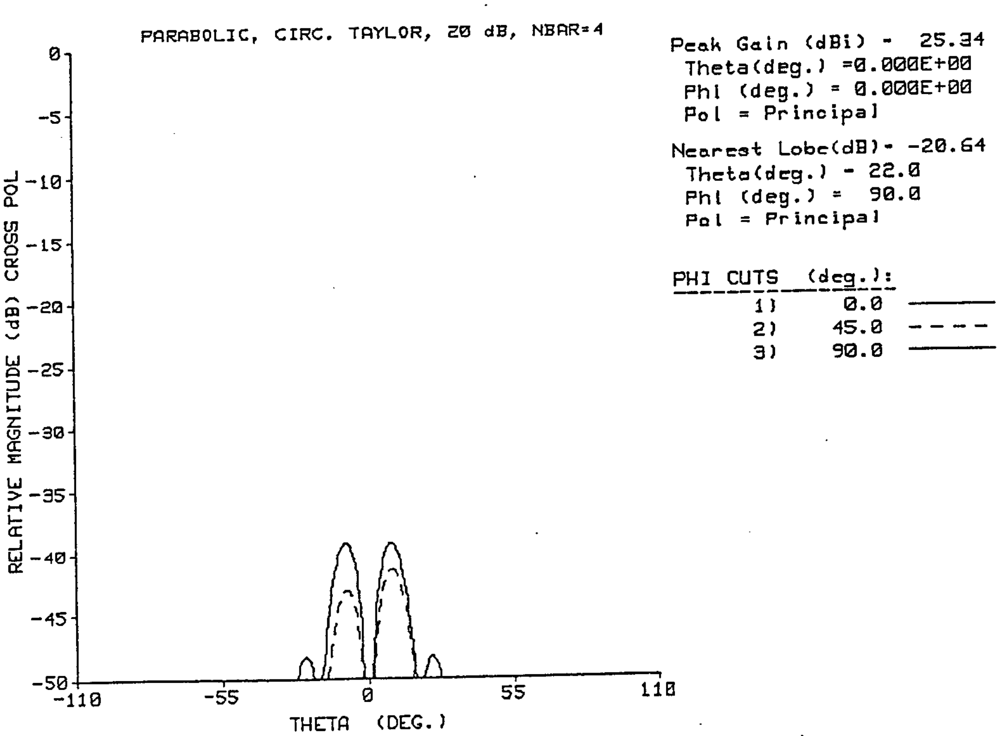


Figure 4. Conformal Array Cross Polarization Sum Patterns

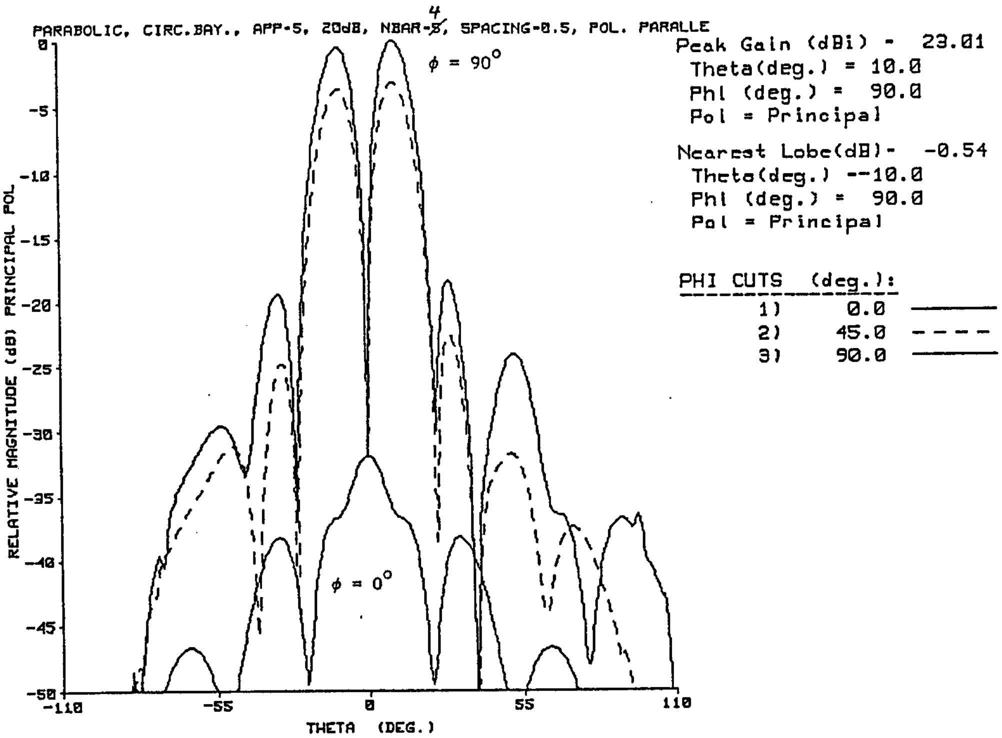


Figure 5. Conformal Array Principal Polarization Difference Patterns

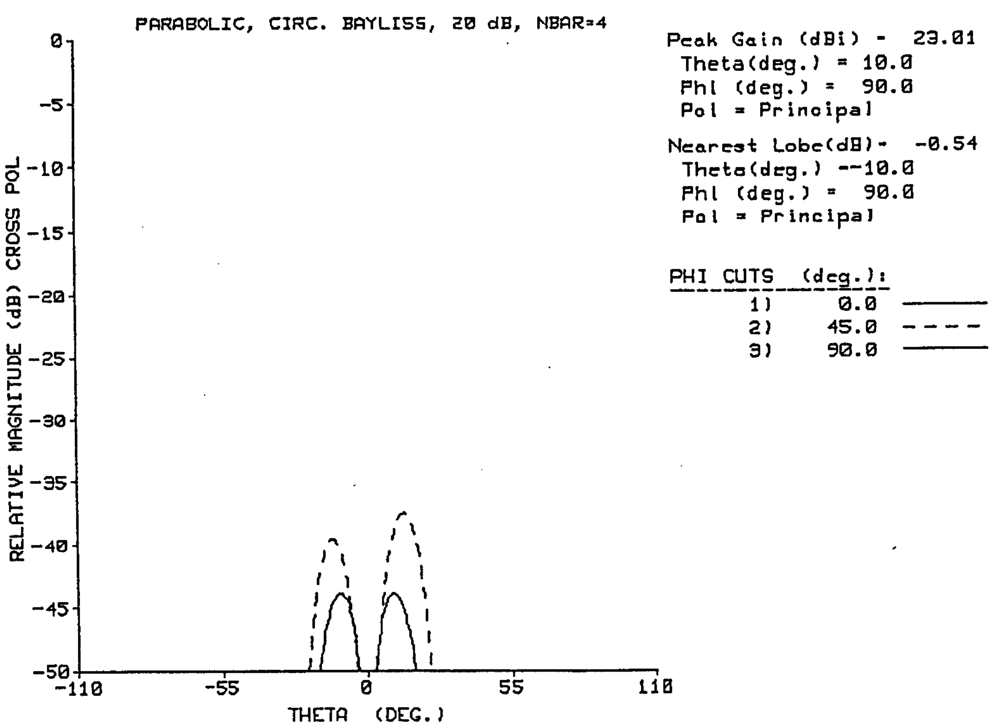


Figure 6. Conformal Array Cross Polarization Difference Patterns

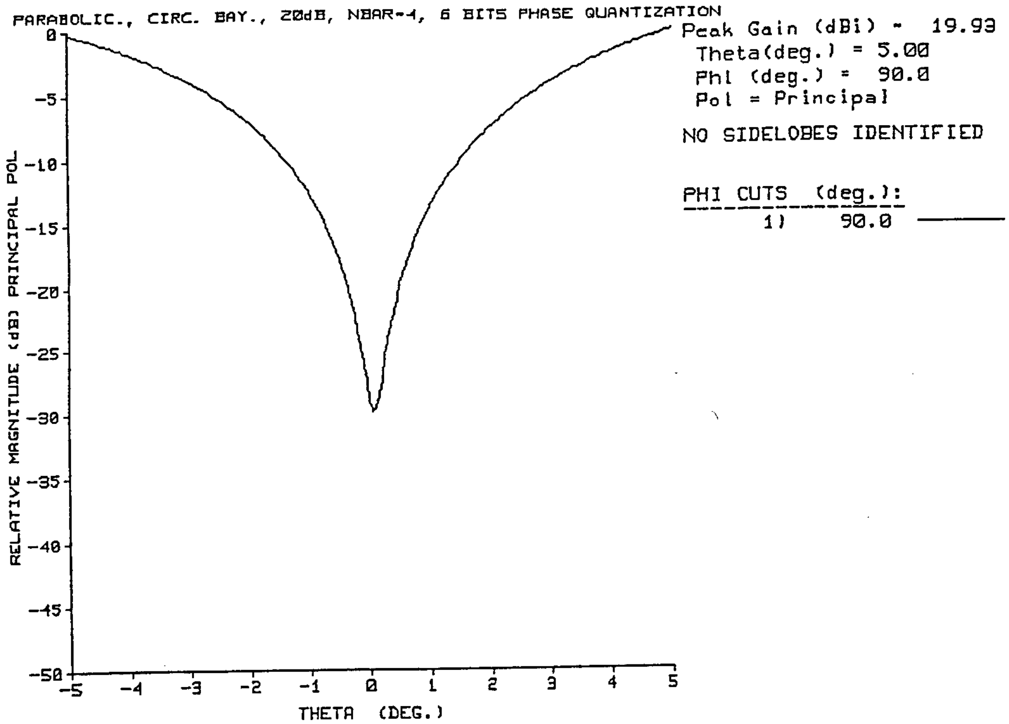


Figure 7. Difference Pattern - Six Bit Phase Shifters

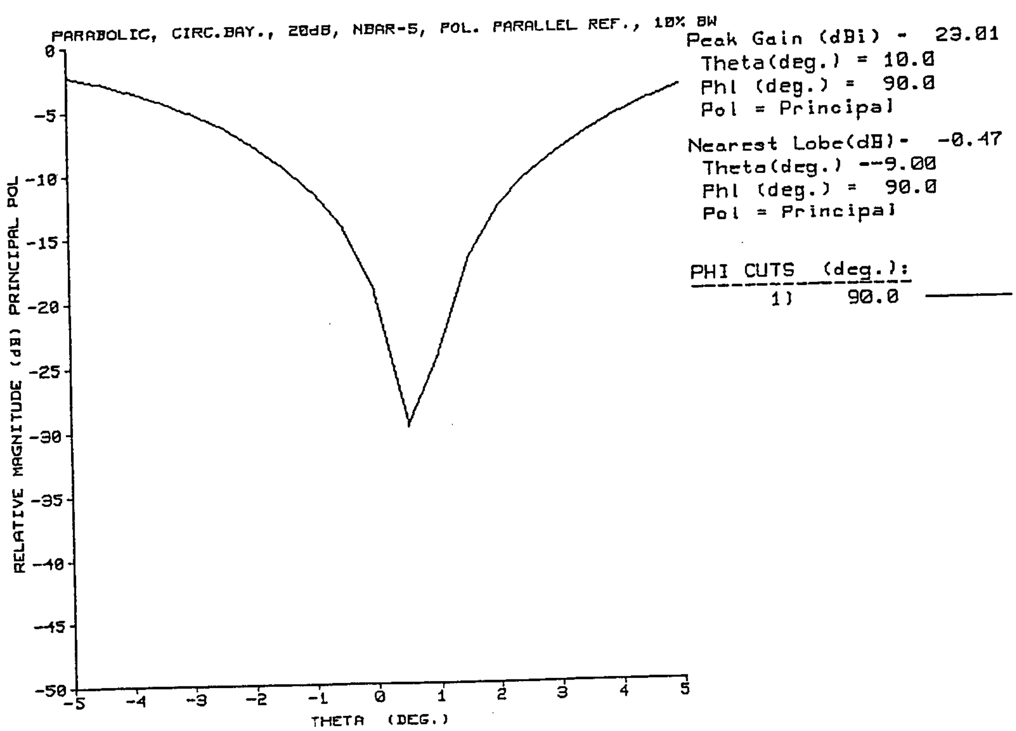
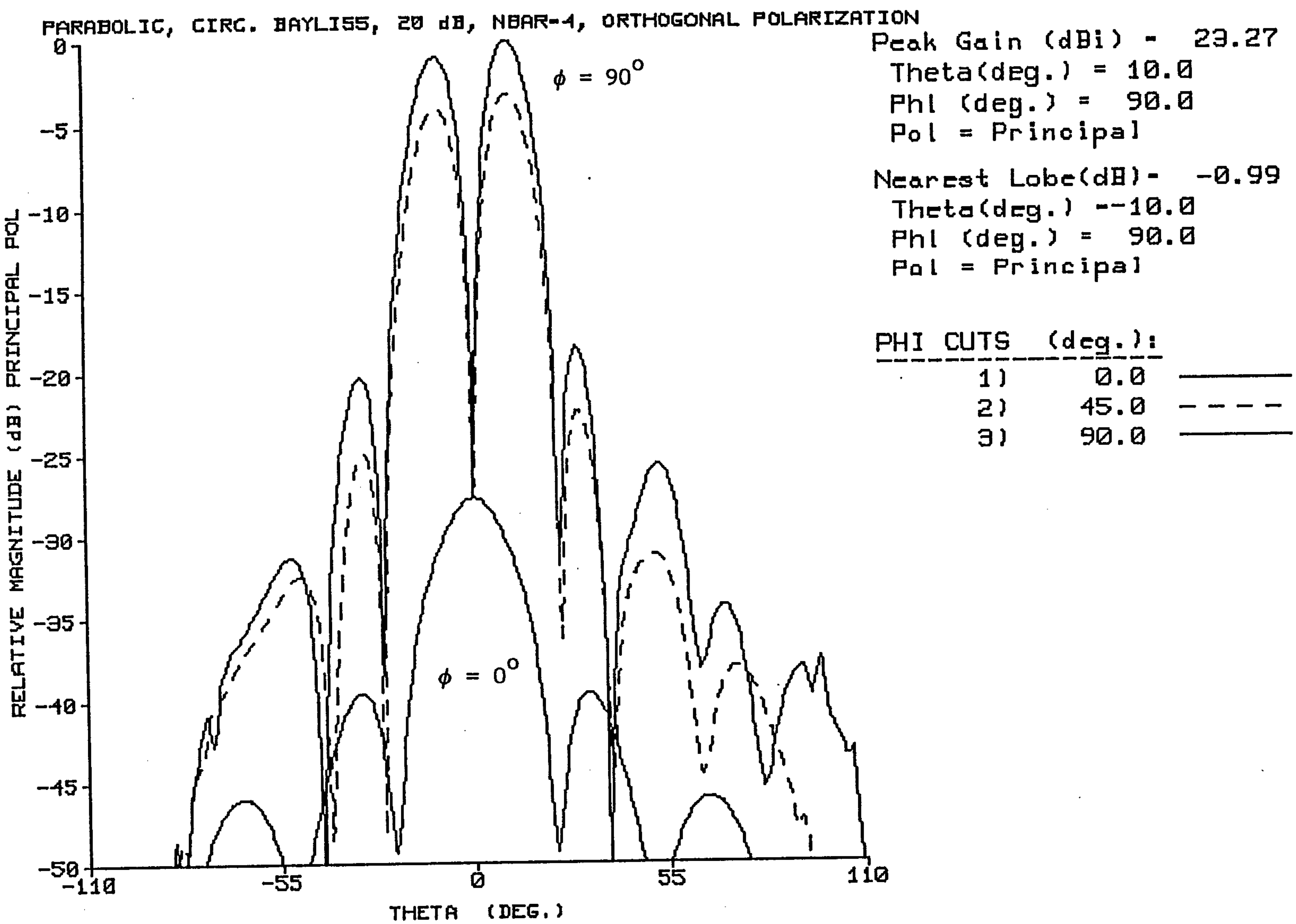


Figure 8. Difference Pattern - Frequency = 5 Percent Above Center Frequency



11-JAN-93

Figure 9. Difference Pattern - Elements Excited for Orthogonal Polarization

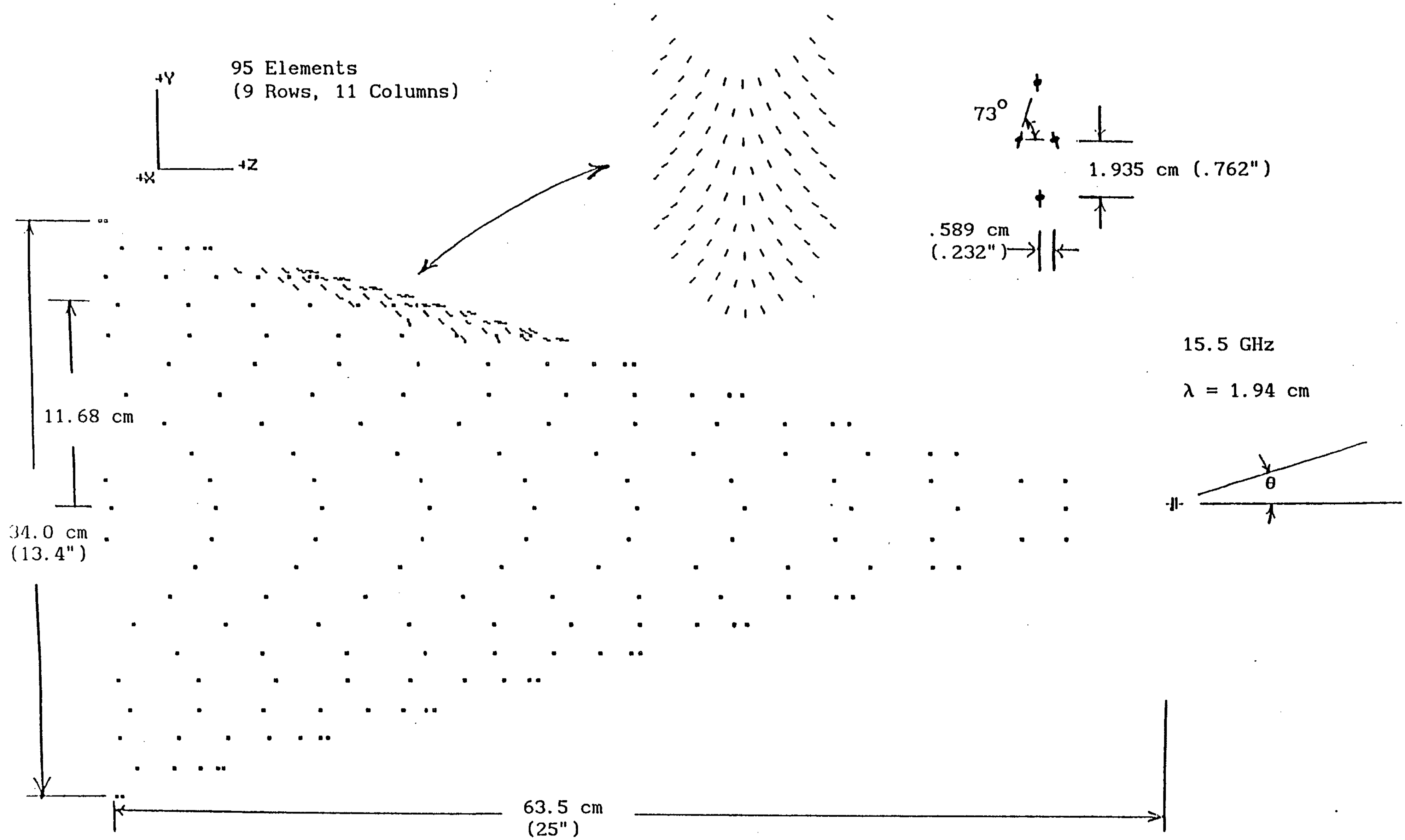


Figure 10. NAWCWPNS Test Article Aperture 1

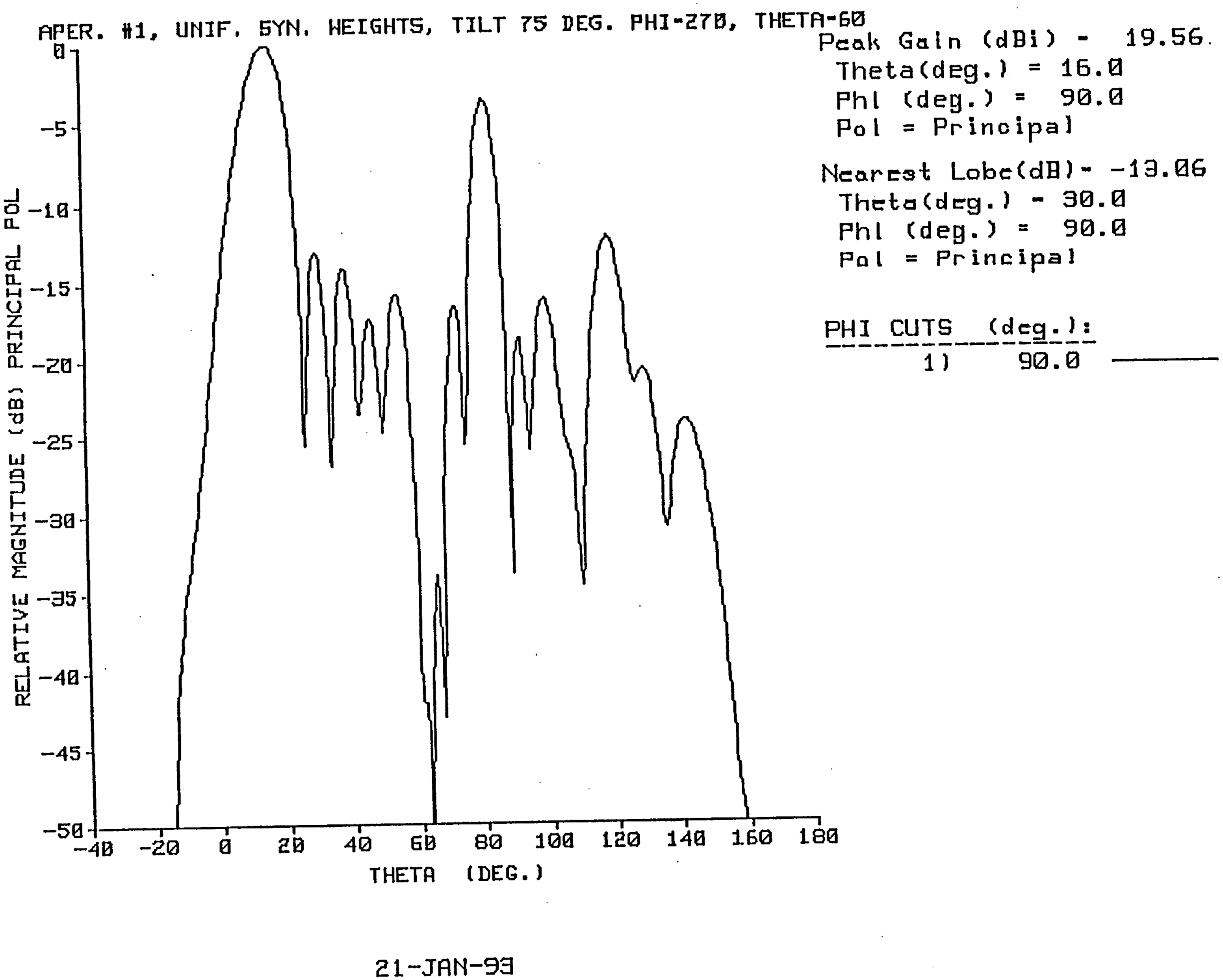


Figure 11. Aperture 1 Conformal Array Pattern

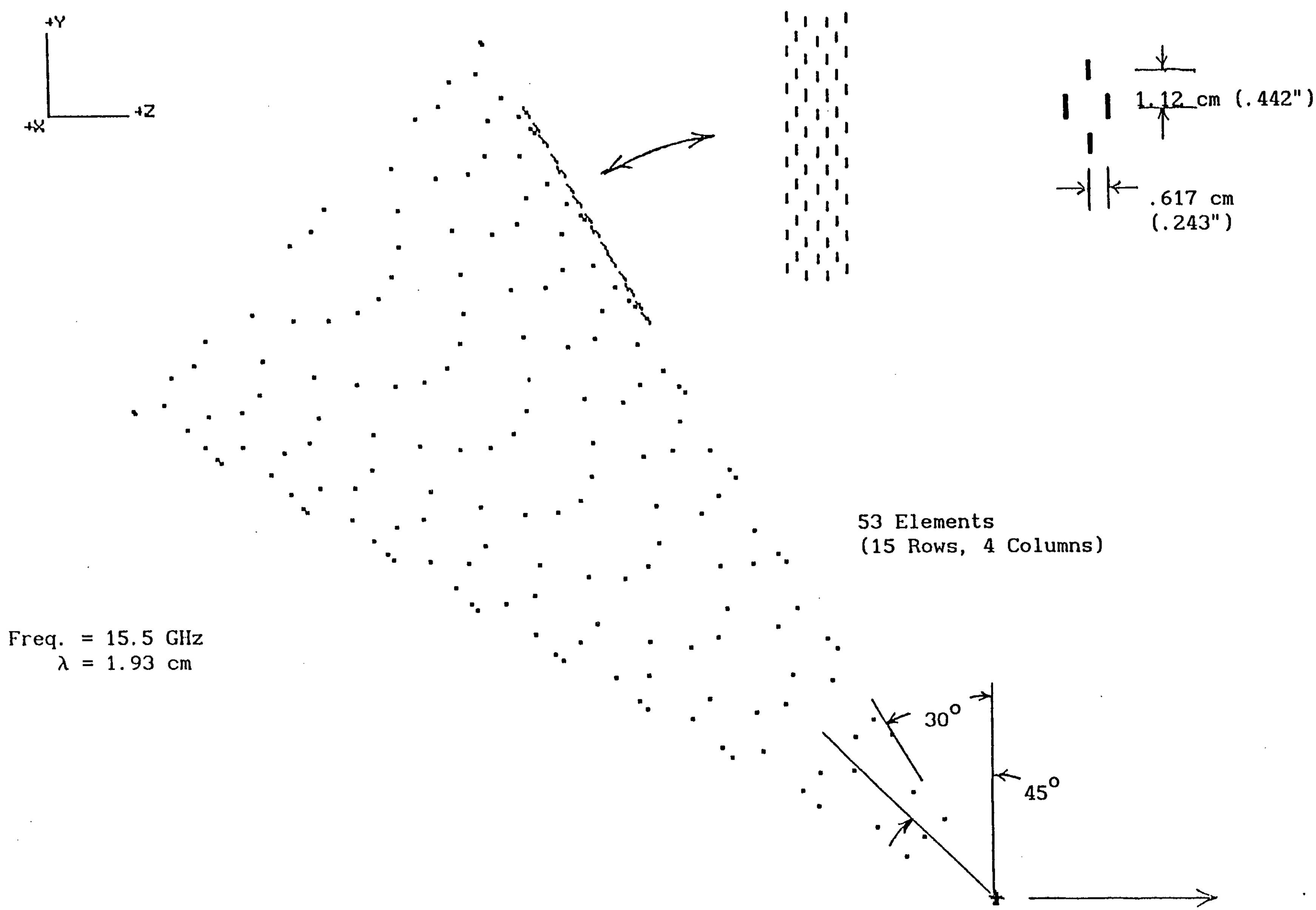


Figure 12. NAWCWPNS Test Article Aperture 2

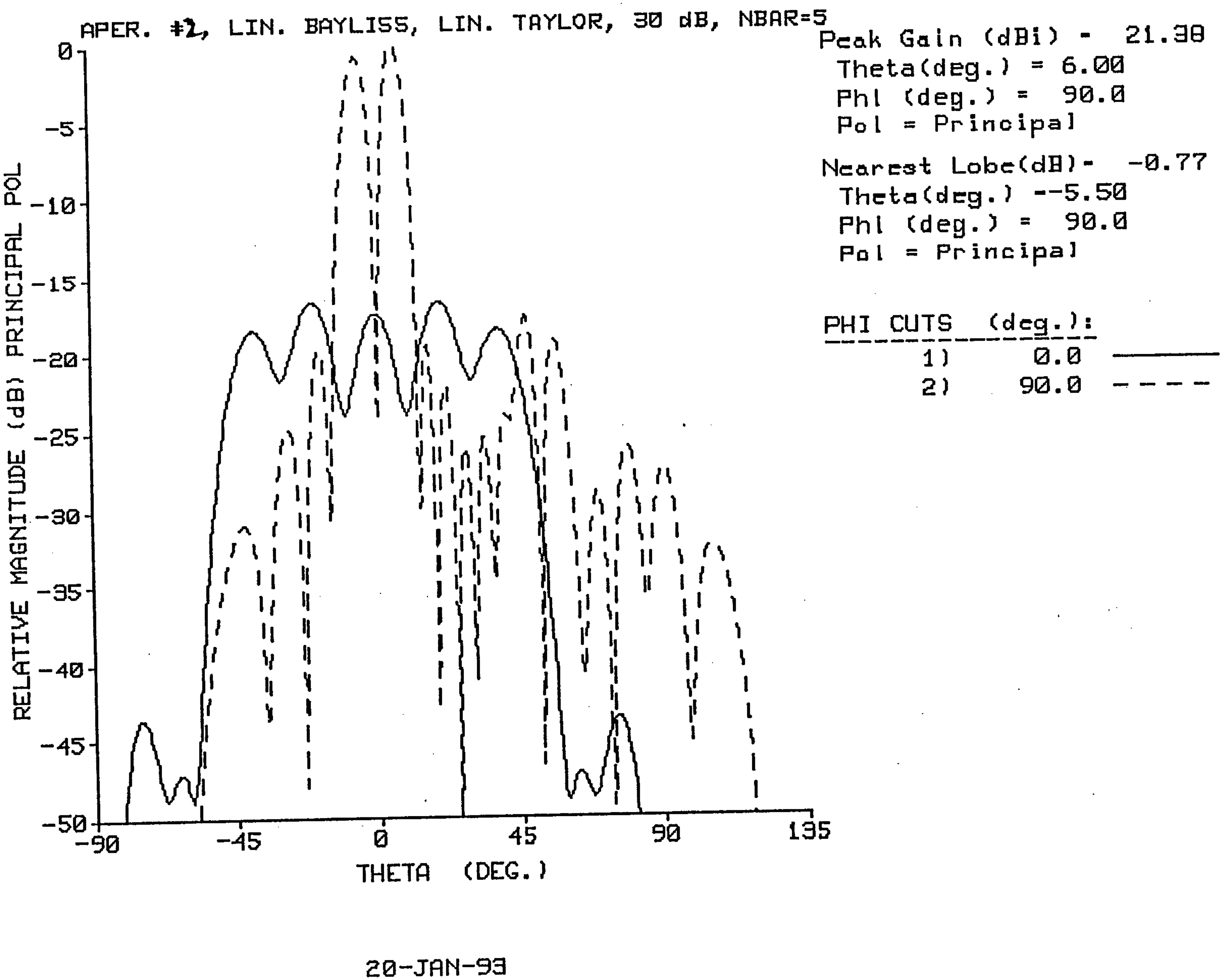


Figure 13. Aperture 2 Conformal Array Difference Patterns (z-Axis View, $\theta = 0^{\circ}$, Corresponds to 45° from Cone Axis)