Testing of the CAL prototype of the CB antenna for patterns, gain, and beam position

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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

TESTING OF THE CAL PROTOTYPE OF THE CB ANTENNA FOR PATTERNS, GAIN, AND BEAM POSITION

G. C. McCORMICK

OTTAWA

JULY 1957

ABSTRACT

Tests have been made on the antenna of the production prototype of the AN/MPQ-501 Counter Mortar Radar manufactured by Canadian Arsenals Limited. The tests were with respect to patterns, beam position over the scan cycle, and gain. Mean beamwidths were 0.87° in azimuth and 0.85° in elevation at the 3-db points, with side lobes varying from 5% at center of scan to 9% at the extreme scan positions. A wide angle lobe due to internal reflections within the scanner was noted, but its amplitude is less than 10%. The gain of the antenna is 45.9 db ± 0.3 db with respect to isotropic, indicating that the antenna efficiency is highly satisfactory. A small difference in rate of scan between high and low beam was noted. A comparison with the McGill University experimental model is made.

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TESTING OF THE CAL PROTOTYPE OF THE CB ANTENNA FOR PATTERNS, GAIN, AND BEAM POSITION

- G.C. McCormick -

1. INTRODUCTION

Testing of the antenna for the production prototype of the AN/MPQ-501 counter mortar radar manufactured by Canadian Arsenals Limited, was carried out during May and June, 1957. The tests were with respect to patterns, determination and calibration of beam position, and gain. VSWR data were obtained by CAL personnel at their plant in Toronto.

The antenna is a Foster scanner, the experimental model of which was designed at McGill University by J.S. Foster and W.M. Telford. Much of the fabrication and testing of this model was also done at McGill University. Pattern tests were carried out at the National Research Council; then there were modifications and further tests [1]. Two substantial alterations of the previous design have been incorporated in the present prototype. First, the region into which the slotted array radiates has been changed from a tapered region to a true parallel-plate region, and the slotted array has, accordingly, been redesigned [2]. Secondly, the barrier teeth have been replaced by a solid barrier-choke combination.

In conducting the tests the scanner was placed on the tiltable turntable at one of the NRC pattern ranges. The receiving antenna was a 4-foot paraboloid mounted on a 100-foot tower at a distance of 1200 feet. There was no evidence of ground reflections or other siting problems. The auxiliary apparatus included that in current use on the pattern ranges, modified to permit the taking of elevation patterns. Microwave components were standard commercial units.

2. PATTERNS

H-plane patterns over the frequency band of ± 1%, for each beam, at the center and extreme ends of scan are shown in Figs. 1 to 6. The beamwidth of the pattern at half-power varies from 0.84° to 0.90°, with a mean of 0.87°*. The mean side-lobe level is 5% at center of scan, increasing to 8% at 0° scan angle, and 9% at 22° scan angle.

E-plane patterns, giving the variation of the radiation field in elevation,

* On all original patterns for this report, ½" of recorder paper equals one main division.

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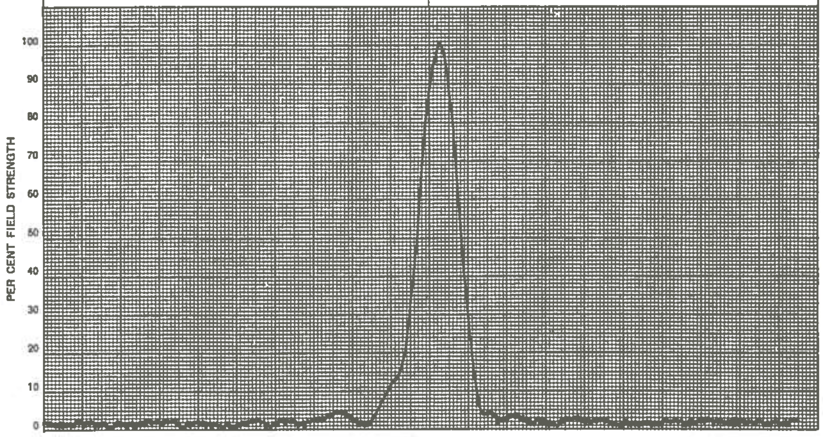
ANTENNA CB — CAL PROTOTYPE PATTERN IN PLANE OF H VECTOR FREQUENCY 15840 MC/S WAVELENGTH .... CMS ANGULAR SCALE: ½ INCH EQUALS 1° RANGE 1200' DATE 4 JUNE 57	ROTOR: 266° (LOW) SCAN ANGLE ≈ 0°



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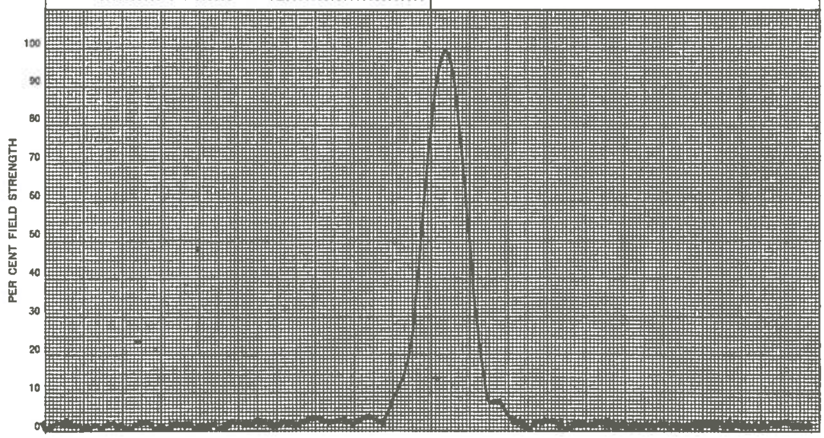
ANTENNA CB — CAL PROTOTYPE PATTERN IN PLANE OF H VECTOR FREQUENCY 15840 MC/S WAVELENGTH .... CMS ANGULAR SCALE: ½ INCH EQUALS 1° RANGE 1200' DATE 4 JUNE 57	ROTOR: 182.5° (LOW) SCAN ANGLE ≈ 11°



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ANTENNA CB — CAL PROTOTYPE PATTERN IN PLANE OF H VECTOR FREQUENCY 15840 MC/S WAVELENGTH .... CMS ANGULAR SCALE: ½ INCH EQUALS 1° RANGE 1200' DATE 4 JUNE 57	ROTOR: 102° (LOW) SCAN ANGLE ≈ 22°

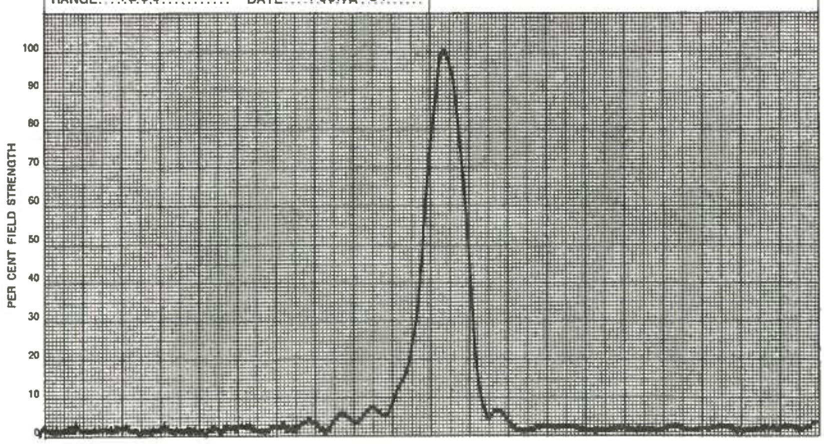


FIG. 1 AZIMUTH PATTERNS, LOW BEAM, 15,840 MC/S

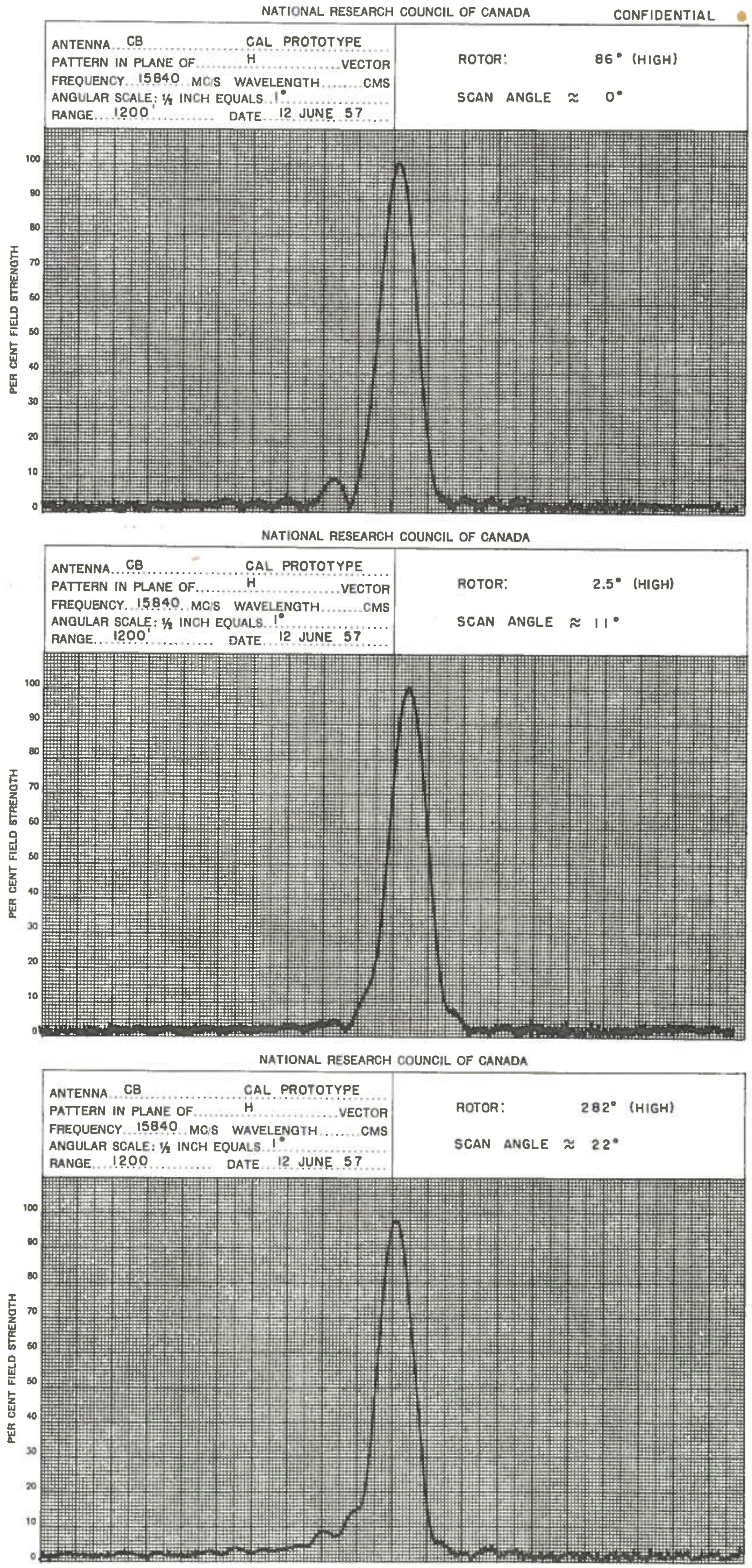


FIG. 2 AZIMUTH PATTERNS, HIGH BEAM, 15,840 MC/S

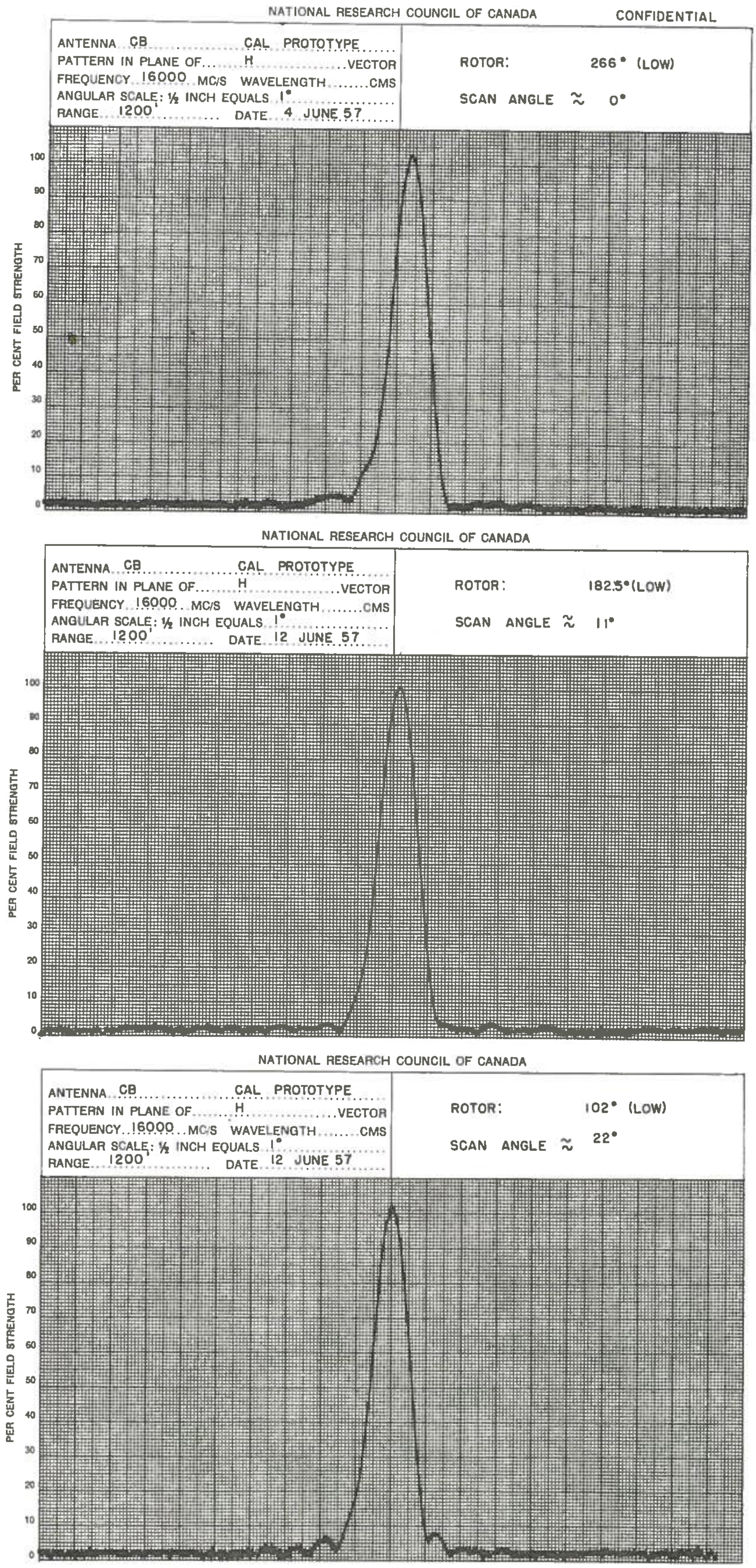


FIG. 3 AZIMUTH PATTERNS, LOW BEAM, 16,000 MC/S

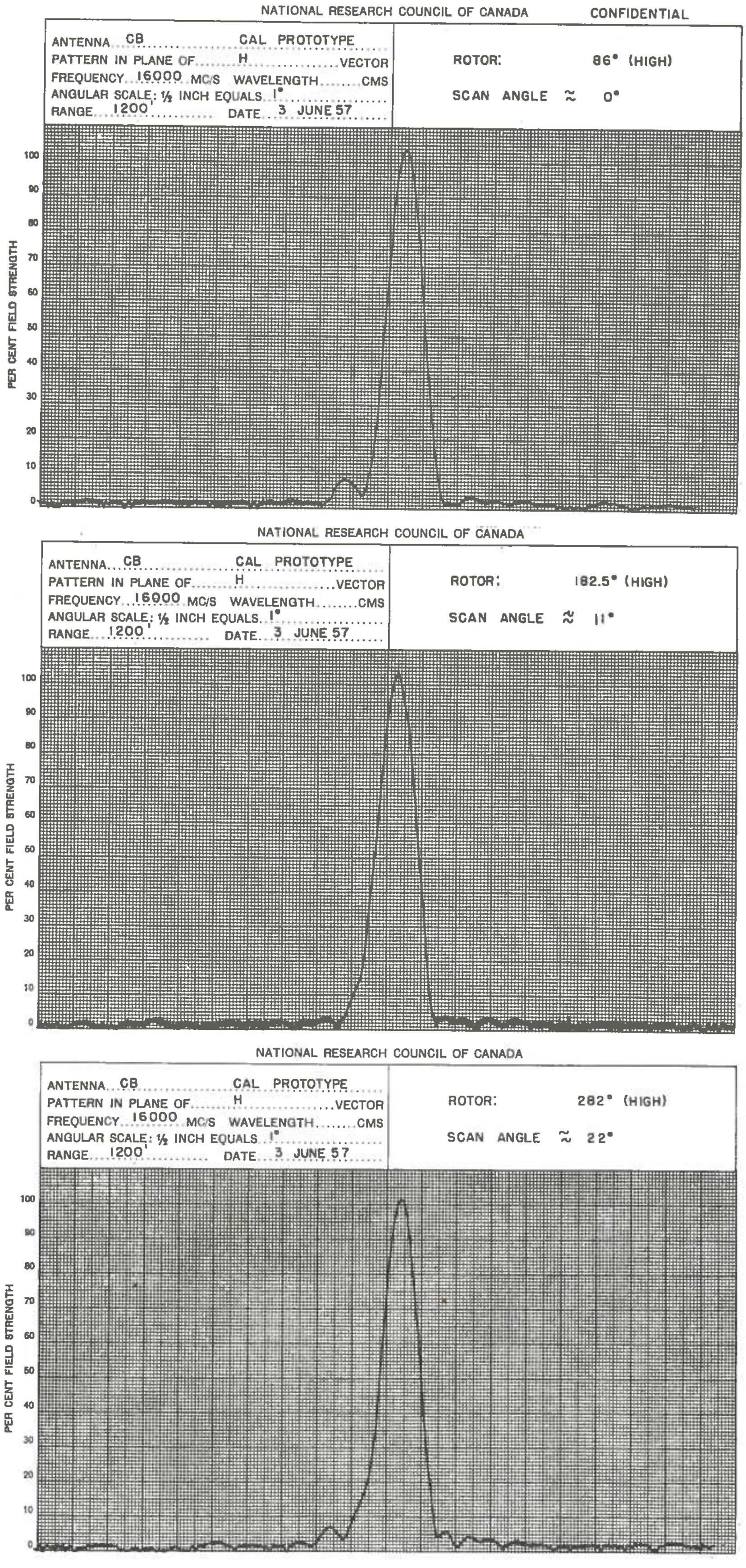
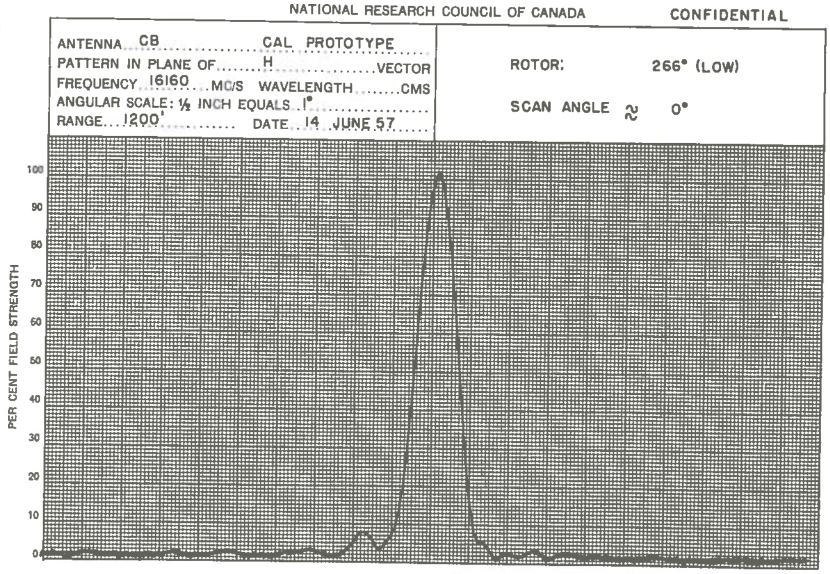
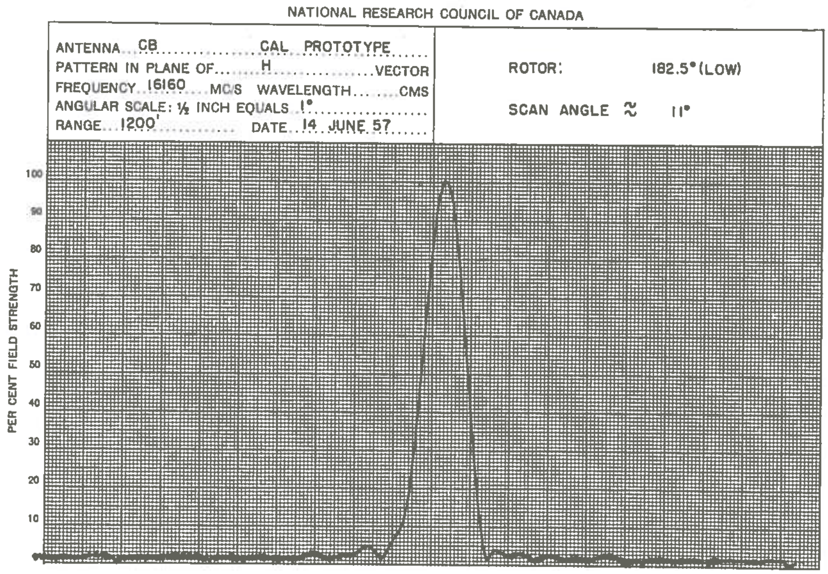


FIG. 4 AZIMUTH PATTERNS, HIGH BEAM, 16,000 MC/S





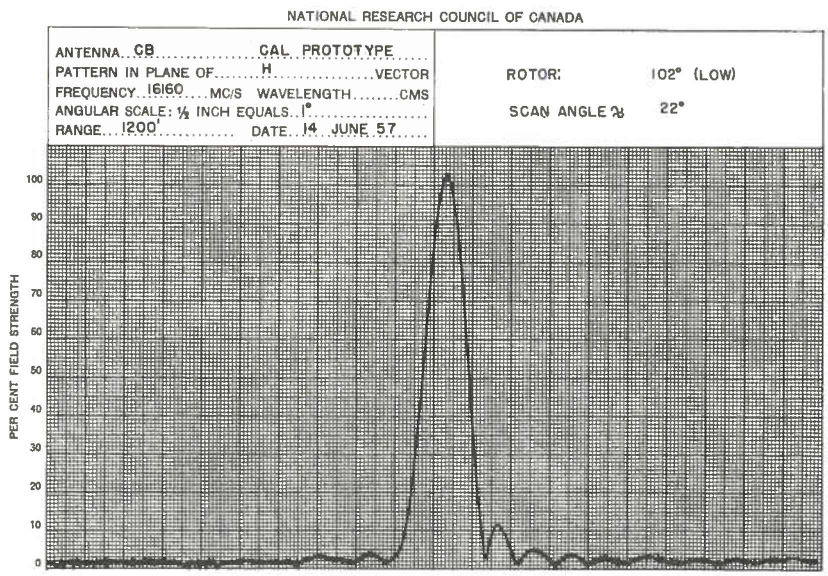


FIG. 5 AZIMUTH PATTERNS, LOW BEAM, 16,160 MC/S

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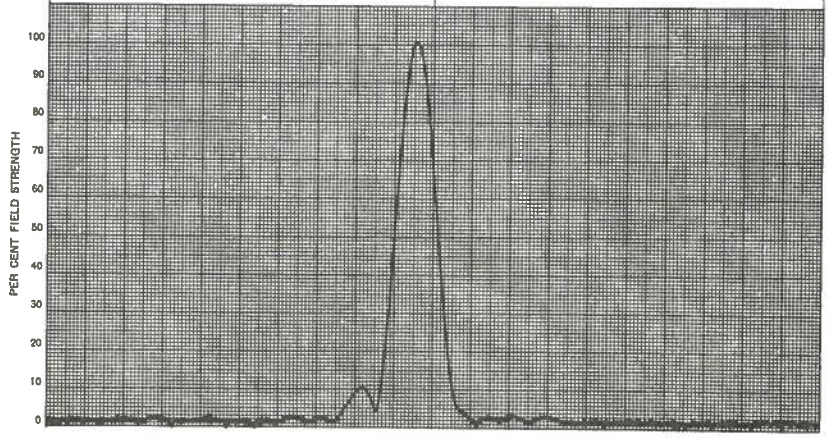
ANTENNA CB CAL PROTOTYPE	ROTOR: 86° (HIGH)
PATTERN IN PLANE OF H VECTOR	
FREQUENCY 16160 MC/S WAVELENGTH CMS	SCAN ANGLE ≈ 0°
ANGULAR SCALE: ½ INCH EQUALS 1°	
RANGE 1200' DATE 8 JUNE 57	



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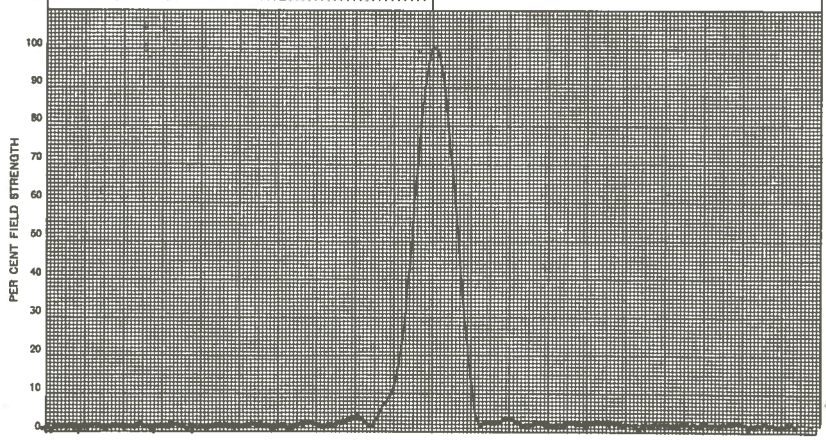
ANTENNA CB CAL PROTOTYPE	ROTOR: 2.5 (HIGH)
PATTERN IN PLANE OF H VECTOR	
FREQUENCY 16160 MC/S WAVELENGTH CMS	SCAN ANGLE ≈ 11°
ANGULAR SCALE: ½ INCH EQUALS 1°	
RANGE 1200' DATE 8 JUNE 57	



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ANTENNA CB CAL PROTOTYPE	ROTOR: 282° (HIGH)
PATTERN IN PLANE OF H VECTOR	
FREQUENCY 16160 MC/S WAVELENGTH CMS	SCAN ANGLE ≈ 22°
ANGULAR SCALE: ½ INCH EQUALS 1°	
RANGE 1200' DATE 8 JUNE 57	

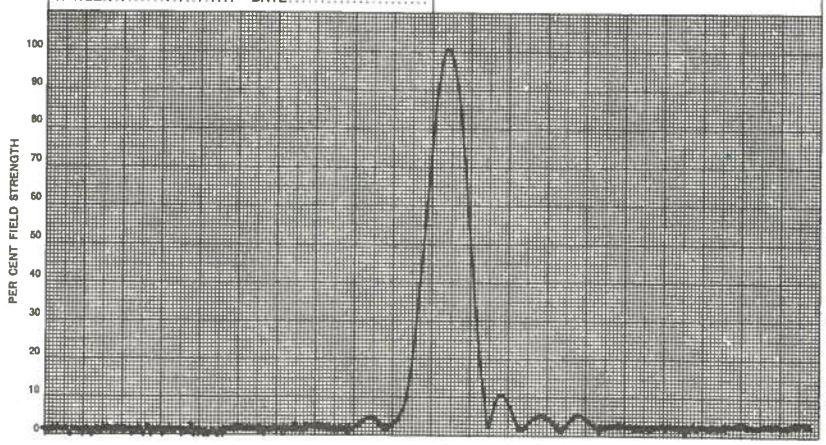


FIG. 6 AZIMUTH PATTERNS, HIGH BEAM, 16,160 MC/S

were recorded by tilting the turntable. Since the servo drive is not connected directly to the axis of tilt, the recorder motion is not related simply to degrees of tilt. However, calibration showed that the recorder motion was linear over the portion used, with one main pattern division equal to 2.02 degrees of tilt. Patterns for high and low beam at the center and ends of scan are shown in Figs. 7 to 9. The beamwidth at half-power did not vary within the error of measurement, and equals 0.85°. Side lobes were 7% or less. Patterns at other scan positions were recorded, and they showed no significant variation from those shown. Minor variations in the side-lobe structure of the pattern of one horn occurred when the other horn was covered with foil.

A considerable number of additional H-plane patterns were recorded in order to trace the existence and extent of any wide-angle lobes due to internal reflections within the scanner. The series of patterns, Figs. 10 and 11, shows the effect of one double reflection across the rotor section, resulting in a lobe at approximately three times the normal scan angle. It will be noted that this lobe has a maximum amplitude of 10% near zero scan angle, decreasing to near zero at about center of scan. The effect was observed over the frequency band on both beams, occurring to approximately the same extent.

By comparison the McGill-NRC experimental model had the same E-plane beamwidth, but an H-plane beamwidth of 1.05°. The reflection lobe had a maximum amplitude of 30%.

3. BEAM POSITION

It was desired to calibrate the change in scan angle with change in rotor position as accurately as possible. It was found that this could be done most directly and precisely by setting the antenna for maximum signal, read on an output meter, either by rotating the turntable or by moving the rotor. Then the position of the antenna, and hence the relative scan angle was read by means of the scanner director. It is estimated that under favourable conditions, the rotor position could be determined to within 0.2°, corresponding to a scan error of 0.4 mil. Fig. 12 shows the results of such a calibration for low and high beam at 16,000 mc/s. The plotted points show the departure from the linear relation,

$$\text{scan angle} = \text{constant} - 2.176 \times \text{rotor scale},$$

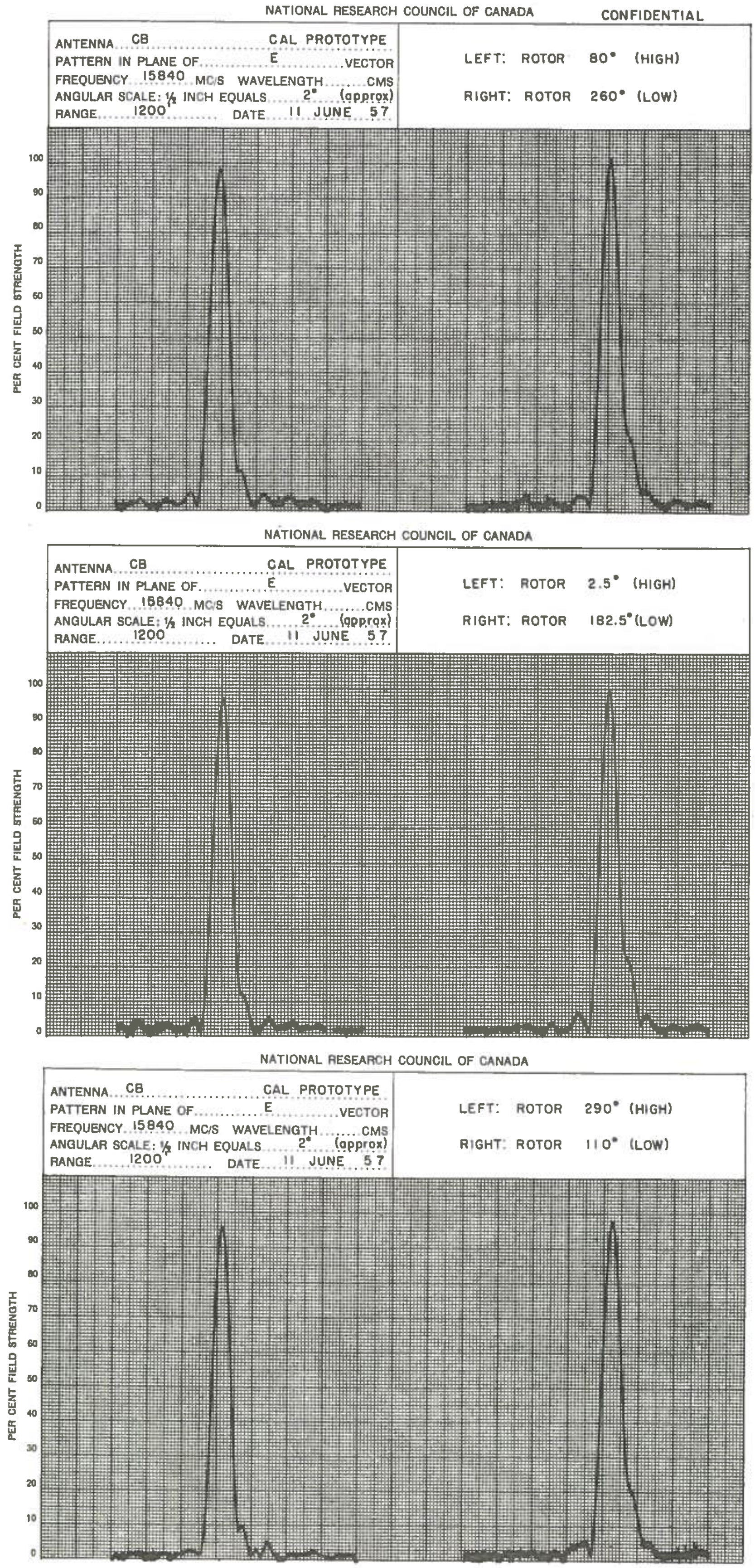
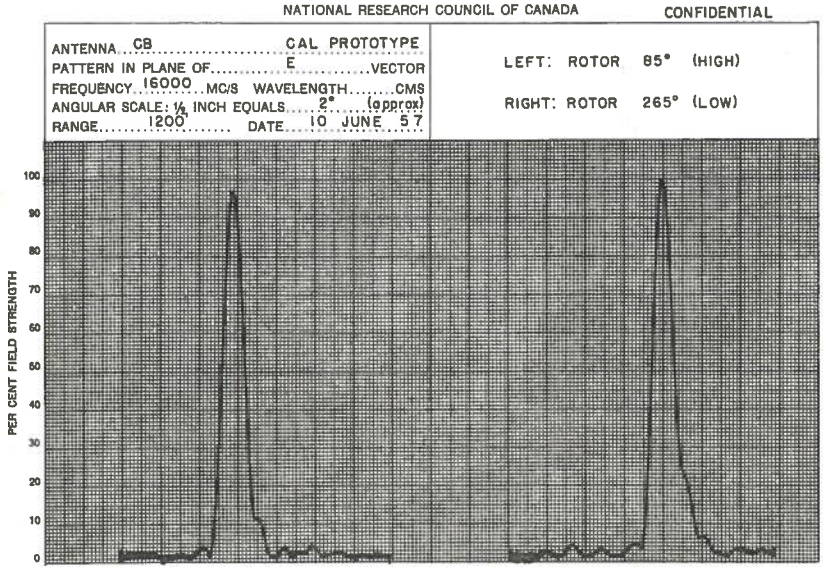
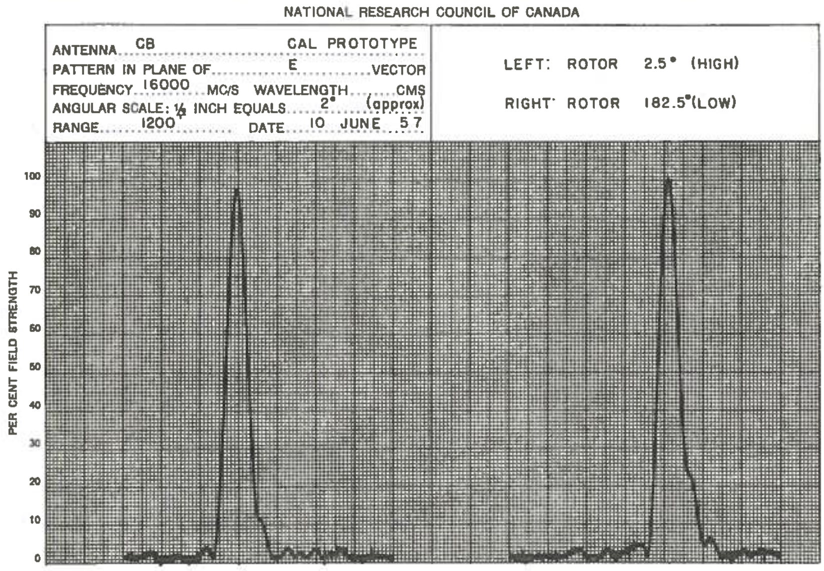


FIG. 7 ELEVATION PATTERNS, 15,840 MC/S





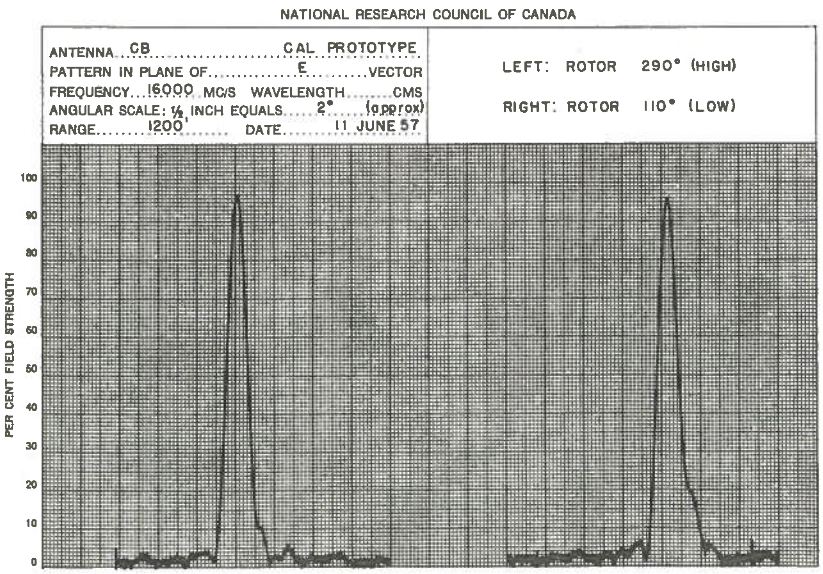


FIG. 8 ELEVATION PATTERNS, 16,000 MC/S

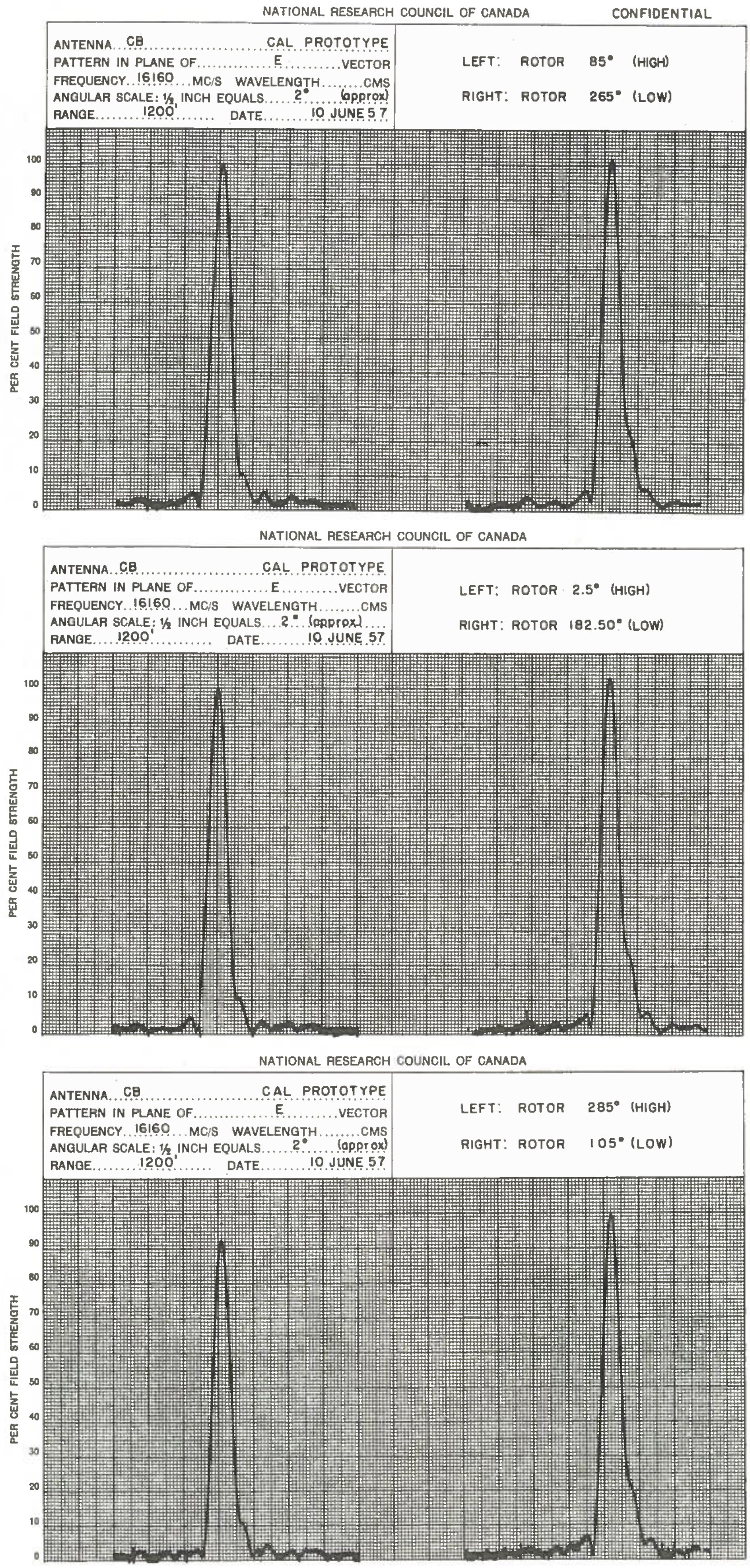


FIG. 9 ELEVATION PATTERNS, 16,160 MC/S

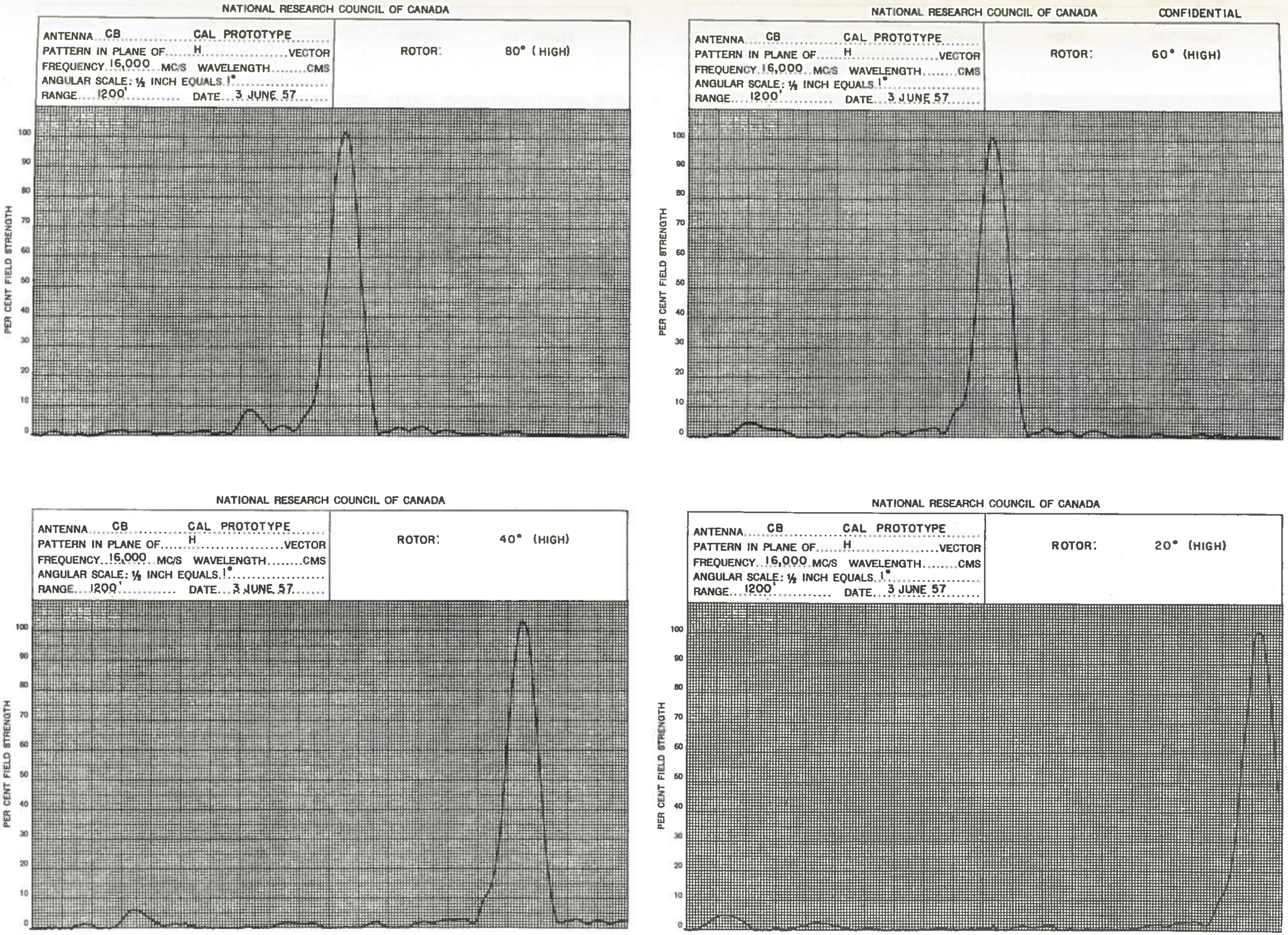


FIG. 10 AZIMUTH PATTERNS, 16,000 MC/S, SHOWING REFLECTION LOBE

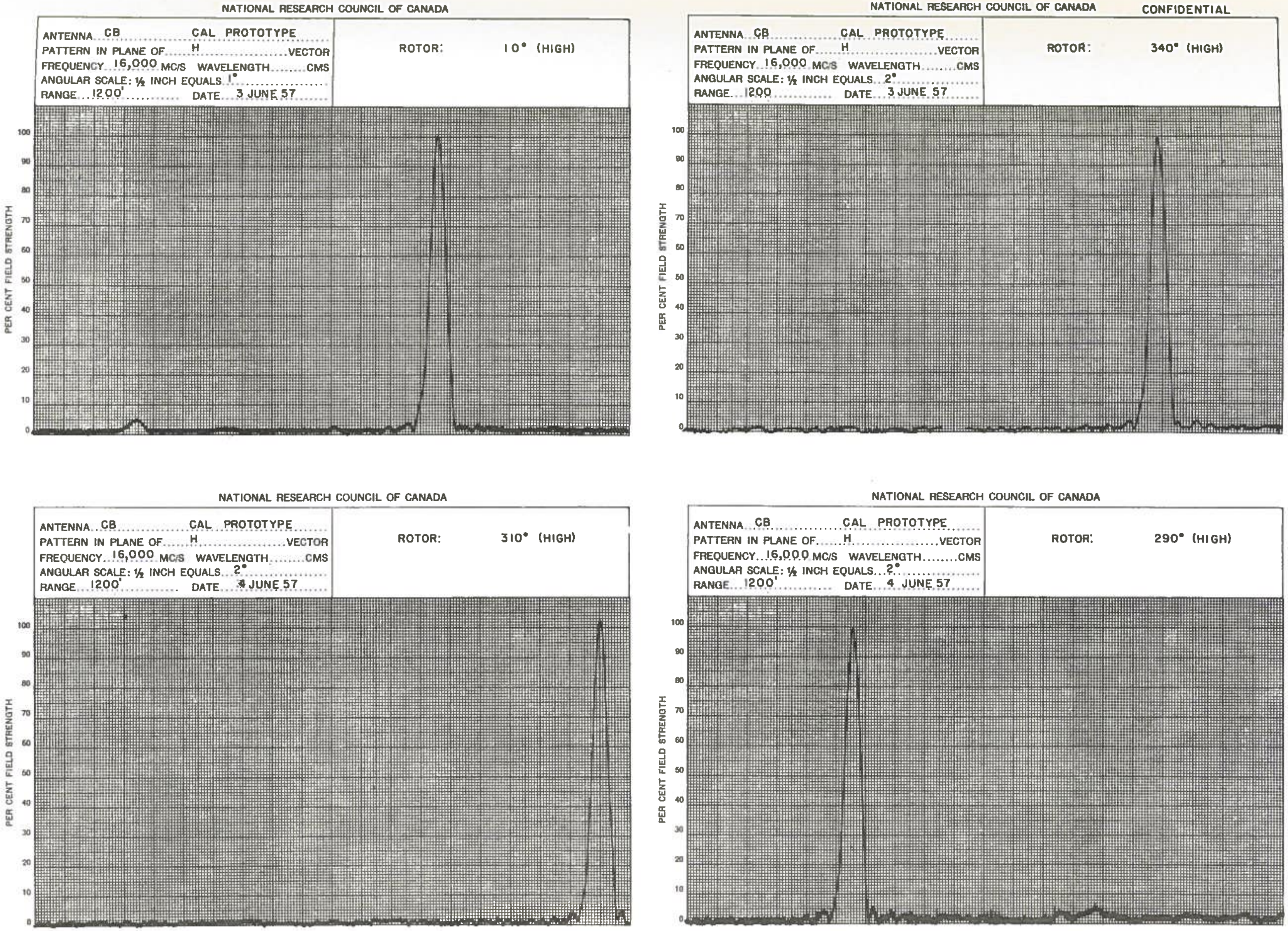


FIG. 11 AZIMUTH PATTERNS, 16,000 MC/S. REFLECTION LOBE DISAPPEARS AT APPROXIMATELY CENTER OF SCAN

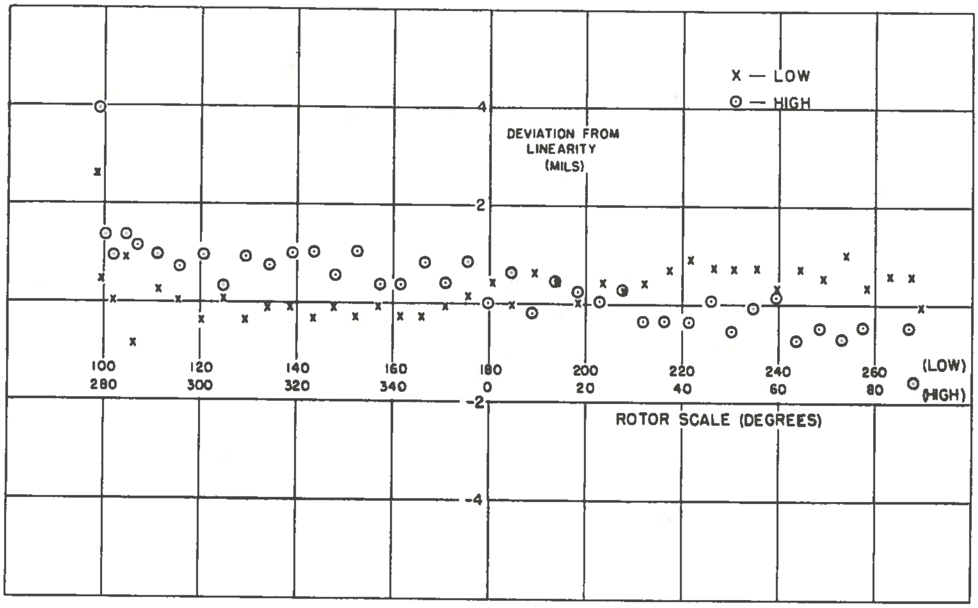


FIG. 12 DEVIATION FROM LINEARITY OF SCAN. THE POINTS ARE THE DIFFERENCE BETWEEN OBSERVED AZIMUTH OF SCAN AND THE CALCULATED VALUE, CONSTANT MINUS (2.176×ROTOR SCALE)

where the scan angle is in mils and the rotor scale in degrees. The corresponding high beam and low beam points are taken 180° apart on the rotor scale. It will be noted that high beam and low beam points have a slightly different slope. At low beam the rate of change of scan angle is 2.171 mils/rotor degree, and at high beam, 2.182 mils/rotor degree. The expected rate of change is 2.170 mils/rotor degree based on a cone angle of 7° 0' 40".

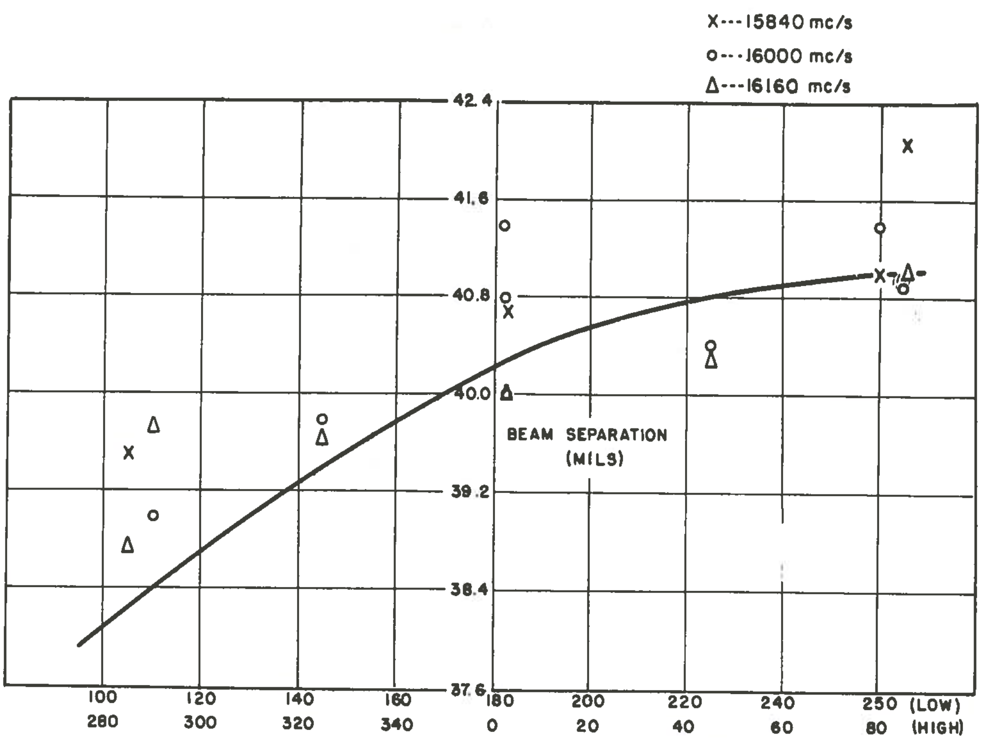


FIG. 13 ANGULAR SEPARATION BETWEEN LOW AND HIGH BEAMS. THE SOLID LINE VARIES AS THE COSINE OF THE SCAN ANGLE

The measured values for the angular separation between high beam and low beam are plotted in Fig. 13. It is to be expected that the two beams should lie on dihedral planes, and that, therefore, the "split angle" should vary in azimuth according to the cosine of the azimuth angle. It will be noted that the observed values exhibit a lesser variation, but that it still extends over approximately 2 mils. The tiltable turntable used in all measurements is essentially a CB mount, and in the determination of elevation angles the axis of tilt was maintained perpendicular to line of sight for all scan angles.

Data such as presented in Fig. 12, obtained over the frequency range, provide a direct determination of the variation of scan angle with frequency.

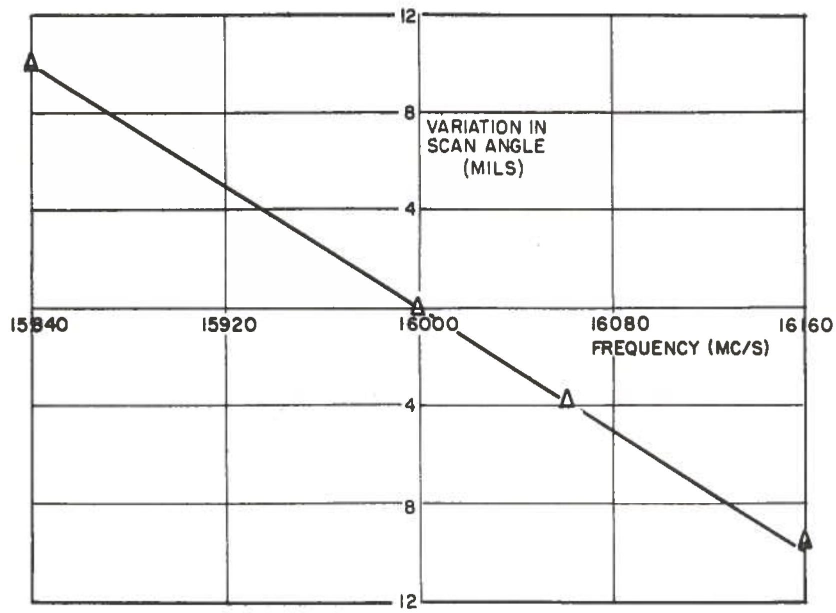


FIG. 14 VARIATION OF SCAN ANGLE WITH FREQUENCY

The information is plotted in Fig. 14, from which it appears that there is a linear variation in scan angle over the operating frequency range given by,

$$\Delta S = 990 \frac{\Delta f}{f} \qquad (1)$$

where ΔS, the change in scan angle, is given in mils, and $\Delta f/f$ is the fractional frequency change. The theoretical value for the change of squint angle with frequency is,

$$\Delta\theta = \left[\frac{\sec\theta}{\sqrt{1 - \left(\frac{\lambda}{2a}\right)^2}} - \tan\theta \right] \frac{\Delta f}{f}, \tag{2}$$

from which,

$$\Delta\theta = 1093 \frac{\Delta f}{f}. \tag{3}$$

It is probable that the susceptance of the slots would account for the difference between Eq. (1) and Eq. (3).

4. RELATIVE GAIN

Typical patterns showing the relative gain of the antenna over the scan range are shown in Figs. 15 and 16. Data were obtained by various means for other frequencies, and for high beam, with results essentially the same. This information, together with that provided in Figs. 7 and 9, may be summarized as follows:

- i) Gain is approximately constant from small scan angles to center of scan; then it decreases gradually to 0.5 db down at the end of scan.
- ii) Gain is 0.2 db less on high beam than on low beam.

The limits of scan in terms of rotor degrees, on the basis of relative gain, extend from 89.4° to 280° on high beam, and from 100° to 269.8° on low beam. There is practically no variation with frequency over the frequency band. The similar figures on the basis of linearity of scan are from 89° to 280° on high beam, and from 100° to 269° on low beam. The latter figures are taken as defining the scan range. This places "center of scan" at 4.5° on the arbitrarily set rotor scale. The total scan angle on the basis of the above limit is 367 mils.

5. ABSOLUTE GAIN

The gain of the scanner at 16,000 mc/s was compared with that of a horn having a theoretical gain of 898, by use of a Hewlett-Packard attenuator, Model P382A, Serial 27. The measured value was 46.1 db, relative to isotropic, from the scanner itself (not allowing for any waveguide run to the scanner). The directive gain calculated from the H-plane and E-plane patterns,

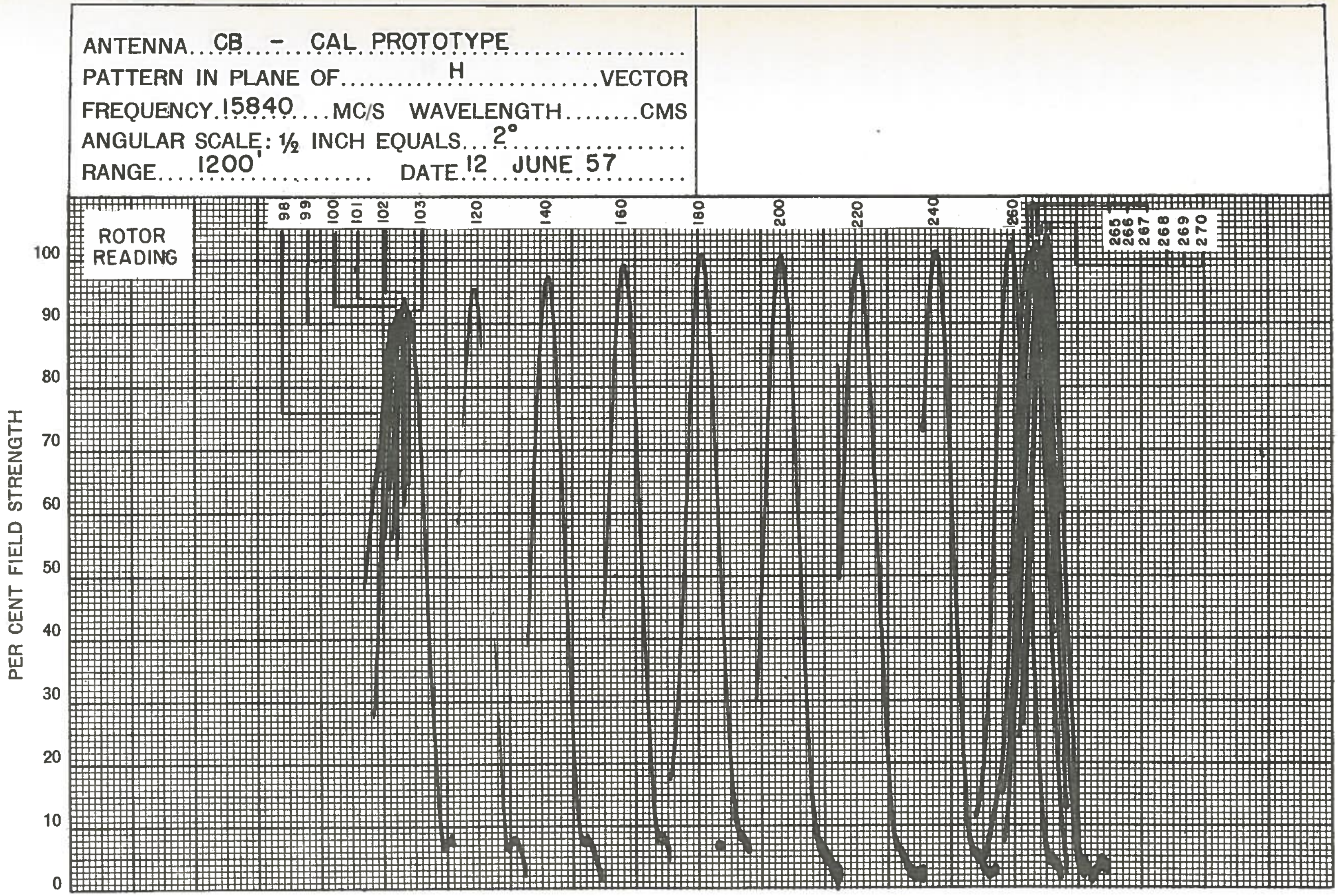


FIG. 15 RELATIVE GAIN AS A FUNCTION OF SCAN ANGLE, LOW BEAM, 15,840 MC/S

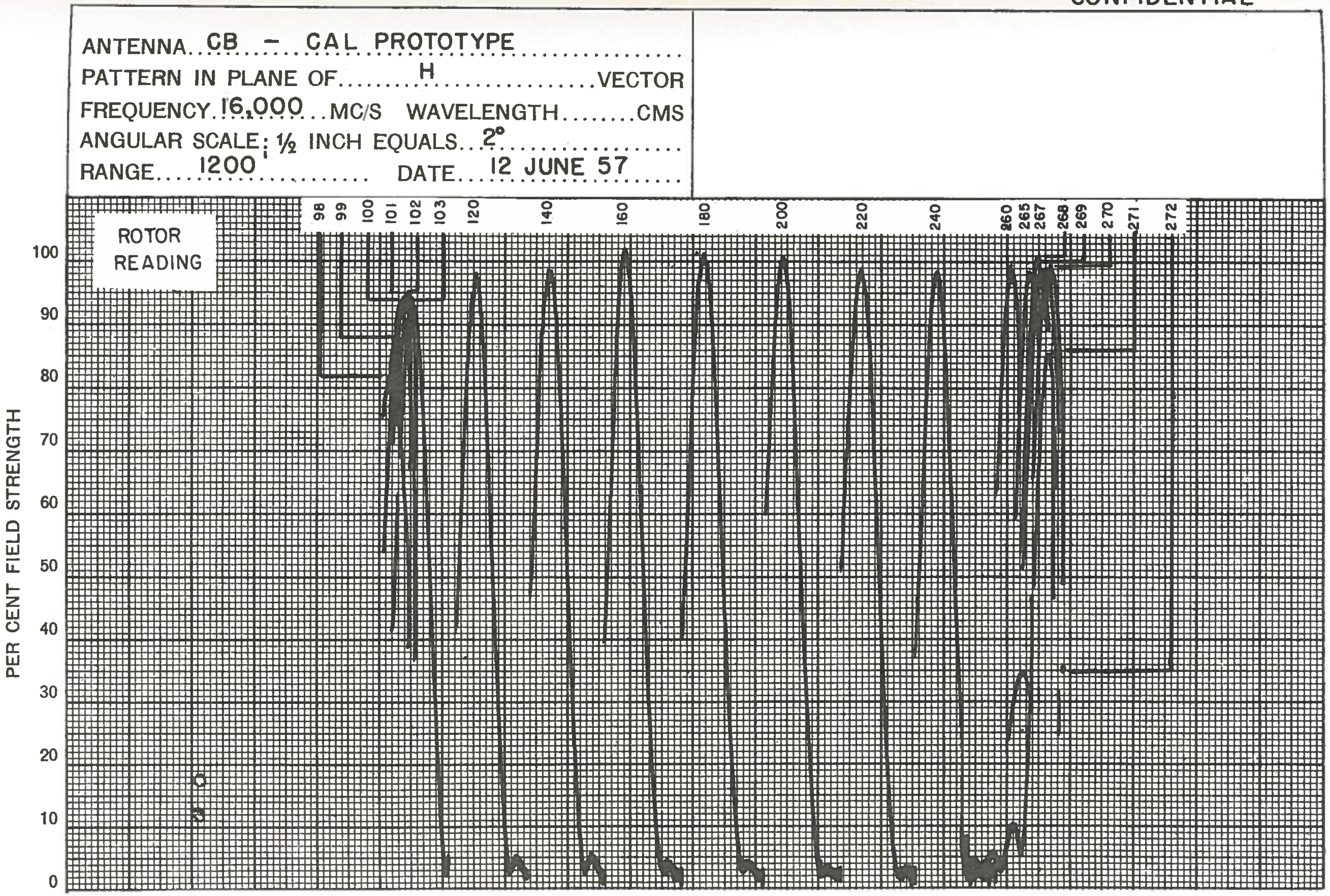


FIG. 16 RELATIVE GAIN AS A FUNCTION OF SCAN ANGLE, LOW BEAM, 16,000 MC/S

of respective widths 0.89° and 0.85°, was 46.7 db. The scanner gain is taken to be 45.9 db ± 0.3 db. The comparable gain of the experimental model was 42.5 db.

6. COMMENTS

The original model of the Foster scanner was shown in experimental and field tests to be an exceptionally fine piece of equipment. However, it was inevitable that a unit of such complicated structure and function should not operate initially at optimum efficiency. It now appears that the prototype model leaves little room for further improvement insofar as gain and the reduction of spurious radiation is concerned.

The difference in rate of scan between low and high beams is on the border of being operationally significant. The reason for this difference is hard to assess.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the very excellent work performed during the course of the tests by Mr. W. G Currie and Mr. Douglas Hay of Canadian Arsenals Limited, and by Mr. Thomas Faddies, Mr. Lorne Bradley and Mr. Rene Farley of the National Research Council. The receiving tower was erected under the direction of Mr. J.C. Barnes of the Radio and Electrical Engineering Division.

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