NATIONAL RADIO ASTRONOMY OBSERVATORY

MEMORANDUM November 14, 1967

To: Spectral Line Users of
140-Foot Telescope

From: S. Weinreb S. Weinreb

You may be interested in the attached description of some baseline perturbation effects caused by reflections from the 140' paraboloid into the feed horn. These effects distort the baseline of spectral line receivers and will be an important consideration in the use of the 50-channel wideband receivers and the new autocorrelation receiver at its widest bandwidths.

SW/cjd

Attachment

Copies to:
- P. Mezger
- T. Wilson
- E. Rifenstein
- B. Burke (MIT)
- M. Balister
- G. Behrens
- F. Gardner
- T. K. Menon
- M. Roberts
- A. Penzias (BTL)
- S. Goldstein (UVA)
- G. K. Walters (Rice)
- D. S. Heeschen
- J. W. Findlay
- H. Hvatum
- H. Brown

Kerr

JC

NATIONAL RADIO ASTRONOMY OBSERVATORY

EFFECT OF FEED-PARABOLOID REFLECTIONS UPON LINE RECEIVER PERFORMANCE ON THE 140' TELESCOPE

S. Weinreb

November 14, 1967

It has been observed that moving the feed location by small amounts along the focal axis of the 140' telescope effects the baseline of the 50-channel, 100 kc channel bandwidth receiver. These effects are shown in Figure 1 where curve (2) is the baseline at the normal focal position, curve (3) is the baseline when the focal position is changed by 1.5 cm (i.e., $\lambda/4$ at 6 cm) and curve (4) is the baseline with a 3.0 cm change. It can be seen that curves (2) and (4) are nearly identical where curve (3) is quite different. These curves were taken with the antenna pointed at zenith, the 6 cm radiometer, a frequency switching difference of 4.15 MHz, and an integration time of 300 seconds.

These effects are due to thermal noise at 300 °K which is transmitted out of the feed horn and is reflected with reflection coefficient, Γ, near the feed horn and reflection coefficient, Γ', at the parabolic reflector. Either reflection, considered alone, is of no consequence. However, the interference pattern between the two reflections causes a sinusoidal baseline modulation with a period of 7.5 MHz (independent of center frequency) on the 140' telescope. An outline of the theory of this effect is shown in Figure 2.

The reflections considered in Figure 2 are for the thermal noise transmitted out of the receiver. It can be shown by a simple thermodynamical argument that the same effect must occur for signals received by the antenna. (Consider the case of the antenna beam pointed at a 300 °K absorber and apply the Second Law.) The total perturbation of the baseline, ΔT, is then given by

$$\Delta T = a(T_1 - T_A) \cos \left(\frac{2\pi f}{b} + \varphi \right)$$

where b = 7.5 MHz for the 140' telescope, T_A is the antenna temperature,

$a = \frac{10^{-1} \times 6 \times 10^{-2}}{17.4}$

For 300 foot at 21 cm. & same $|\Gamma|$

$a = \frac{10^{-1} \times .21}{39} = .5 \times 10^{-3}$

T_1 is temperature of the noise coming out of the receiver, φ is an unknown phase angle, and a is dependent on the receiver reflection coefficient, Γ, and antenna focal length, F ($a = |\Gamma| \lambda/F = 0.3 \times 10^{-3}$ for the 140' telescope and 6 cm receiver).

The sinusoidal baseline modulation effect measured between 5009 and 5019 MHz is shown in Figure 3. The spectrum is obtained by putting together three 5 MHz wide spectra. The 7.5 MHz period of the sine wave confirms that the reflection is from the paraboloid (and not feed support legs, for example).

Several conclusions can be drawn:

1) The effect will not cancel out in ON-OFF measurements of strong continuum sources because of the dependence on T_A.

2) The effect is the major baseline distortion on the 6 cm radiometer and will become stronger as wavelength is increased.

3) The distortion can be eliminated by averaging spectra taken at focal positions $+\lambda/8$ and $-\lambda/8$ from the nominal focal position; see Figure 4. This will reduce the antenna gain slightly.

4) Matching of the feed and parametric amplifier will reduce the magnitude of the effect. However, it is doubtful that a VSWR less than 1.10 ($\Gamma = 0.05$) can be obtained for the combination of components.

5) Some sort of scattering structure at the reflector vertex may be needed for critical observations.

RESULTS OF MOVING FOCUS POSITION OF 6CM RADIOMETER

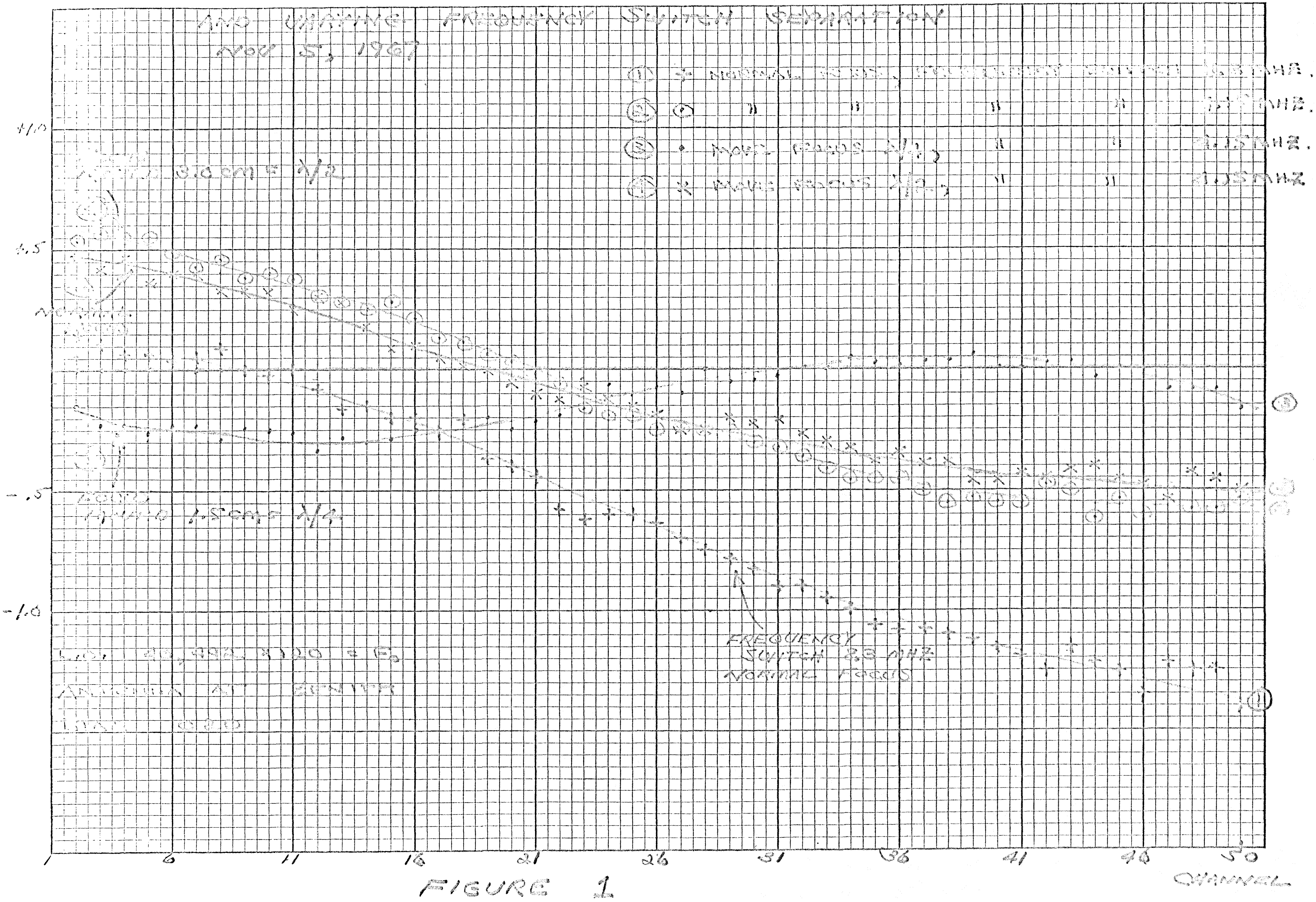
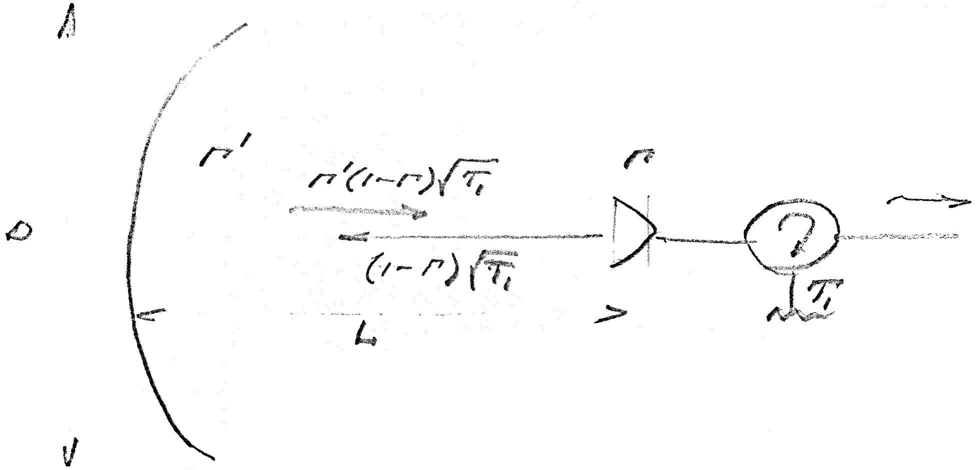


FIGURE 1

D = [illegible] m $\qquad$ $f \approx 17.9$m $\qquad$ $f = \frac{c}{2L} = \frac{3\times10^{8}}{2\times17.9} = 8.4$ MHz

[illegible]

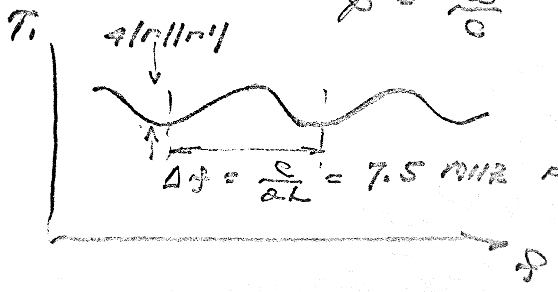
300 foot. $\quad l = 30$m $\quad \Delta f = \frac{3\times10^{8}}{60} = 5\times10^{6} = 5$Mc.



INPUT TEMPERATURE CAUSED BY REFLECTIONS:

$$\Delta T = T_1\left[|\Gamma'|^2 + |\Gamma|^2 + 2|\Gamma||\Gamma'|\cos 2\beta L\right]$$

$$\beta = \frac{\omega}{c}$$



$|\Gamma'| \approx \frac{\lambda}{2L} = \frac{6\times10^{-2}}{36} = 1.6\times10^{-3}$ FOR 140' @ 6cm

$|\Gamma| = .10$ FOR VSWR OF 1.20 AT FEED LOOKING INTO RECEIVER

$T_1 \cdot 4|\Gamma||\Gamma'| = .64\times10^{-3}\times300 = 0.2°$

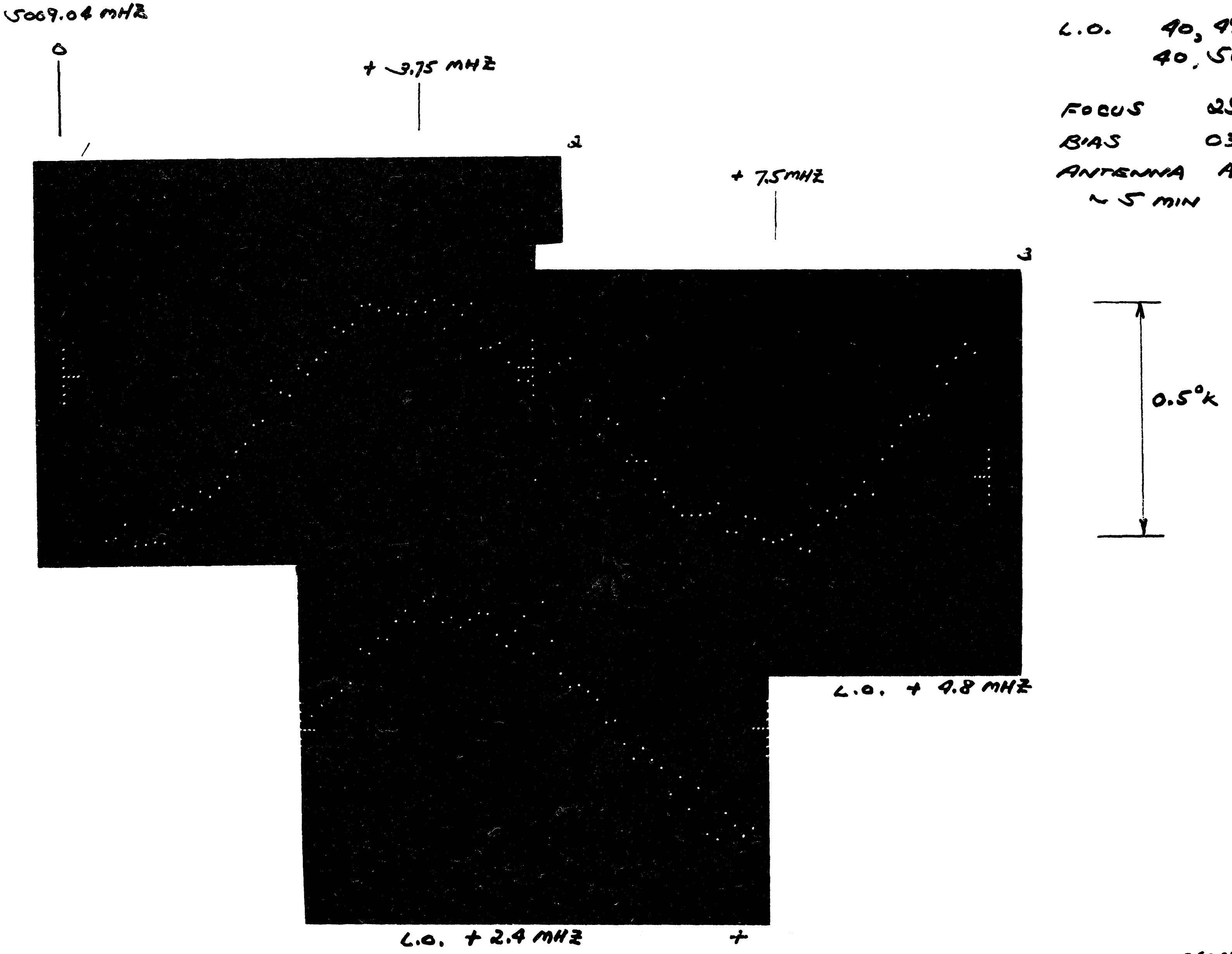
FREQUENCY SWITCHING CAN GIVE 0.4°

TOTAL EFFECT OF REFLECTIONS IS:

$$\Delta T = (300° - \underset{\substack{\uparrow\\ \text{ANTENNA TEMPERATURE}}}{T_A})\cos\left(\frac{2\pi f}{7.5\text{ MHz}} + \underset{\substack{\nwarrow\\ \text{UNKNOWN PHASE ANGLE}}}{\varphi}\right) \times .32\times10^{-3}$$

FIGURE 2

COMPOSITE BASELINE OVER 10 MHZ TAKEN FROM THREE 5 MHZ SPECTRA



L.O. 40, 492.0 kc = f_0
40, 526.6 kc = f_1, f_2

FOCUS 255 mm
BIAS 035
ANTENNA AT ZENITH
~ 5 MIN INTEGRATION

NOV. 10, 1967

FIGURE 3

K & E 99 9980 74579

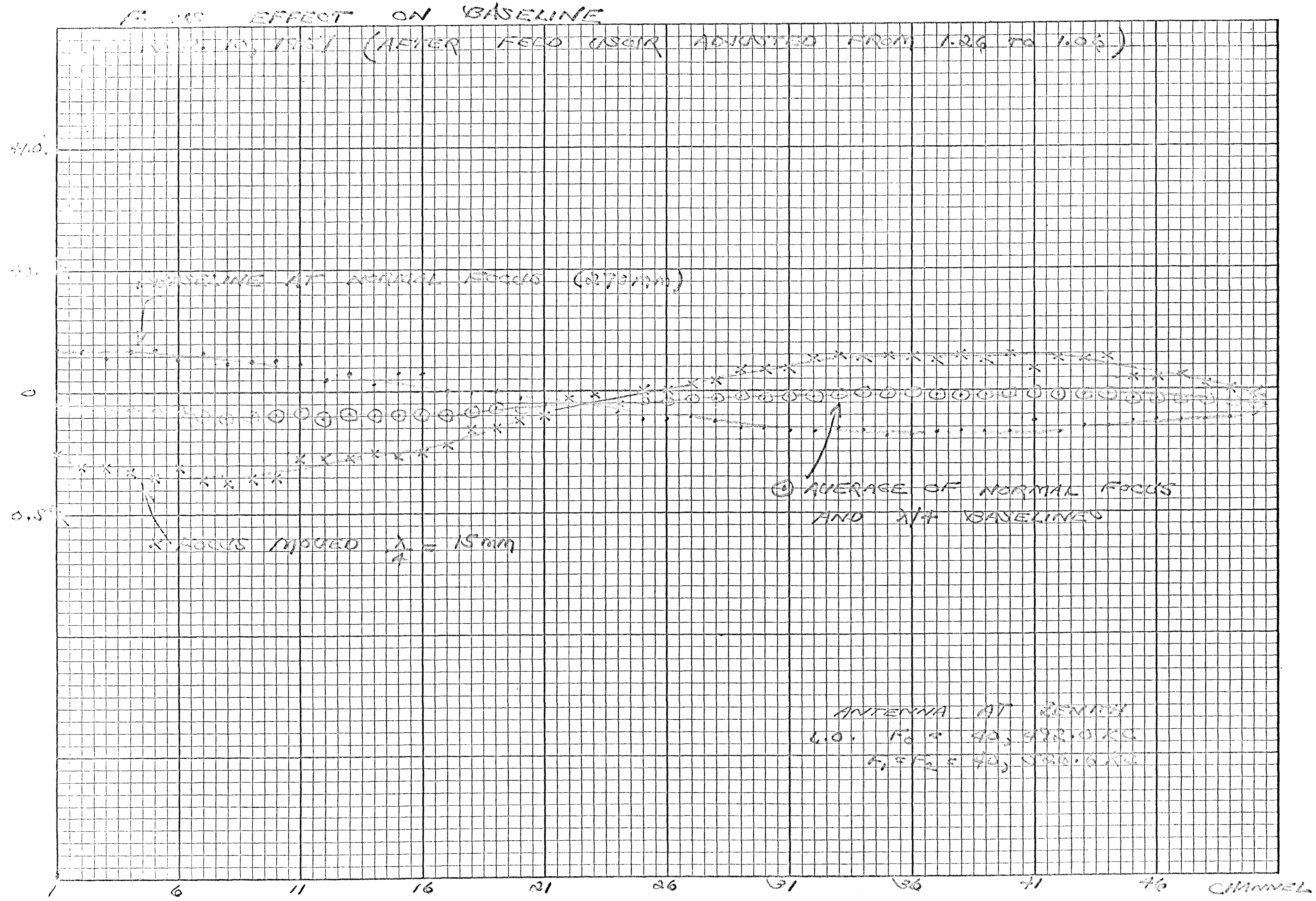


FIGURE 4