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GAIN CALCULATIONS OF A 2800-MHz STANDARD HORN FOR SOLAR NOISE OBSERVATIONS

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OTTAWA
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ABSTRACT

Schelkunoff's formula was used to calculate variations in the gain of a pyramidal horn for small changes in the dimensions of the horn, which is employed to observe the solar flux in the frequency band 1900-3900 MHz. At 2700 MHz, the gain of 417 shows a variation of ±0.2% for construction errors of ±0.25 cm in critical dimensions.

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GAIN CALCULATIONS OF A 2800-MHz STANDARD HORN FOR SOLAR NOISE OBSERVATIONS

- Margaret M. Steen -

The absolute evaluation of the 10.7-cm solar flux observations, made with small paraboloidal antennas over the past 20 years by the Radio and Electrical Engineering Division of NRC, has been made by intermittent comparison with the flux simultaneously observed by a moderately large pyramidal horn (1). This procedure was adopted since the horn is relatively easy to construct to known dimensions and its effective area, used in the calculation of the flux, is accurately known.

A recent evaluation of the solar spectrum from 9400 MHz to 560 MHz by H. Tanaka and T. Kakinuma (2) suggested that the level of the Ottawa observations at 2800 MHz could be in error by about 15% and consequently suggested that new absolute evaluations of the flux would be desirable. As part of this program, the original horn was examined and the gain recalculated. The dimensions of the horn actually constructed are shown in Fig. 1. This differs from the pyramidal horn used in the calculations by the presence of a flange used to strengthen the aperture, and of a section tapered from horn throat to standard $3 \times 1\frac{1}{2}$-inch waveguide. In future experiments, it is proposed to replace this taper with one which will agree with the horn used in the calculations.

The major source of error in the calculation of the gain is the neglect of diffraction effects at the aperture and throat of the horn. In the present horn, with an aperture of many wavelengths, this error is believed to be about 1%. Recent studies of the gain of pyramidal horns by Hamid (3) have included diffraction effects and these should be considered in future studies of the horn. Errors in gain arising from construction errors have been systematically studied by calculating the gain for small changes in horn dimensions of 0.5-cm steps.

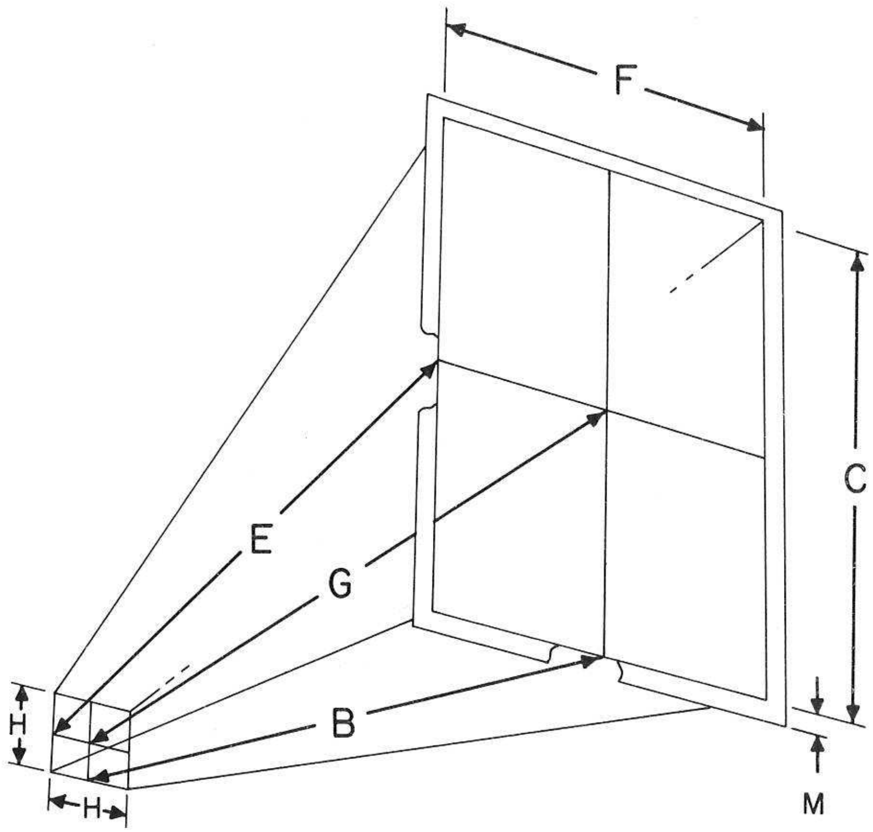
A program was written for the IBM-360 using the formula for calculating the gain of a horn given by Schelkunoff (4).

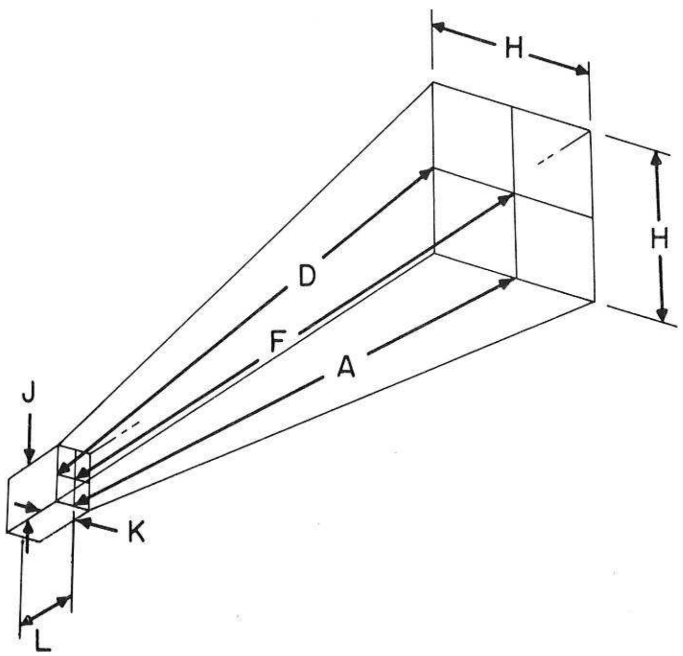
$$G = 10 \log_{10} \left\{ \frac{8\pi ab}{\lambda^2} \cdot \frac{C^2(w) + S^2(w)}{w^2} \cdot \frac{[C(u) - C(v)]^2 + [S(u) - S(v)]^2}{(u - v)^2} \right\}$$

where
$$C(z) = \int_0^z \cos \frac{\pi\alpha^2}{2}\, d\alpha,$$

$$S(z) = \int_0^z \sin \frac{\pi\alpha^2}{2}\, d\alpha,$$

are the Fresnel integrals and





DIMENS.	INCHES	CM
A	36.10	91.7
B	98.0	248.9
C	48.0	121.9
D	36.17	91.9
E	97.0	246.4
F	36.0	91.4
G	96.0	243.8
H	8.5	21.6
J	2.84	7.2
K	1.34	3.4
L	6.0	15.2
M	1.5	3.8

INSIDE DIMENSIONS

Fig. 1 Dimensions of pyramidal horn used in absolute determination of solar flux at 2800 MHz

$$u = \frac{1}{\sqrt{2}} \left(\frac{\sqrt{\lambda \ell_H}}{a} + \frac{a}{\sqrt{\lambda \ell_H}} \right),$$

$$v = \frac{1}{\sqrt{2}} \left(\frac{\sqrt{\lambda \ell_H}}{a} - \frac{a}{\sqrt{\lambda \ell_H}} \right),$$

$$w = \frac{b}{\sqrt{2\lambda \ell_E}} .$$

The variables a, b, ℓ_E, ℓ_H, and λ are defined as follows:

a = H-plane aperture dimension
b = E-plane aperture dimension
ℓ_E = E-plane slant length
ℓ_H = H-plane slant length
λ = wavelength in inches

These are shown in Fig. 2.

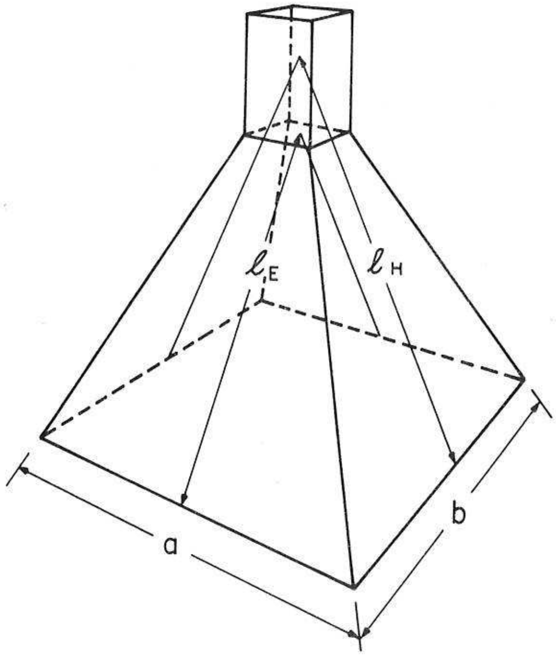


Fig. 2 Dimensional symbols of pyramidal horn used in calculation

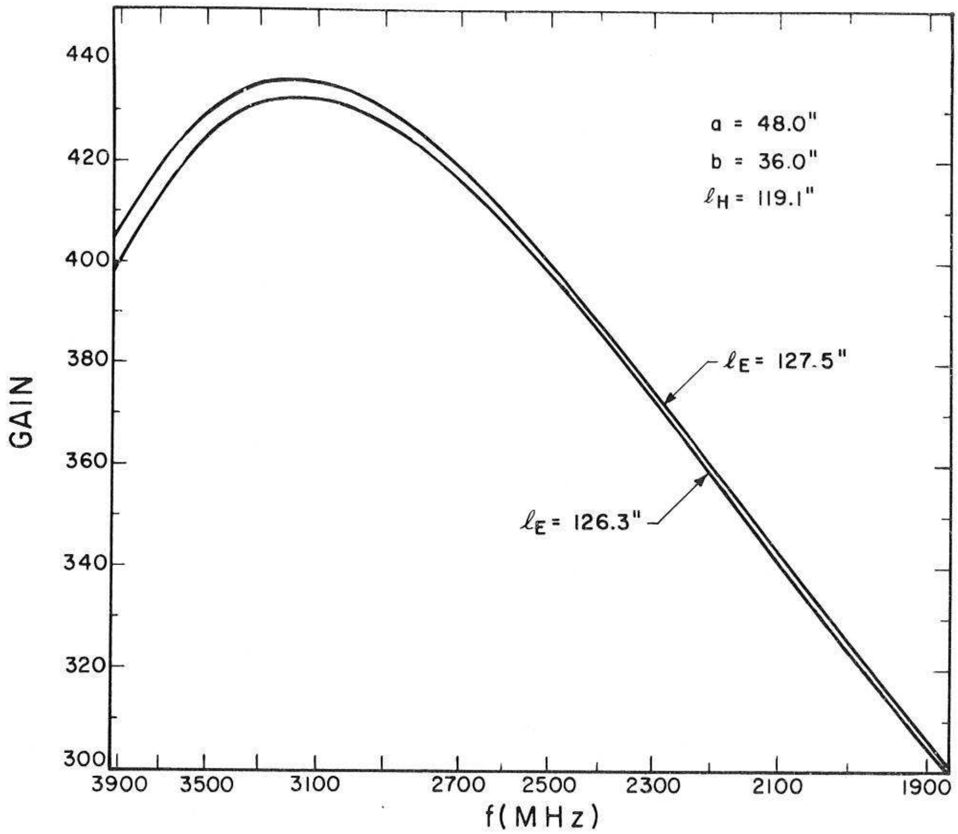


Fig. 3 Gain of horn vs frequency with E-plane slant lengths of 126.3 inches and 127.5 inches

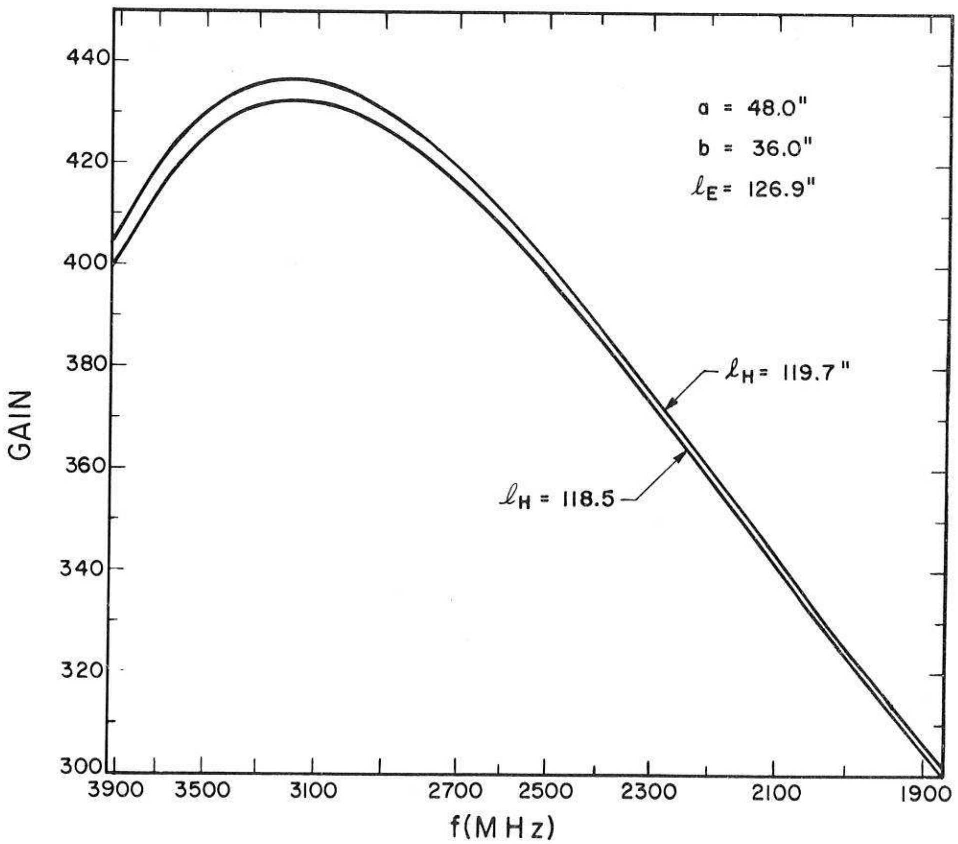


Fig. 4 Gain of horn vs frequency with H-plane slant lengths of 118.5 inches and 119.7 inches

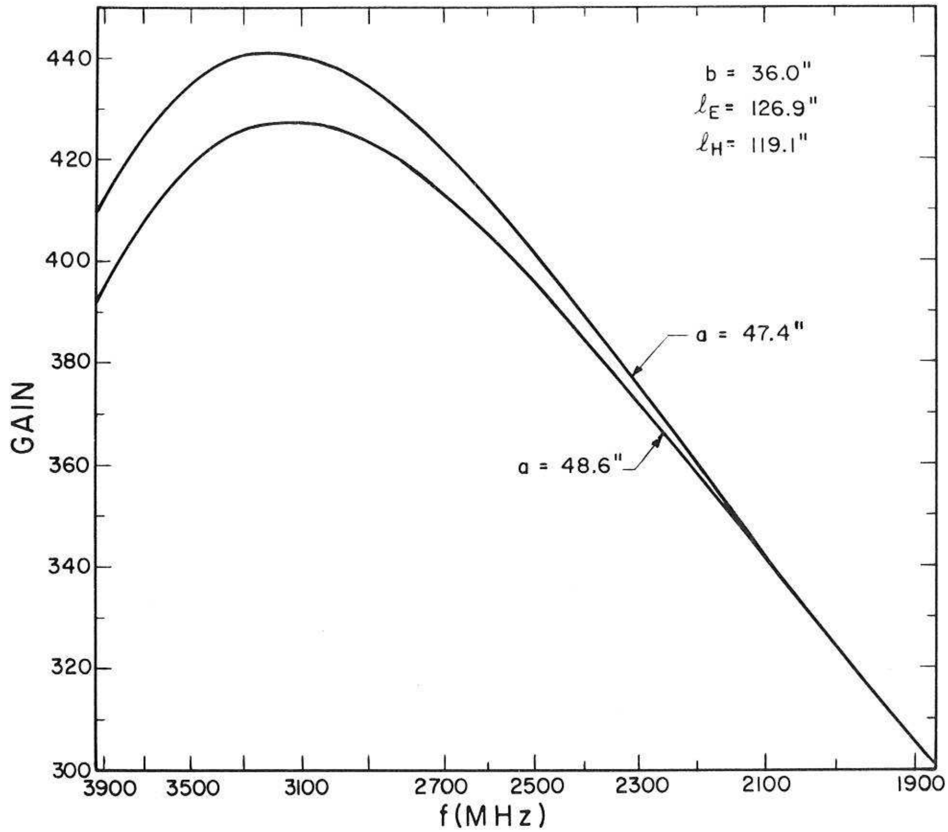


Fig. 5 Gain of horn vs frequency with H-plane aperture dimensions of 47.4 inches and 48.6 inches

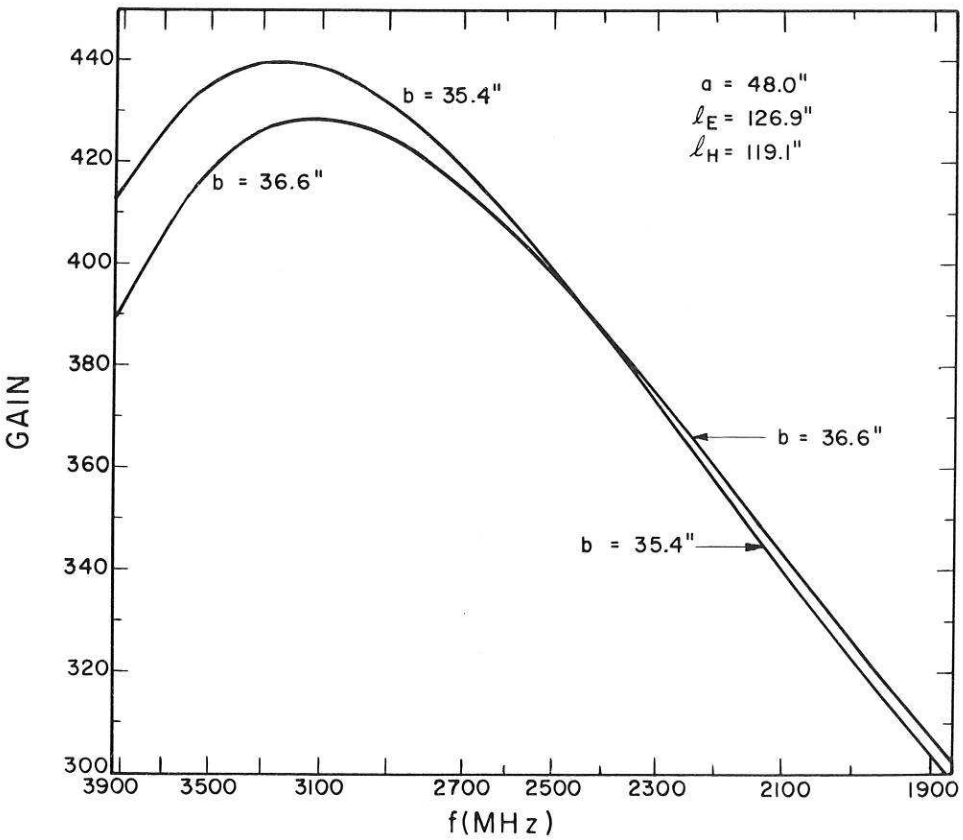


Fig. 6 Gain of horn vs frequency with E-plane aperture dimensions of 35.4 inches and 36.6 inches

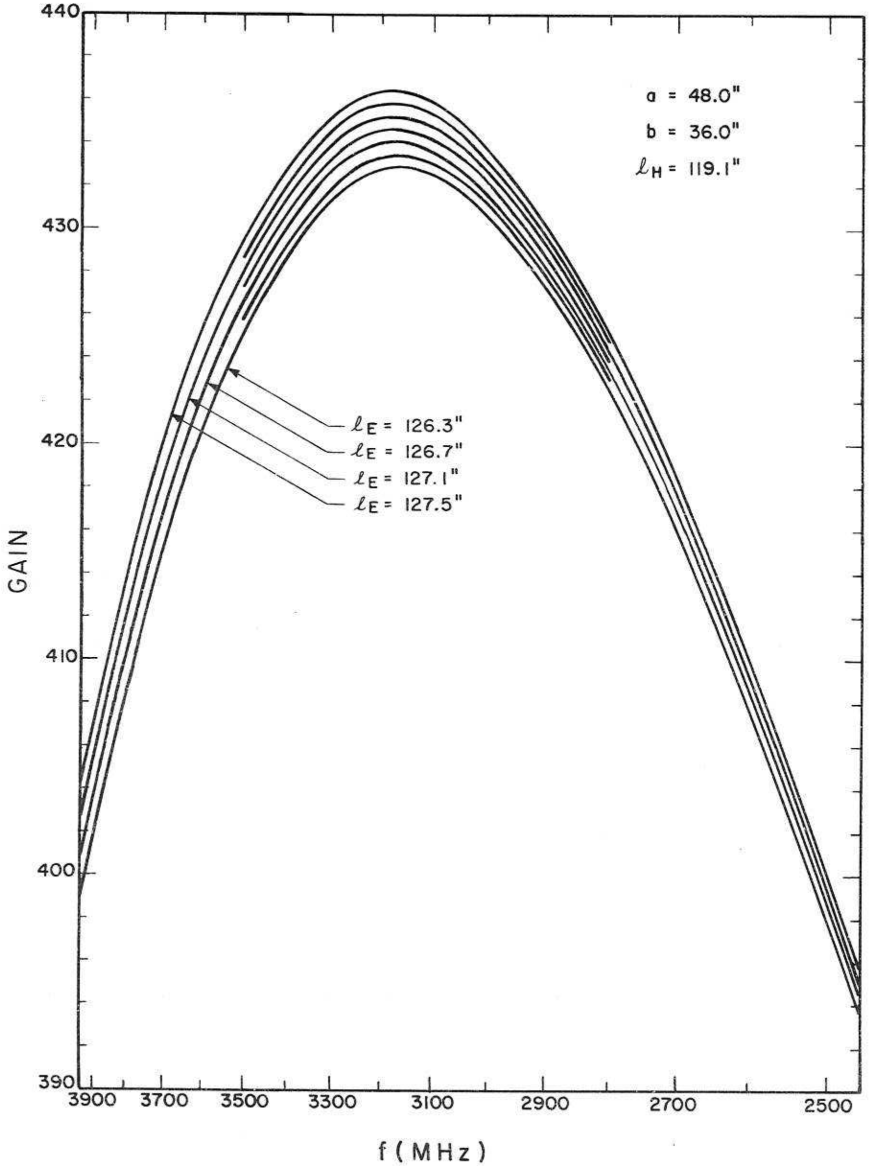


Fig. 7 Gain of horn vs frequency with various E-plane slant lengths

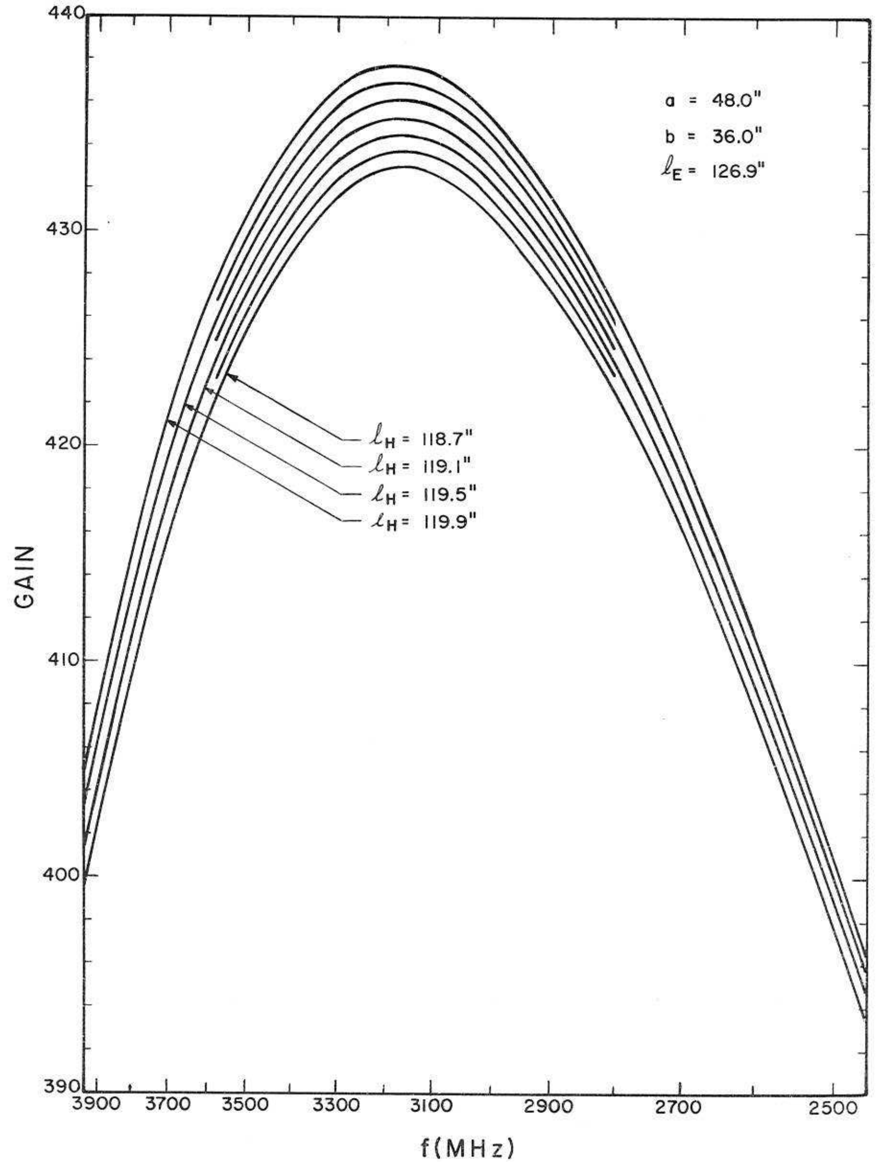


Fig. 8 Gain of horn vs frequency with various H-plane slant lengths

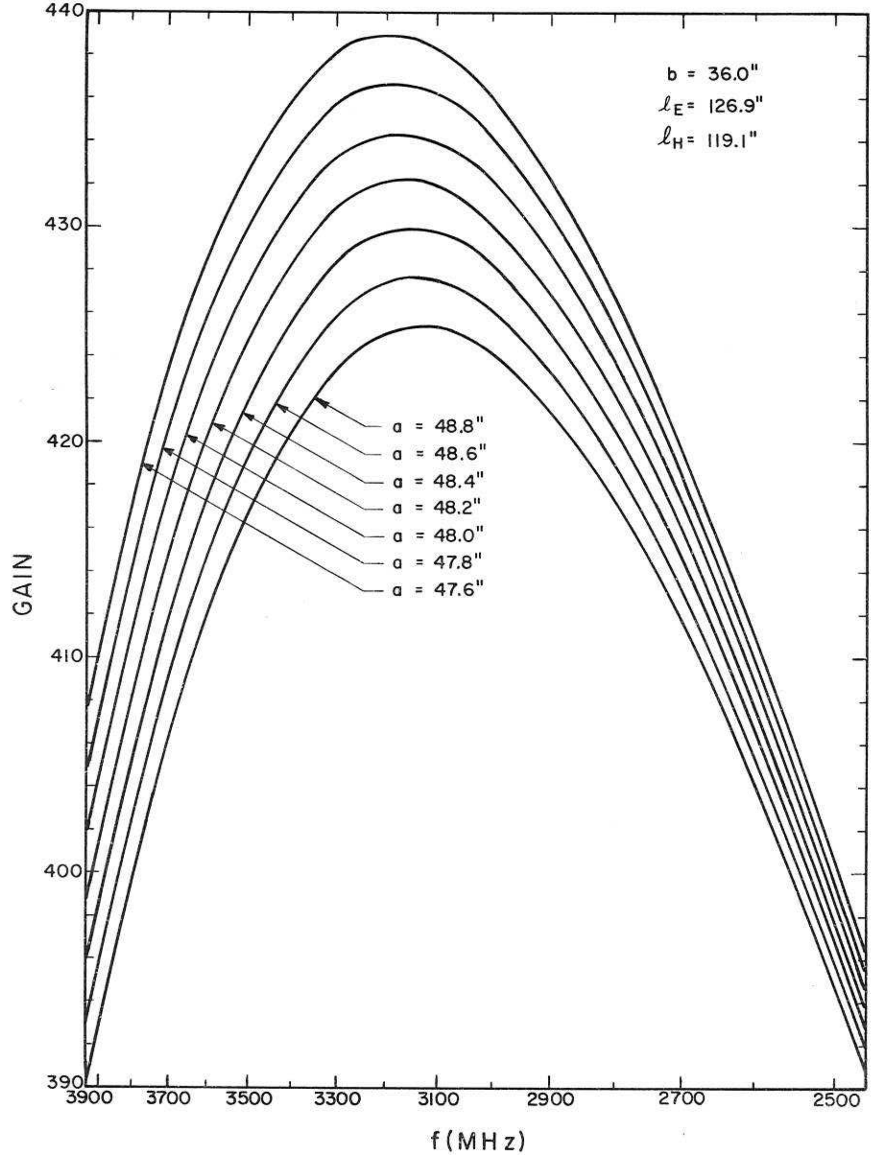


Fig. 9 Gain of horn vs frequency with various H-plane aperture dimensions

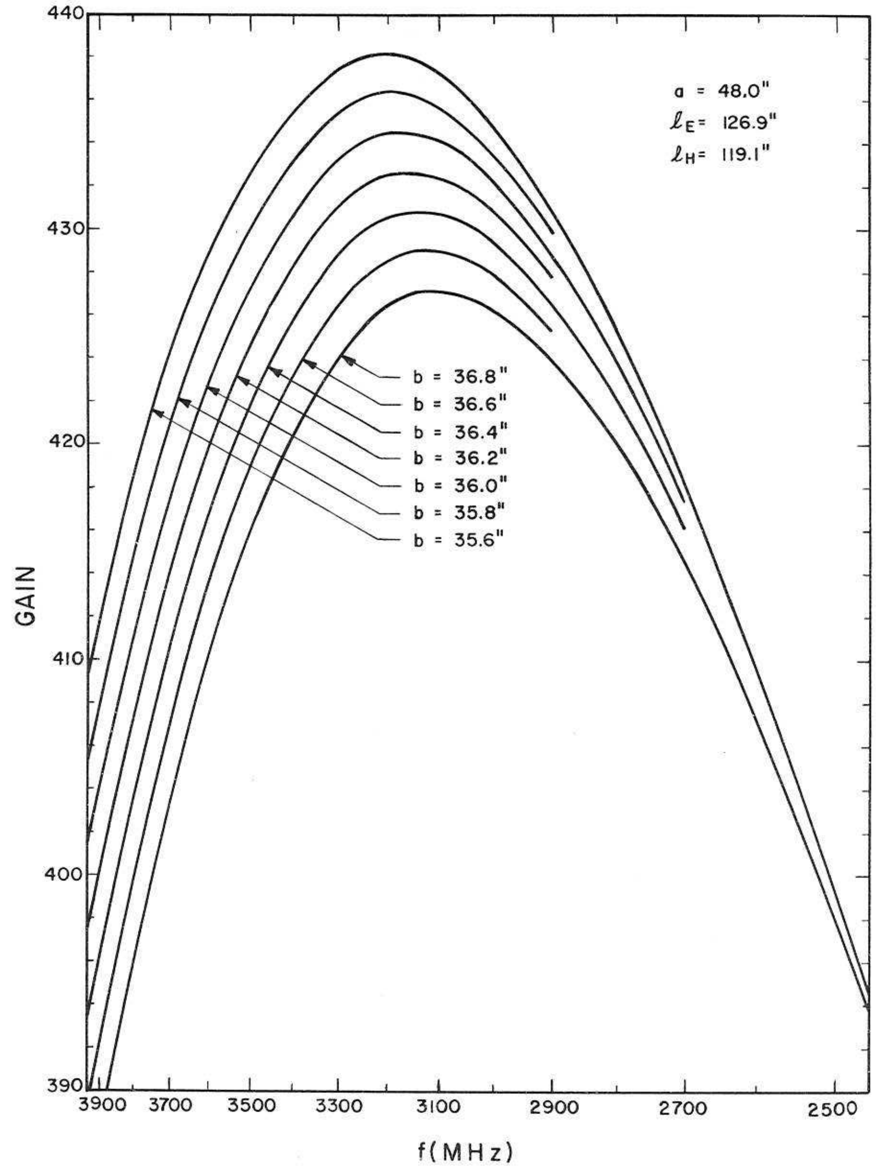


Fig. 10 Gain of horn vs frequency with various E-plane aperture dimensions

The range of each variable is:

$a = 47.6\ (.2)\ 48.8$ inch
$b = 35.6\ (.2)\ 36.8$ inch
$\ell_E = 126.3\ (.2)\ 127.5$ inch
$\ell_H = 118.7\ (.2)\ 119.9$ inch

with centre values of

$a = 48.0$ inch $= 121.9$ cm
$b = 36.0$ inch $= 91.4$ cm
$\ell_E = 126.9$ inch $= 322.3$ cm
$\ell_H = 119.1$ inch $= 302.5$ cm

As the dimensions of one variable are changed, the other three are fixed at their centre value.

This horn is optimum or has maximum gain at $\lambda \cong 3.8$ inches (9.65 cm). Dimension changes at wavelengths larger than this value have a much less pronounced effect on the gain than at shorter wavelengths, as was expected. Changes in aperture dimensions produce a greater effect on the gain than similar changes in slant length. We also notice that as the slant lengths increase, the gain increases, but as the aperture dimensions increase, the gain decreases at wavelengths about the optimum value (Figs. 3-10). The gain at the nominal frequency of 2800 MHz is 424 and is to be compared with the gain of 428 originally calculated in reference (1). The gain at the centre of the 2700-2690 MHz band allocated to the radio astronomy service is 417. At this frequency the rms error in gain is ±0.2% for an error of ±0.25 cm in construction as shown in Fig. 11. Examination of the various curves will show that most of this arises from the errors in the width of the horn aperture in the E-plane.

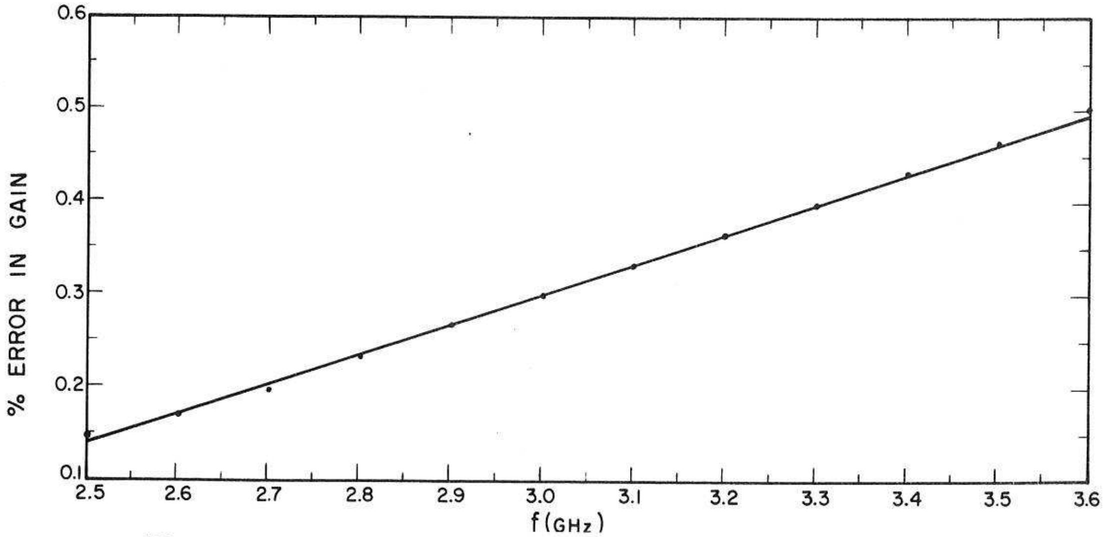


Fig. 11 Percentage error vs frequency in calculated gain of horn

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APPENDIX: IBM 360 Fortran program for calculating the gain of a pyramidal horn

```
      ICOUNT=1
      ELE=126.30
      ELH=119.10
      A=48.00
      B=36.00
      WRITE(3,11)
   11 FORMAT('    LE          LH          A          B'/)
      WRITE(3,4)ELE,ELH,A,B
    4 FORMAT(F7.2,2F10.2,F9.2/)
   17 WRITE(3,5)
    5 FORMAT('  LAMBDA              GAIN'/)
      BLAM=3.00
   13 F=SQRT(BLAM*ELH)/A
      D=A/SQRT(BLAM*ELH)
      UU=.707107*(F&D)
      VV=.707107*(F-D)
      WW=B/SQRT(2.0*BLAM*ELE)
      FNUM=(25.13274*A*B)/(BLAM*BLAM)
      X=1.570796*UU*UU
      CALL CS(C,S,X)
      CU=C
      SU=S
      X=1.570796*VV*VV
      CALL CS(C,S,X)
      CV=-C
      SV=-S
      X=1.570796*WW*WW
      CALL CS(C,S,X)
      CW=C
      SW=S
      G=ENUM*(((CW*CW)&(SW*SW))/(WW*WW))*(((CU-CV)**2&(SU-SV)**2)/
     $(UU-VV)**2)
      WRITE(3,6)BLAM,G
    6 FORMAT(F7.2,F17.4/)
      IF(BLAM-6.00)9,10,10
    9 BLAM=BLAM&.30
      GO TO 13
   10 GO TO (18,19,20,21),ICOUNT
   18 ELE=ELE&.20
      WRITE(3,38)ELE
   38 FORMAT(' LE= ',F6.2//)
      IF(ELE-127.50)17,31,31
   31 ICOUNT=2
      ELE=126.90
      ELH=118.30
      WRITE(3,11)
      WRITE(3,4)ELE,ELH,A,B
   19 ELH=ELH&.20
      WRITE(3,39)ELH
   39 FORMAT(' LH= ',F6.2//)
      IF(ELH-119.70)17,33,33
   33 ICOUNT=3
      ELH=119.10
      A=47.20
      WRITE(3,11)
      WRITE(3,4)ELE,ELH,A,B
   20 A=A&.20
      WRITE(3,40)A
   40 FORMAT(' A= ',F5.2//)
      IF(A-48.60)17,35,35
   35 ICOUNT=4
      A=48.00
      B=35.20
      WRITE(3,11)
      WRITE(3,4)ELE,ELH,A,B
   21 B=B&.20
      WRITE(3,41)B
   41 FORMAT(' B= ',F5.2//)
      IF(B-36.60)17,37,37
   37 CALL EXIT
      END
```