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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

A SPLIT-BEAM PARABOLIC ANTENNA FOR THE BI-STATIC DOPPLER DETECTION SYSTEM

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ABSTRACT

An antenna designed and constructed for the bi-static Doppler detection system, with an asymmetrical split beam operating at 500 megacycles per second, is described. Radiation patterns are given.

A SPLIT-BEAM PARABOLIC ANTENNA FOR THE BI-STATIC-DOPPLER DETECTION SYSTEM

- F.V. Cairns -

INTRODUCTION

The design and construction of a 500 megacycle per second, split-beam antenna was undertaken in May, 1954, as a "crash project" to provide the Defence Research Telecommunications Establishment with an antenna suitable for making tests on the Doppler detection system during the summer of 1954. Information available at that time indicated that the ideal patterns in the horizontal and vertical planes were those shown in Figs. 1 and 2. Horizontal polarization was required, and it was desirable that the centers of radiation of the two beams should be separated by less than a wavelength. The antenna was needed by July 1, 1954; consequently speed in construction was more important than refinement of the design for optimum performance.

DESIGN

A doubly curved reflector with electromagnetic horn feed was chosen as the most suitable type of antenna. It was felt that this offered the best chance of providing an antenna which would meet the requirements approximately, in the time available. This type of antenna was selected partly because the Radio and Electrical Engineering Division had had previous experience in the design and construction of this type of antenna. In addition, a design for suitable waveguide-to-coaxial transitions was immediately available.

It was apparent that there was conflict between the horizontal radiation pattern requirement and a tolerable physical size for the application contemplated. It was therefore agreed with DRTE that the horizontal aperture should be 20 feet, and the ideal horizontal pattern should be approximated as closely as practicable with this aperture. A height of 8 feet was considered adequate to produce the required vertical pattern.

The reflector was designed using the technique developed by Chu[1] and Dunbar[2]. The design had to be modified, however, to produce the asymmetrical split beam.

A 20" x 48" aperture was chosen for the feed horns. The radiation patterns were measured on an X-band model at 8050 megacycles per second (see Fig. 3(a) and 3(b)), and the center-section vertical rib was computed on the basis of the measured H-plane pattern of the model horn. The horizontal sections were calculated as two half-parabolic sections with foci separated by 11 inches, instead of the usual parabolic sections. The centers of the horns were separated by 21 inches, and each horn illuminated 16 feet of the 20-foot horizontal aperture to the -10 db level. The horns were inclined 5° in the horizontal plane to achieve this.

Since the centers of the horns are separated by 21 inches, and the foci by only 11 inches, each horn feeds half the reflector 5.5 inches from its focus, and the other half 11 inches from its focus. It was expected that this would produce two beams separated by 6° with considerable asymmetry. No attempt was made to compute this pattern in detail, but it was estimated that the half-power beamwidth should be approximately 8°, and the side-lobe level -20 decibels, assuming each horn illuminated 16 feet of the aperture according to the previously measured pattern of Fig. 3(a).

It was thought that there was considerable danger of aperture blocking and mutual coupling because of the relatively large size of the horns. According to principles of geometric optics used in the design, the horns do not intercept reflected energy from the reflector. However, geometric optics can give only approximate results when calculating the performance of a reflector 1.0λ x 5λ. Attempts to minimize aperture blocking and mutual coupling between the horns, and still meet other requirements, resulted in a reflector which was double-valued near the outer edges. This area is relatively lightly illuminated and it was thought that the removal of this portion would have little effect on the performance of the antenna.

The mechanical design was based on the need for rapid construction. Vertical ribs, as computed by the above procedure, were cut from plywood sheets and assembled in a wooden framework with metal rods and spacers to provide stiffening. The surface was covered with 1/4-inch mesh wire screen. Fig. 4 is a photograph of the complete antenna mounted on the turntable for pattern measurements.

The detailed structure of the reflector is tabulated in Appendix I in the form of x and y co-ordinates for the 21 ribs.

MEASUREMENTS

It was found that the mutual coupling between horns was 35 decibels below unity, with the reflector absent. The coupling with the reflector present was not measured directly, but it was much greater than this. The effect on the radiation patterns was considerable. However, it was found that careful choice of the location of the short-circuits, required for switching the beam, in the transmission lines feeding the horns can make the effect on the radiation patterns negligible.

The measured radiation patterns in the horizontal and vertical planes are shown in Figs. 5 and 6. The radiation patterns for only one frequency are shown. There are no significant changes in either the vertical or horizontal patterns in the band of frequencies between 480 and 500 megacycles per second, provided the short-circuit is placed properly. The correct location of the short-circuit at different frequencies is given in Fig. 7.

The gain of the antenna was not measured accurately. However, the gain of the complete antenna was compared with that of the horn, and the gain of the horn calculated. This gave a power gain of 65 over an isotropic radiator.

CONCLUSIONS

The performance of the antenna, although it falls short of the ideal, seems to be satisfactory. There are, however, a number of ways in which it could be improved with further work.

The vertical pattern could probably be made to approach the ideal more closely by re-location of the feed horns. The determination of the proper location would require only the measurement of radiation patterns with the horns in different positions. This measurement is not feasible on the full-size antenna, but it could be done easily on a 1/6-scale model.

Some radiation patterns which were measured, but not reproduced here, indicate that the decision to illuminate only 16 feet of the aperture with each horn was too conservative. The horizontal aperture of the feed horns could be reduced, thus broadening the primary E-plane pattern so that each horn would illuminate the entire reflector. This should increase the gain slightly and also cause more asymmetry in the beams. Both of these changes would be beneficial.

It should be possible to eliminate the double-valued portion of the reflector. This, however, would require a complete re-design of the antenna and probably some experimental work with a scale model.

* * * * * * *

ACKNOWLEDGMENT

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REFERENCES

(1) L.J. Chu, "Microwave Beam-Shaping Antennas", Research Laboratory of Electronics, M.I.T., Report 40, June, 1947.

(2) A.S. Dunbar, "Calculation of Doubly-Curved Reflectors for Shaped Beams", Proc. I.R.E., Vol. 36, p. 1289, 1948.

APPENDIX I

DETAILS OF REFLECTOR SURFACE*

Curves A and B		Curve C		Curve D		Curve E	
y	x	y	x	y	x	y	x
96.00	11.65	96.00	12.10	96.00	13.45	96.00	15.60
93.00	10.65	93.00	11.10	92.85	12.40	92.70	14.50
87.60	9.10	87.60	9.55	87.50	10.85	87.40	13.00
82.25	7.70	82.25	8.20	82.20	9.50	82.15	11.65
76.90	6.60	76.90	7.10	76.90	8.40	76.90	10.55
71.55	5.75	71.55	6.20	71.60	7.55	71.70	9.70
65.95	5.15	66.00	5.60	66.10	6.95	66.30	9.15
60.94	4.80	61.00	5.25	61.15	6.60	61.45	8.80
55.70	4.70	55.76	5.15	56.00	6.50	56.40	8.70
50.50	4.90	50.60	5.35	50.90	6.65	51.40	8.90
45.34	5.30	45.45	7.80	45.85	7.10	46.45	9.30
40.30	6.00	40.45	6.50	40.90	7.80	41.65	9.95
35.30	7.00	35.50	7.45	36.05	8.75	36.95	10.90
30.40	8.35	30.65	8.80	31.40	10.05	32.55	12.10
25.70	10.13	26.05	10.55	27.00	11.70	28.55	13.60
21.25	12.50	21.70	12.85	22.95	13.80	25.05	15.45
17.10	15.55	17.65	15.80	19.25	16.55	21.90	17.75
13.34	19.15	14.00	19.30	15.85	19.80	18.95	20.60
9.95	23.05	10.65	23.15	12.75	23.40	16.15	23.80
6.90	27.16	7.70	27.20	9.95	27.25	13.60	27.30
4.31	31.45	5.10	31.40	7.45	31.30	11.30	31.05
2.00	35.73	2.85	35.65	5.25	35.40	9.25	34.95
0.00	40.00	0.85	39.85	3.35	39.35	7.45	38.55

* All dimensions given in Appendix I are in inches
See Fig. 8 for identification of curves.

Curve F		Curve G		Curve H		Curve I		Curve J		Curve K	
y	x	y	x	y	x	y	x	y	x	y	x
96.00	18.65	96.00	22.55	96.00	27.35	96.00	32.95	96.00	39.45	77.75	40.00
92.45	17.50	92.15	21.30	91.75	25.95	91.30	31.40	95.65	39.30	76.90	39.80
87.20	15.95	87.00	19.80	86.70	24.45	86.40	30.00	90.75	37.70	72.90	39.15
82.05	14.65	81.90	18.50	81.75	23.20	81.60	28.75	86.00	36.35	68.70	38.70
76.90	13.60	76.90	17.50	76.90	22.20	76.90	27.80	81.40	35.15	65.25	38.45
71.85	12.75	72.00	16.65	72.20	21.45	72.40	27.05	76.90	34.25	61.70	38.40
66.55	12.20	66.85	16.10	67.25	20.90	67.70	26.55	72.65	33.55	58.10	38.55
61.85	11.85	62.35	15.80	62.95	20.60	63.70	26.25	68.25	33.10	54.75	38.80
57.95	11.75	57.65	15.70	58.50	20.50	59.50	26.20	64.55	32.80	51.70	39.20
52.10	11.95	53.00	15.90	54.05	20.70	55.35	26.35	60.65	32.75	49.35	39.70
47.30	12.35	48.40	16.25	49.75	21.05	51.35	26.70	56.85	32.90	48.25	40.00
42.65	12.90	44.00	16.85	45.65	21.60	47.55	27.20	52.17	33.20		
38.25	13.85	39.90	17.70	41.90	22.35	44.25	27.85	47.80	33.65		
34.15	15.00	36.25	18.70	38.80	23.20	41.80	28.55	47.00	34.20		
30.70	16.30	33.45	19.75	36.85	23.90	40.85	28.85	45.25	34.65		
27.95	17.75	31.70	20.65	36.30	24.20						
25.60	19.50	30.30	21.70	36.05	24.40						
23.25	21.75	28.75	23.25	35.45	25.00						
20.90	24.40	27.02	25.20	34.45	26.15						
18.70	27.45	25.25	27.60	33.25	27.75						
16.65	30.75	23.55	30.35	31.95	29.90						
14.80	34.30	21.95	33.55	30.70	32.60						
13.15	37.45	20.45	36.00	29.40	34.30						

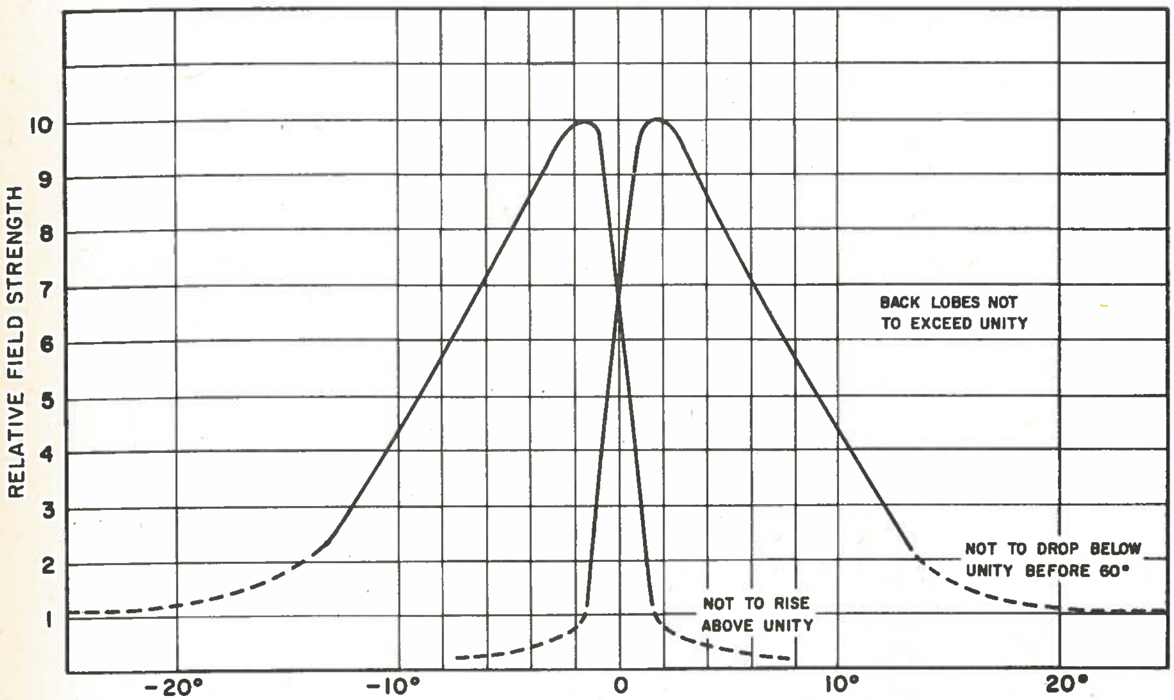

FIG. 1 — IDEAL HORIZONTAL PATTERN

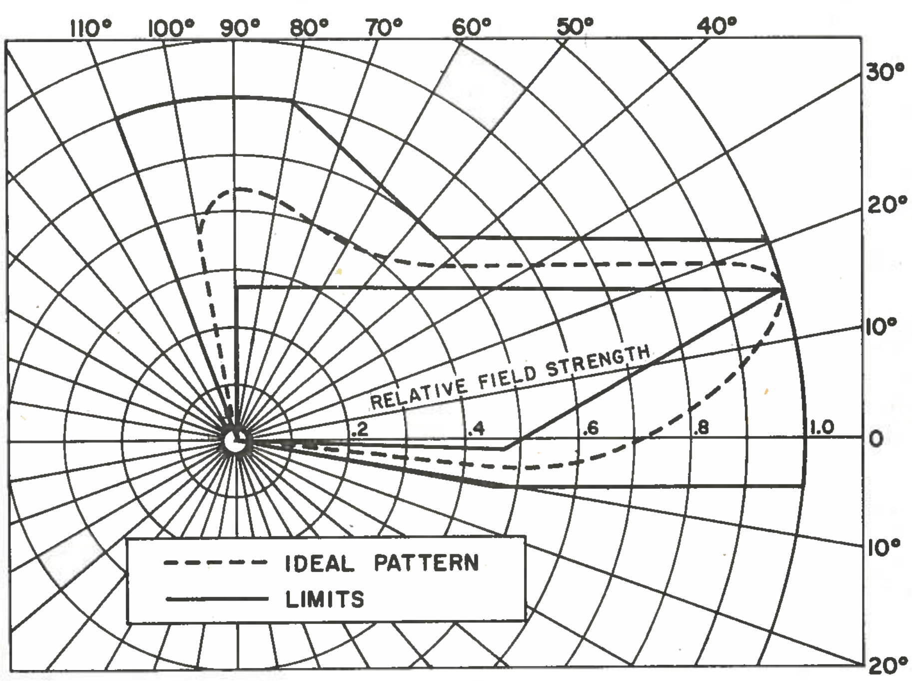

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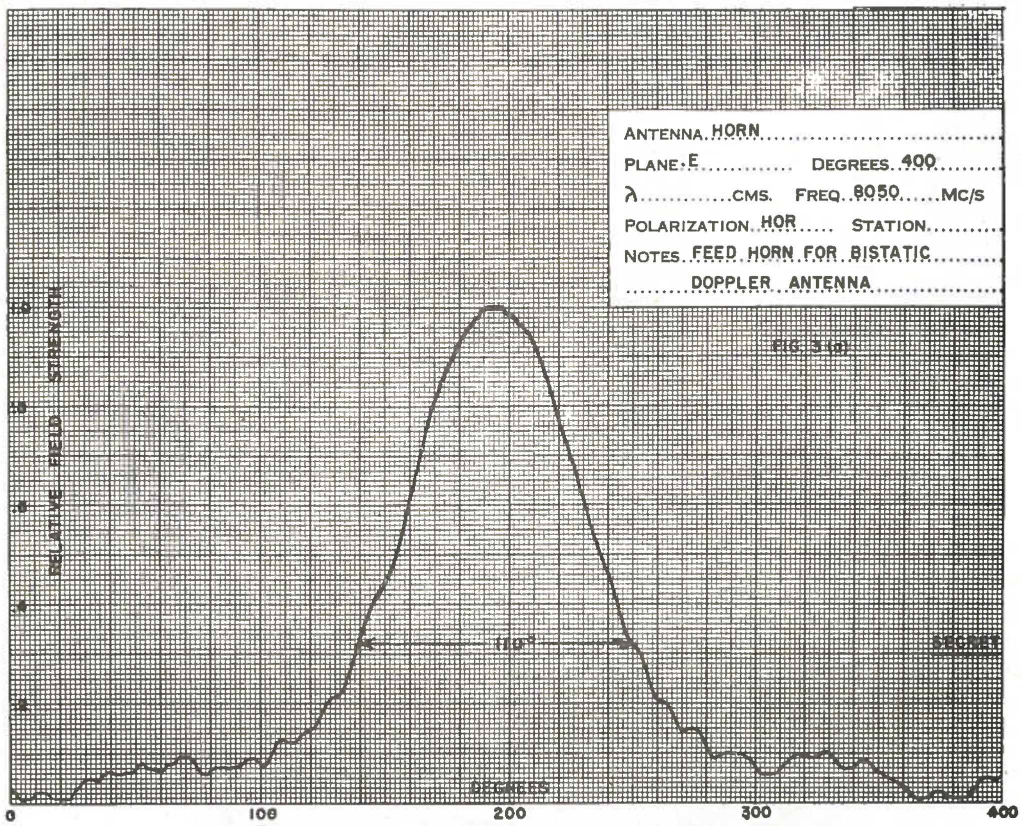
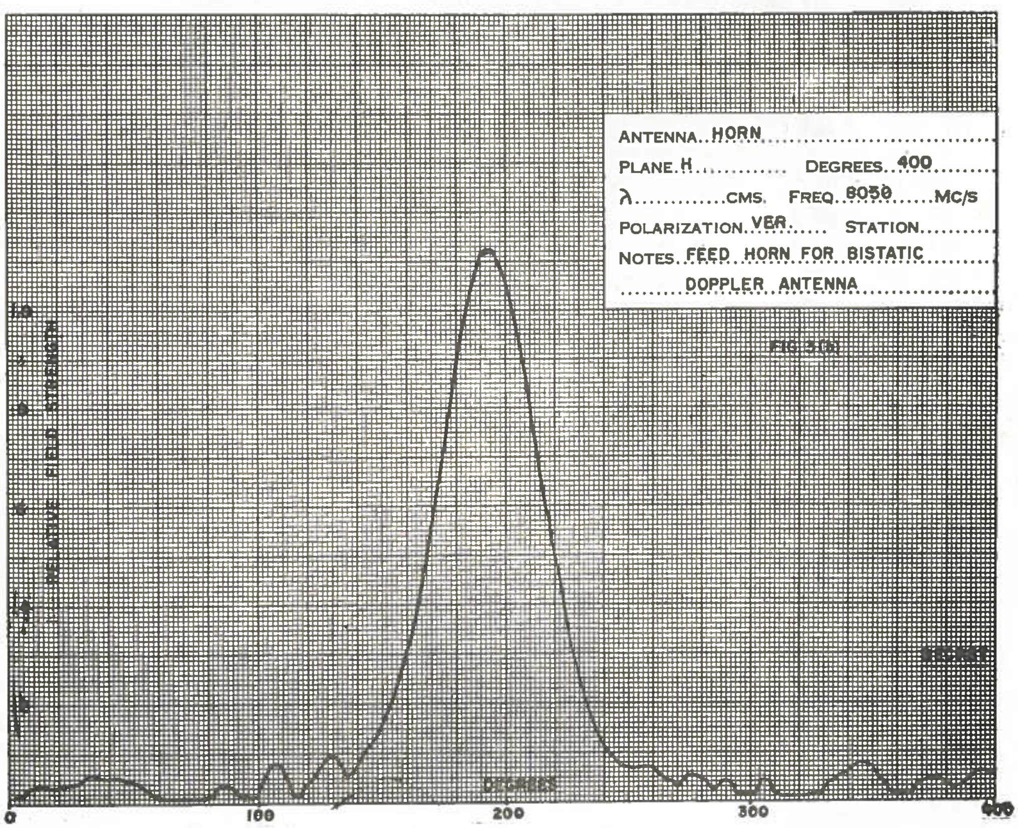
FIG. 2 — IDEAL VERTICAL PATTERN


ANTENNA HORN
PLANE E DEGREES 400
λ CMS. FREQ 8050 MC/S
POLARIZATION HOR STATION
NOTES FEED HORN FOR BISTATIC
DOPPLER ANTENNA
FIG. 3 (a)
RELATIVE FIELD STRENGTH
110°
SECRET
DEGREES
0
100
200
300
400


ANTENNA HORN
PLANE H DEGREES 400
λ CMS. FREQ 8050 MC/S
POLARIZATION VER. STATION
NOTES FEED HORN FOR BISTATIC
DOPPLER ANTENNA
FIG. 3(b)
RELATIVE FIELD STRENGTH
SECRET
DEGREES
0
100
200
300
400

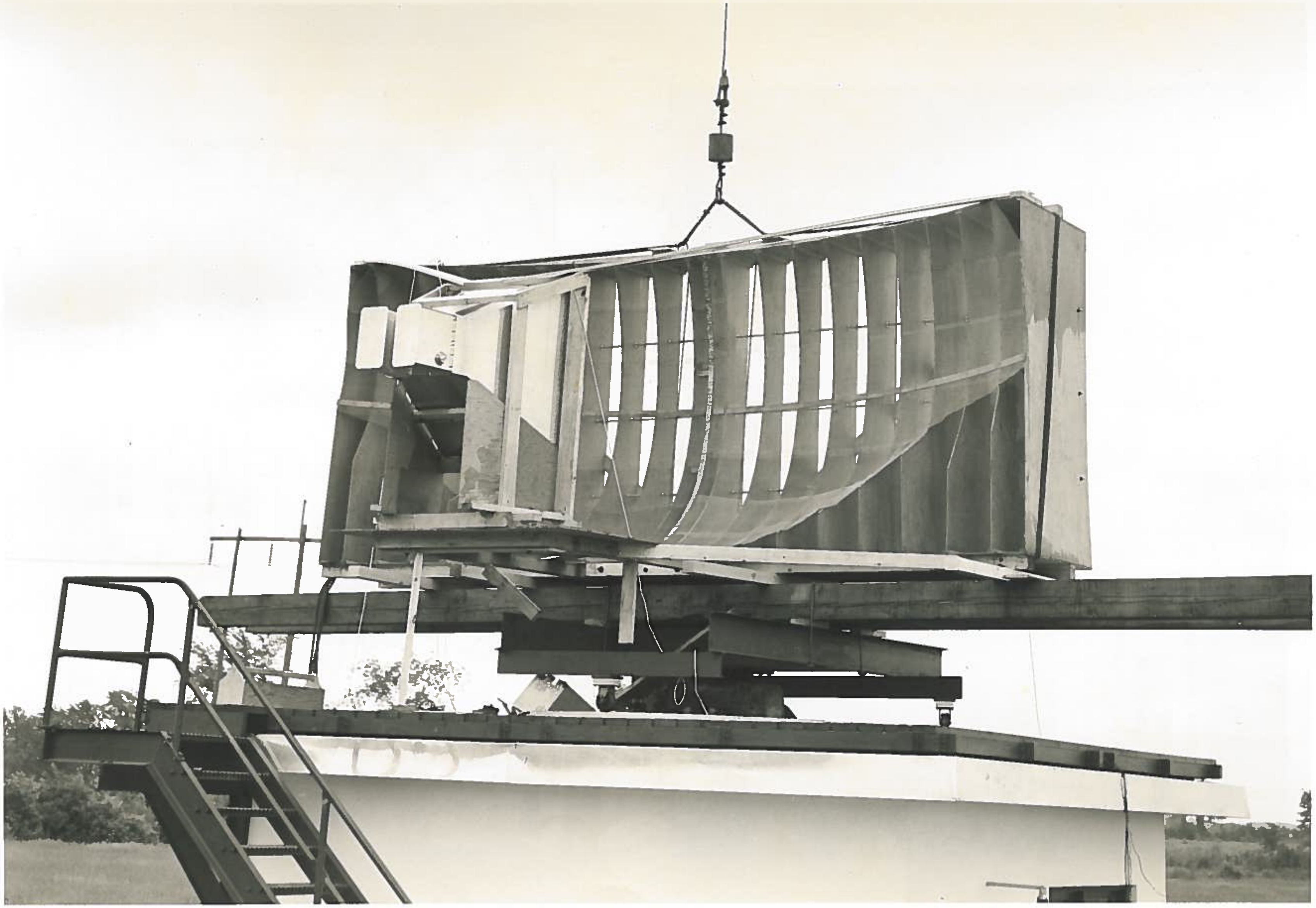


FIG. 4 SPLIT-BEAM PARABOLIC ANTENNA

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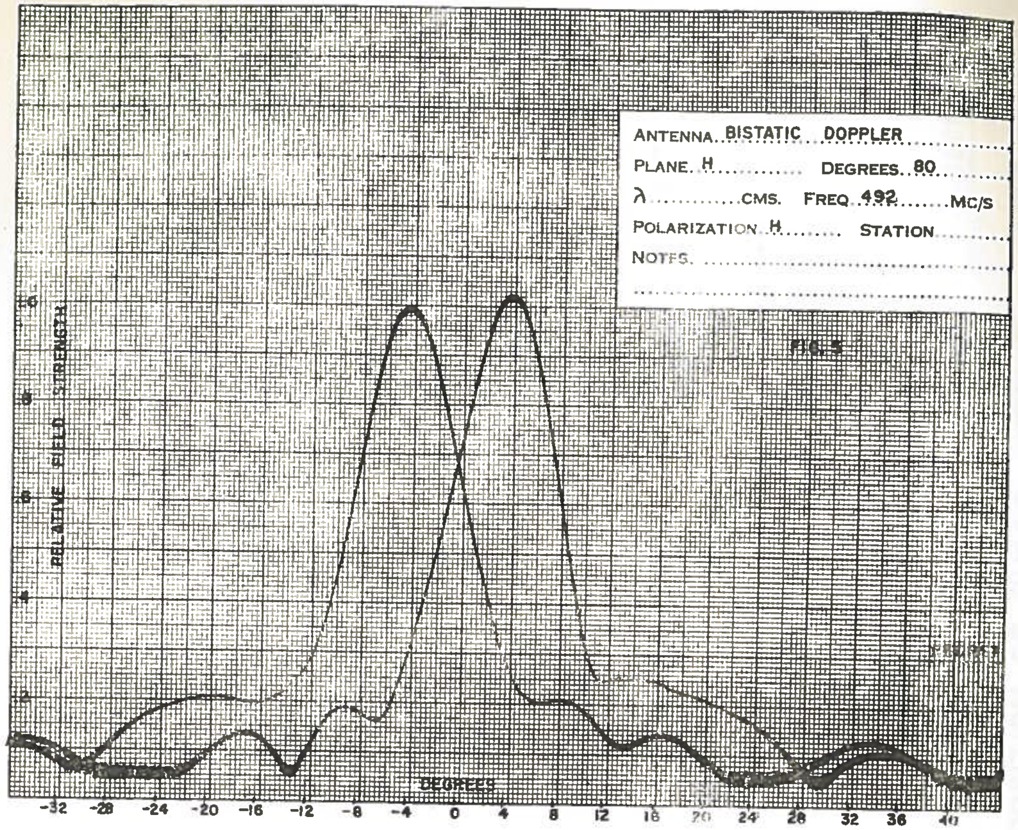

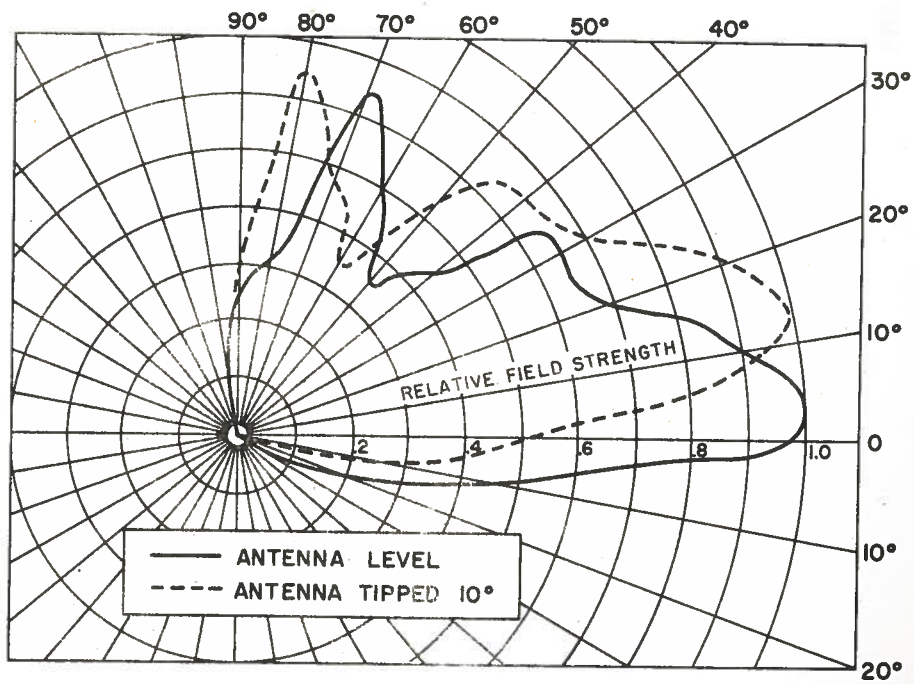

FIG 6 — VERTICAL PATTERN OF ANTENNA

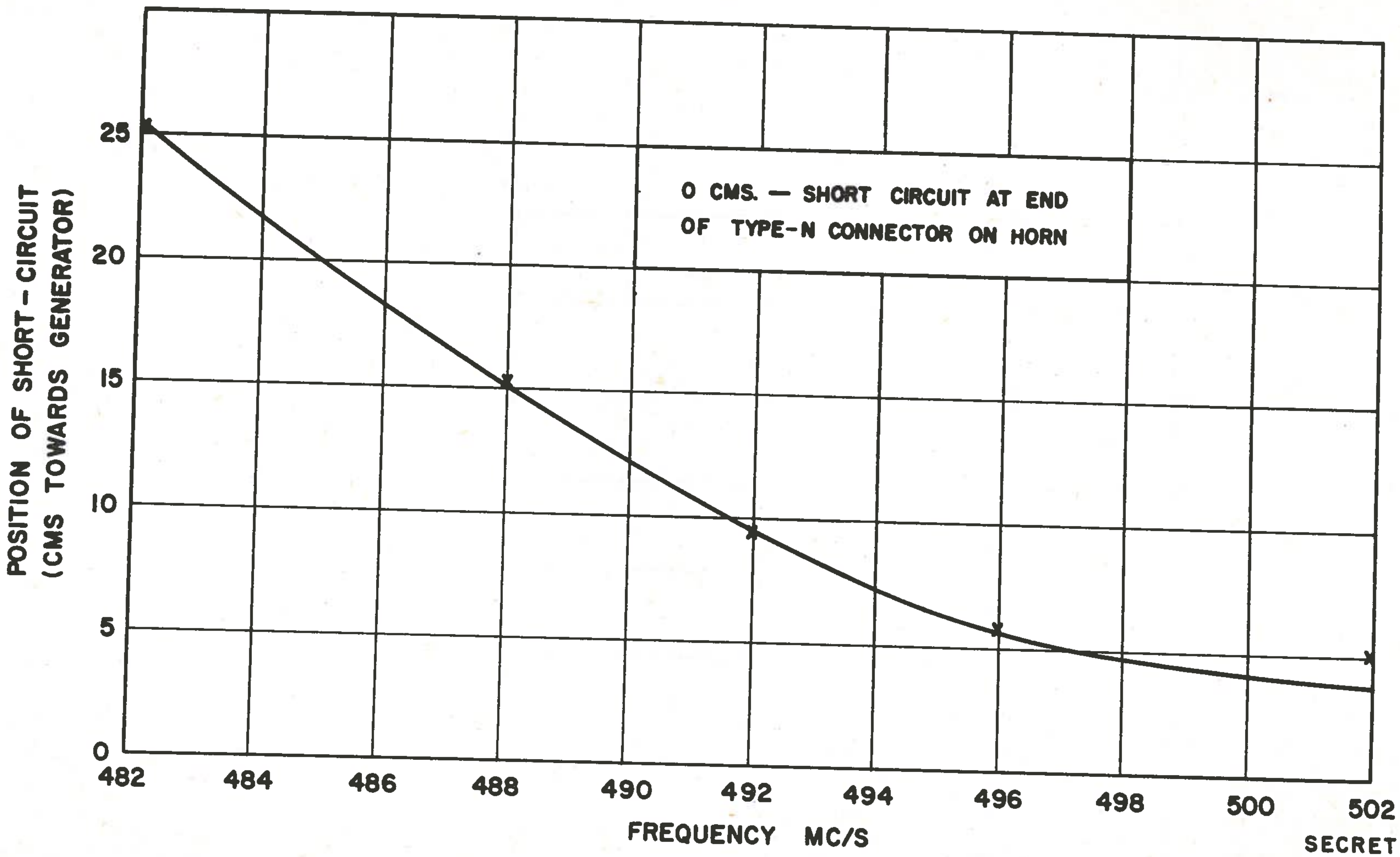

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FIG. 7 — CURVE SHOWING POSITION OF SHORT-CIRCUIT FOR BEST PERFORMANCE AT DIFFERENT FREQUENCIES

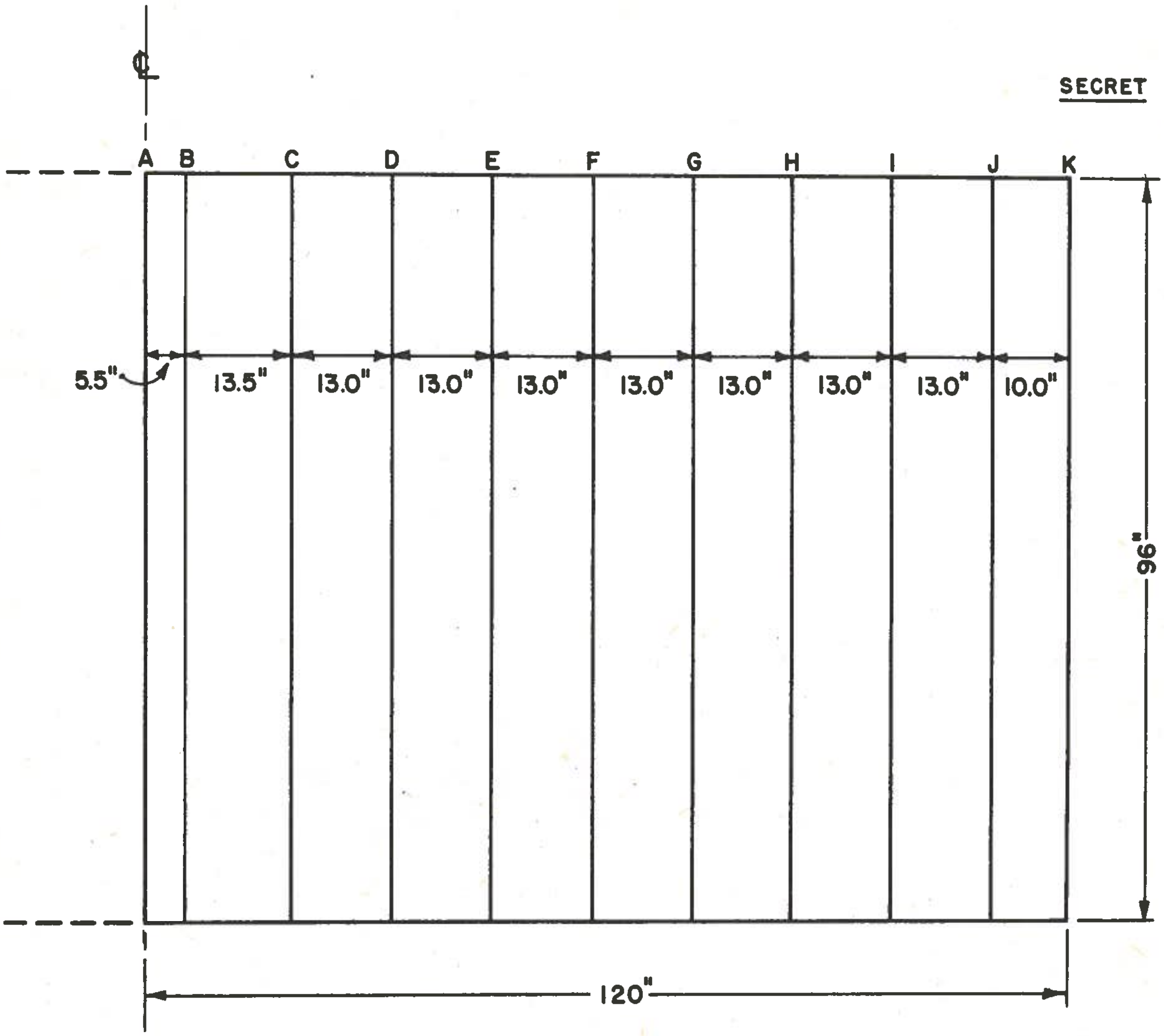

FIG. 8

IDENTIFICATION OF RIBS