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THE AN/MPS-501B ANTENNA: MODIFICATION OF THE FEED

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ABSTRACT

The feed of the AN/MPS-501B antenna, consisting of a 13-foot slotted array with horn, has been modified to suppress second-order beams. The original horn has been replaced by a parallel-plate horn which, with reasonable manufacturing tolerances, should reduce the residual second-order beams to a level of two percent or better. On account of anti-jamming considerations, the array has been redesigned to reduce side lobes, as well as to accommodate the modified horn.

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THE AN/MPS-501B ANTENNA: MODIFICATION OF THE FEED

- G.C. McCormick -

INTRODUCTION

The antenna for the mobile radar designated AN/MPS-501B, consists of a parabolic cylinder 14 feet in length, fed by a non-resonant slotted-waveguide array. Proper flooding of the reflector is obtained by the use of a narrow horn in conjunction with the array. A report on the production model of this antenna has been issued previously [1].

In common with most antennas based on the slotted-waveguide array, the AN/MPS-501B normally produces four second-order beams. The nature of these, and methods for their suppression have been discussed by Gruenberg [2]. For the antenna under discussion, the maximum amplitude of the second-order beams at 2800 mc/s was found to be 11 percent [1]. It was felt, in view of the importance of anti-jamming techniques which require a main lobe as free as possible from spurious side radiations, that the second-order beams should be suppressed.

Initially a parallel-plate horn similar to that used in the modification of the AN/FPS-502 antenna [3] was designed and tested. However, second-order beams persisted to the extent of 2.5 percent at 2800 mc/s and 4 percent at 2900 mc/s. Accordingly a horn with a longer parallel-plate region was built in order to increase the suppression of the second-order beams. Proper positioning of this horn required the construction of new mounts for the feed. This replacement was simpler than had been anticipated.

Anti-jamming considerations also suggest the desirability of a reduction in regular side lobes. It was decided to attempt to realize side lobes 26-db down (5 percent amplitude) or better, over at least part of the frequency band, and the necessary sacrifice of about 10 percent in gain (5 percent in range) was thought to be justified, in order to achieve this purpose.

FEED DESIGN

A cross-sectional diagram of the final modified horn fitted over standard S-band waveguide is shown in Fig. 1, together with similar diagrams of the original horn and of the initial parallel-plate horn. It will be noted that the longer parallel-plate horn necessitates a backward displacement of 1.25" in the mounting of the horn assembly. However, there is sufficient space, and all that is required is a minor alteration in the mounting castings and a slight alteration in the curved section of waveguide.

The radiation in the throat region of the horn can be specified in terms of modes

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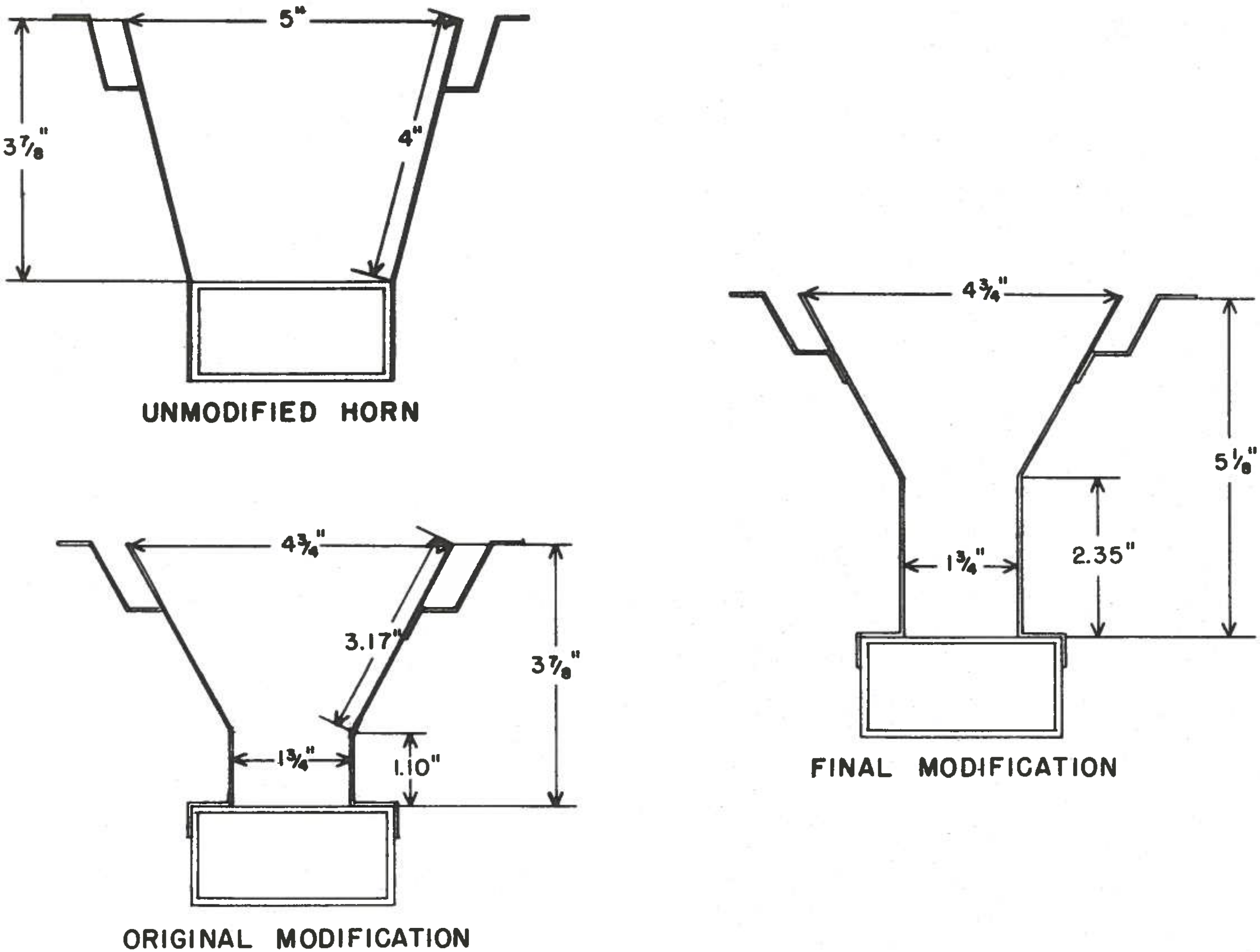

FIG. 1

CROSS SECTIONS OF UNMODIFIED AND MODIFIED HORNS appropriate to a longitudinal periodic structure confined laterally to a parallel-plate region. On this basis the principal radiation, which is the origin of the main lobe, is a TEM-mode of propagation constant equal to that of the medium, i.e., air. It will be assumed, except for alternation about the center line, that slot length, width, and offset lie on a smooth curve. Further, it will be supposed that the horn region is symmetrical about the center line of the array. Such a condition gives equal weight to slots lying on either side of the center line, and any departure from this condition will be termed an "asymmetry". It follows, on this basis, that the modes from which the second-order beams derive are a combination of TE_{11} and TM_{11}, with the propagation constant, β, given by,

$$\beta = 2\pi\left[\left(\frac{1}{\lambda}\right)^2 - \left(\frac{1}{d} - \frac{1}{\lambda_g}\right)^2 - \frac{1}{4s^2}\right]^{\frac{1}{2}} , \qquad (1)$$

where λ is the free-space wavelength, λ_g the guide wavelength, d the slot separation, and s the width of the parallel-plate region. If s is sufficiently small, β is imaginary, and the modes are attenuated with an attenuation constant, α , where,

$$\alpha = 2\pi\left[\left(\frac{1}{d} - \frac{1}{\lambda_g}\right)^2 + \frac{1}{4s^2} - \frac{1}{\lambda^2}\right]^{\frac{1}{2}} , \qquad (2)$$

and the amount of second-order beam suppression is given by,

$$\rho = \exp(\alpha t), \qquad (3)$$

where t is the effective length of the parallel-plate region.

Referring to Fig. 1, and using λ = 4.21" (2800 mc/s), λ_g = 6.30", d = 3.63", s = 1.75", Eq. (2) gives α = 1.24 (inches)$^{-1}$. t is somewhat greater than the physical length of the parallel-plate region, and can be conservatively taken to be equal to 2.35". It follows from Eq. (3) that ρ = 18.5 for the parallel-plate horn of Fig. 1, at the design frequency, 2800 mc/s. The suppression factor can be expected to be less at higher frequencies, and greater at lower frequencies.

A Gaussian amplitude taper was used as the basis for the design of the slotted array. The taper was so adjusted that amplitudes at the ends of the aperture equal 0.183 times that at the center. This theoretical aperture distribution produces side lobes 30-db down in the distant field. The gain, in terms of a uniform distribution of equal length, is 16 percent less, and the beamwidth 33 percent greater.

The slot conductance as a function of slot length and offset is markedly dependent on the region into which the slot radiates. Laboratory measurements using a number of 10-slot test sections with a four-foot length of horn, provided the data used in the design of the array for the horn with a parallel-plate region of length 1.1". Tests indicated a slight increase of slot conductance with a change to the longer parallel-plate region. Since this should produce a slightly more conservative aperture field, it was felt that no change in the slotted array was necessary.

HORIZONTAL FIELD (H-PLANE)

The feed was installed in the antenna and patterns recorded on low beam, medium beam, and high beam (all in Position 3). Patterns taken at 2700 mc/s, 2800 mc/s, and 2900 mc/s, are shown in Figs. 2 to 4. A tabulation of beamwidth at half-amplitude, and of maximum side-lobe level, is given below:

TABLE I

Beam Position	Frequency (mc/s)	Beamwidth (degrees)	Maximum Side Lobe (percent)
Low Beam	2700	2.54	7
	2800	2.48	3
	2900	2.38	6
Medium Beam	2700	2.44	8
	2800	2.50	6
	2900	2.42	5
High Beam	2700	2.52	8
	2800	2.44	7
	2900	2.34	4

The tabulated values may be compared with the beamwidth for the comparable uniform array, 1.87°; for the 30-db Gaussian, 2.48°; and with the measured values for the unmodified array, 2.3° — all at 2800 mc/s.

VERTICAL FIELD (E-PLANE)

A direct comparison between the vertical fields of the modified and unmodified antennas was made by taking sections of the horizontal pattern at relatively close range for various angles of antenna tilt. This work indicates that there has been no change in the position of any beam, and no change in the width at low and medium beam. However, there appeared to be a significant narrowing at high beam, from 18.2° at half-amplitude with the original feed to 15.7° at half-amplitude with the modified feed.

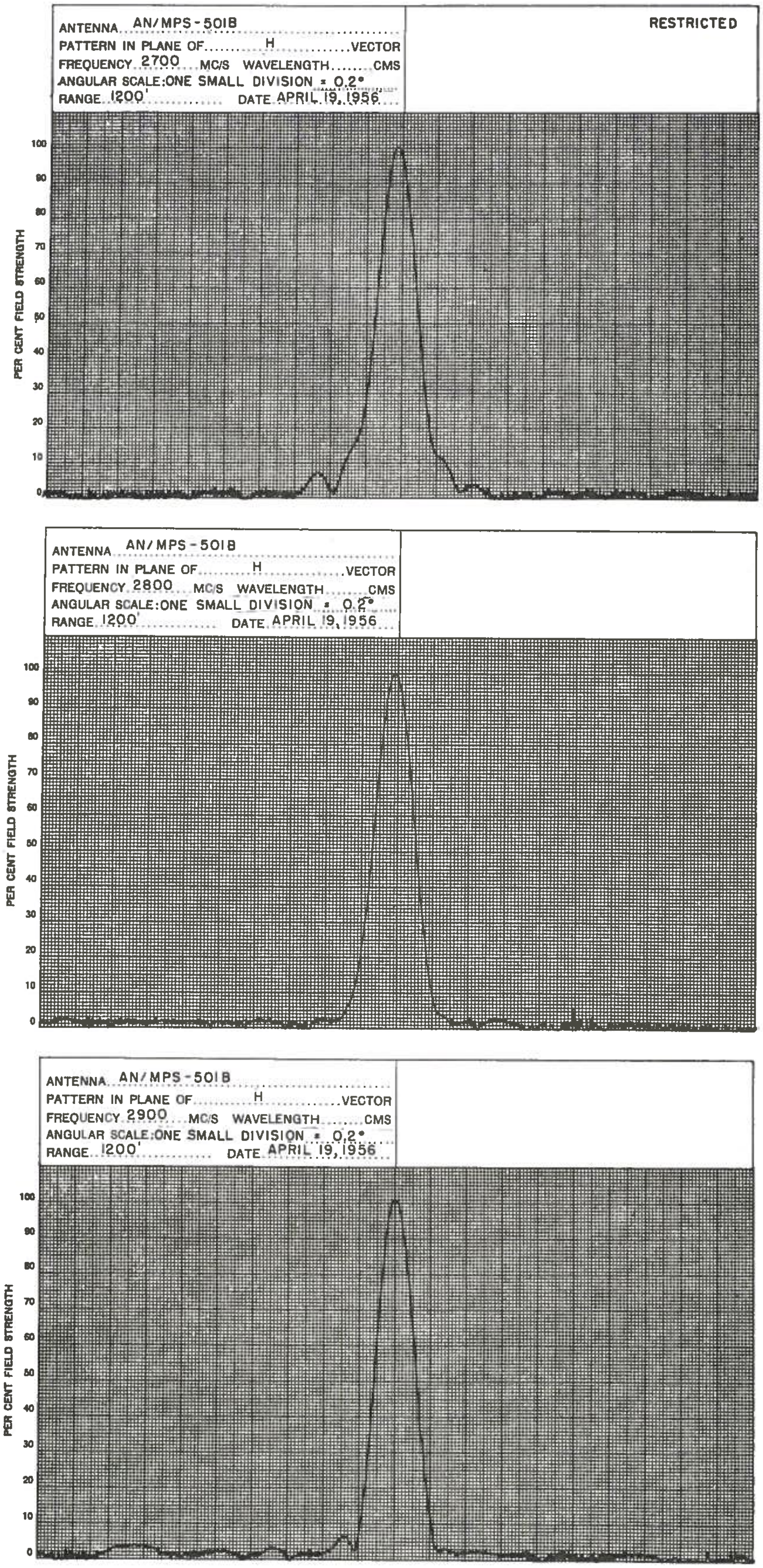

FIG. 2

RADIATION PATTERNS TAKEN AT LOW BEAM — HORN AND ARRAY MODIFIED

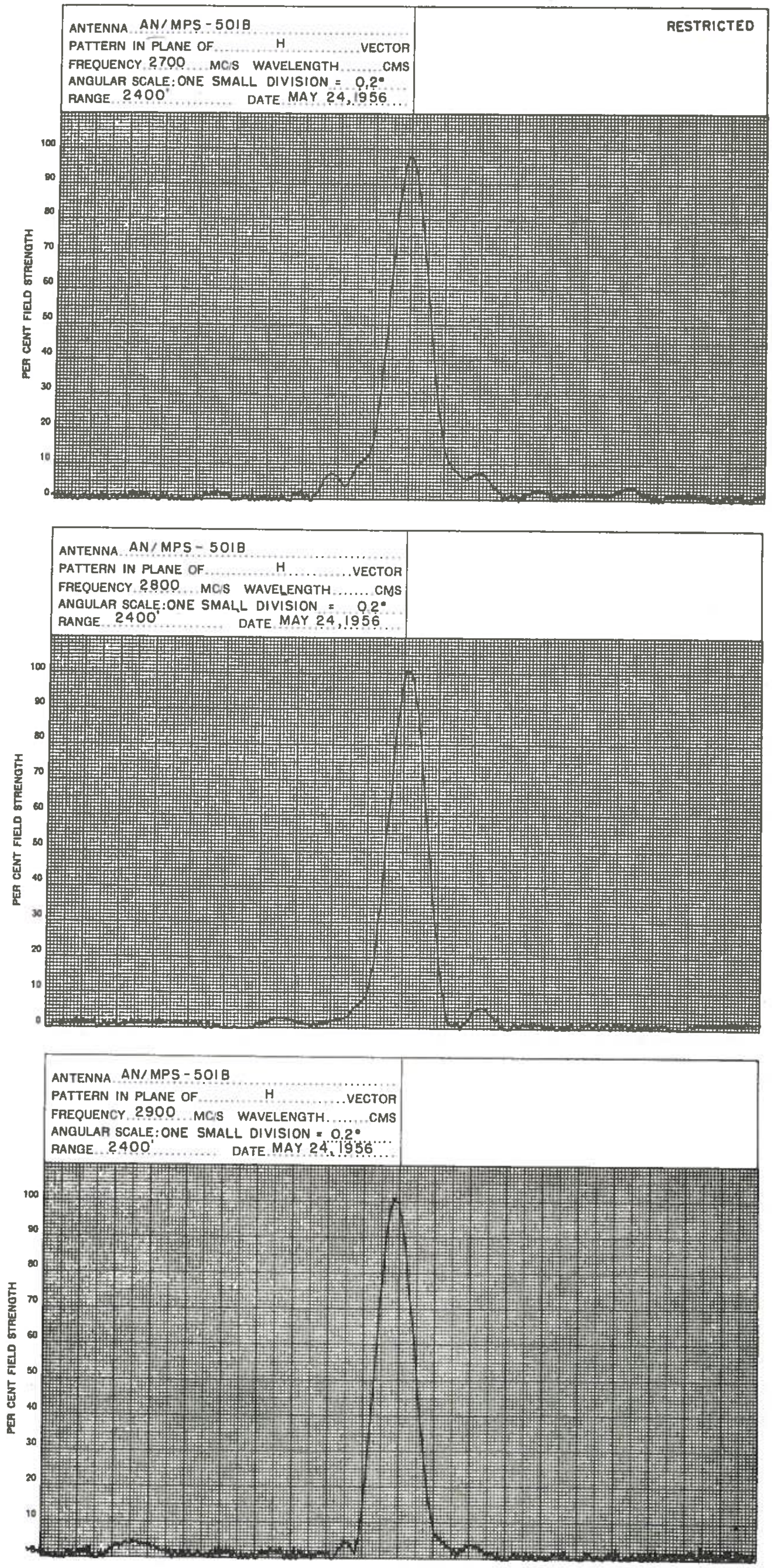

FIG. 3

RADIATION PATTERNS TAKEN AT MEDIUM BEAM — HORN AND ARRAY MODIFIED

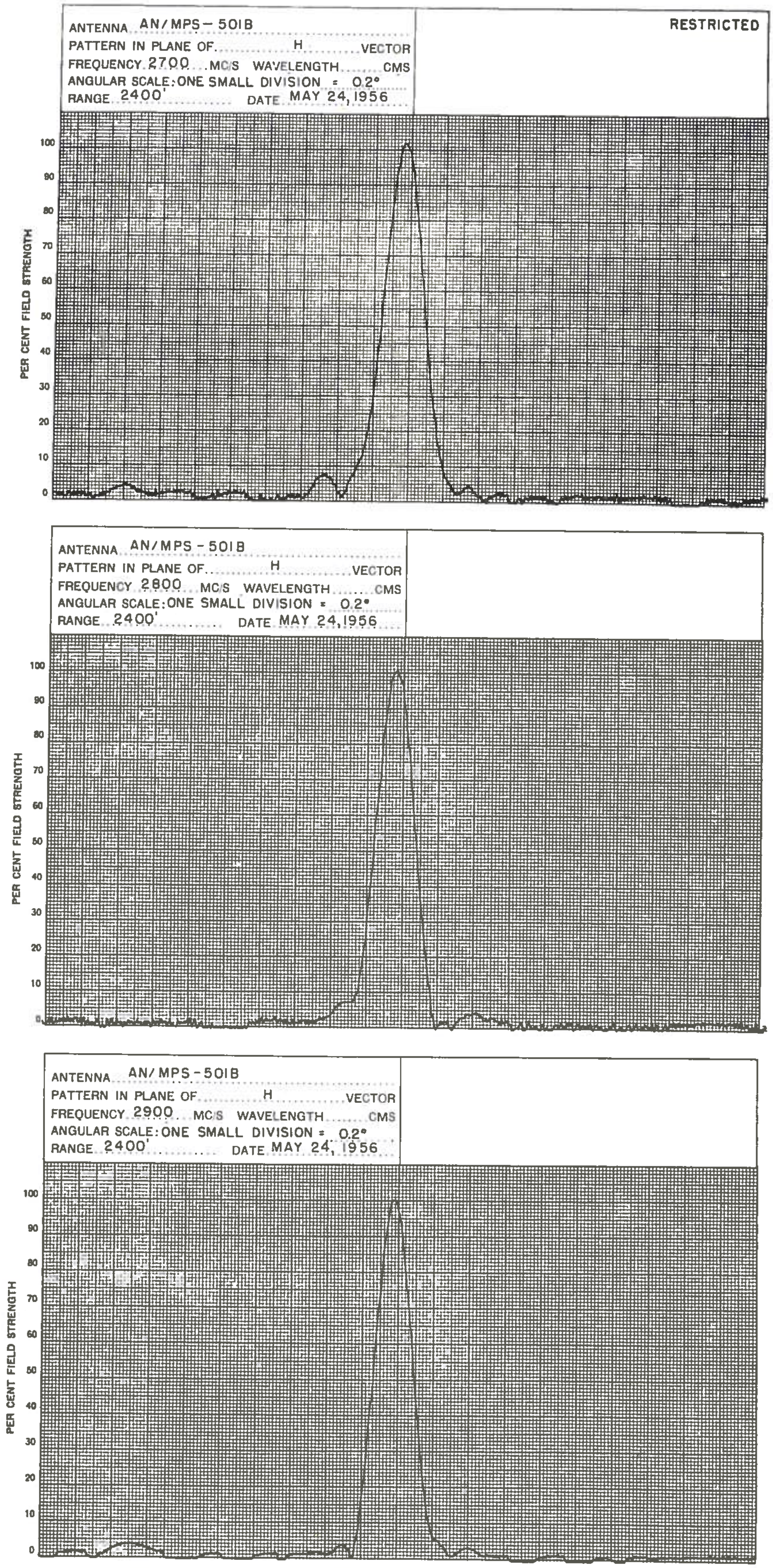

FIG. 4

RADIATION PATTERNS TAKEN AT HIGH BEAM — HORN AND ARRAY MODIFIED

VSWR AND POWER LEFT OVER

The voltage standing-wave ratio of the array with the horn, assembled in the antenna, was measured over the frequency band. The values are given in Table II.

TABLE II

FREQUENCY (mc/s)	VSWR
2700	1.14
2720	1.10
2740	1.12
2760	1.07
2780	1.07
2800	1.04
2820	1.06
2840	1.05
2860	1.05
2880	1.08
2900	1.08

The power left over was 3.5 percent at 2800 mc/s, rising to 13 percent at 2900 mc/s, and 2700 mc/s. The design value of power left over was 2.3 percent at 2800 mc/s.

SECOND-ORDER BEAMS

Horizontal patterns for various angles of tilt were recorded in order to establish the degree of suppression of the second-order beams. Typical of such is that shown in Fig. 5 on which it will be noted that a barely perceptible second-order beam can still be observed. Patterns with a 10-db expansion, giving an amplitude magnification of 3.2, were recorded in order to reveal the detail of low-level lobes. From these it was apparent that second-order beams of amplitude up to 3 percent could be expected at all frequencies and all angles of tilt.

Since a suppression factor of 18.5 as determined above, would reduce the second-order beams to less than 1 percent, it is apparent that those observed are due to the presence of a zero mode. Such a mode arises from asymmetries in the construction of the array and of the horn [2], and no parallel-plate region or other structure is capable of suppressing it. When the seating and alignment of the horns were made as accurate as possible, a significant improvement in the level of the second-order beams resulted.

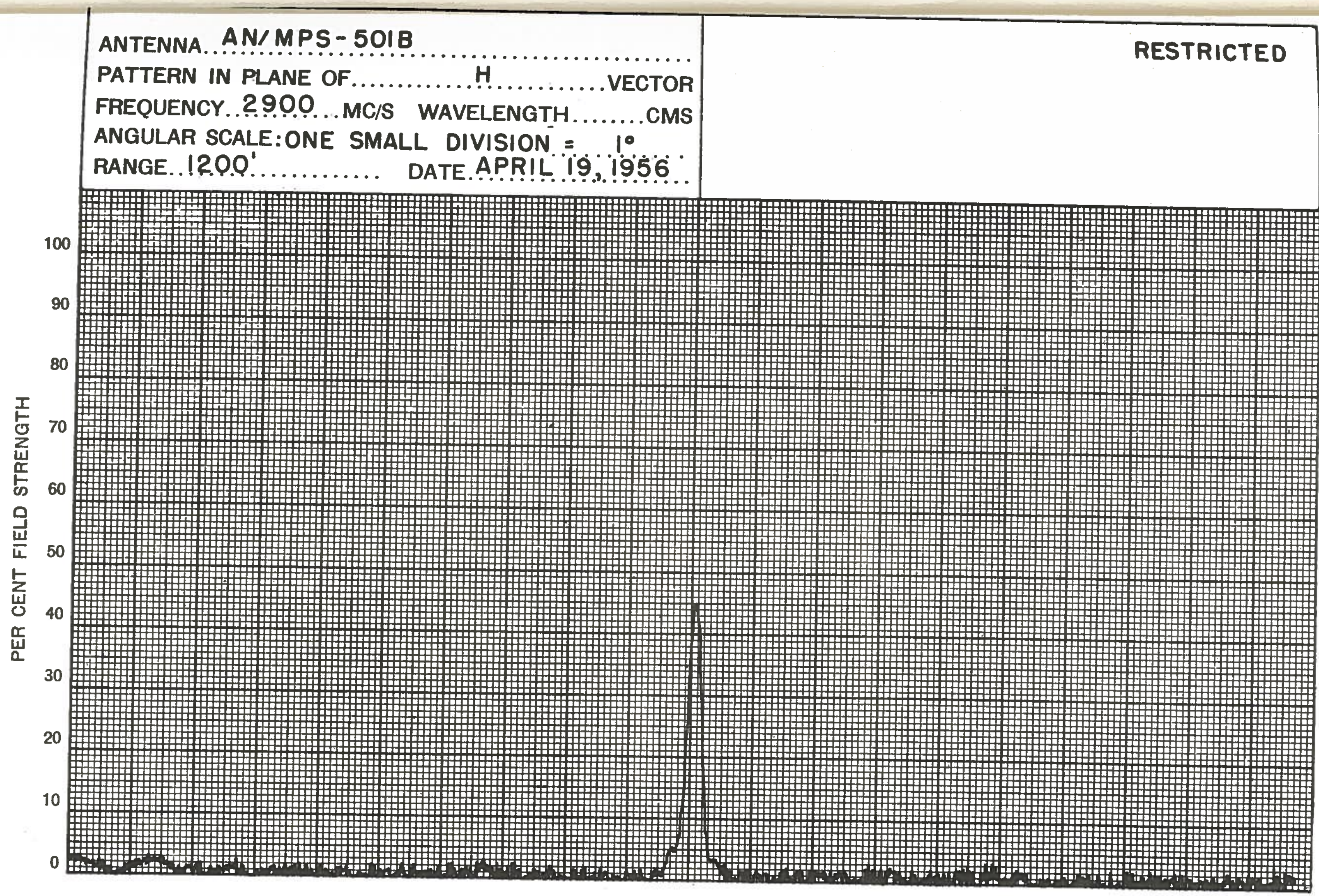

FIG. 5

RADIATION PATTERN TAKEN AT 9° TILT, NORMALIZED TO MAXIMUM FIELD STRENGTH EQUALS 100 PERCENT AT 0° TILT

It is clear that careful production techniques to fairly close tolerances are essential. To produce second-order beams no greater than 1 percent, the error in the location of the center-line with respect to the inside walls of the waveguide must be no greater than 0.002". It should be established by inspection that there is no periodic error in either offset or slot length which would create a difference between slots on one side of the center-line as against those on the other.

Manufacturing tolerances for the horn region are more difficult to assess. However, it is recommended that the horn be well seated on the waveguide and make good electrical contact, and that the parallel-plate region be accurately perpendicular to the waveguide and accurately centered.

It is believed that with the precautions outlined, second-order beams can be reduced to less than 2 percent amplitude, a level at which they will not exceed background radiations from the surrounding terrain.

OTHER SOURCES OF SPURIOUS RADIATION

Since it is desirable that all wide-angle radiation from the antenna be less than 35 db down, sources other than second-order beams from which it might originate, were given some attention. These are listed in the order of their estimated importance:

a) Back Radiation — Under certain conditions a significant amount of radiation is known to pass under the parabolic reflector. This could be eliminated or reduced by suitably placed screens or reflectors.

b) The Wave Reflected within the Array — Any mismatch at the end of the array or along its length tends to set up a reflected wave, resulting in a radiation lobe at twice the squint angle. This lobe was observed to have an amplitude of 3 percent at 2800 mc/s, and 5 percent at 2900 mc/s. If the mismatch occurs along the length of the array it may be impossible to eliminate the lobe, except at a particular frequency.

c) Slot Grouping — No experimental information with respect to the cutting of slots in groups has been obtained; but since the grouping imposes a periodicity along the array it can be anticipated that wide-angle lobes of a few percent amplitude would result.

d) Second Principal Order — The second principal order is observed to be present at 2900 mc/s only. It produces two lobes in the neighborhood of 90° from the main lobe, having an amplitude of about 4 percent.

CONCLUSIONS

The feed for the AN/MPS-501B antenna has been modified using a parallel-plate horn to suppress second-order beams. It has been found that in addition to the parallel-plate horn, careful manufacturing techniques are necessary if the suppression is to be completely satisfactory. Other sources of wide-angle radiation have been considered.

The slotted array has been redesigned for operation with the modified horn region, and also in order to reduce side lobes.

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