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3-mm SINGLE SIDEBAND CALIBRATION FILTERS

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The millimeter line receivers used by NRAO at Kitt Peak are all of the double sideband type. They receive signals in two bands symmetrically spaced on each side of the local oscillator frequency, i.e. at $f = f_{LO} \pm f_{IF}$. Calibration of these receivers is normally carried out using broadband sources, such as cold loads, which inject noise into both signal channels. In the observation of molecular lines, however the signal of interest enters through only one channel. Therefore to determine the strength of the signal from the wideband calibration it is necessary to assume that the response of the receiver in both the signal and image channels is the same. For low IF frequencies the signal and image frequencies are close together and this is normally a fair assumption. However in the present receivers, f_{IF} = 1400 MHz, and the signal and image channels are separated by 2800 MHz. In this case it becomes more important to determine the relative responses of the two reception channels. A method has been devised to do this involving narrow passband, low insertion loss, filters. The passbands of the filters are centered on various well known molecular lines in the 3-mm wavelength region and are sharp enough to reject the image channel by at least 20 dB. The insertion of such a filter between the receiver feed horn and the mixer converts the receiver to a single sideband receiver. If the receiver is then calibrated in this configuration, the strengths of various strong molecular line sources can be measured and these sources can then be used as calibration sources in the double sideband mode for comparison to weaker sources. (It is desirable to normally operate in the double sideband mode, as the insertion loss of the filter degrades the noise temperature of the receiver.)

This report covers the design, construction, and tests of the five filters. A future report will cover their use on receivers and the resulting observations.

DESIGN

The criteria chosen were that the passband insertion loss be less than 3 dB and the rejection at the image channel, $f_c \pm 2800$ MHz, be greater than 20 dB. The following table lists the filter passbands, insertion losses, and observable molecular lines.

TABLE 1

SINGLE SIDEBAND CALIBRATION FILTERS

FILTER	PASSBAND (-0.2 dB) (GHz)	INSERTION LOSS (dB)	MOLECULAR LINES
1	114.95-115.50	2.0	$^{12}C^{16}O$
2	112.30-112.45	2.5	$^{12}C^{17}O$
3	109.80-110.30	2.8	$^{12}C^{18}O$, $^{13}C^{16}O$
4	88.10-89.60	1.0	$H^{12}C^{14}N$, X-Ogen
5	85.60-86.90	0.9	$H^{13}C^{14}N$, $H^{12}C^{15}N$ Schneider 86.245 GHz

Rejection at images of molecular line frequencies is at least 20 dB.

These lines were chosen because they are commonly observed, are visible in sufficient sources to make observations convenient, and are of sufficient strength to be easily observable taking into account the insertion losses of the filters.

The filters are of the coupled cavity, waveguide type and were designed according to the procedure given on p.457 of "Microwave Filters, Impedance-Matching Networks, and Coupling Structures", by Matthaei, Young and Jones.

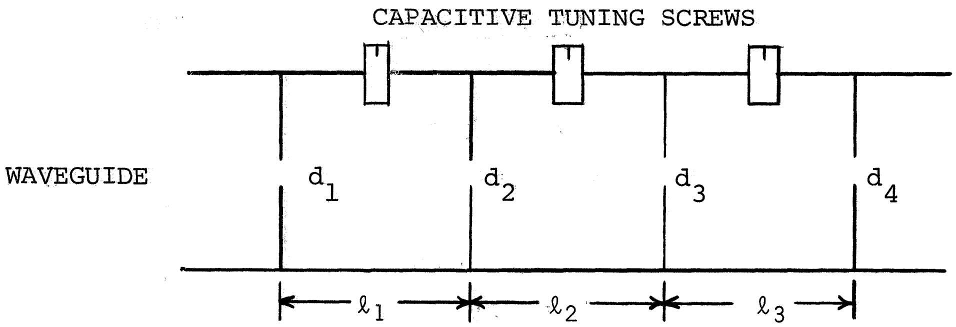


FIGURE 1. THREE CAVITY FILTER

This procedure has been computerized for the HP-9830A calculator which made it convenient to quickly access the results of changing parameters. The result of the design yields the distance between the irises, ℓ_n, and the iris susceptances.

From the iris susceptances the sizes of the irises, d_n, can be determined. It was decided to use centered circular irises because of their ease of construction. The "Microwave Engineers Handbook" Vol. 1, by T. S. Saad gives graphs of iris diameters vs susceptance. Capacitive tuning screws were added to the finished designs to correct for errors due to machining tolerances and assembling.

Table 2 gives the resulting spacer and iris dimensions.

TABLE 2

FILTER	SPACER THICKNESS (inches)	IRIS DIAMETER (inches)
1	$\ell_1 = \ell_2 = .053$	$d_1 = d_3 = .033$ $d_2 = .018$
2	$\ell_1 = \ell_2 = .057$	$d_1 = d_3 = .0295$ $d_2 = .0165$
3	$\ell_1 = \ell_3 = .057$ $\ell_2 = .060$	$d_1 = d_4 = .033$ $d_2 = d_3 = .0186$

TABLE 2 (cont.)

FILTER	SPACER THICKNESS (inches)	IRIS DIAMETER (inches)
4	$\ell_1 = \ell_3 = .079$ $\ell_2 = .084$	$d_1 = d_4 = .0425$ $d_2 = d_3 = .0260$
5	$\ell_1 = \ell_3 = .0855$ $\ell_2 = .090$	$d_1 = d_4 = .043$ $d_2 = d_3 = .025$

Experience with initial designs showed that the spacers should be made about .002" thinner than determined by the calculations. This has the effect of raising the resonant frequency slightly. The tuning screws are then used to tune to the exact frequency desired. The spacer thicknesses in Table 2 are the actual ones used. Calculations showed that the increased attenuation due to the insertion of the tuning screws was less than 0.1 dB which was considered negligible.

CONSTRUCTION

The method of construction was to sandwich spacers and irises together and to rely upon compression contact between parts. Figure No. 4 shows a typical filter assembly. When the filter assembly screws are drawn down tight, the irises, which are made from 0.001" copper sheet, tend to buckle into the cavities slightly which changes their resonant frequencies. For this reason, the end pieces are made in such a way so that fastening the filter into a waveguide system does not change the pressure on the irises. The filter assembly screws must be drawn down uniformly and very tightly. The iris buckling referred to above can cause another problem. This occurs if two adjacent irises buckle away from each other. This causes too large a cavity which then resonates at a lower frequency than desired. The easiest remedy is to reverse the offending iris, after buckling has occurred, so that no two adjacent irises are buckled away from each other.

TESTS

Because the passbands of the filters are so narrow, it is necessary that the frequency of the test source be known very accurately. The quoted dial accuracy of the wavemeters used was ±1/2%. This translates to ±500 MHz at a frequency of 100 GHz. It can be seen that this is not accurate enough for the present purposes. For this reason, the wavemeters were calibrated over the range of interest using a frequency counter, harmonic mixer and spectrum analyzer as shown in Figure 2.

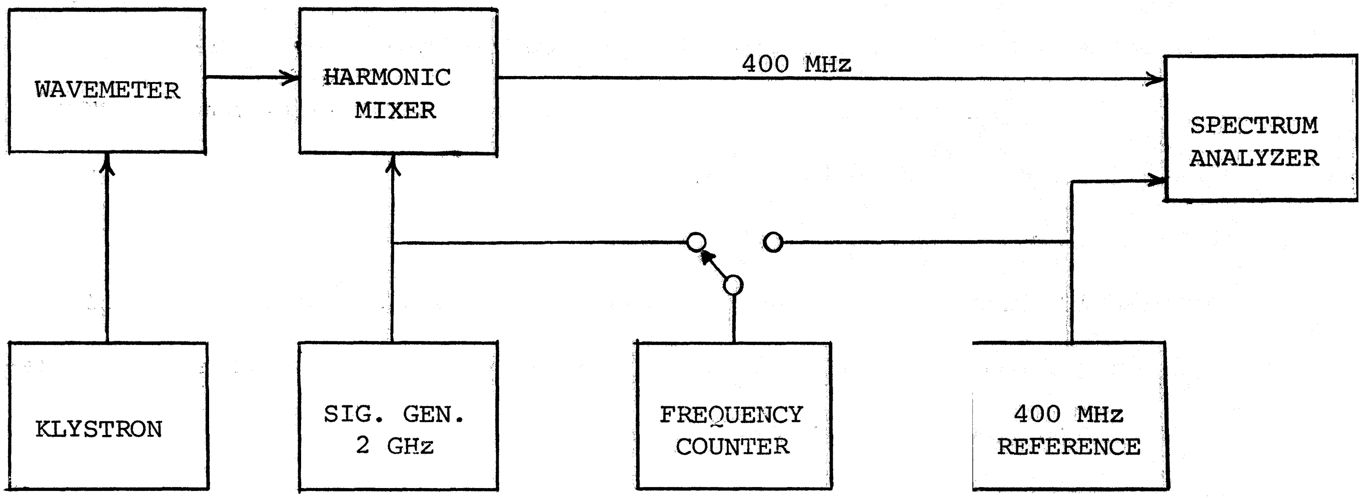


FIGURE 2. WAVEMETER CALIBRATION

Curves were then drawn of wavemeter dial reading vs true frequency. The wavemeters were in fact off by as much as 200 MHz.

In tuning the 3-cavity filters it was necessary to first assemble only two cavities and tune them to resonance at the center frequency. The third cavity could then be added and tuned. The first two cavities were also readjusted because of interaction. Filters 1, 2 and 3 were tuned and measured point by point using the substitution method, Figure 3.

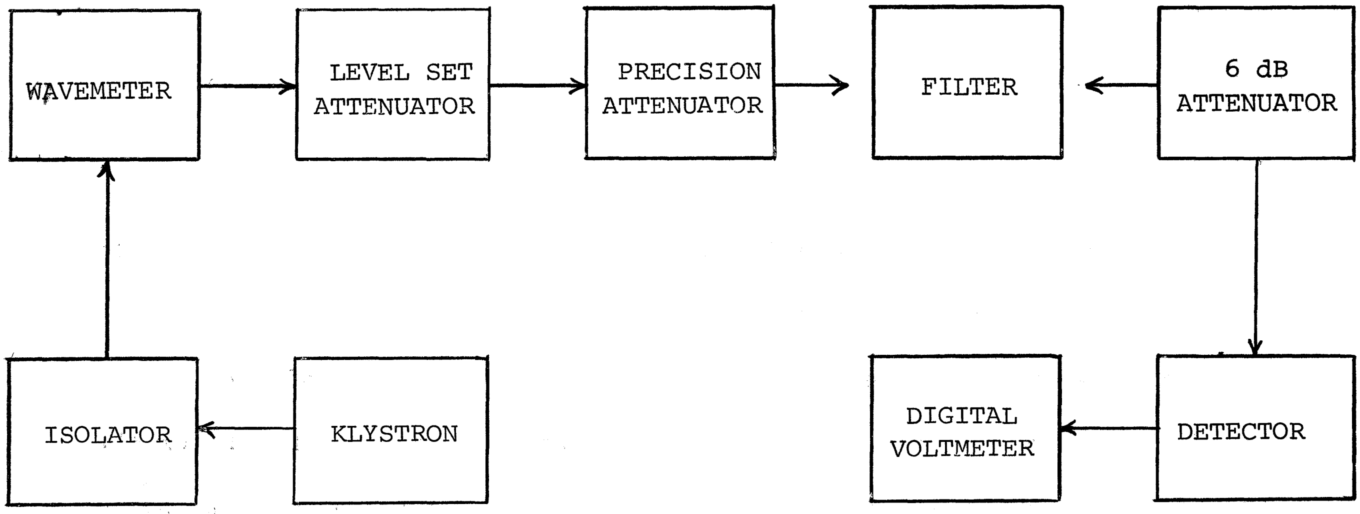
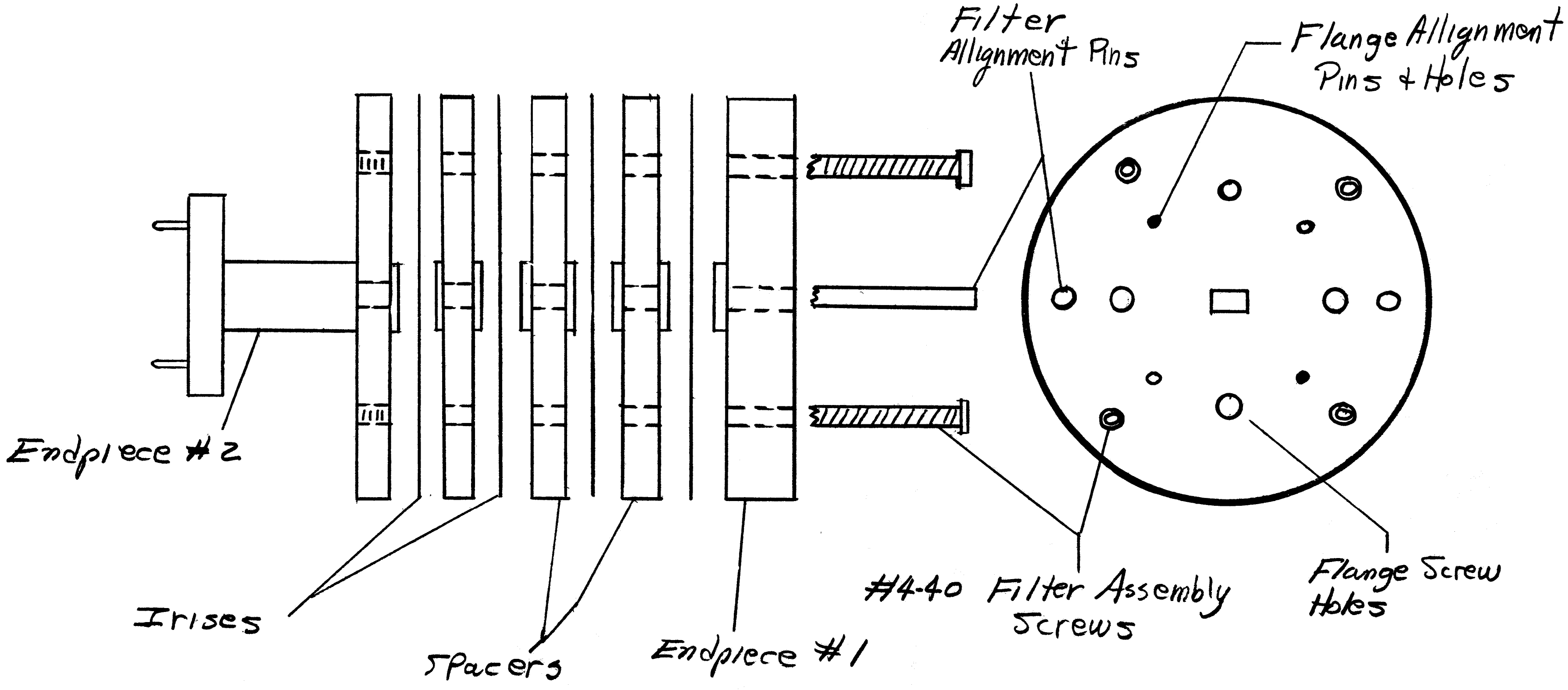


FIGURE 3. FILTER MEASUREMENT

Filters 4 and 5 were first tuned to approximate resonance on the above set-up and then their passband shapes were fine adjusted using a swept source (BWO). The sweeper did not have a uniform enough output at the higher frequencies to be used for filters 1, 2 and 3.

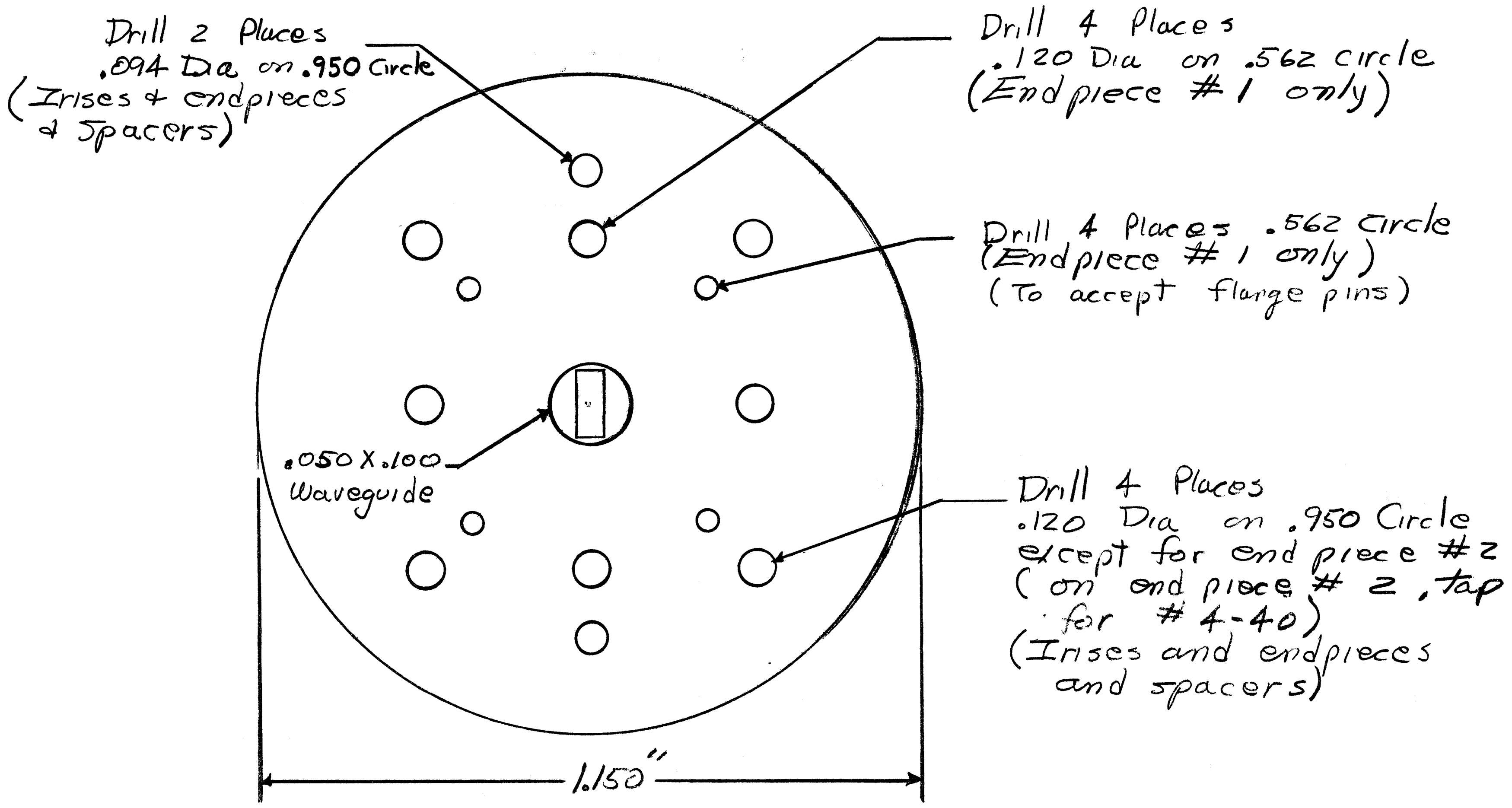
Figures 10 through 14 show the final measured responses of the five filters.

Following final alignment, the tuning screws were covered with epoxy to prevent detuning due to either vibration or sinister forces.



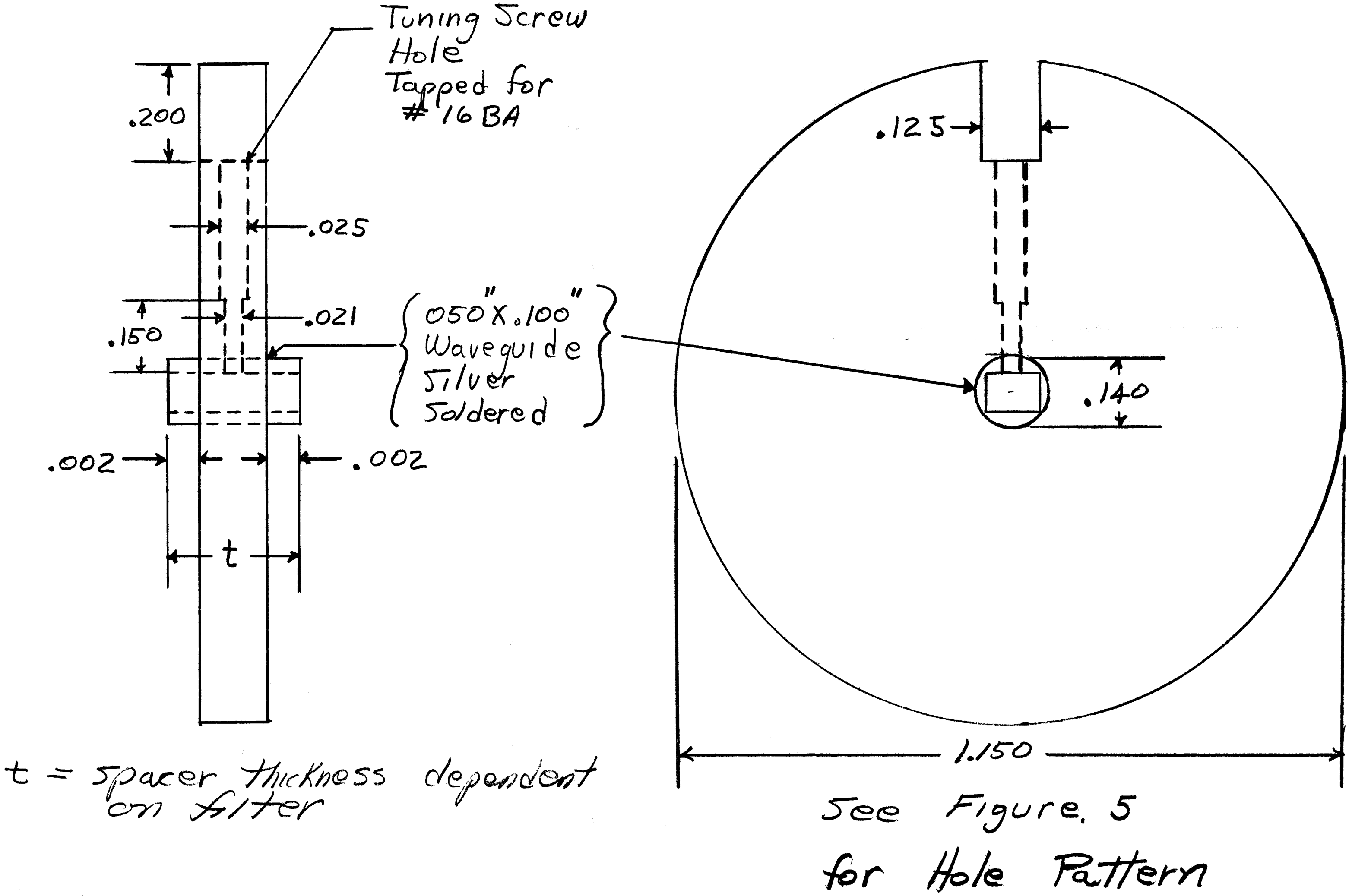
Filter Assembly

Figure 4



Hole Pattern for CO Filter Spacers, Irises, and End Pieces

Figure 5

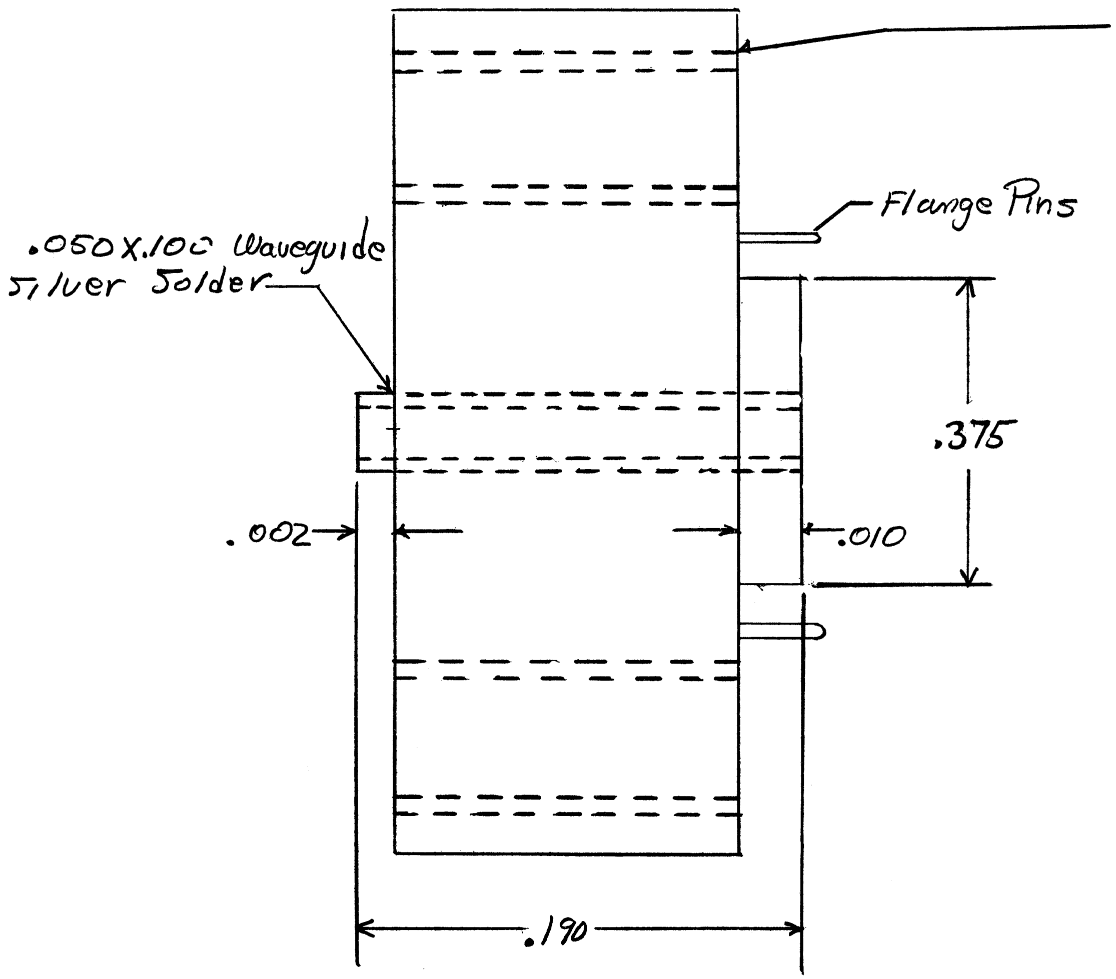


t = Spacer thickness dependent on filter

See Figure 5 for Hole Pattern

Filter Spacers

Figure 6



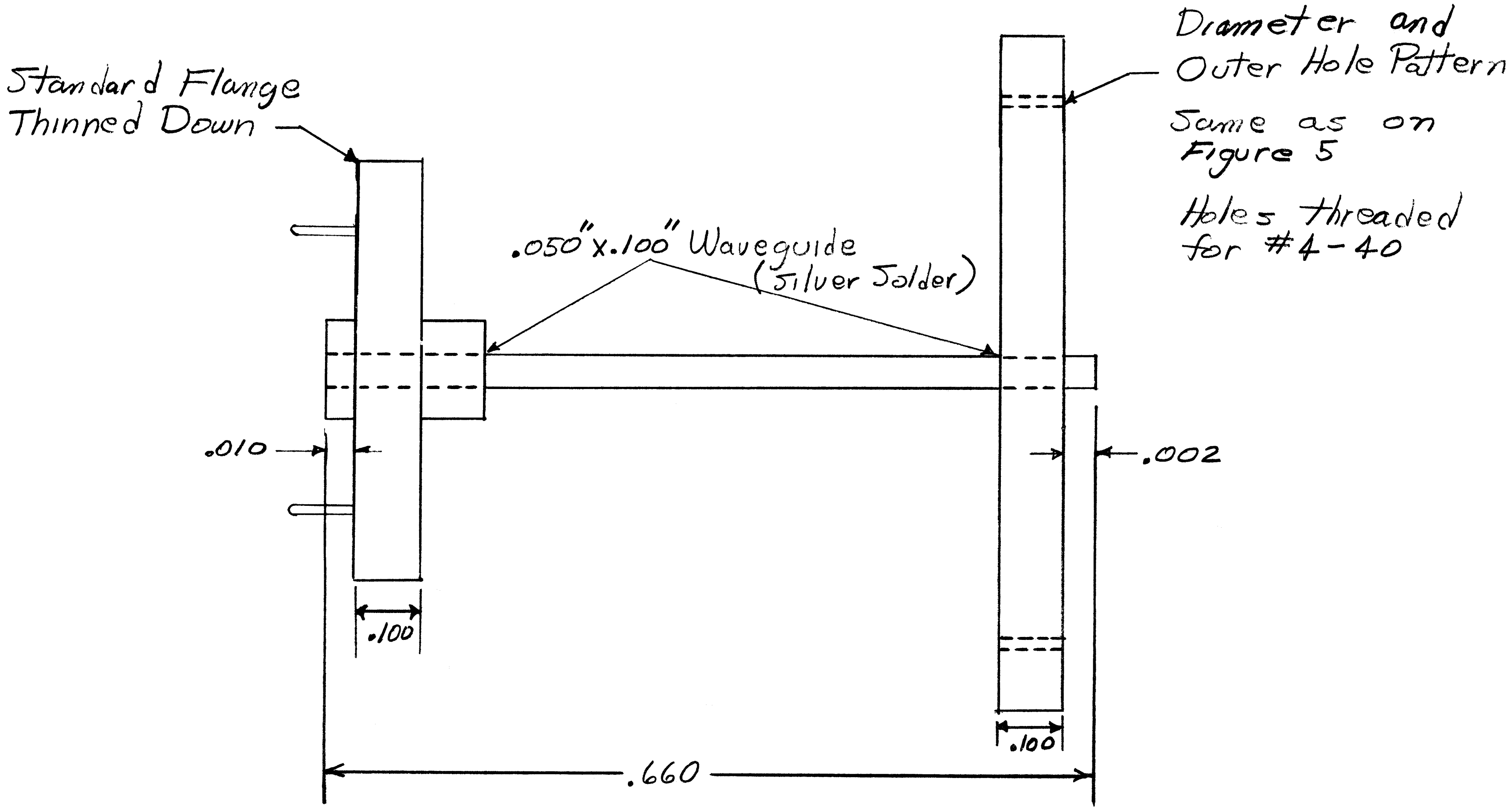
Diameter and hole pattern
same as on Figure 5

Outer screw holes: #4-40 clear

Flange screw holes threaded
~~for~~ #4-40

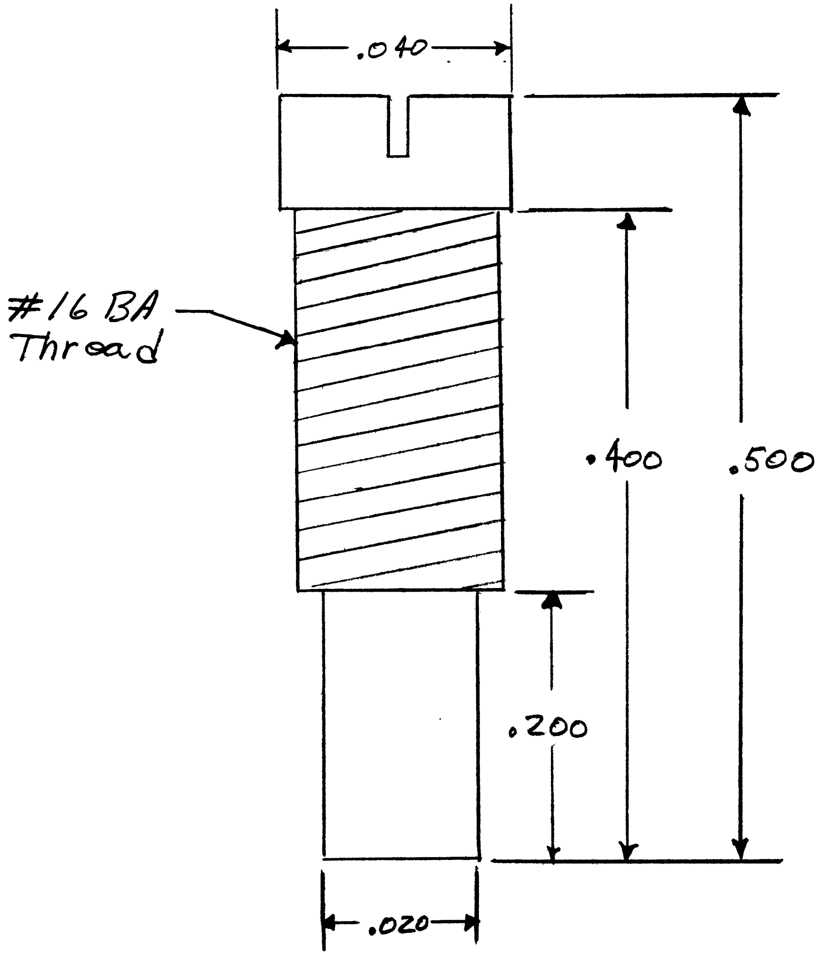
Endpiece #1

Figure 7



Endpiece # 2

Figure 8



Tuning Screw

Figure 9

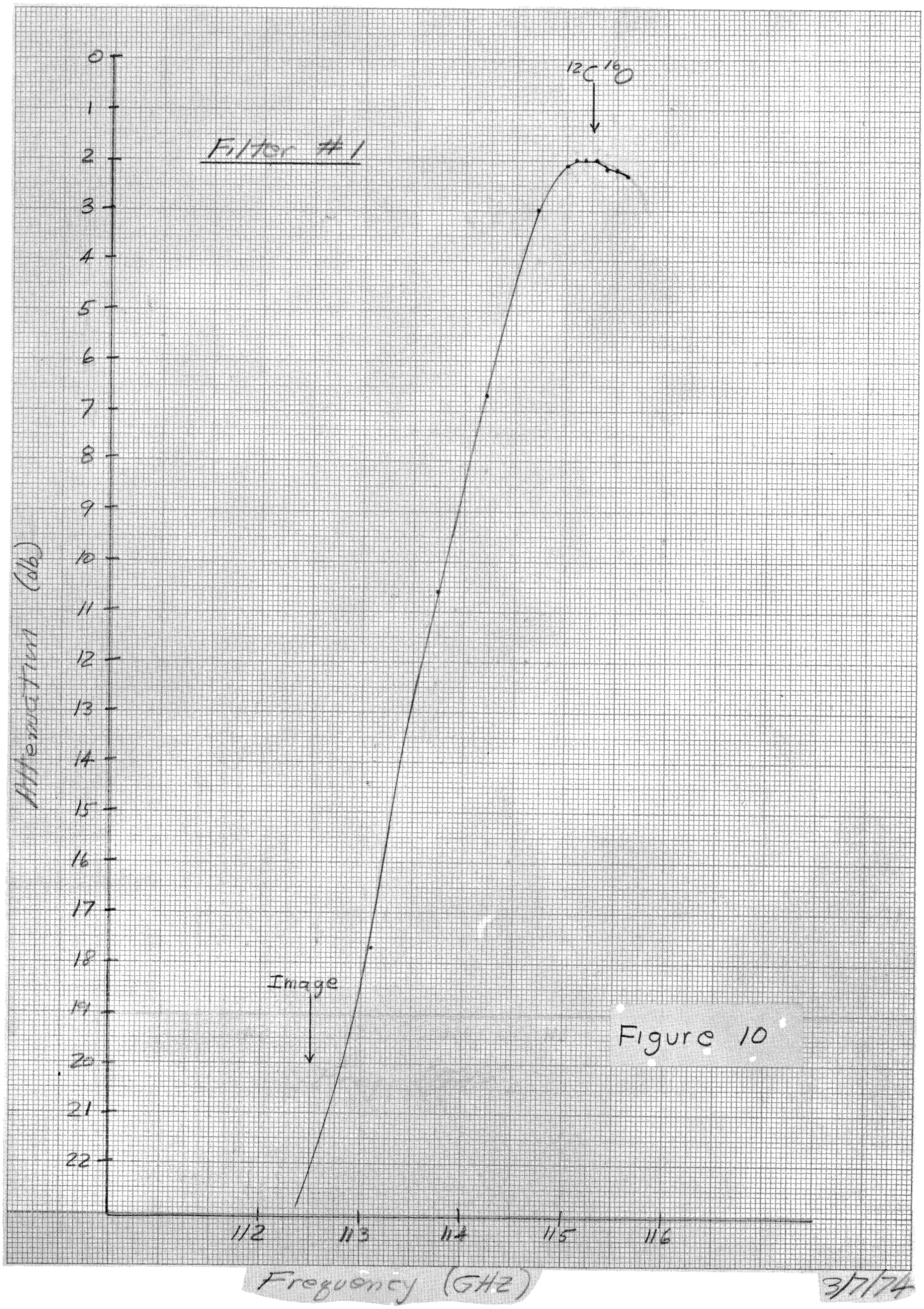


Figure 10

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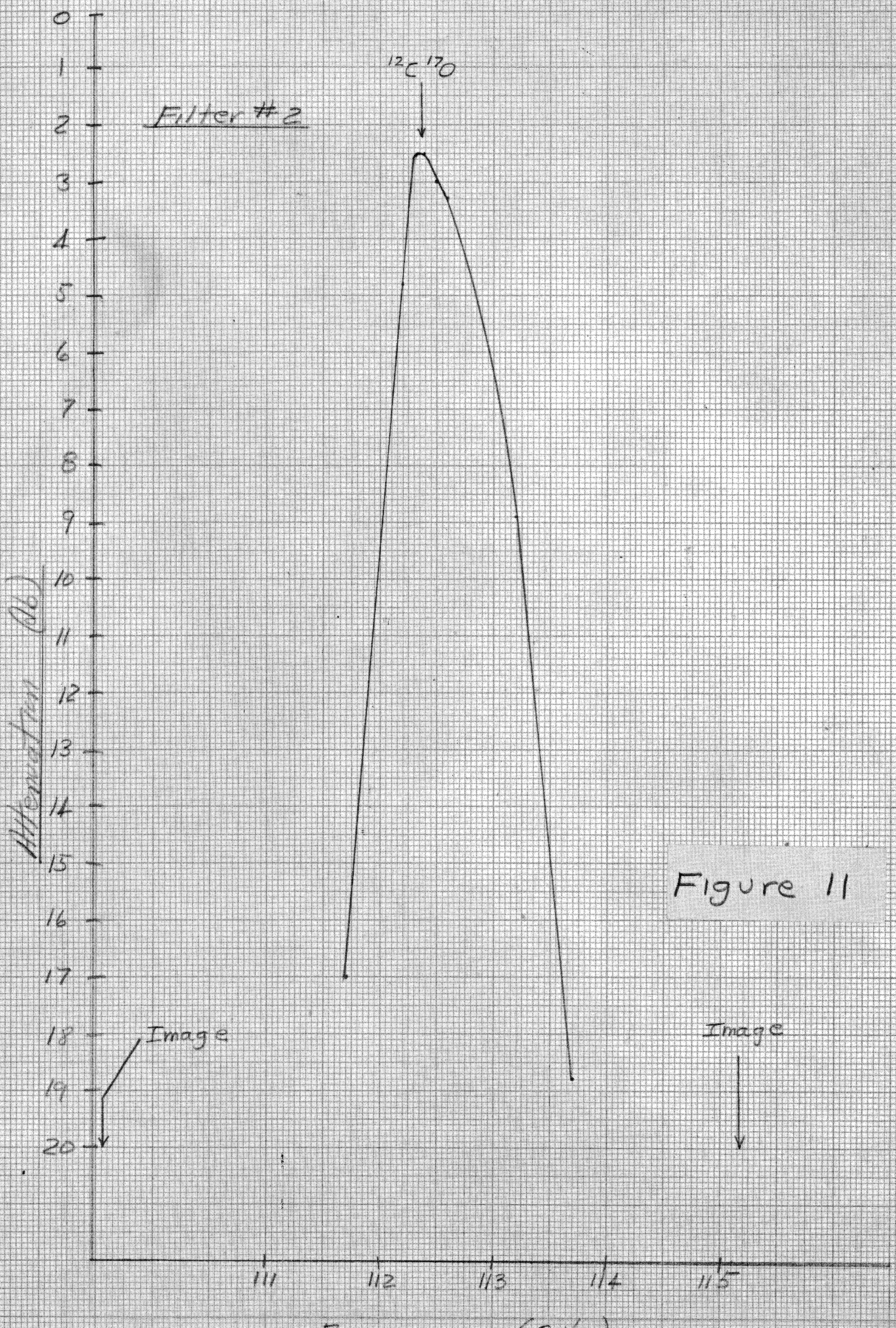

Figure 11

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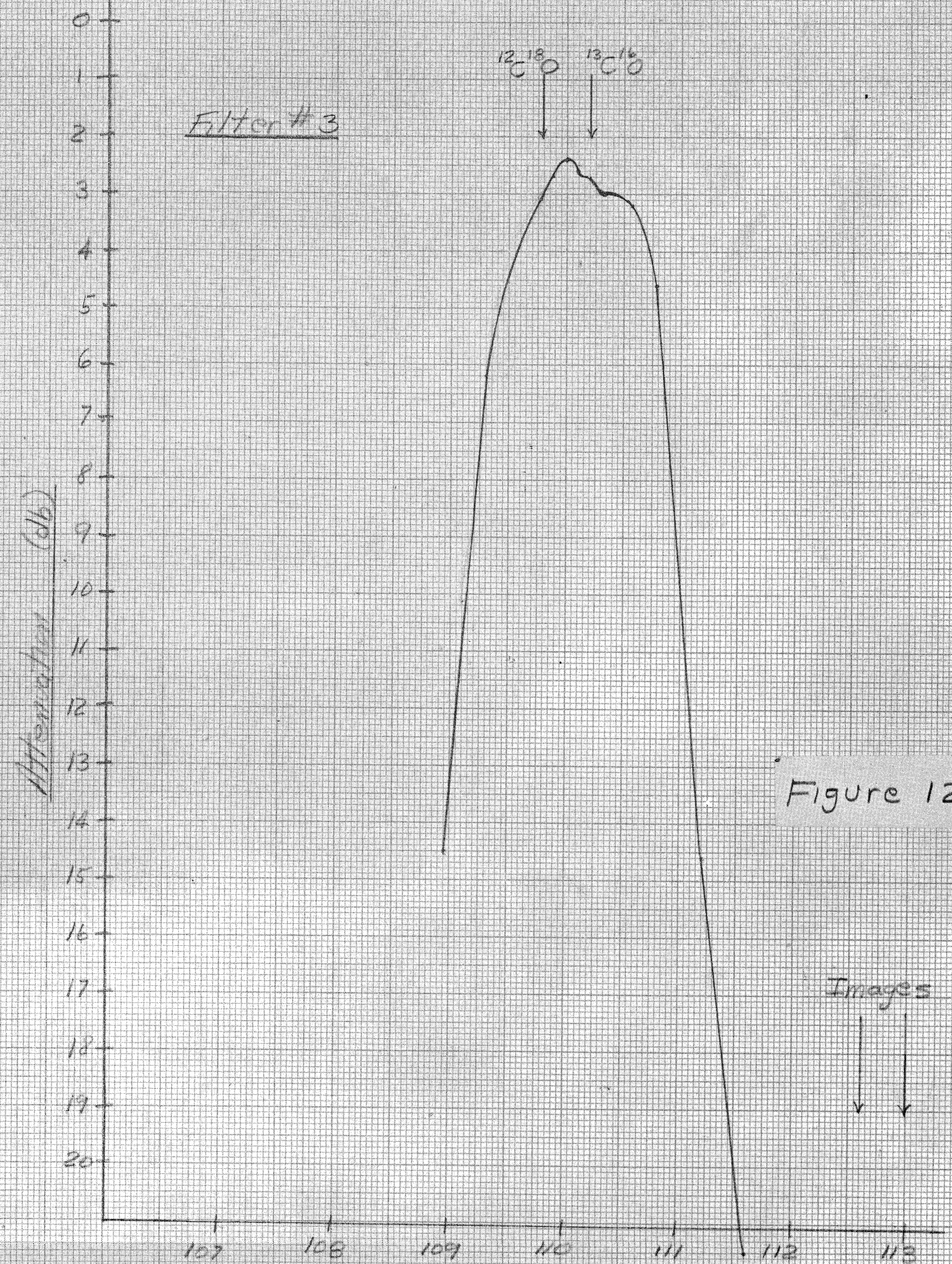

Figure 12

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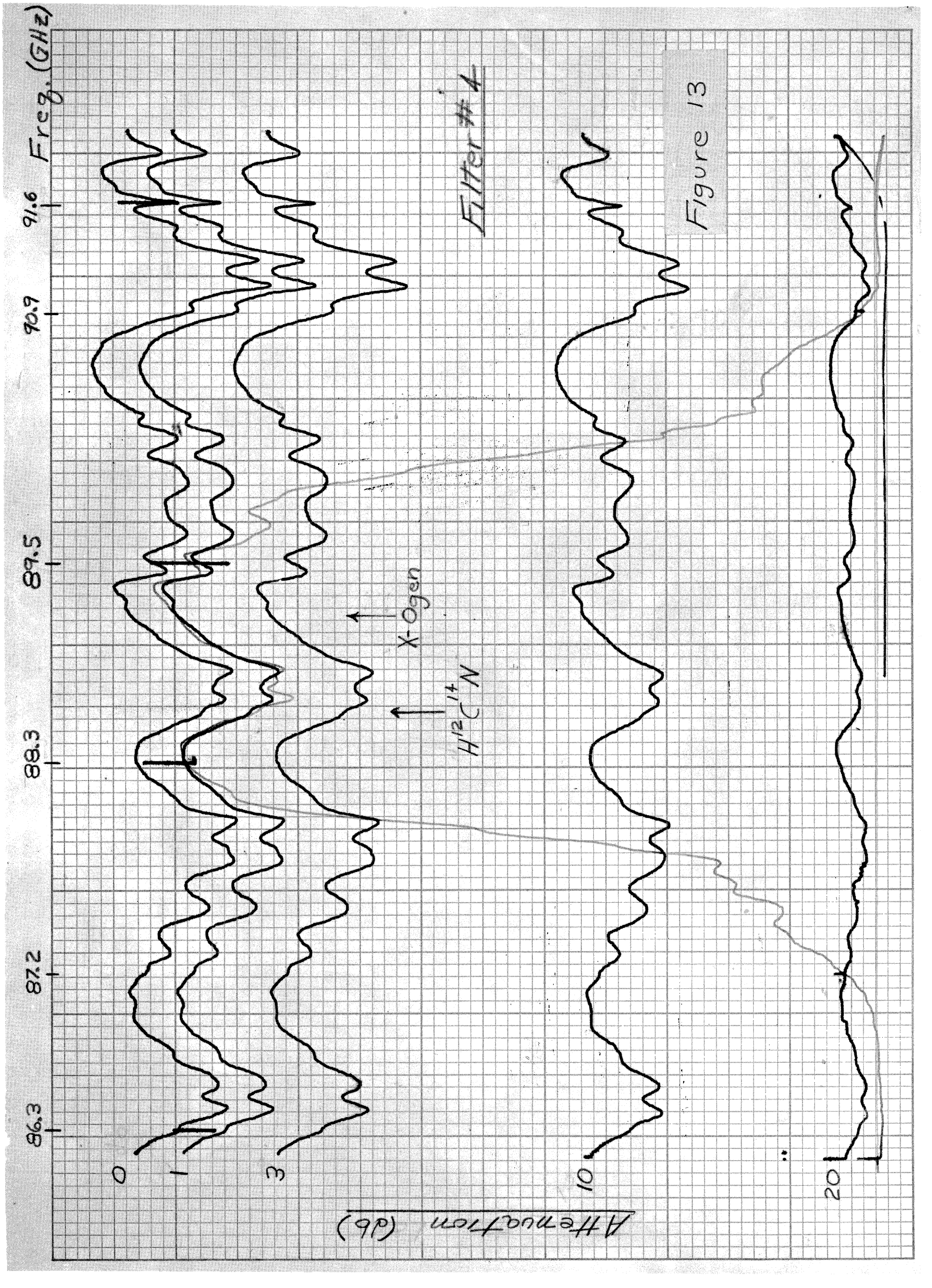
Figure 13

Freq. (GHz)
91.6
90.9
89.5
88.3
87.2
86.3
Filter # 4
X-ogen
$H^{12}C^{14}N$
0
1
3
10
20
Attenuation (db)

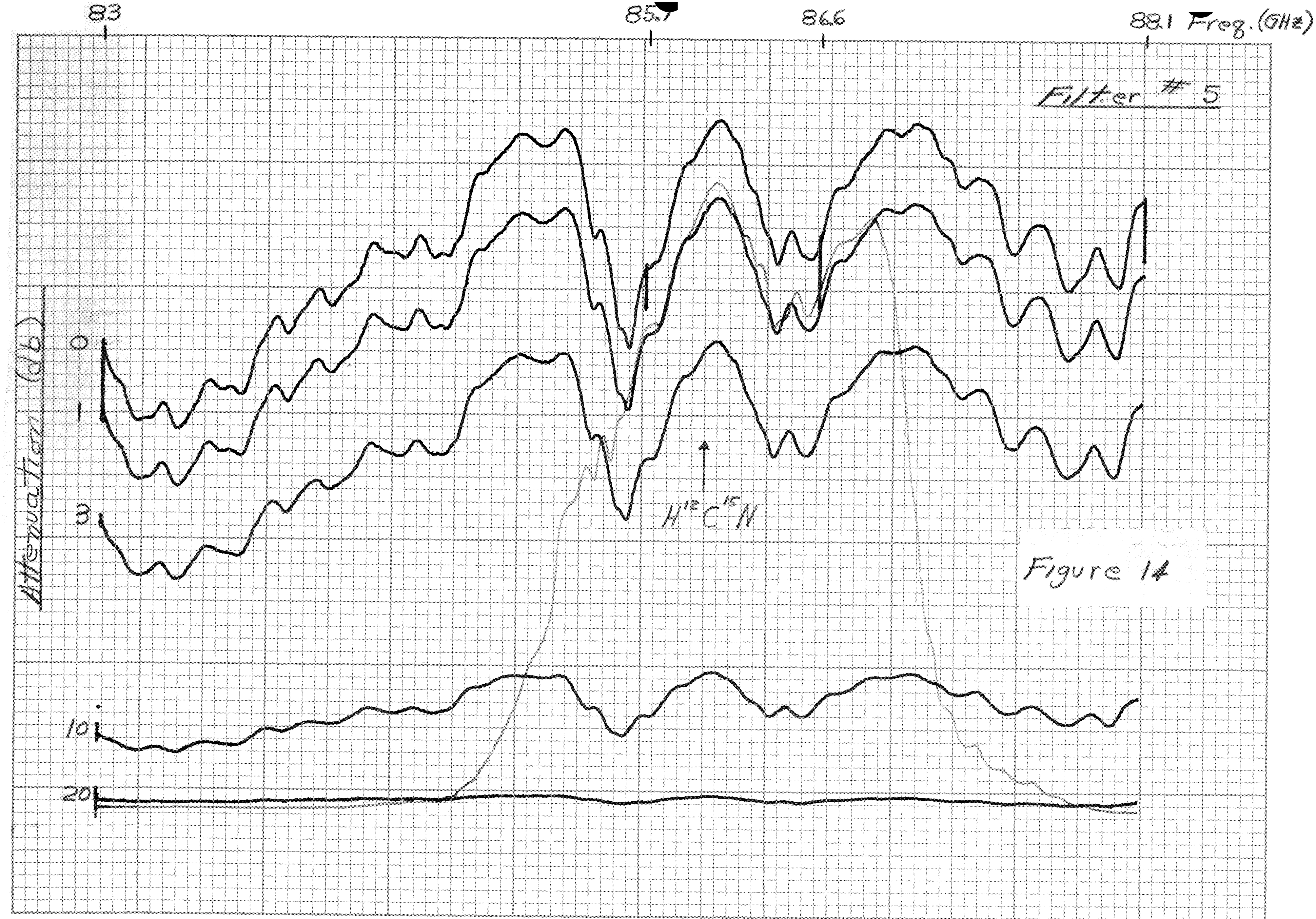

Figure 14

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