

AN ELECTRICALLY-SMALL MONOPOLE PHASED ARRAY ANTENNA FOR WIDE BAND APPLICATIONS

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ABSTRACT

An electrically-small, lightweight, and low RCS (radar cross-section) Monopole Array Antenna has been developed for wide band application. The monopoles were printed on a low dielectric constant ($\epsilon_r = 2.3$) substrate and fed by a modified meanderline microstrip feed structure, with quarter-wavelength stubs to improve feed efficiency. The operational frequency is from 0.65 to 2.0 GHz. The physical size of the monopole array measures only 0.125 wavelength in height. The weight is about 0.3 pounds. A four-element subarray was built and tested. Its overall physical size is 2.5 inches in height by 10 inches in length by 24.4 inches in width. The measured gain and pattern data are presented, as well as the low RCS property and many applications of the monopole array.

INTRODUCTION

The physical size limitation and operational frequency bandwidth are the two major classical problems in antenna design. For the conventional dipole array, the log-periodic array structure has been used to increase frequency bandwidth as reported by Isbell and Carrel (1,2) and others. The size reduction technique using antenna loading, such as transmission line loading, inductance and capacitive loading, has been investigated by Difonzo (3). For the monopole array, the broadband feed has been reported by many researchers (4,5). However, the reduced size and broadband printed-monopole phased array has not been reported in the literature.

It is the purpose of this paper to present a realized electrically-small printed-monopole phased array for wide band application. The element design and feed line design will be described in the next section. The discussion of the measured element and array

performance will follow, together with the low RCS property of the array and possible applications.

ELEMENT DESIGN

The limitation imposed on the element design is the size constraints. The maximum height allowed is 2.5 inches, including, ground plane thickness. The maximum length is 10 inches. The operational frequency range is about 3:1 bandwidth, with the lowest frequency of 0.65 GHz. In addition, low RCS is desired.

To meet the above requirements, a printed-monopole array antenna has been developed as shown in Figure 1. The key success in the element design is the use of an antenna loading technique similar to the one described in reference (3). The detail of element design is the Company's proprietary information and will not be described here. The dielectric constant and substrate thickness used is $\epsilon_r = 2.3$ and $t = 0.032$ inches, respectively.

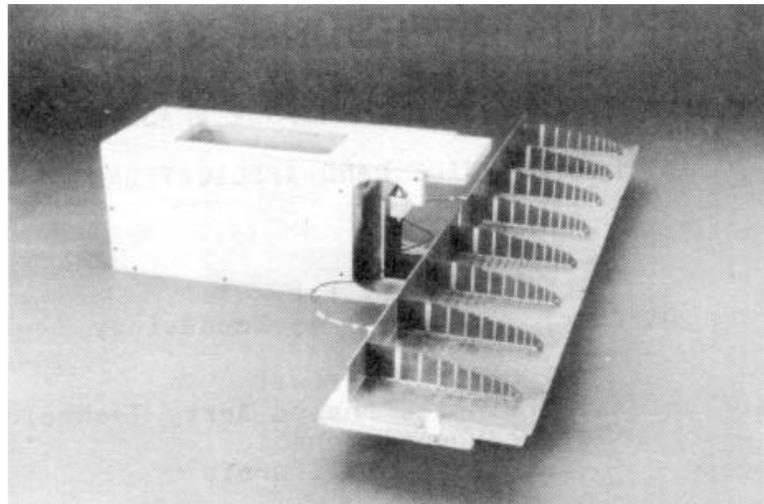


FIGURE 1 A PHOTO TO SHOW AN EIGHT-ELEMENT PRINTED-MONOPOLE PHASED ARRAY ATTACHED TO A WOODEN TEST FIXTURE

The measured principal plane radiation patterns of a $1/4 \lambda$ wire on top of a 9 inch by 9 inch ground plane were compared to that of a $1/8\lambda$ printed-monopole on the same sized ground plane, where λ is wavelength in free space, as shown in Figure 2. The comparison of the data for the two elements agreed in both E- and H-planes. This result established the transformation from the thin wire to the printed-monopole array. Figure 3 shows the measured return loss at the input port of each element in a printed-monopole array. It should be mentioned here that each monopole element was tuned to 50 ohms with all adjacent elements terminated. With all elements excited, the input impedance of each monopole will not be 50 ohms due to the mutual coupling effect. Figure 4 shows two

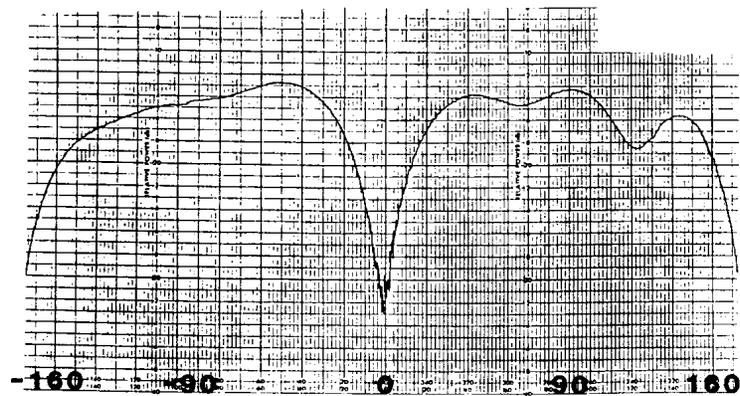
typical patterns measured in E- and H-plane for a printed-monopole array element. The beam squint upward shown in Figure 4 is due to the ground plane effect. The element gain measured as a function of frequency is shown in Figure 5. Note that the nominal gain across the frequency band is about 5 dBi.

FEED LINE DESIGN

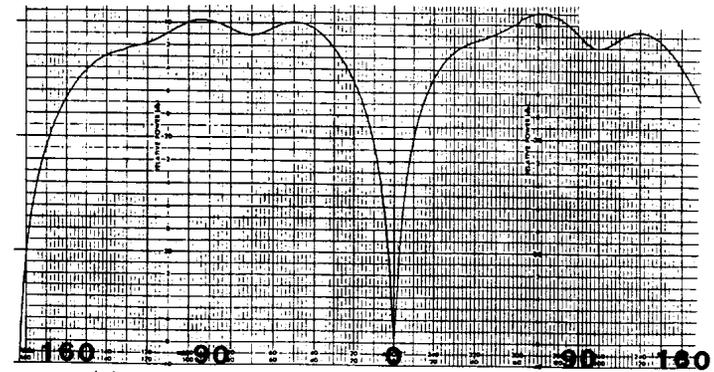
The feed of a monopole array cannot be accomplished by using the conventional log-periodic dipole array feed technique which uses the transposition of wires to provide 180 degrees phase shift between two consecutive elements. As a result, Ingerson (4) and Green (5) have proposed an impedance modulation technique to improve the match over a broad frequency range. The feed line used here, however, is different from theirs. It is a modified meanderline microstrip structure. It consists of a 50 ohm microstrip transmission line with a quarter-wavelength stub located at a quarter-wavelength past the feed point of each monopole element. The function of each stub is to prevent the energy from passing through each radiating, element and to improve the feed line efficiency. The dielectric constant and thickness of the feed line substrate is again $\epsilon_r = 2.3$ and $t = 0.032$ inches. The measured feed line loss vs. frequency is shown in Figure 6. The maximum feed line loss is about 1 dD. The measured return loss of a printed-monopole array is shown in Figure 7. The worst VSWR is less than 2.5:1 for the designed printed-monopole elements. It should be pointed out that the monopole elements for the frequency F_2 and F_3 shown in this figure have been purposely left out. Therefore the measured VSWR is high. If a continuous coverage over the frequency band is desired, higher dielectric constant substrate can be used to broaden the bandwidth.

SUBARRAY PERFORMANCE

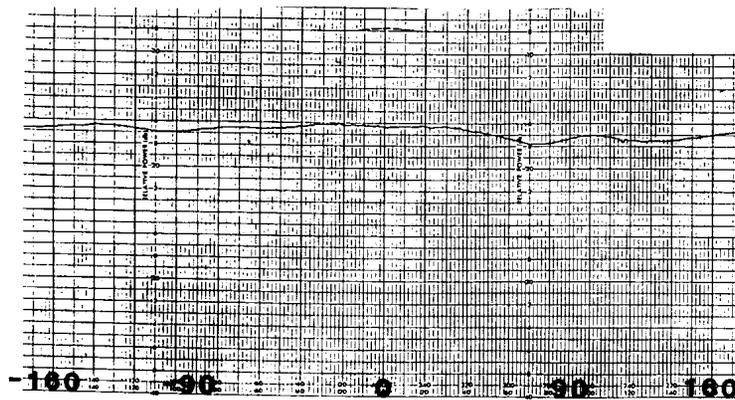
Two four-element printed-monopole subarrays were built and tested. The two subarrays were assembled together to make an eight-element linear array as shown in Figure 1. The element spacing for the test frequency is 1.03λ . The measured typical subarray patterns in H-plane for scan angles of 0 degrees, 15 degrees, 30 degrees, and 45 degrees are shown in Figure 8. It is noted that at scan angles of 30 degrees and 45 degrees, grating lobes appeared in the visible region as expected. Figure 9 shows the measured typical F-plane subarray pattern which has a peak between 20 degrees to 60 degrees due to ground plane effect. In general, the measured subarray patterns are very well behaved. The measured peak gain is 10.8 dBi. The overall size of the subarray is 2.5 inches in height by 10 inches in length by 24.4 inches in width.



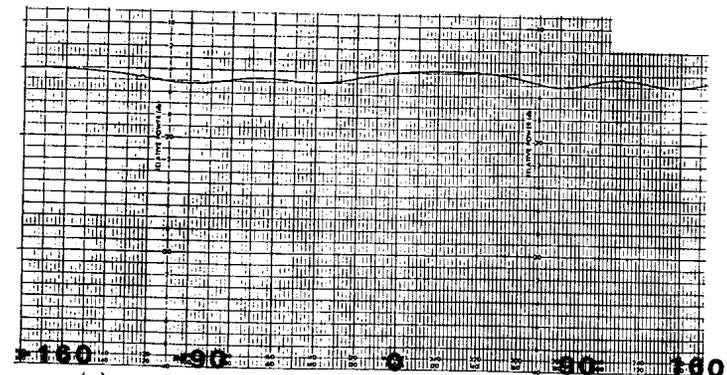
(A) E-PLANE QUARTER-WAVELENGTH WIRE MONOPOLE ANTENNA



(B) E-PLANE ONE EIGHTH-WAVELENGTH PRINTED-MONOPOLE ANTENNA



(C) H-PLANE QUARTER-WAVELENGTH WIRE MONOPOLE ANTENNA



(D) H-PLANE ONE EIGHTH-WAVELENGTH WIRE MONOPOLE ANTENNA

FIGURE 2 MEASURED RADIATION PATTERNS OF A QUARTER-WAVELENGTH WIRE MONOPOLE AND A ONE EIGHTH-WAVELENGTH PRINTED-MONOPOLE ON A 9-INCH GROUND PLANE

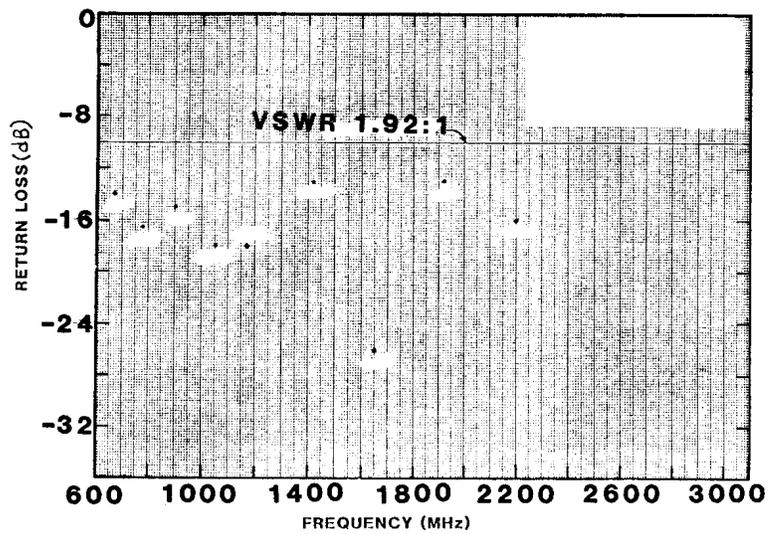
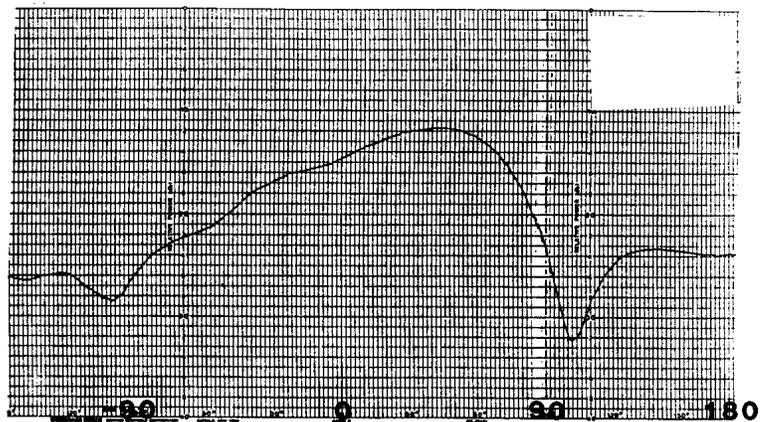
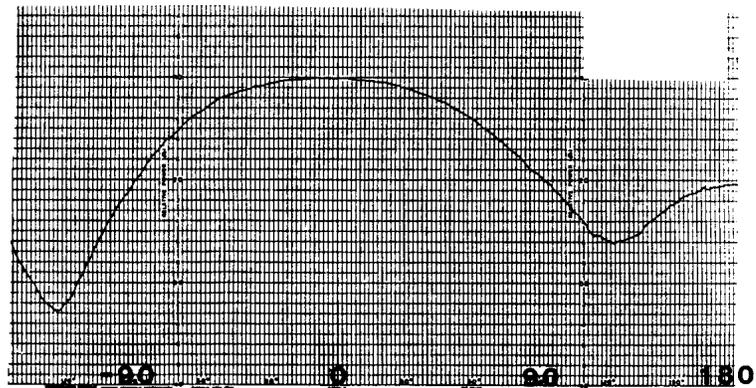


FIGURE 3 MEASURED RETURN LOSS AT THE INPUT PORT OF EACH PRINTED-MONOPOLE ELEMENT AS A FUNCTION OF FREQUENCY



(A) E-PLANE PATTERN



(B) H-PLANE PATTERN

FIGURE 4 MEASURED TYPICAL E- AND H-PLANE PATTERNS OF A PRINTED-MONOPOLE ELEMENT

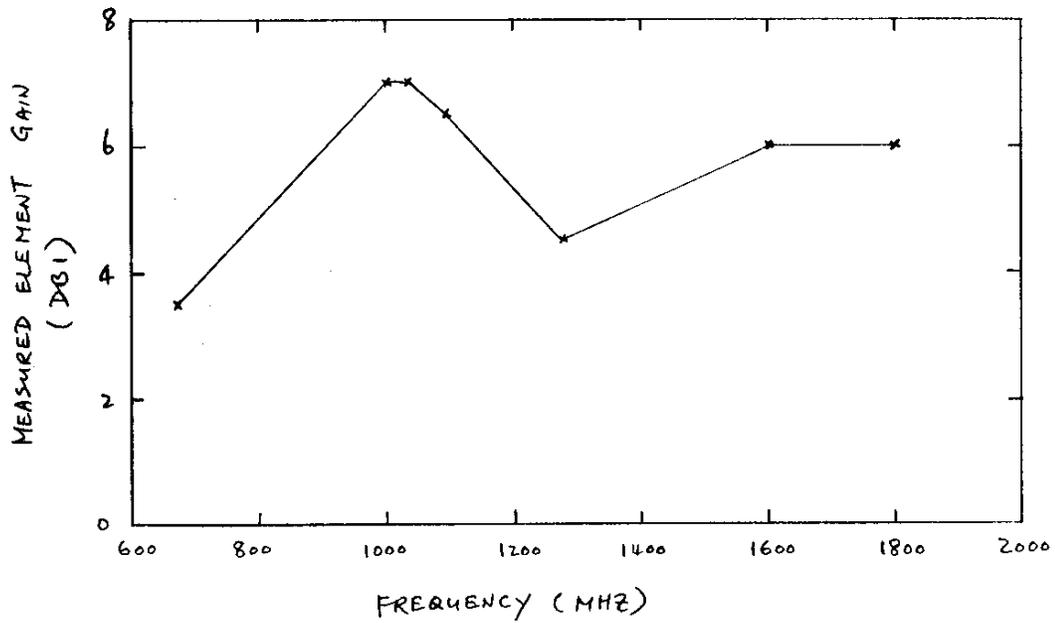


FIGURE 5 MEASURED PRINTED-MONOPOLE ELEMENT GAIN AS A FUNCTION OF FREQUENCY

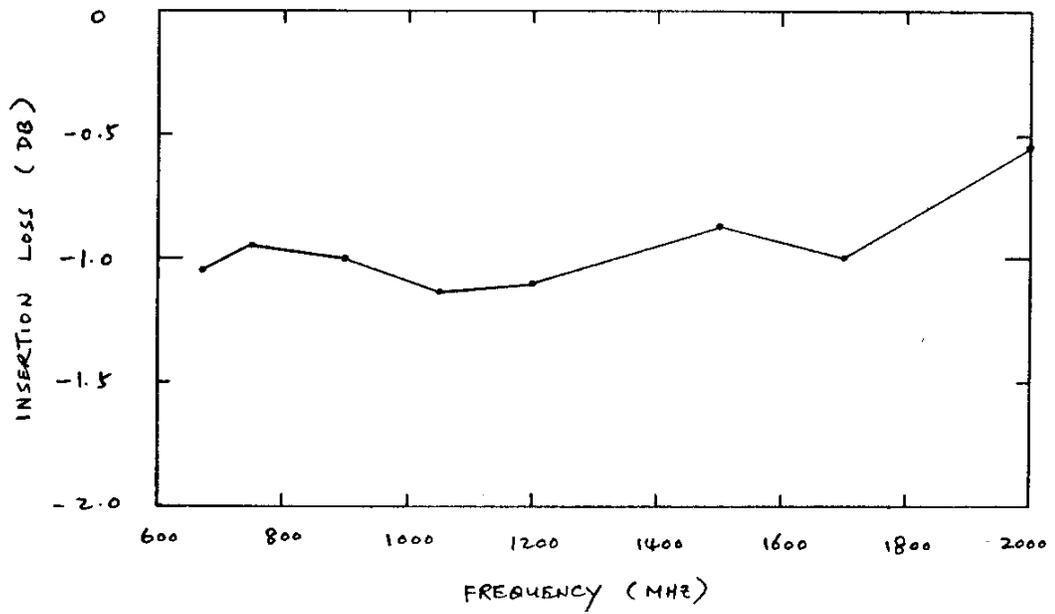


FIGURE 6 MEASURED FEED LINE LOSS OF A PRINTED-MONOPOLE ARRAY AS A FUNCTION OF FREQUENCY

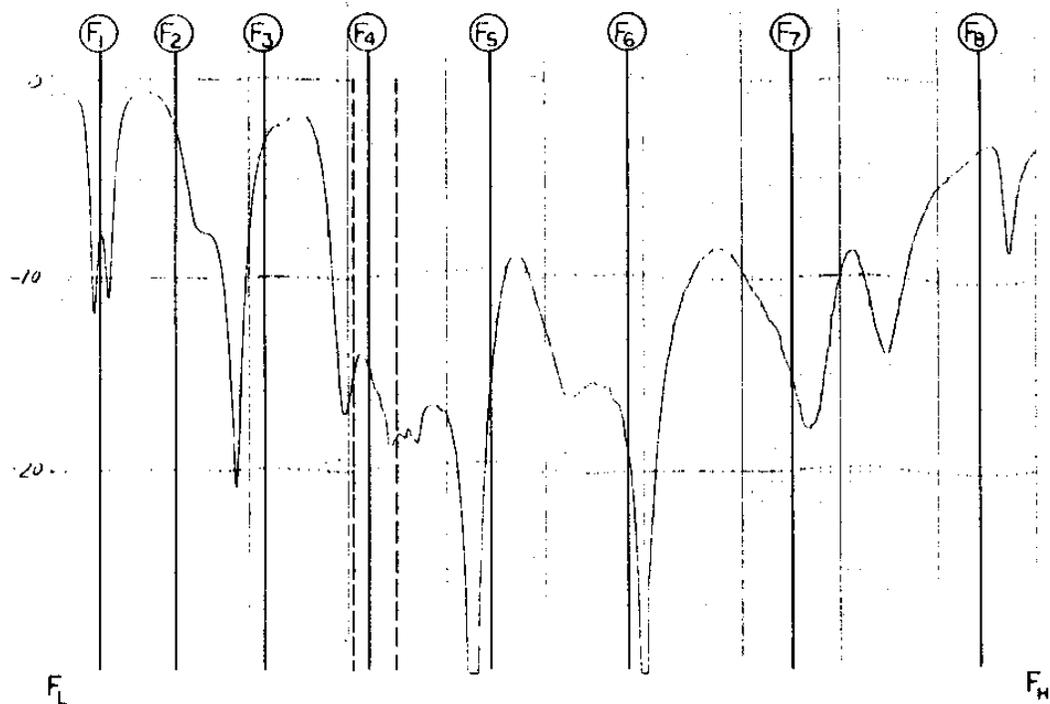


FIGURE 7 MEASURED RETURN LOSS AT THE INPUT PORT OF A MODIFIED MEANDERLINE FEED LINE FOR A PRINTED-MONOPOLE ARRAY AS A FUNCTION OF FREQUENCY

The weight of a four-element subarray is 1.2 pounds. It should be pointed out that the gain, size and weight of the four-element subarray does not include beam forming network.

Due to the array geometry, the RCS of the printed-monopole array is very small.

CONCLUSIONS

The newly developed electrically-small printed-monopole phased array antenna has broad operational frequency bandwidth (3:1), light weight, and low RCS properties. It can be used as ground terminals, shipboard arrays as well as airborne antennas. It is envisioned that this type of phased array may find its applications in the areas of monopulse tracking, communication link, radar, countermeasures jamming, wide directional finding, main-beam arm decoy systems, ELINT, and many others.

The four-element subarray element spacing can be varied depending on application requirements. The subarray is a building block for either a planar or linear phased array. The printed-monopole and feed line make the production cost affordable and performance repeatable and reliable.

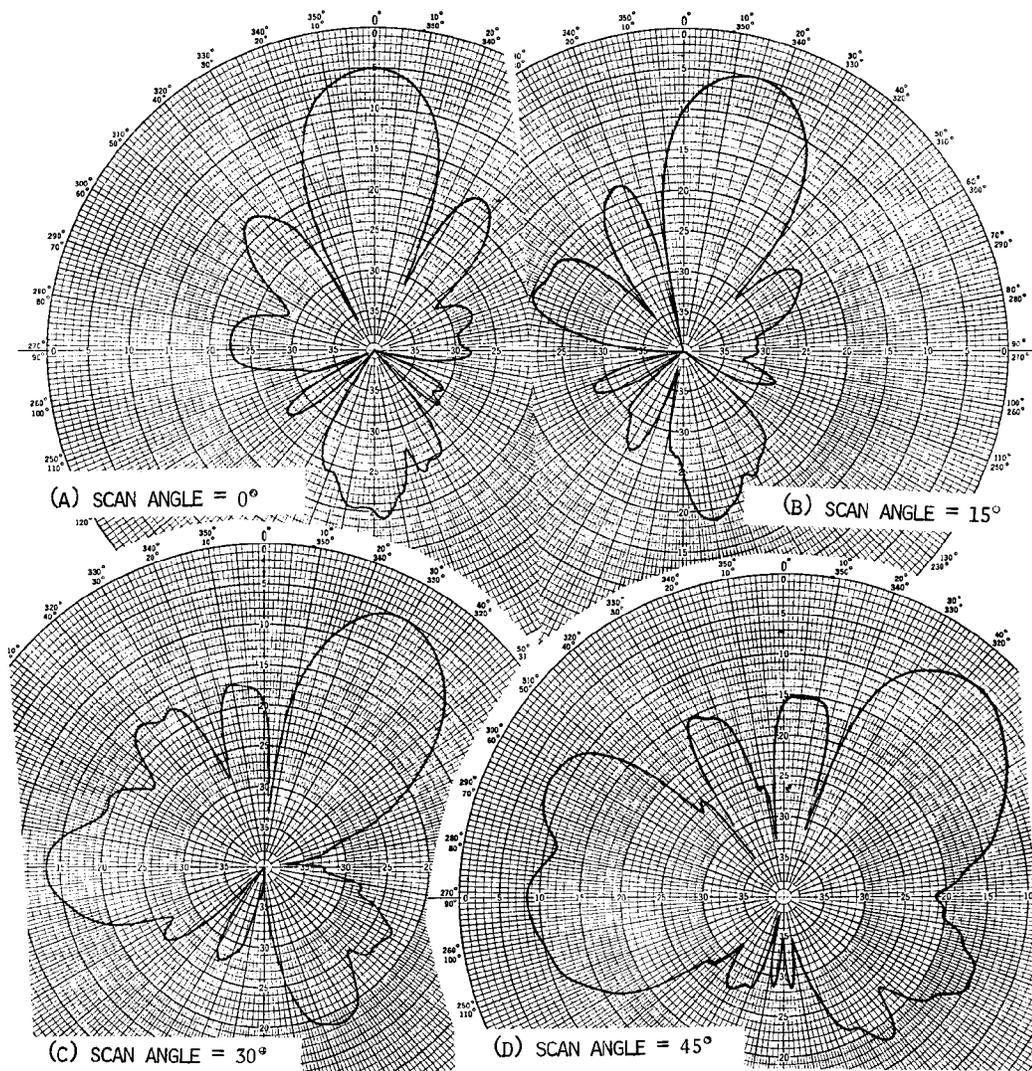
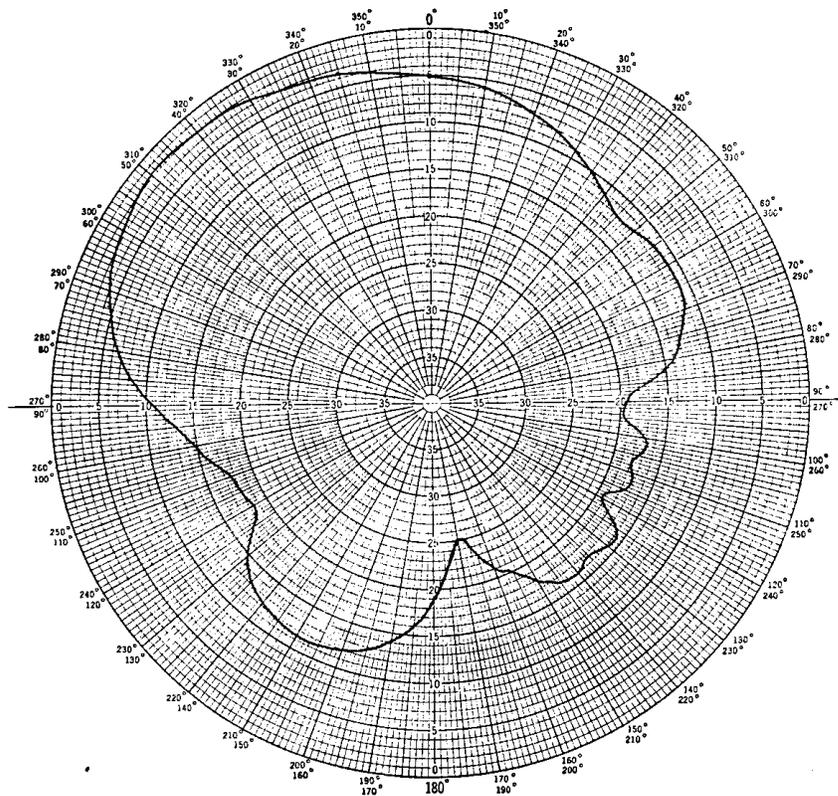


FIGURE 8 MEASURED TYPICAL FOUR-ELEMENT SUBARRAY H-PLANE PATTERNS FOR SCAN ANGLES OF 0° , 15° , 30° , AND 45° , ELEVATION ANGLE IS 0° .

ACKNOWLEDGEMENT

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**FIGURE 9 MEASURED TYPICAL FOUR-ELEMENT
SUBARRAY E-PLANE PATTERN FOR SCAN ANGLE 0°
IN BOTH E- AND H-PLANES**

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