REPORT SD-TR-86-85

(12)

AD-A175 706

A Wideband Low-Sidelobe Source Antenna for a VHF Antenna Range

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30 September 1986

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Prepared for

SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Station
P.O. Box 92960, Worldway Postal Center
Los Angeles, CA 90009-2960

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245, under Contract No. F04701-85-C-0086 with the Space Division, P.O. Box 92960, Worldway Postal Center, Los Angeles, CA 90009-2960. It was reviewed and approved for The Aerospace Corporation by M. J. Daugherty, Director, Electronics Research Laboratory.

Lt Wesley R. Dotts, CGX, was the project officer for the Mission-Oriented Investigation and Experimentation (MOIE) Program.

This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SD-TR-86-85	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER A175706
4. TITLE (and Subtitle) A WIDEBAND LOW-SIDELOBE SOURCE ANTENNA FOR A VHF ANTENNA RANGE		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER TR-0086(6925-06)-2
7. AUTHOR(s) H. E. King and Jimmy L. Wong		8. CONTRACT OR GRANT NUMBER(s) F04701-85-C-0086
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Aerospace Corporation El Segundo, Calif. 90245		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Space Division Los Angeles Air Force Station Los Angeles, Calif. 90009-2960		12. REPORT DATE 30 September 1986
		13. NUMBER OF PAGES 21
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Low Sidelobe Antenna,
Open Sleeve Dipole,
VHF Antenna Array,

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The RF characteristics of a four-element diagonal array configured to yield low sidelobes, dual circular polarization with low axial ratio and high front-to-back ratio are described. The array was designed for use as source antenna in a VHF test range, where the test antenna is nearly omnidirectional and ground multipath effects are a major problem. To achieve broadband performance, crossed open-sleeve dipoles were used as array elements. The array is capable of operation over a 1.66:1 band with a VSWR of < 2:1.

DD FORM 1473 (FACSIMILE)

19. KEY WORDS (Continued)

20. ABSTRACT (Continued)

Experimental studies were made by means of scale model antennas in the 240 to 400 MHz band. The axial ratio is < 1 dB, and the sidelobe/backlobe levels vary from -25 dB to -30 dB over the measurement frequency range.

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I. INTRODUCTION

In the pattern measurements of low-gain, wide-beamwidth antennas an illuminating source antenna with low sidelobes is required to minimize the effects of ground multipath signals. In the VHF frequency region, the antenna physical size required to provide a directional pattern becomes relatively large and a single dipole, Yagi dipole array, or dipole-reflector antenna is often employed as the source antenna. Although these antennas are simple to construct, there are certain limitations — narrow bandwidth, wide beamwidth and high sidelobes/backlobes with poor multipath-rejection characteristics. The present study is concerned with the development of a low-sidelobe source antenna for a VHF test range. The design parameters are listed below:

- 48-80 MHz and 110 - 150 MHz
- VSWR < 2:1
- Low pattern level at 63.4° relative to beam peak
- Axial ratio $\leq$ 1 dB
- Dual circular polarization
- Minimal size

A four-element, uniformly fed array of turnstile dipoles arranged in a 2 x 2 configuration was selected for the design study. In the diagonal plane, the 2 x 2 array provide an equivalent 1:2:1 (binomial) amplitude distribution which has the inherent characteristics of low sidelobes (Ref. 1). To meet the broad bandwidth performance, open-sleeve dipoles (Ref. 2) were chosen as array elements.

The experimental studies were made by means of scale model antennas in the 240 to 400 MHz band; thus, all the results presented herein are given in terms of the scale frequencies. To optimize the multipath-rejection performance, measurements were made as function of element spacing, ground plane size and dipole-to-reflector spacing.

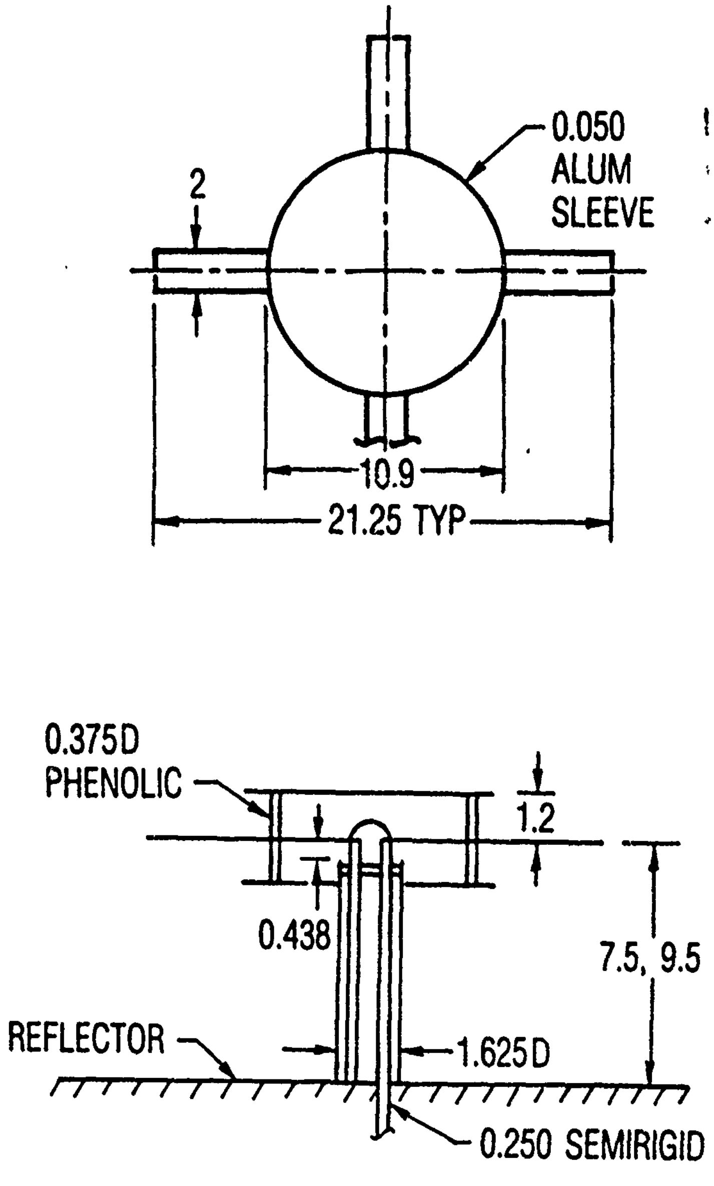
II. DESCRIPTION OF ANTENNA

The array utilizes two sets (designated as A and B) of mutually perpendicular dipoles. Each set consists of four similarly oriented, linearly polarized dipoles fed with a 4-way power divider (Microlab/FXR Model D4-OTN). To acquire dual circular polarization, the input ports of the two 4-way power dividers are connected to a 4-port quadrature hybrid (Merrimac Model QHM 2.312 G).

To achieve a broadband VSWR performance over the required operating frequency range (1.66:1 ratio), crossed open-sleeve dipoles were employed as array elements (Ref. 3). The basic element consists of a conventional dipole with two closely spaced parasitic sleeves as shown in Fig. 1. The dipole arm is constructed from a flat 2-in. wide brass sheet and has a total length of 21.25 in. The dipoles are fed from a balun constructed from 0.250-in. diameter semirigid coaxial cable. The two sleeves, 10.9 in. diameter, are spaced 1.2-in. from the dipole arms. The measured VSWR of the orthogonal dipoles (A and B) is $\leq$ 1.85 from 240 to 400 MHz as shown in Fig. 2(a).

The VSWR characteristics measured at the inputs to the 4-way power dividers for both the A and B set of dipoles are shown in Fig. 2(b). The VSWR response is in general similar to the individual dipole VSWR of Fig. 2(a). However, some difference is noted and is caused by interaction between the dipoles, interconnecting cables, and the power divider. The measured VSWR at the inputs (ports 1 and 4) to the quadrature hybrid is < 1.22:1, and is also shown in Fig. 2(b). These two input ports are isolated and provide the connections for left-hand and right-hand circular polarization operation of the array.

The amplitude and phase characteristics of the quadrature hybrid are shown in Fig. 3. The amplitude unbalance is < 1 dB and the quadrature relation is within 2°.



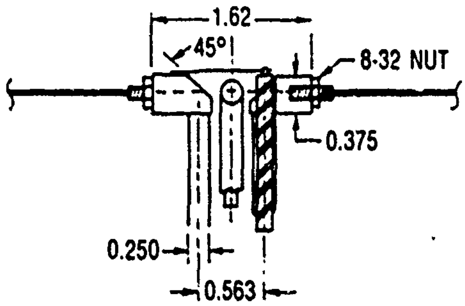
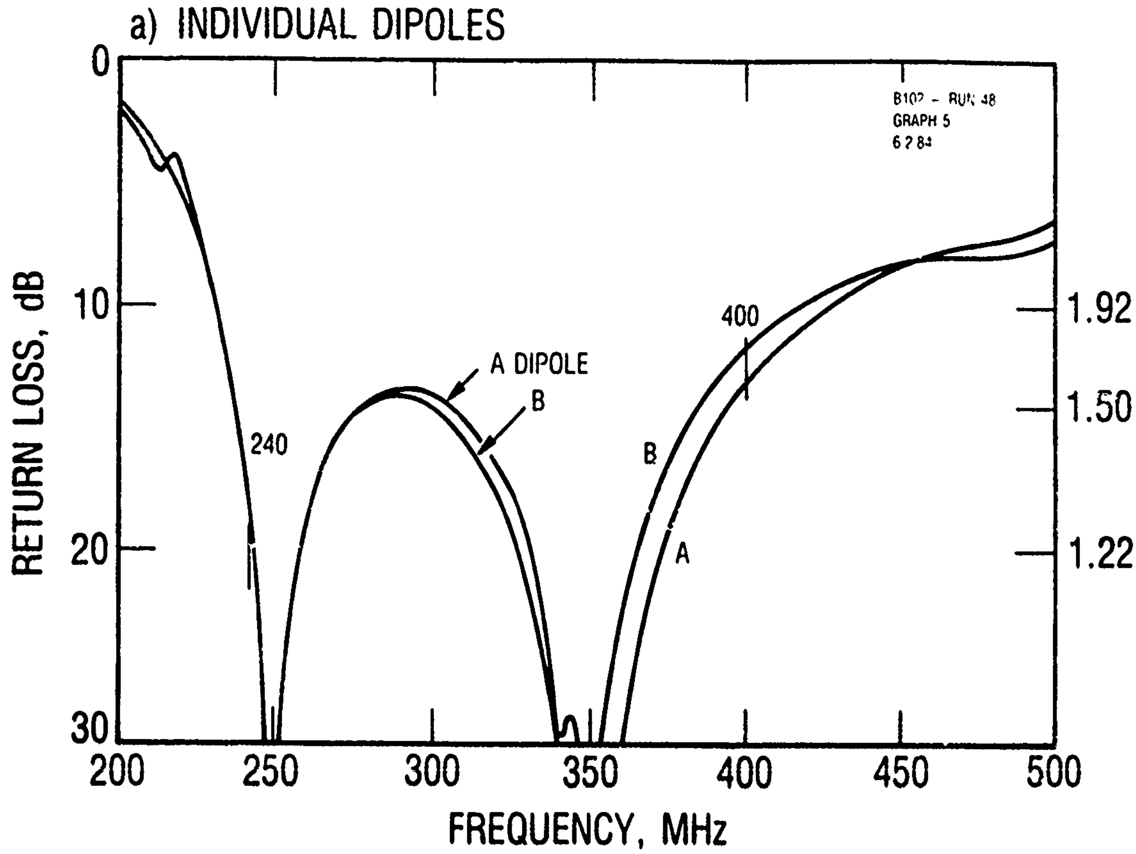


Fig. 1. Details of crossed, open-sleeve dipole.



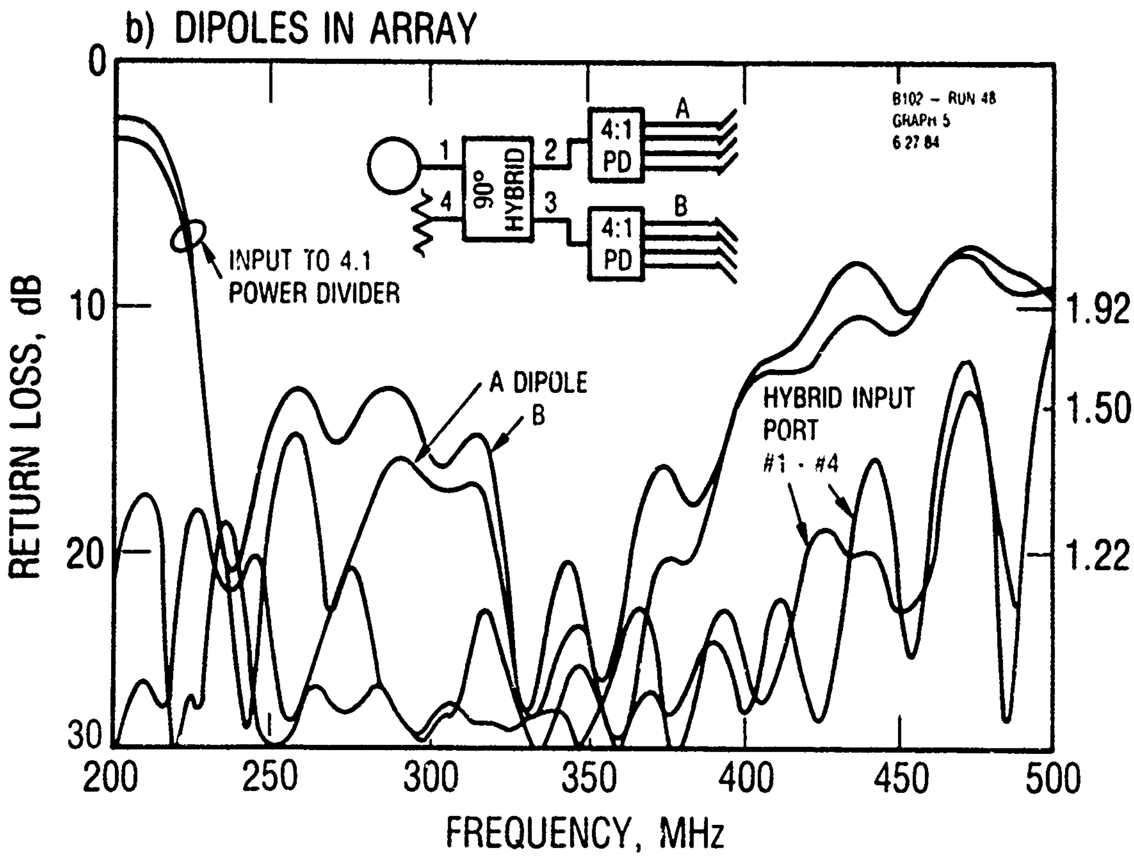


Fig. 2. Dipole and power divider network VSWR characteristics.

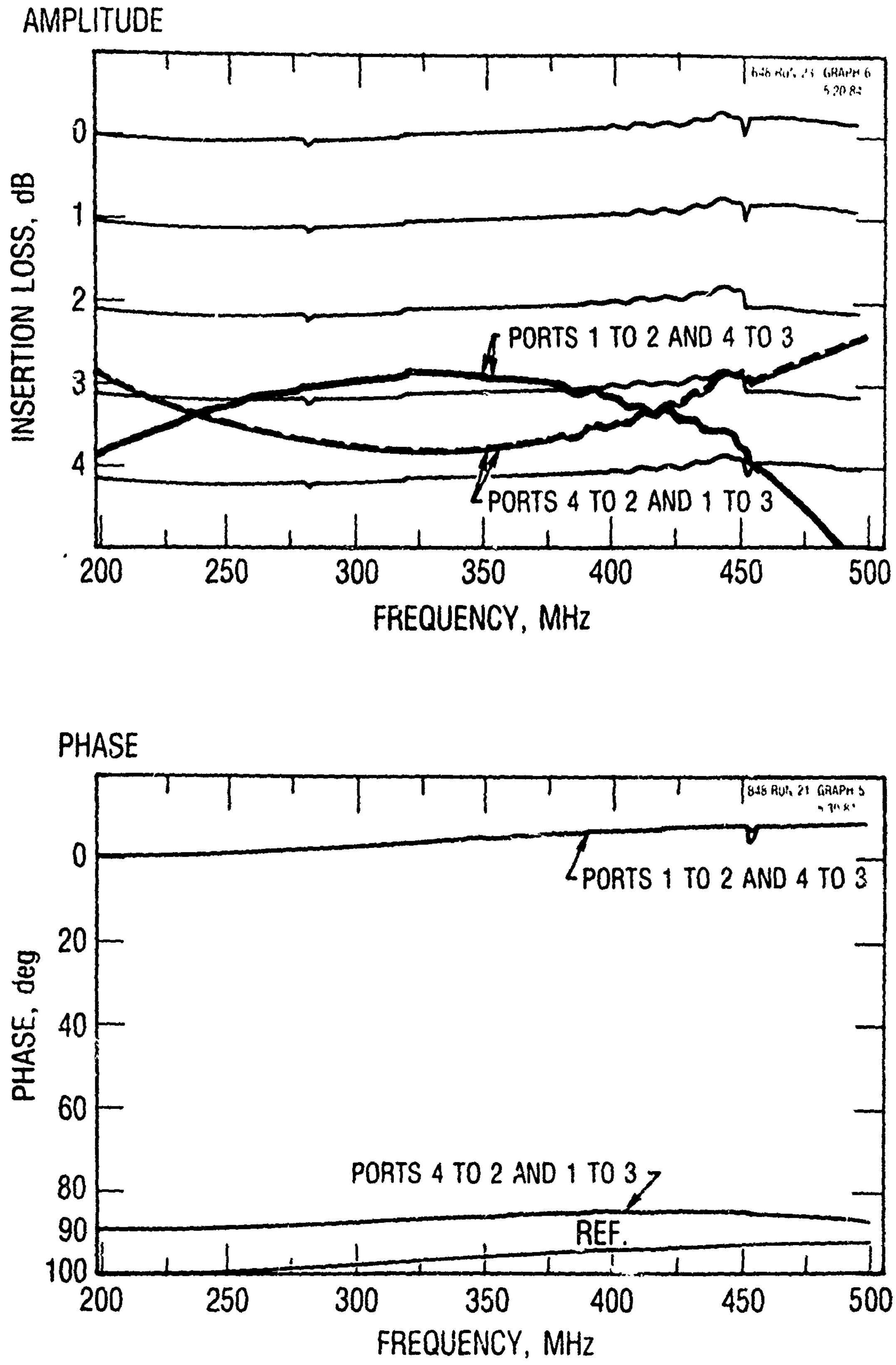


Fig. 3. 90° hybrid phase and amplitude characteristics.

III. MEASURED RESULTS

A detailed experimental study was made of the radiation pattern characteristics of the 4-element array as a function of the design parameters, which include reflector size, element spacing, dipole-to-reflector spacing and dipole orientation. The objective of the present study was to optimize the multipath rejection performance by minimizing the pattern gain level at an angle of approximately 63.4° from the array axis. The 63.4° angle corresponds to the ground (multipath) specular reflection point for an antenna range where the separation between the source and test antenna is the same as the height above the ground.

Radiation patterns of the array were measured at five test frequencies in a slant range as illustrated in Fig. 4. A 240-400 MHz corner reflector (Ref. 4) was used as illuminating antenna for these measurements. Axial ratio was recorded by rotating the linearly polarized corner reflector about the boresight axis. The multipath specular reflection angle is ~ 55.8° for the slant range. Since the corner reflector patterns are relatively directional (Ref. 4), multipath errors are expected to be insignificant for the array measurements. The crossed polarization level is < -28 dB.

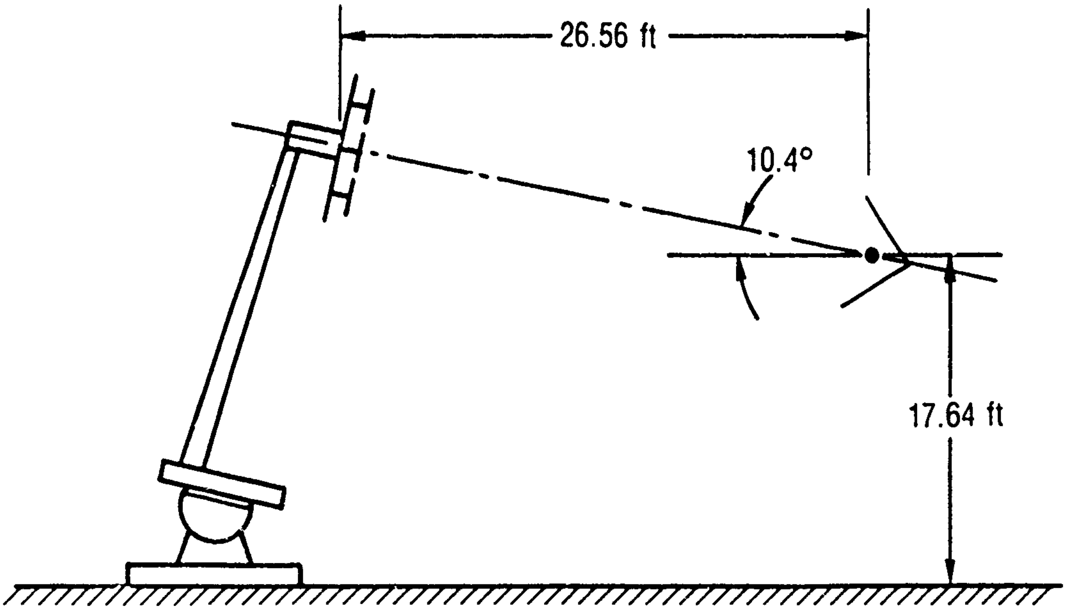


Fig. 4. Antenna-range geometry for pattern measurements.

With a dipole-to-reflector spacing of 9.5 in. and an element spacing of 25 in., patterns were recorded for a 4-, 5-, and 6-ft square reflector. The measured patterns for the 4-ft and 6-ft square reflectors are shown in Figures 5 and 6, respectively. A summary of results, which include the pattern level at 63.4°, the half-power beamwidth (HPBW) and the front-to-back ratio (F/B), is shown in Fig. 7. The 63.4° pattern level relative to the beam peak, which is of primary interest for our present application, represents the highest linearly polarized signal (worst-case multipath) as indicated by the E_ϕ component. The measured results clearly illustrate that the large 6-ft reflector yields better multipath rejection performance. However, from a mechanical standpoint a smaller physical size is preferable.

Also for the same 9.5 in. dipole-to-reflector spacing and a 6-ft reflector, patterns were measured with the dipole-to-dipole or element spacing varied from 25 in. to 35 in. The results are summarized in Fig. 8, which indicate that the optimum element spacing lies between 25 and 30 inches.

The measured on-axis axial ratio (AR) is < 1 dB from 240 to 400 MHz for all the cases investigated. Typical AR plots are shown in Fig. 9. The AR values are essentially the same as the hybrid imbalance as shown in Fig. 3. The measured AR variations as the array is rotated are believed to be caused by range and instrumentation errors.

It is noted from Figures 7 and 8 that the HPBW curves become flattened at the high end of the operating band. The beamwidth widening is caused by the fact that the dipole-to-reflector spacing is $> \lambda/4$ when the operating frequency exceeds 310 MHz; i.e., the element pattern flattens or begins to bifurcate as the frequency is increased. To minimize the element-pattern beamwidth, the dipole-to-reflector spacing was reduced to 7.5 in., which is equivalent to $\lambda/4$ at 400 MHz. Also, an element spacing of 27.5 in. was chosen based on the results of Fig. 8. Patterns were then recorded for 4-, 5- and 5.5-ft square reflectors, and the results are summarized in Fig. 10. Again, the larger 5.5-ft reflector yields better performance than the smaller reflectors. The 5.5-ft reflector size was considered to be a good choice on the basis of both mechanical and RF considerations; i.e., low 63.4° pattern level and low sidelobe/backlobe levels are realized with a relatively small reflector. The measured patterns are shown in Fig. 11.

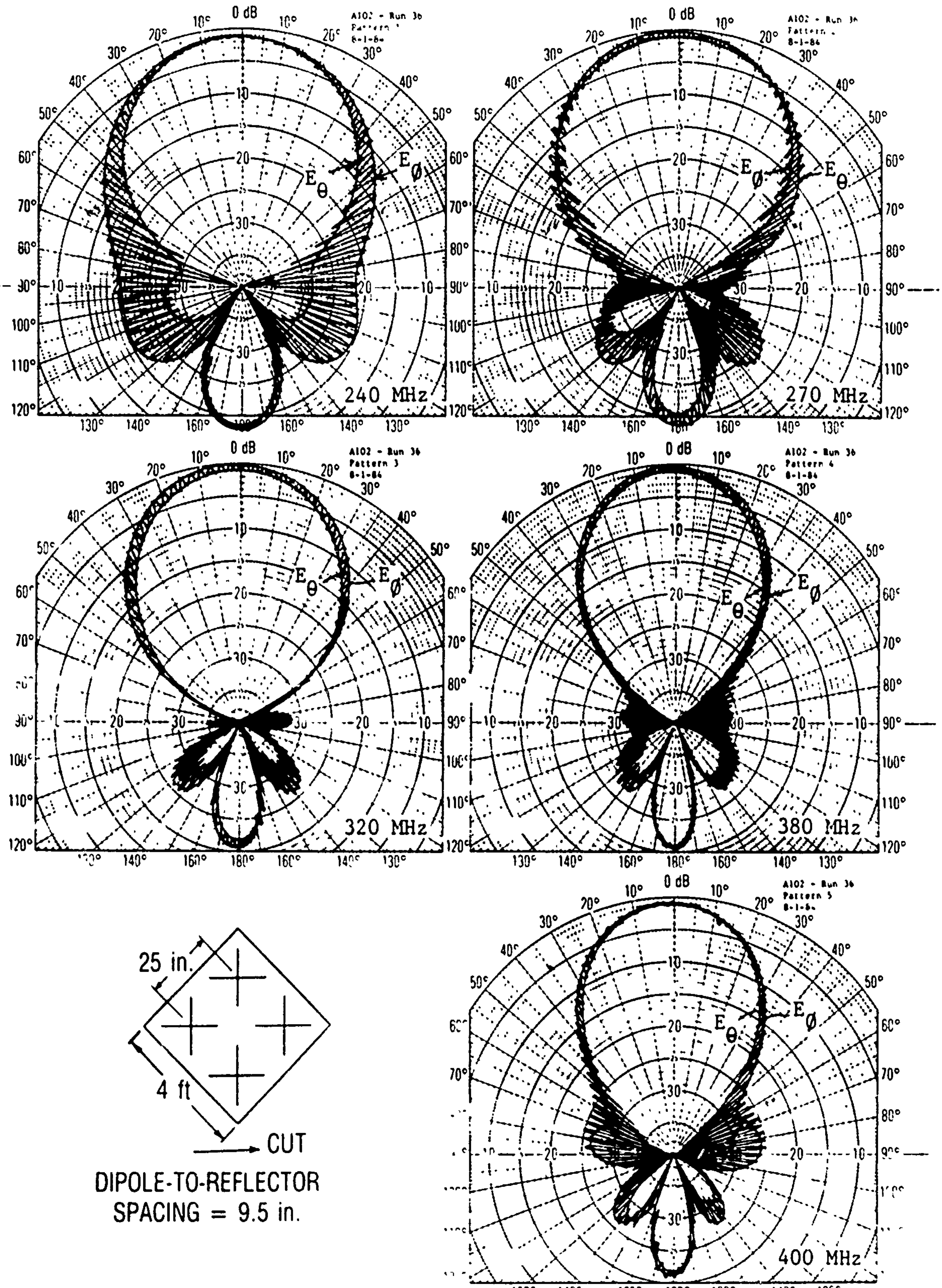


Fig. 5. Radiation patterns of 4-element diagonal array with 4 x 4 ft reflector, 25 in. dipole spacing 9.5 in. dipole-to-reflector spacing.

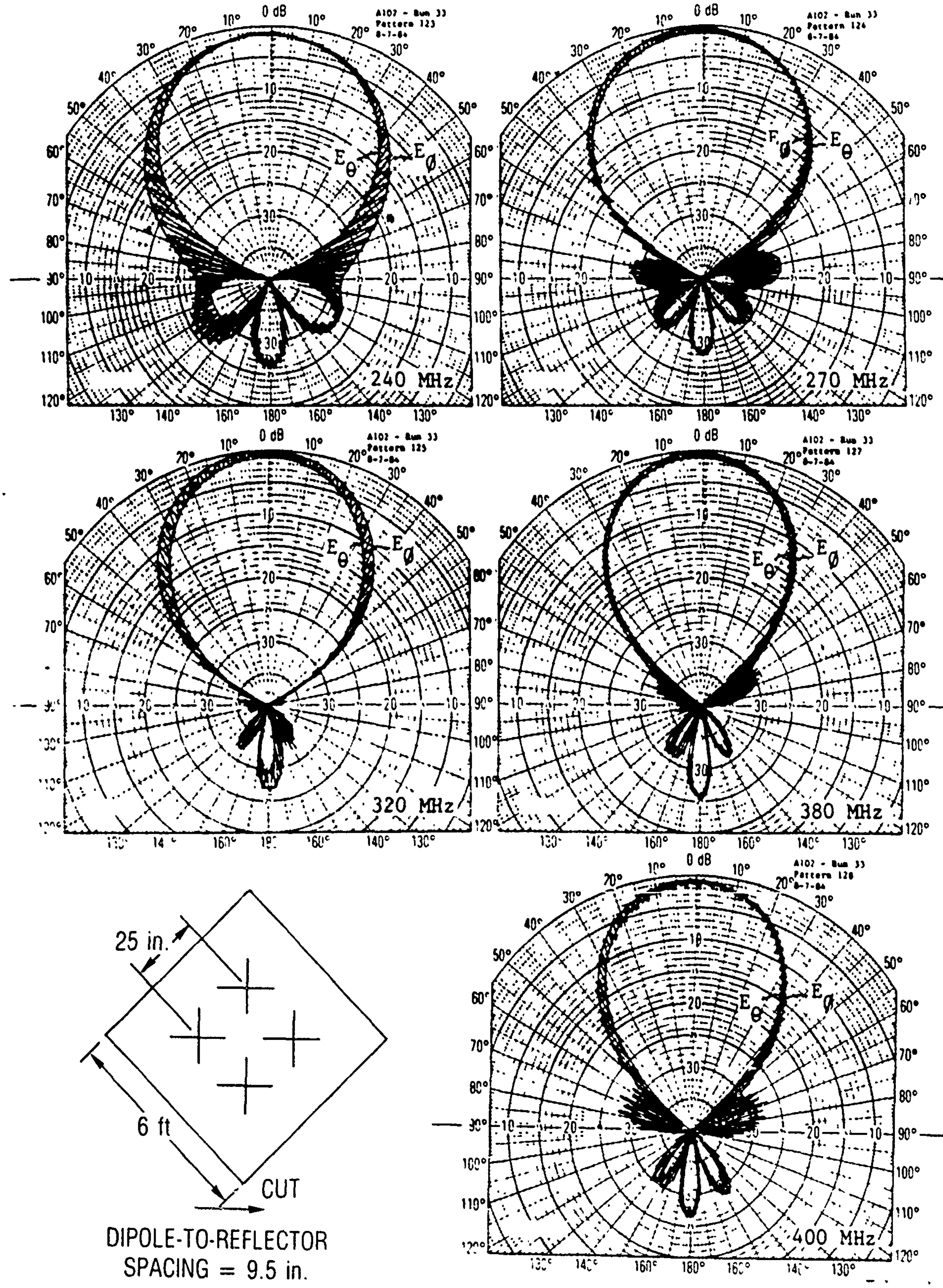


Fig. 6. Radiation patterns of 4-element diagonal array with 6 x 6 ft. reflector, 25 in. dipole spacing, 9.5 in. dipole-to-reflector spacing.

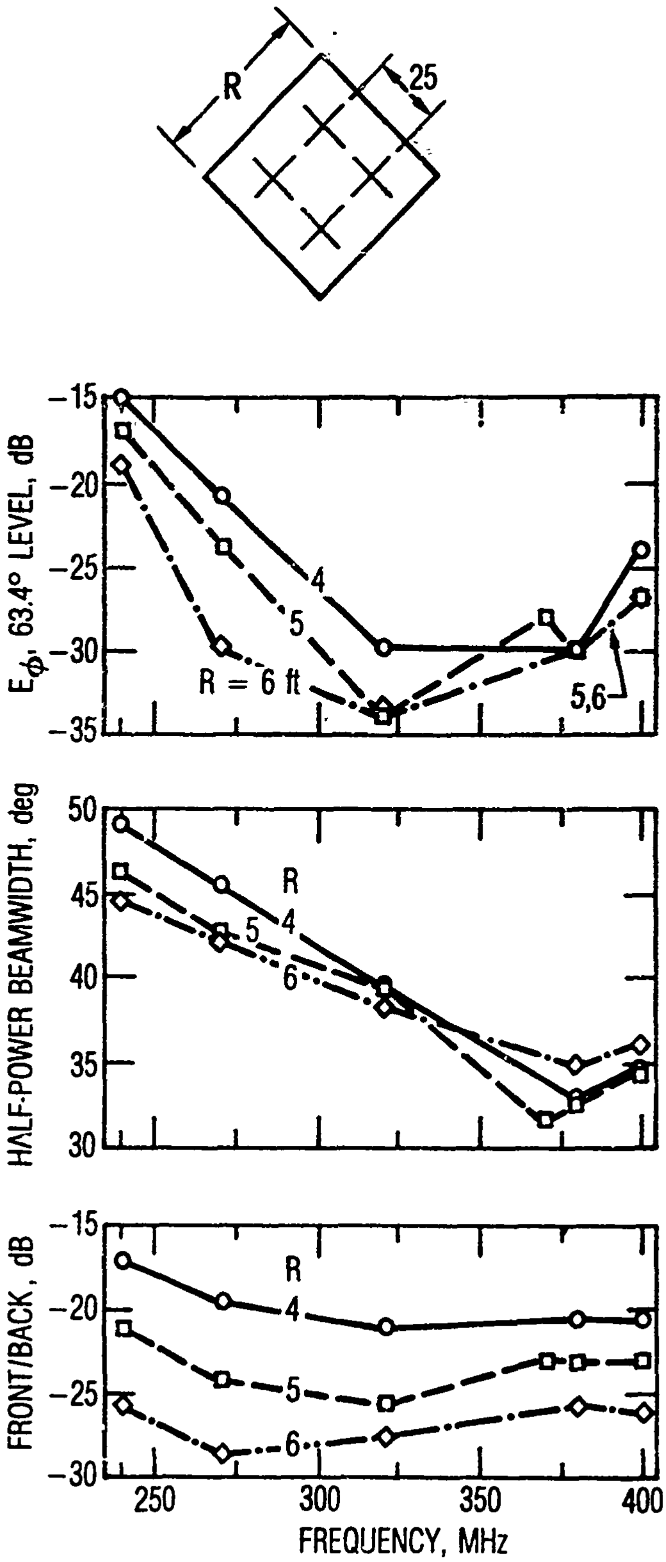


Fig. 7. Radiation characteristics of a 4-element diagonal array for 4, 5, and 6-ft reflectors, dipole spacing of 25 in. and dipole-reflector spacing of 9.5 in.

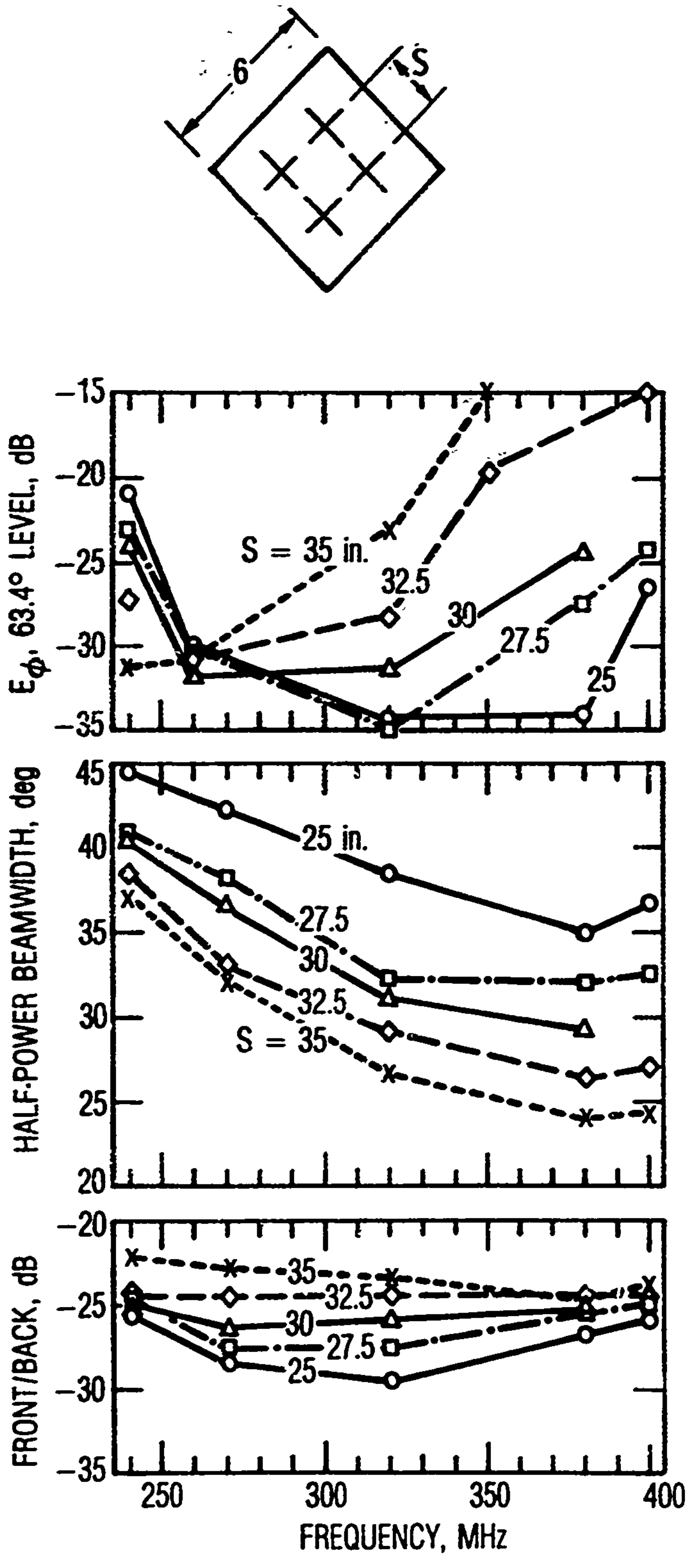


Fig. 8. Radiation characteristics of 4-element dipole array for various dipole spacings, dipole-reflector spacing of 9.5 in., mounted on a 6 ft reflector.

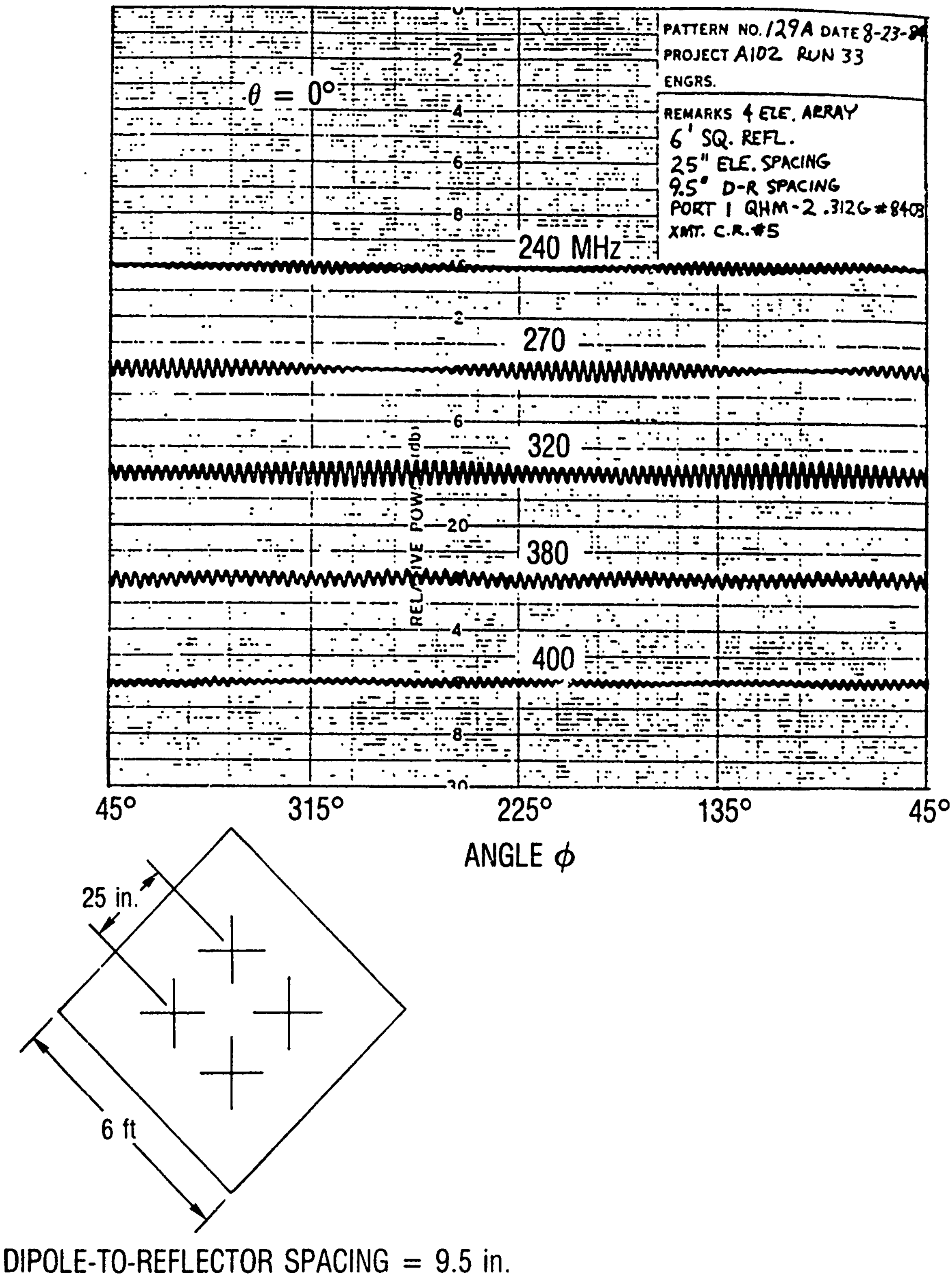


Fig. 9. Typical axial ratio plots of 4-element array.

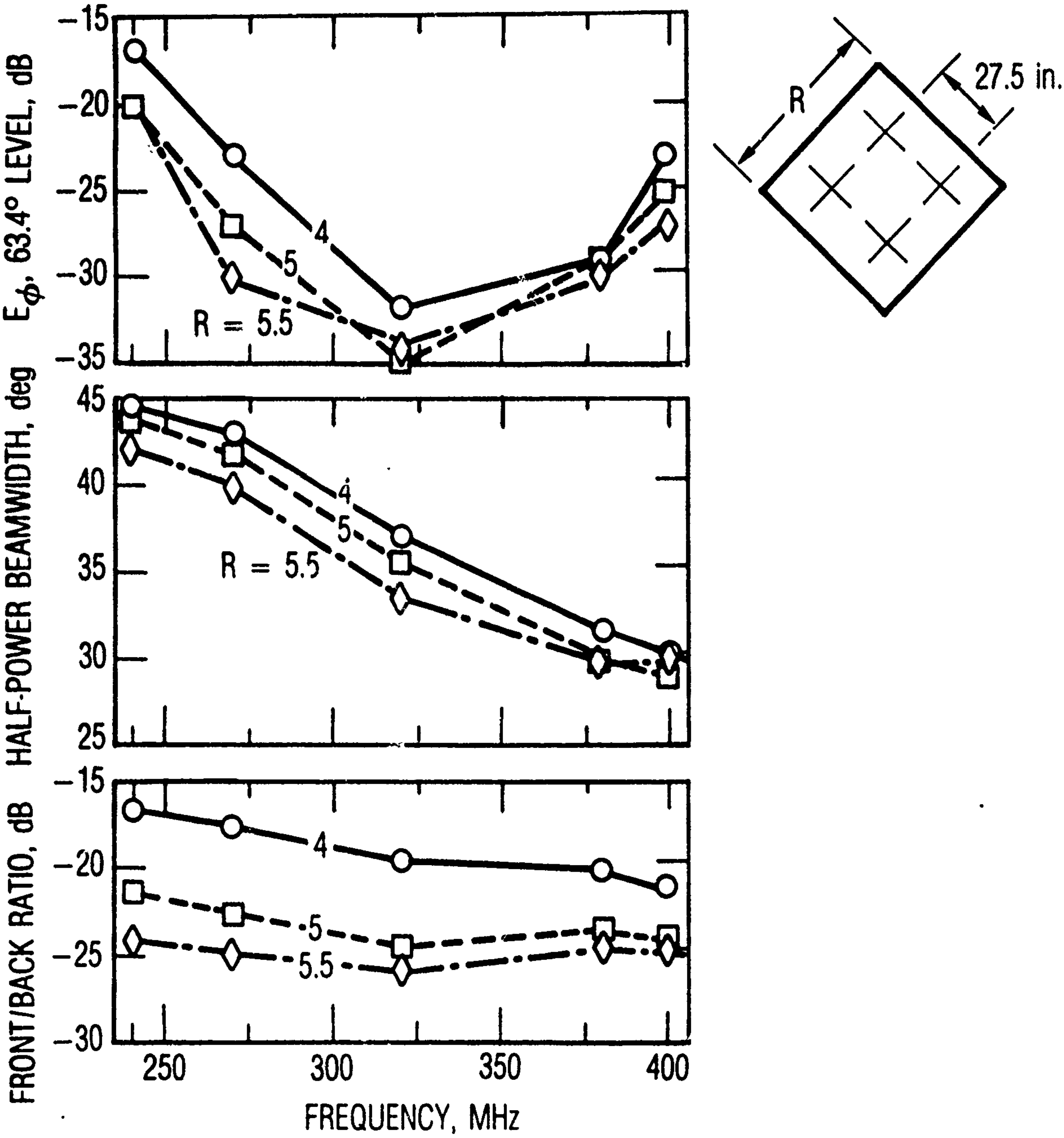


Fig. 10. Radiation characteristics of 4-element diagonal array for 4, 5, and 5.5 ft reflectors, dipole spacing of 27.5 in. and dipole-reflector spacing of 7.5 in.

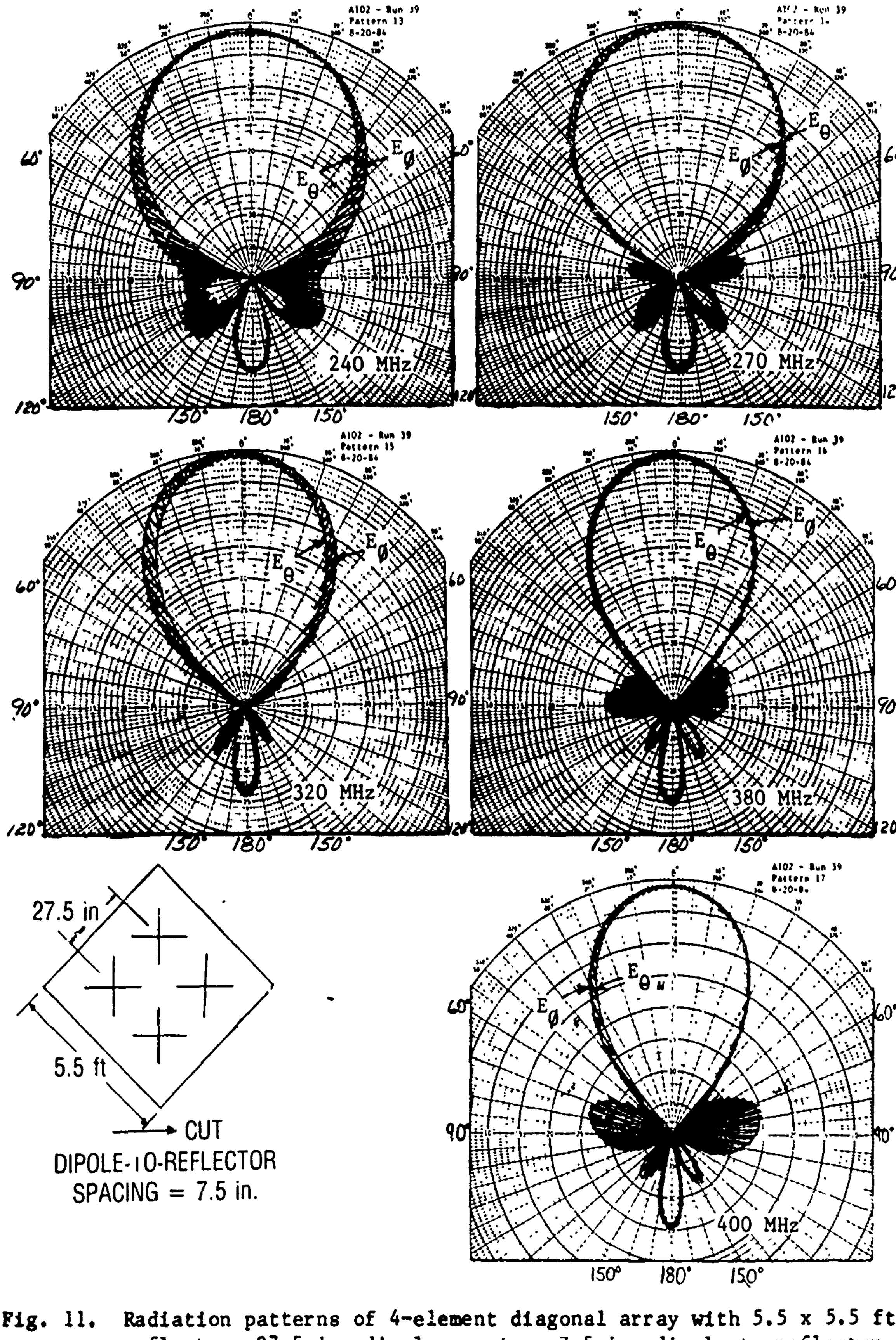


Fig. 11. Radiation patterns of 4-element diagonal array with 5.5 x 5.5 ft reflector, 27.5 in. dipole spacing, 7.5 in. dipole-to-reflector spacing.

The effects of dipole orientation were also investigated. Measurements were made with the dipole axes oriented either parallel to the reflector edges or at a 45° angle. However, little or no difference in the pattern characteristics was observed.

In an attempt to further improve the pattern and sidelobe/backlobe characteristics, the use of cavities or walls surrounding the dipoles was considered. Two types of cavities were investigated: (1) a circular wall around each of the four individual dipoles and (2) a wall around the periphery of the square reflector. Measurements indicated that there are no significant RF improvements over a plane reflector.

IV. CONCLUSIONS

A 4-element diagonal array has been developed for use as source antenna in a VHF omnidirectional-antenna test range, where multipath-induced errors are a major problem. The array is capable of operation over a 1.66:1 bandwidth with dual circular polarization. Although the present array design is optimized to provide a low 63.4° pattern level and low sidelobe/backlobes in the 240 to 400 MHz band, the design can be scaled to other VHF/UHF frequencies and used for other range geometries.

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