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NRL Report 5875

**ANTENNA PATTERNS OF ARRAYS OF CORNER
REFLECTORS BETWEEN 13 AND 27 MC**

[UNCLASSIFIED TITLE]

F. E. Boyd

Radar Techniques Branch
Radar Division

January 3, 1963



U. S. NAVAL RESEARCH LABORATORY
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CONTENTS

Abstract	ii
Problem Status	ii
Authorization	ii
INTRODUCTION	1
DESCRIPTION OF ANTENNAS	1
ANTENNA PATTERNS	1
ANTENNA GAIN	2
CONCLUSIONS	2
ACKNOWLEDGMENT	4
REFERENCES	4

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ABSTRACT
[Unclassified]

Horizontal patterns and vertical coverage patterns of a fixed broadside array of twenty corner reflectors, and a positionable array of two corner reflectors for the 13 to 27 Mc range conform with theoretical expectations. The fixed array is electrically steered over a 60-degree sector. The gain of the fixed array drops as much as 5.7 db with steering due to pattern deterioration and mutual coupling effects.

PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing on this and other phases.

AUTHORIZATION

NRL Problem R02-23
Project RF 001-02-41-4007

Manuscript submitted November 9, 1962.

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**ANTENNA PATTERNS OF ARRAYS OF CORNER
REFLECTORS BETWEEN 13 AND 27 MC
[Unclassified Title]**

INTRODUCTION

The antennas described in this report, a fixed antenna and a positionable antenna, were built for the U.S. Naval Research Laboratory under contract by the Radio Corporation of America. They are used in the Project Madre radar system having a peak power of 5 megawatts. Models of the antennas were made by RCA, and the patterns they obtained from these 1/33 scale models provide the bulk of the data presented here. A brief pattern check of the completed installation, made under a contract with Bendix (1), is in good agreement with these model studies. Additional information on the vertical pattern of the positionable antenna has been published in an NRL report (2).

DESCRIPTION OF ANTENNAS

The antennas are located at the Chesapeake Bay Annex of the U.S. Naval Research Laboratory, Randle Cliff, Maryland. The fixed antenna is placed near the edge of a cliff overlooking the bay, and the positionable antenna is placed on a 180-foot tower immediately behind the fixed antenna (Figs. 1-3). It is therefore able to "look" over the fixed antenna.

Both antennas are broadside arrays made up of 90-degree corner reflectors fed with horizontal dipoles spaced 24-1/2 feet out from the apex. Elements, in this case corner reflectors, arranged side-by-side are called a row, whereas one element above the other is called a bay. Each corner reflector is 30 feet long and 35 feet high, except that the reflectors at the ends of each row extend an additional 15 feet for the purpose of back lobe control. The reflectors are made of horizontal pipes spaced 2 feet apart except in the truncated apex, where they are 1 foot apart.

The fixed antenna is a broadside array of 20 elements. The array is arranged with two elements vertically and ten horizontally. The beam is steered ± 30 degrees from broadside by varying the electrical phase of the energy fed to the vertical bays of the antenna. The mechanical phase shifters used for this purpose are continuously variable. To provide control over the vertical coverage pattern, the upper and lower rows of elements may be excited as follows: both rows fed in phase, both rows fed out of phase, lower row alone, or upper row alone. A taper of 8 db in the illumination is used to provide acceptable side lobes.

The positionable antenna is similar to the fixed antenna, with the exception that it consists of only two elements placed side by side. Also, the antenna is rotatable to allow complete choice of azimuth selection without the need for phase shifting. Both antennas operate over the range 13.5 to 27 Mc. Details of the construction and feed system will be found in Ref. 3.

ANTENNA PATTERNS

Azimuth (horizontal) patterns, Figs. 4 through 9, of the fixed antenna were made from the 1/33 scale model. The envelope of the vertical coverage diagrams, Figs. 10 through 18, for both antennas was also obtained from the scale models; however, the lobe

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Table 1
Summary of Fixed Antenna Lobes and Beamwidths

Operating Frequency (Mc)	Test Frequency (Mc)	Angle of Beam (degrees from broadside)	First Sidelobe (db below main lobe)	Secondary Sidelobes		Backlobe* (db below main lobe)	Half-Power Beamwidth (degrees)
				(db below main lobe)	Angle from main lobe (degrees)		
27	900	0	16	-	-	30	8
27	900	+30	17	6	-72	30	8.3
21	700	0	21	-	-	30	9.5
21	700	+30	21	14.7	-106	30	11
13.5	450	0	20	-	-	19.5	13.5
13.5	450	+30	14	14.7	-50	18	14

*Backlobes are defined as angles greater than ± 90 degrees in azimuth from the direction of the main lobe and not more than 40 degrees above the horizon.

structure due to surface reflection has been calculated using the antenna heights indicated in Fig. 1. Azimuth patterns of the positionable antenna for both the model and the full size antenna are given in Figs. 16-18.

All elevations are given in feet above mean sea level. Furthermore, the data being collected with the completed system are beginning to confirm these patterns (2). The Bendix measurements indicate that the horizontal plane patterns are actually slightly narrower and the side lobes lower than those on the model.

A summary of fixed antenna azimuth pattern lobes is given in Table 1. In this table a secondary lobe, one that develops as a result of steering, is distinguished from the normal sidelobes. In addition, the positionable vertical antenna-lobe data have been tabulated in Table 2.

ANTENNA GAIN

The gain of the two antennas, given in Table 3, is free-space gain and does not take into account the 3-db gain realized from surface reflection.

The gain figures for the element were obtained from the model measurement; all others have been computed. Gain measurements of the full scale antennas have not been completed due to the high cost and difficulty involved.

Beam steering of the fixed antenna is accompanied by degradation of the pattern and power losses in the feeder system. The extent of these losses is given in Figs. 19 through 22.

CONCLUSIONS

The data presented are sufficient to allow computation of the radar system performance under most conditions. There will probably always be some uncertainty in the

Table 2
Elevation Angles of Lobes and Nulls of the Positionable Antenna*

Lobe	Null	n	Elevation Angle at Given Frequency (degrees)					
			13.5 Mc		19.6 Mc		27 Mc	
			h_E	h_W	h_E	h_W	h_E	h_W
1	1	1	3.3	5.0	2.3	3.4	1.66	2.5
		2	6.6	9.9	4.6	6.9	3.3	5.0
2	2	3	9.9	14.9	6.8	10.3	5.0	7.5
		4	13.3	19.9	9.1	13.7	6.6	10.0
3	3	5	16.5	24.9	11.4	17.2	8.3	12.4
		6	19.9	29.8	13.7	20.6	9.9	14.9
4	4	7	23.2	34.8	16.0	24.0	11.6	17.4
		8	26.5	39.8	18.2	27.4	13.2	19.9
5	5	9	29.8	44.8	20.5	30.8	14.9	22.4
		10	33.1	-	22.8	34.3	16.6	24.9
6	6	11	36.4	-	25.1	37.7	18.2	27.4
		12	39.7	-	27.4	41.1	19.9	29.8
7	7	13	43.0	-	29.7	-	21.6	32.3
		14	-	-	32.0	-	23.2	34.8
8	8	15	-	-	34.2	-	24.8	37.3
		16	-	-	-	-	26.5	-
9		17	-	-	-	-	28.2	-

*Elevation angle in degrees = $14100 n/hf$, where h_E = height of 315.5 ft, h_W = height of 210 ft, and f is the frequency in megacycles.

Table 3
Antenna Gain Relative to an Isotropic Radiator (One Way)

Frequency	Gain (db)		
	Positionable	Fixed*	Per Element
13.5	10.2	19.4	9.4
21	12.6	20.9	10.9
27	15.1	23.2	13.2

*These figures are for boresight (beam direction normal to the array); at other steering angles the gain will be reduced by the amount shown in Figs. 18 through 21.

coverage pattern when the ground-reflection area is partly over water and partly over land (with the added possibility of widely different elevations). In the event that highly accurate performance figures are desired, it would be necessary to conduct further gain measurements.

ACKNOWLEDGMENT

The antenna scale model measurements and gain calculations were made by the Radio Corporation of America, Moorestown Missile and Surface Radar Division under the direction of Aaron Leder, A. J. Sietz, Walter Warren, and N. Artuso. The full-scale airborne pattern checks were made by Bendix Radio under the supervision of E. Grempler.

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1. Georgallis, P.C., "AN/ASM-13 Pattern Measurements of the Madre Antenna," Bendix Report on Contract Nonr 3169(00)(X) (Confidential), Jan. 1962
2. Headrick, J.M., Curley, S.R., Thorp, M.E., Ahearn, J.L., Utley, F.H., Headrick, W.C., and Rohlf, D.C., "Madre Evaluation Report III," NRL Memorandum Report 1316 (Secret Report, Unclassified Title), Feb. 1, 1962
3. Boyd, F.E., and Rohlf, D.C., NRL Report 5903 (Secret Report)

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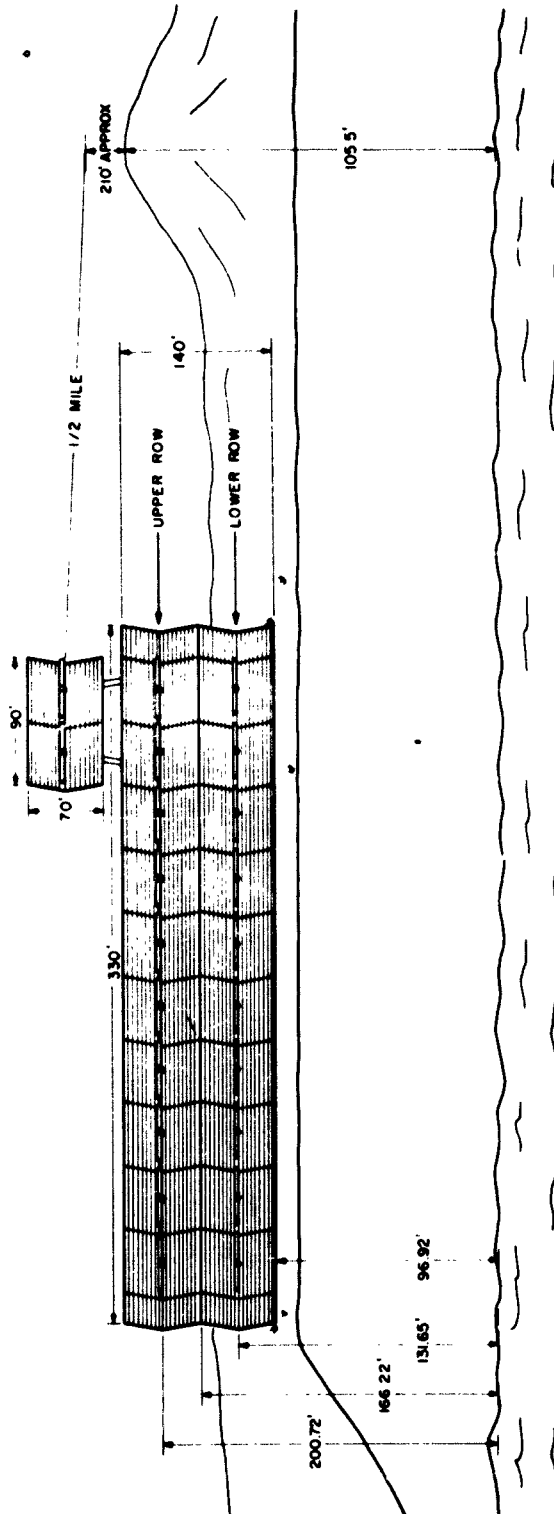


Fig. 1 - Dimensions and elevations of the antennas. All elevations are given in feet above mean sea level. Tides are insignificant compared to the wavelengths involved. The 105.5-foot elevation depicted to the rear of the antennas is an estimated average.

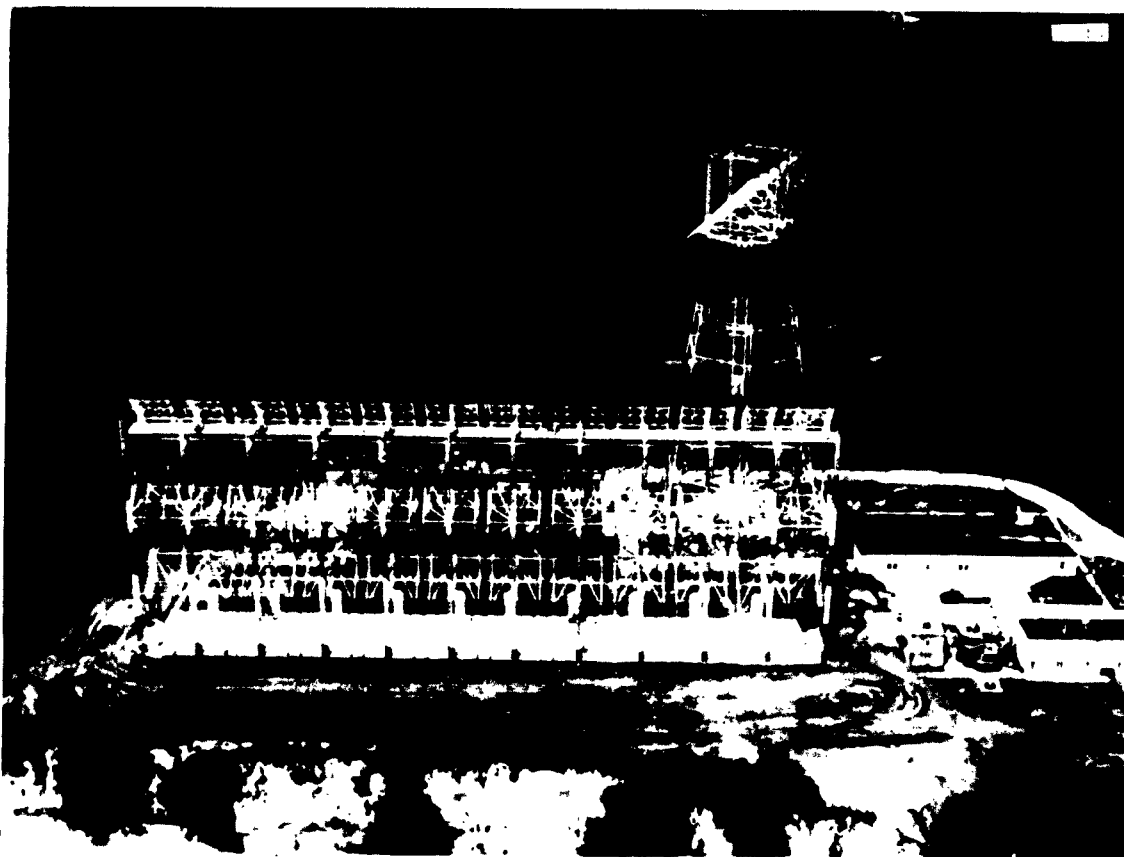


FIG. 2 - Front view of the antennas. The positionable antenna is on a 180-foot tower behind the fixed antenna.

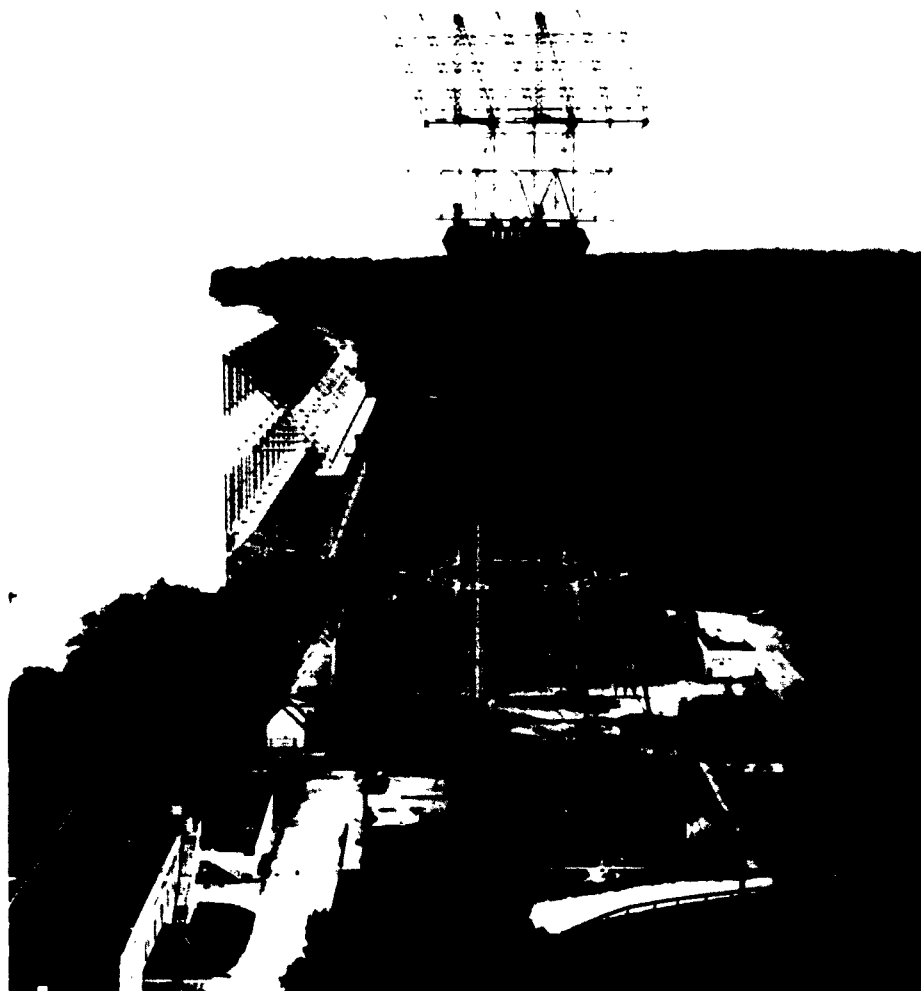


Fig. 3 - Side view of the antennas

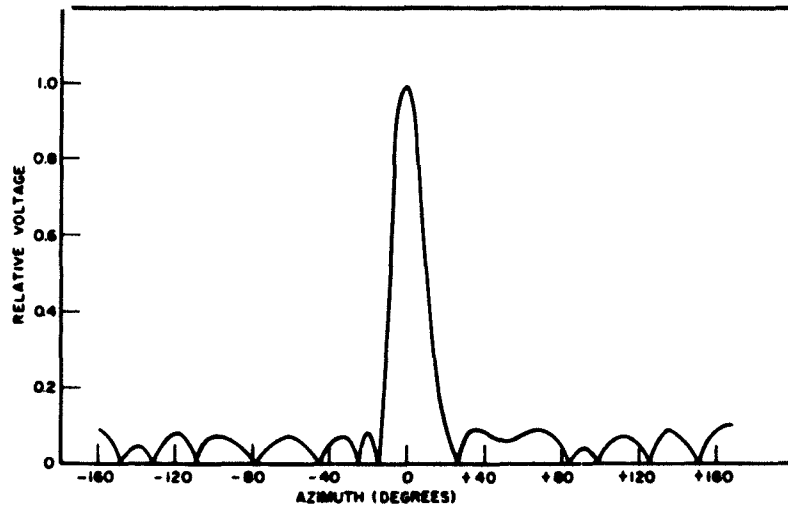


Fig. 4 - Horizontal pattern of the fixed antenna, 13.5 Mc,
zero degrees

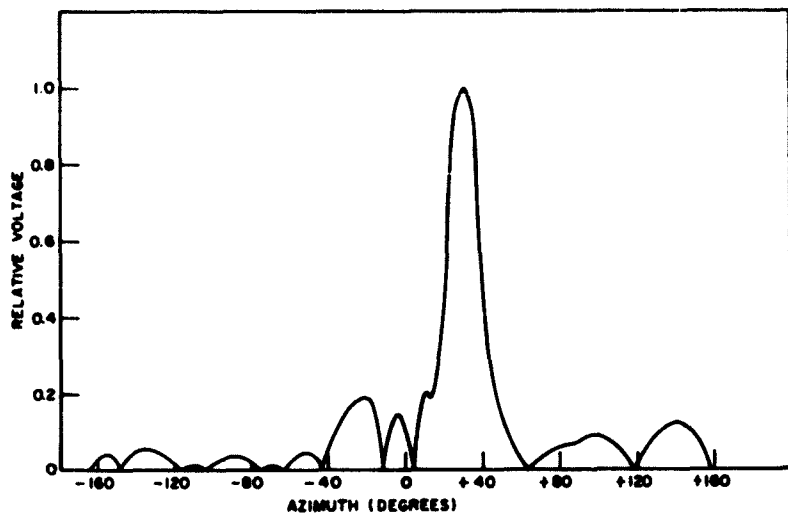


Fig. 5 - Horizontal pattern of the fixed antenna, 13.5 Mc,
30 degrees

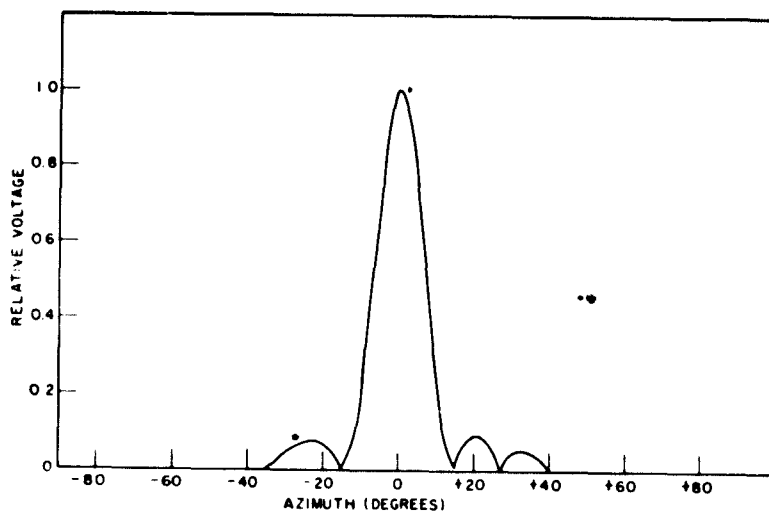


Fig. 6 - Horizontal pattern of the fixed antenna,
21 Mc, zero degrees

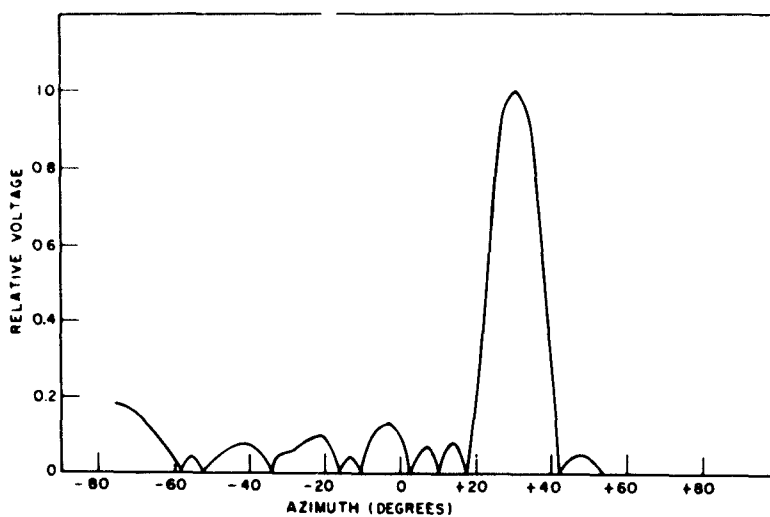


Fig. 7 - Horizontal pattern of the fixed antenna,
21 Mc, 30 degrees

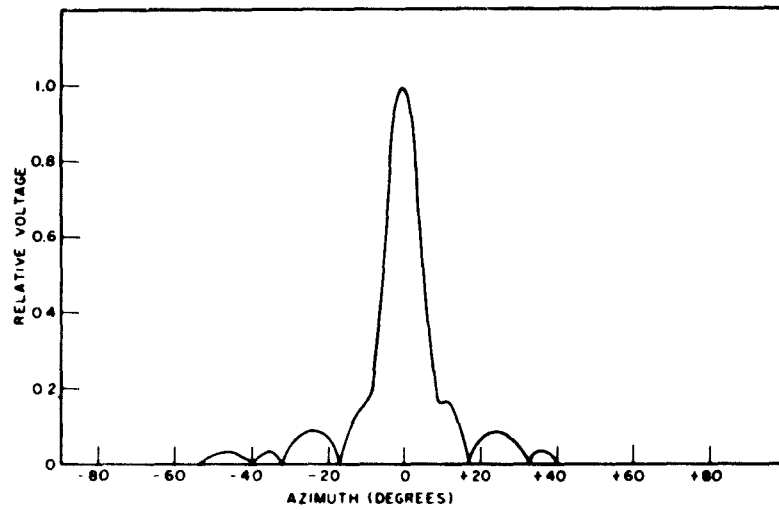


Fig. 8 - Horizontal pattern of the fixed antenna,
27 Mc, zero degrees

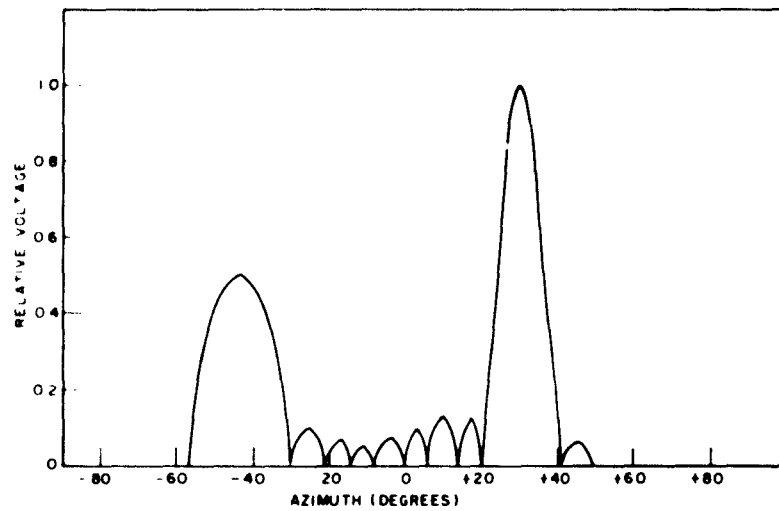


Fig. 9 - Horizontal pattern of the fixed antenna,
27 Mc, 30 degrees

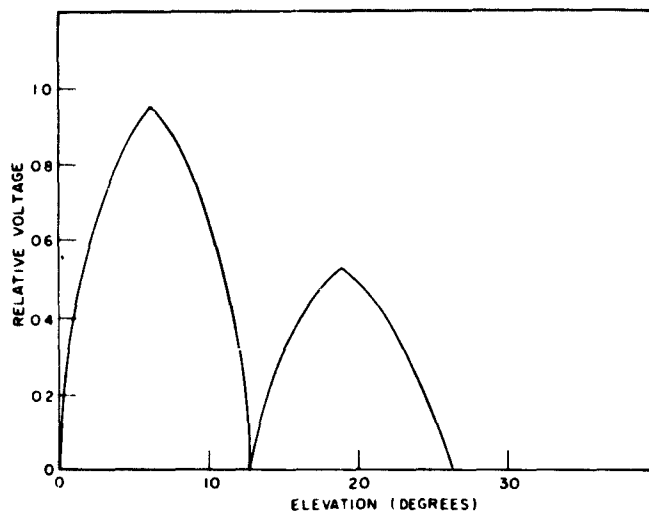


Fig. 10 - Vertical pattern of the fixed antenna,
13.5 Mc, in-phase rows

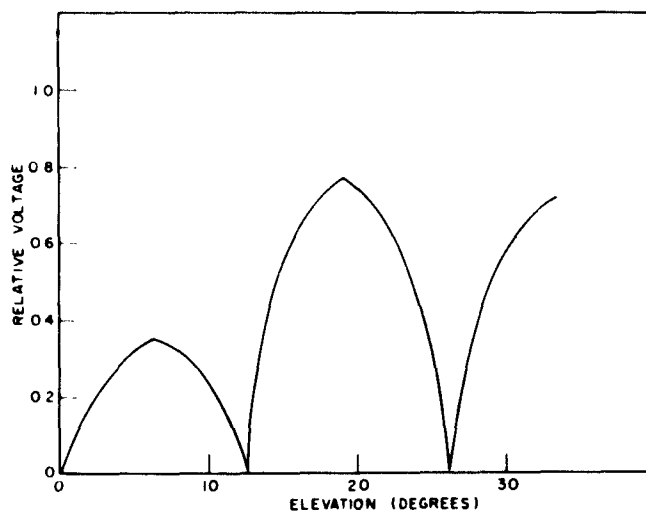


Fig. 11 - Vertical pattern of the fixed antenna,
13.5 Mc, anti-phase rows

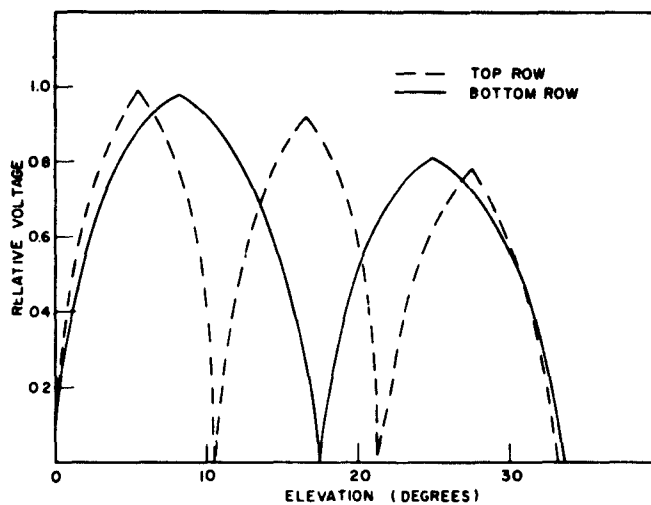


Fig. 12 - Vertical pattern of the fixed antenna,
13.5 Mc, single row

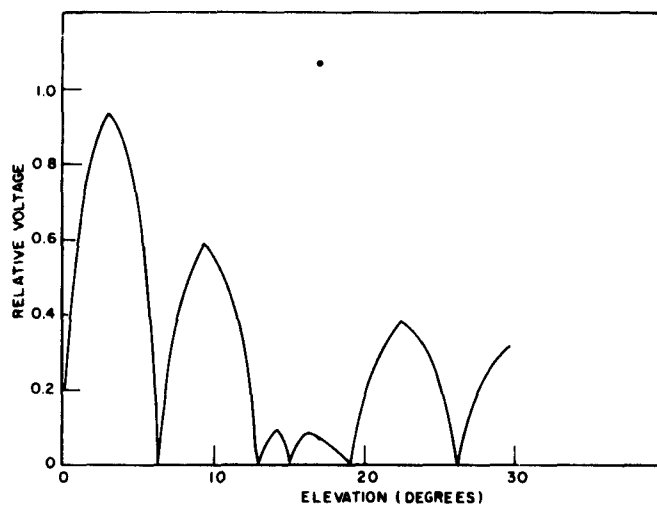


Fig. 13 - Vertical pattern of the fixed antenna,
27 Mc, in-phase rows

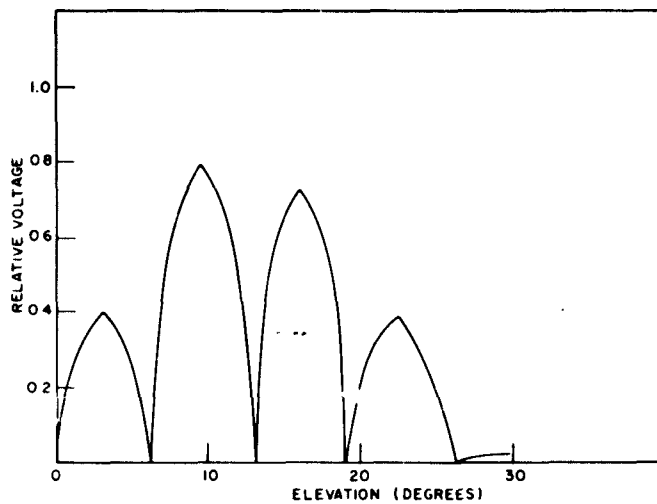


Fig. 14 - Vertical pattern of the fixed antenna,
27 Mc, anti-phase rows

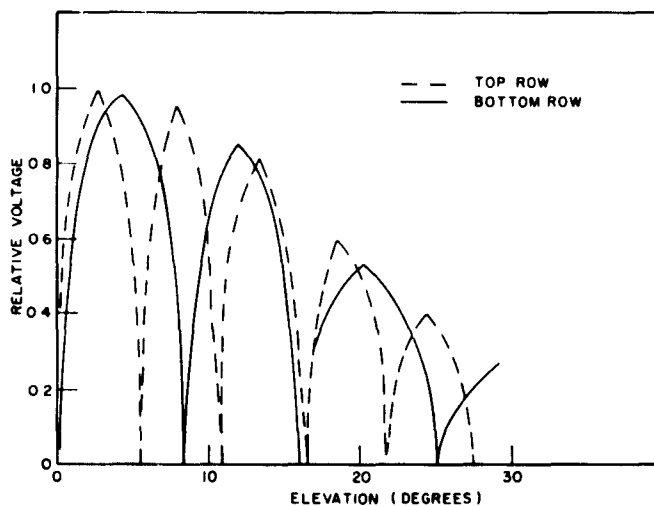


Fig. 15 - Vertical pattern of the fixed antenna,
27 Mc, single row

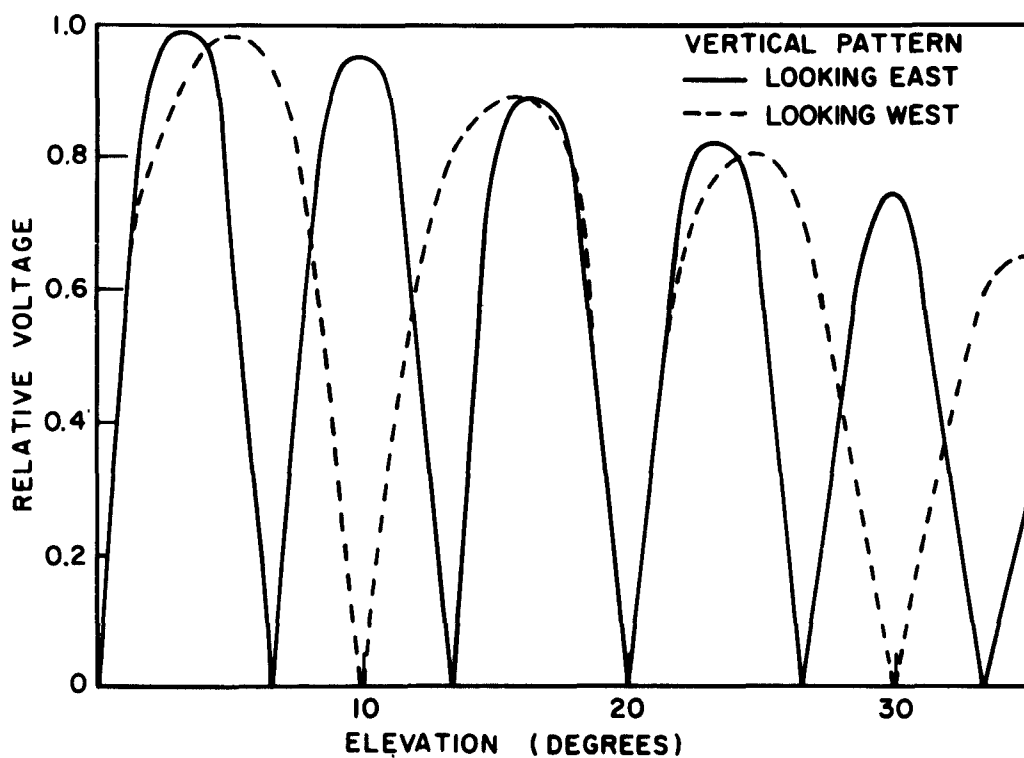
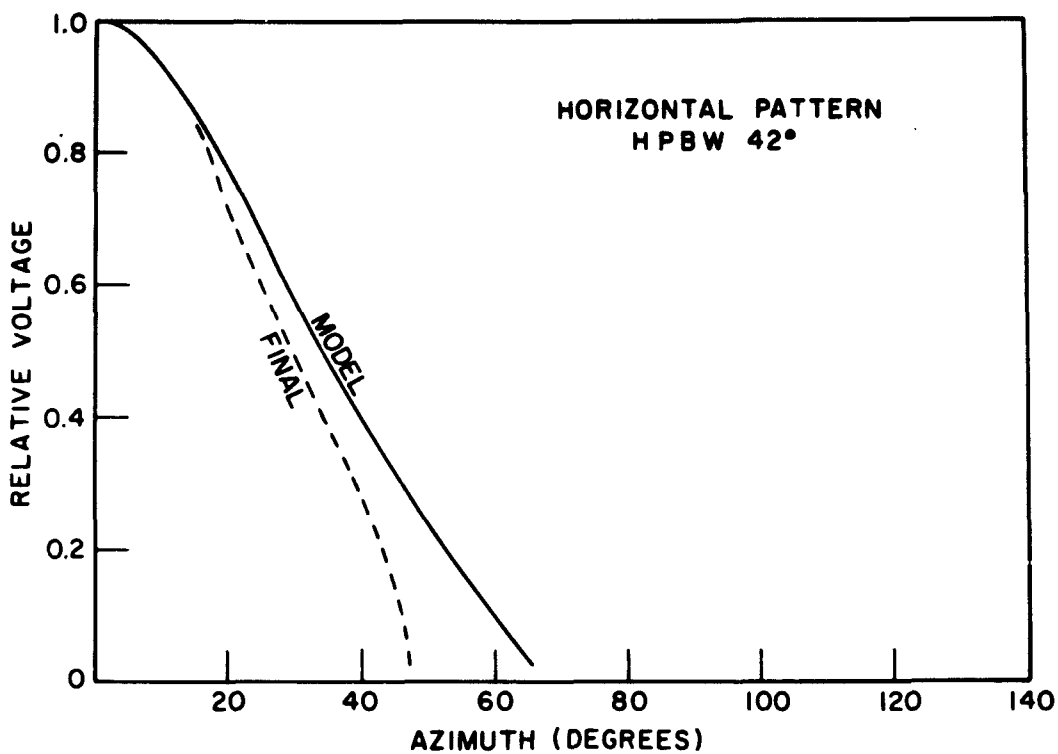


Fig. 16 - Patterns of the positionable antenna at 13.5 Mc

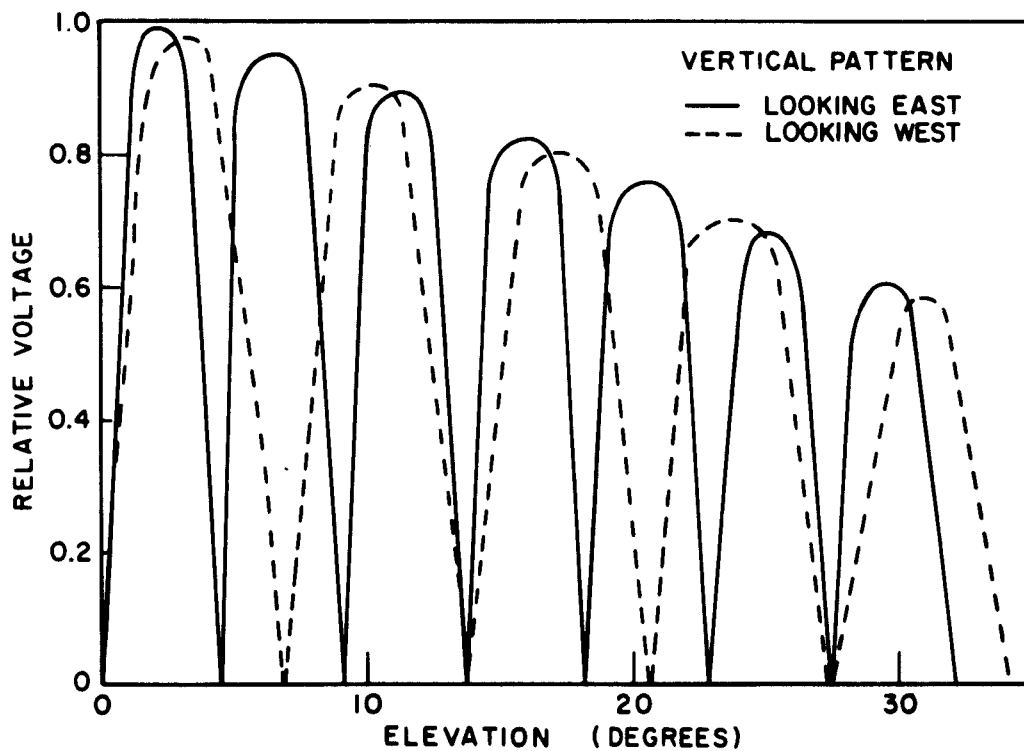
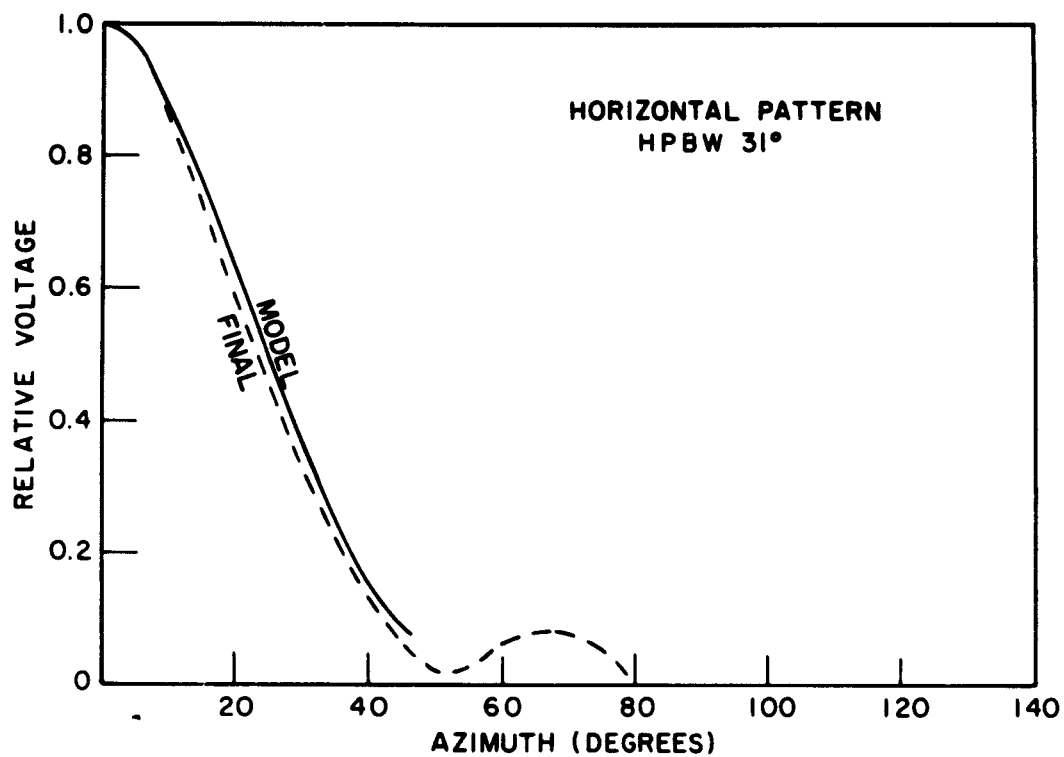


Fig. 17 - Patterns of the positionable antenna at 19.6 Mc

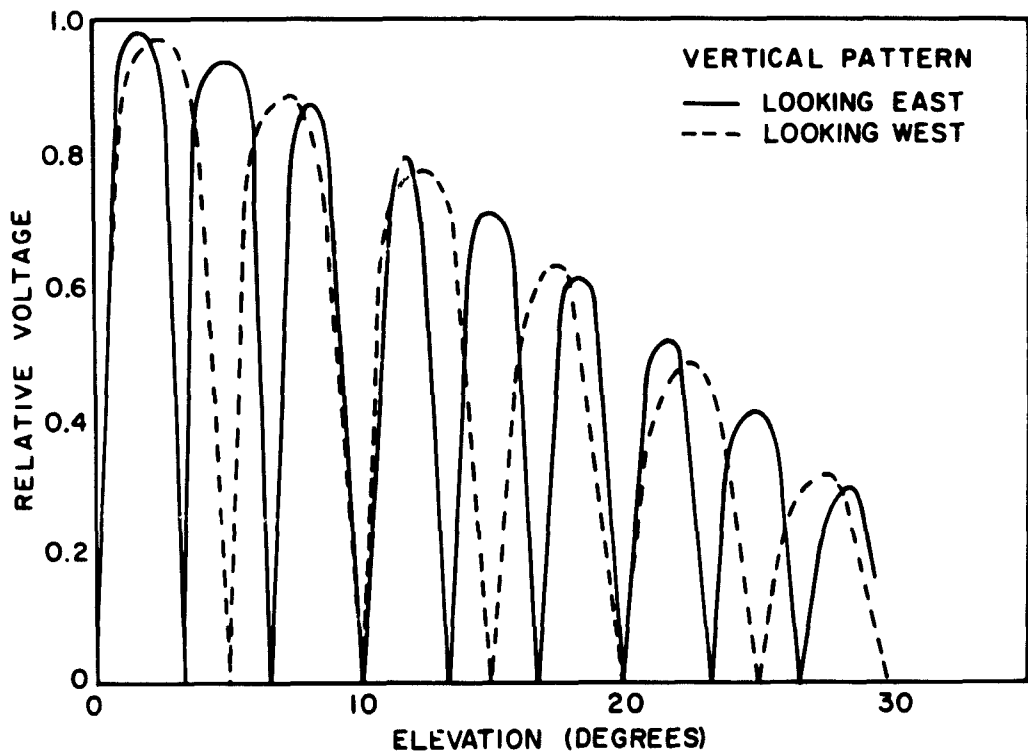
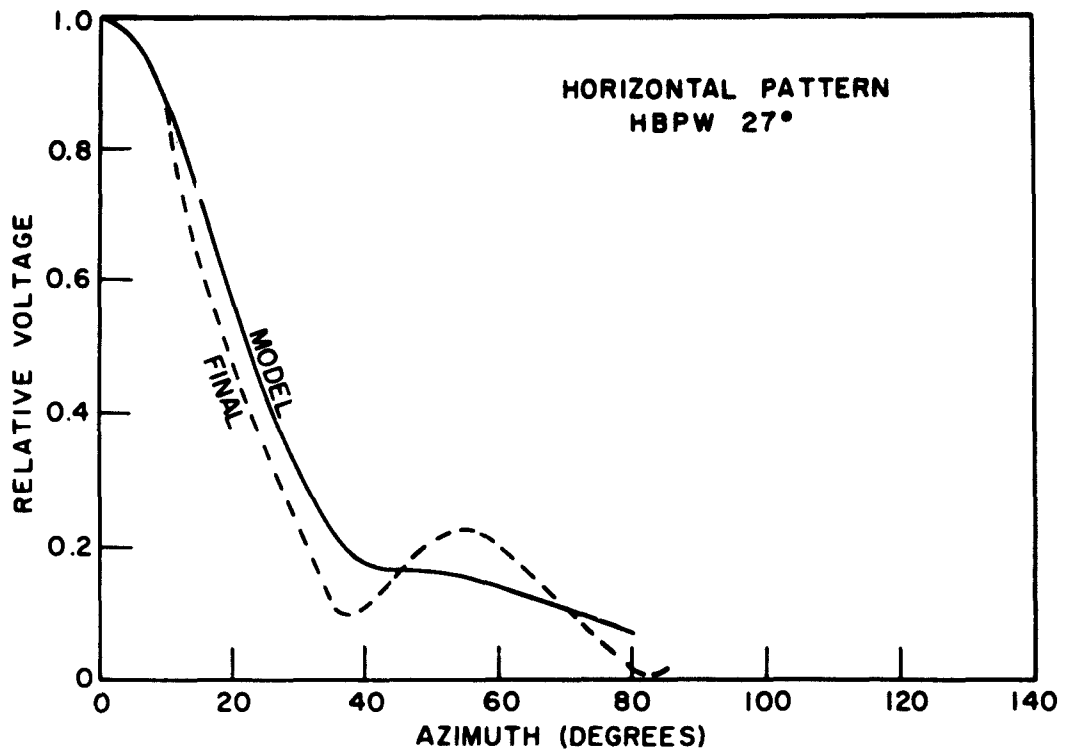


Fig. 18 - Patterns of the positionable antenna at 27 Mc

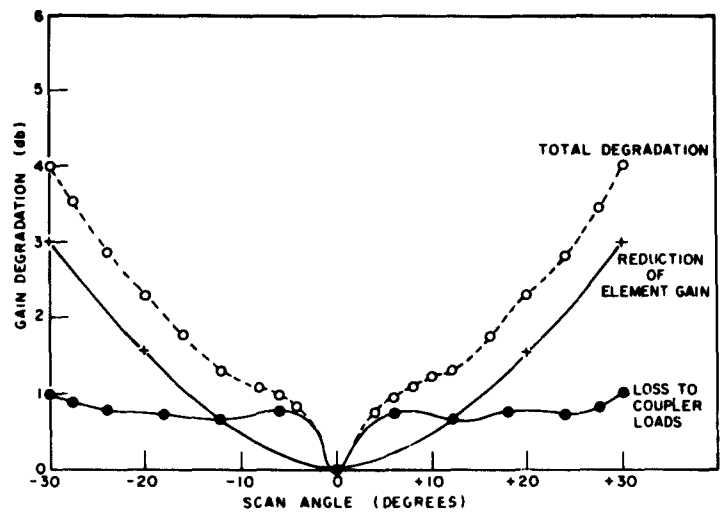


Fig. 19 - Losses of the fixed antenna due to beam steering at 13.68 Mc

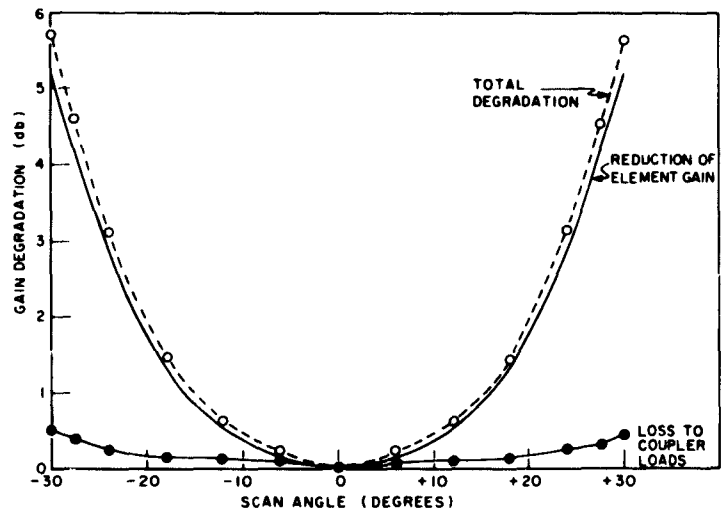


Fig. 20 - Losses of the fixed antenna due to beam steering at 18.036 Mc

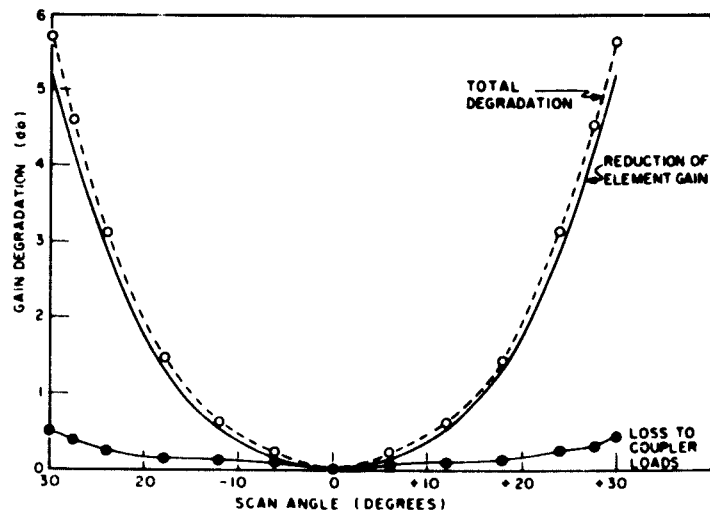


Fig. 21 - Losses of the fixed antenna due to beam steering at 23.10 Mc

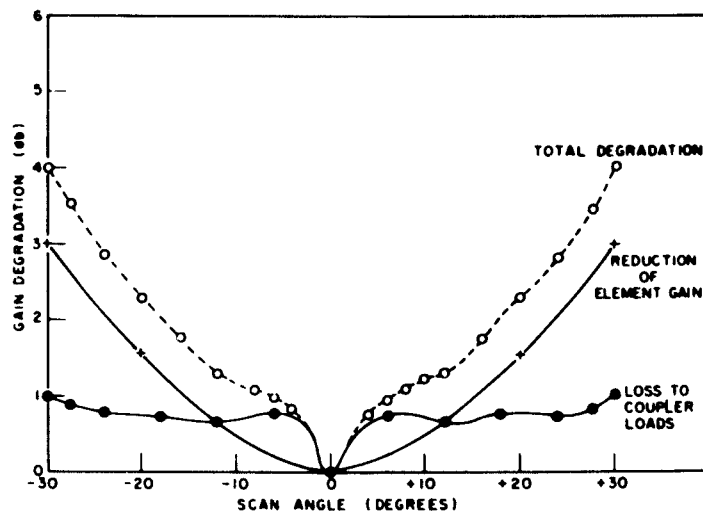


Fig. 22 - Losses of the fixed antenna due to beam steering at 26.6 Mc

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Formal: 5589, 5811, 5824, 5825, 5849, 5862, 5875, 5881, 5903, 5962, 6015, 6079, 6148, 6198, 6272, 6371, 6476, 6479, 6485, 6507, 6508, 6568, 6590, 6611, 6731, 6866, 7044, 7051, 7059, 7350, 7428, 7500, 7638, 7655. Add 7684, 7692.

Memo: 1251, 1287, 1316, 1422, [REDACTED], 1500, 1527, 1537, 1540, 1567, 1637, 1647, 1727, 1758, 1787, 1789, 1790, 1811, 1817, 1823, 1885, 1939, 1981, 2135, 2624, 2701, 2645, 2721, 2722, 2723, 2766. Add 2265, 2715.

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