NRL REPORT NO.R-3219

GENERAL PURPOSE AUDIO AMPLIFIER

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Problem No. 34R10-22 January 8, 1948

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ABSTRACT

The need for a good general purpose audio amplifier, especially for use in microwave testing of all kinds, has long been apparent. This paper outlines the main features that should be incorporated in such an amplifier, including detailed work on automatic normalization.

PROBLEM STATUS

This report concludes the work on this phase of problem 34R10-22 except for cooperation with the contractor in the event that a contract is let for producing these amplifiers.

Work will continue on the basic problem 34R10-22.

GENERAL PURPOSE AUDIO AMPLIFIER

In testing microwave antennas, the modulation frequency of the test signal from a transmitter varies from a few hundred cycles to a few thousand cycles, this modulation frequency being fixed for any one test or series of tests. The antenna under test is generally used as a receiving antenna on a rotating mount and the energy picked up goes to a bolometer or crystal. Consequently, the modulation frequency output is a direct measure of the microwave energy picked up. This procedure requires a high gain, linear audio amplifier with good signal-to-noise ratio, in order to measure the output on a meter or recording device. Such an amplifier should have the following characteristics:

(1) Good sensitivity (ability to handle signals down to 10^{-7} volts)

(2) Low noise level

(3) Freedom from interference and pickup (not only immune to h-f signals, 30 Mc and up, but also well shielded from 60- and 120-cps induction fields)

(4) Rugged portability and simple controls (self-contained power supply)

(5) Logarithmic <u>and</u> linear scales

(6) Narrow frequency band, selectable anywhere in the region of 400 - 5000 cps

(7) Meter removable from chassis to facilitate remote readings

(8) Automatic normalization

(9) Ratio expander for S.W.R. measurements.

There are two amplifiers currently available which meet most of the first six or seven requirements. The purpose of this research was to find out if all the first seven plus automatic normalization were possible. The ratio expander was left for future development. Since the first seven characteristics have been attained, it is merely a matter of engineering to combine them in a single amplifier (see appendix). The main problem, therefore, was to produce automatic normalization.

The primary purpose of automatic normalization is to overcome the errors introduced by transmitter variation. At present it is necessary to monitor the transmitter and then normalize all readings and graphs from the monitor readings. If some voltage proportional to transmitted power is used to control the gain of the main amplifier, then automatic normalization is achieved. This was done by amplifying and rectifying such a voltage and using the d-c output to vary the bias on a portion of the main amplifier. The monitoring voltage can be obtained directly from the transmitter or picked up by an antenna and bolometer, as shown in the block diagram of Figure 1.

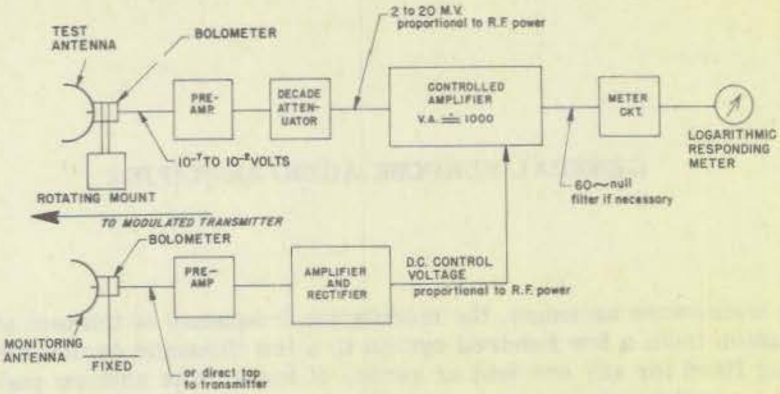


Fig. 1 - Block Diagram

The first step was to construct an amplifier (shown in Figure 1) as the controlled amplifier. To average tube characteristics, a three-stage resistance-coupled amplifier was constructed using 6SK7 tubes. The constants of the circuit were adjusted to give an overall gain of about 1000 to 1500 without distortion and then further adjusted to make the amplification a linear function of the added grid bias over as large a range of grid bias as possible (Figure 2). Notice that the bias voltage was obtained by rectifying the signal and then putting it through a cathode-coupled, d-c amplifier. This system normalized over about a three-db change in input, but the adjustment was fussy. Before pursuing this further, therefore, two other methods of normalization were tried.

One method was to have the monitoring signal control the amount of feedback in the main amplifier. This was done by varying the bias on a tube in the feedback circuit, as shown in Figure 3, but the method introduced so many new problems that it was abandoned. The second method was to read some difference voltage between the main signal and a monitoring voltage. Since the level of the main signal varies over a wide range, while the monitoring signal does not, it is apparent that a non-linear device in the monitoring circuit is necessary to keep the levels at the same order of magnitude. If these two responses maintain a nearly constant difference over the range required, normalization is secured. This scheme, as shown in Figure 4, was tried and was abandoned because adjustment was critical and the range very limited. This scheme might, however, be practical in some applications where the power level is substantially constant.

Hence a return to the original three-stage controlled amplifier seemed indicated. The original amplifier was simplified and improved. To increase the range and incidentally to eliminate the batteries shown in Figure 2, the monitoring circuit was redesigned as shown in Figure 5. This gave a pure d-c output up to 23 volts, which varied <u>linearly</u> with the a-c input from the monitor pre-amplifier. This circuit gave a uniform response from 400-5000 cps with the constants shown, since the $0.2\mu f$ capacitor kept the low-frequency response up. It is designed so that the meter (placed in the cathode circuit to prevent loading) will show when the normalizing range is reached. This adjustment is made by the monitor pre-amplifier gain control.

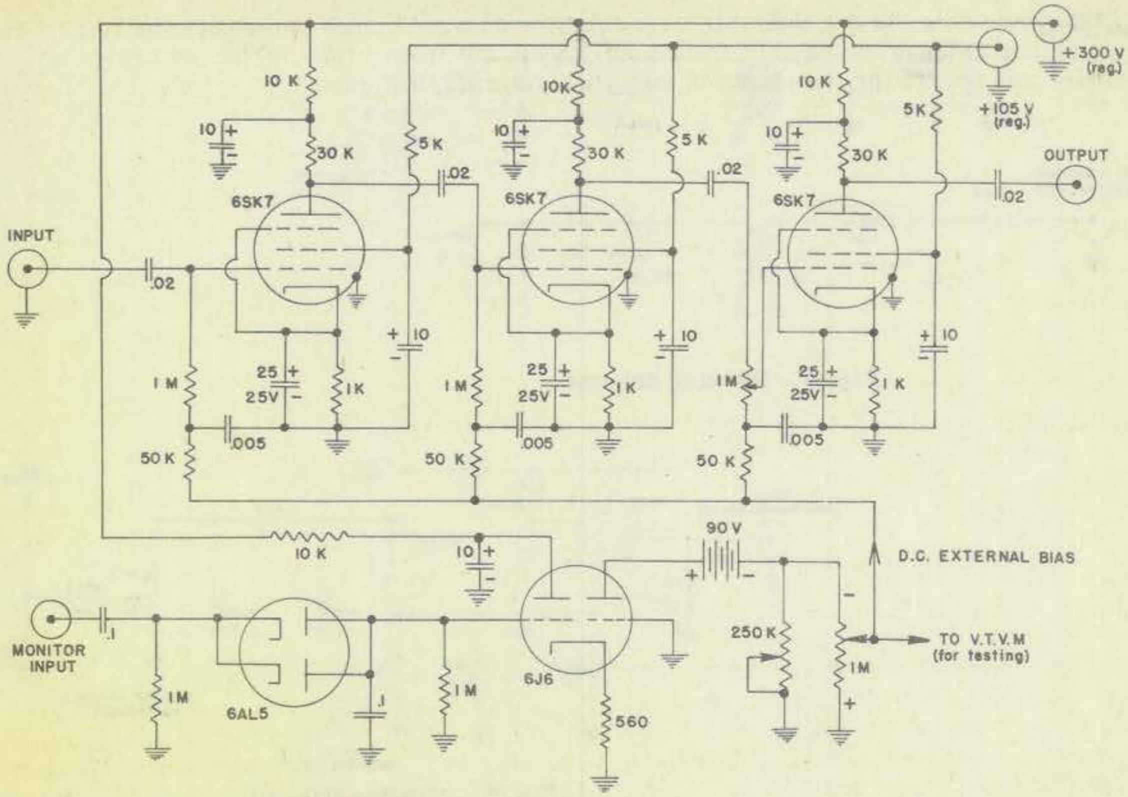


Fig. 2 - One Method of Achieving Automatic Normalization

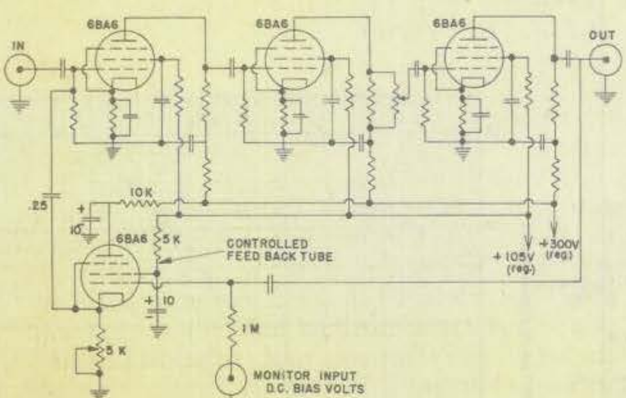


Fig. 3 - Feedback Method
(Linear Amplifier)

The next problem was to construct a signal meter circuit. Since a linear decibel scale was wanted, it was decided to build a linear circuit and use a logarithmic responding meter. Since a shaped pole-piece Weston meter movement was available, the circuit shown in Figure 6 was developed. This circuit was adapted from the Ballantine V.M. circuit without the feedback, using a simple cathode follower. This circuit gave a good linear voltage response as shown in the graph in Figure 6. Due to the prevalence of 60-cycle pickup in the Laboratory, a 60-cycle, twin-T, null filter was inserted ahead of the meter circuit and this eliminated the 60-cycle trouble that shielding did not cure.

CONCLUSIONS

It is believed that a good, portable, all-purpose amplifier can be constructed using the above normalizing scheme. Figures 7 and 8 give some results. Figure 7 shows the

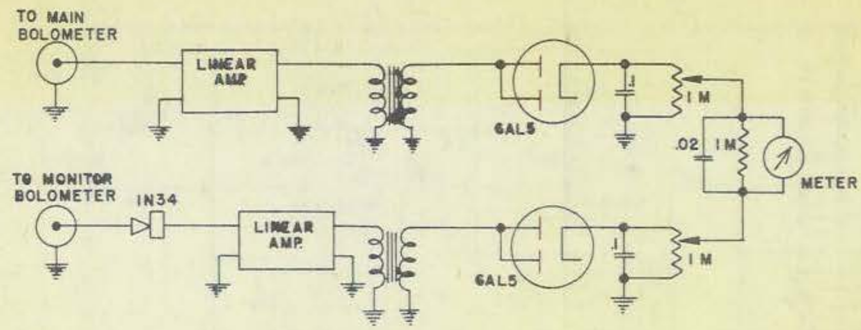


Fig. 4 - Bucking Scheme

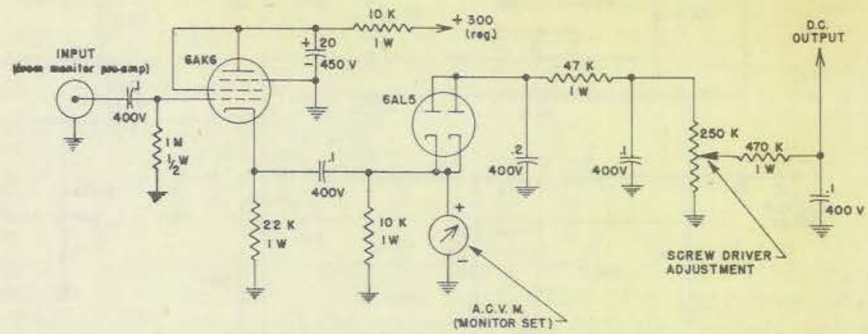


Fig. 5 - Monitor Circuit
(Adjusted by Gain Control on Monitor Pre-amplifier)

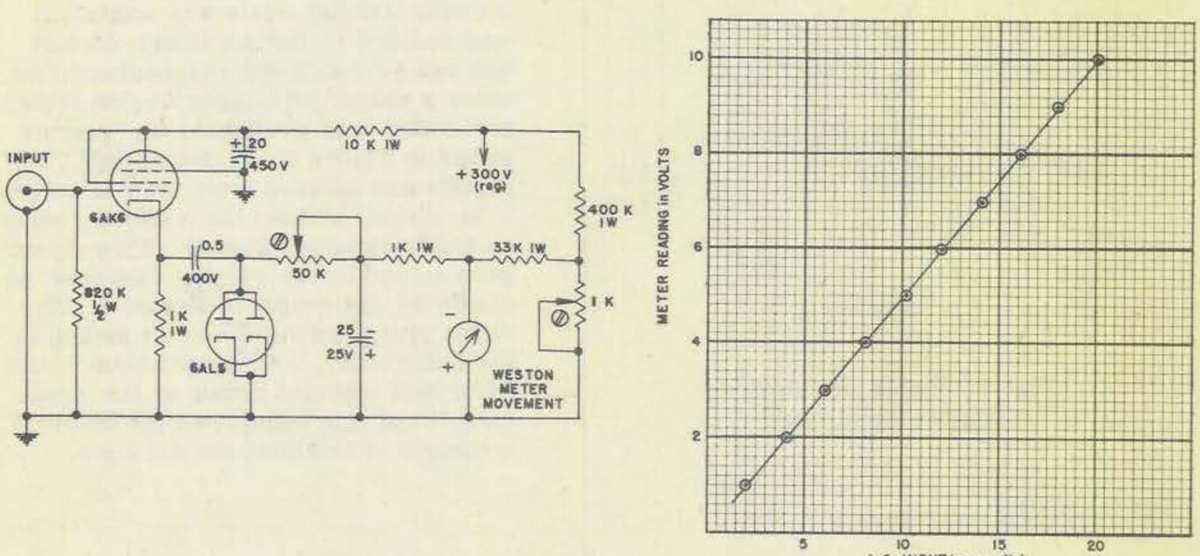


Fig. 6 - Meter Circuit and Response

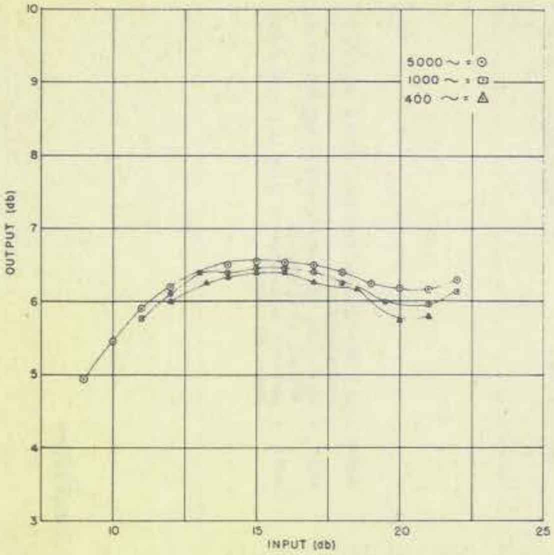


Fig. 7 - Normalization Curve Using 6BA6's

normalizing curves for different frequencies in one of the preliminary models. Further research extended the range of normalization and eliminated frequency variations. Figure 8 shows that a 13-db variation in input will cause less than 1/4-db change in output and is relatively independent of frequency from 400 to 5000 cps. The complete schematic is shown in Figure 9. An output a-c jack to feed a recording system should be added to this.

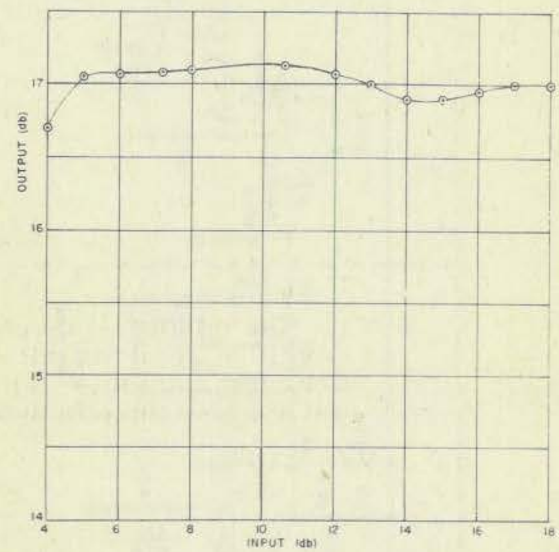


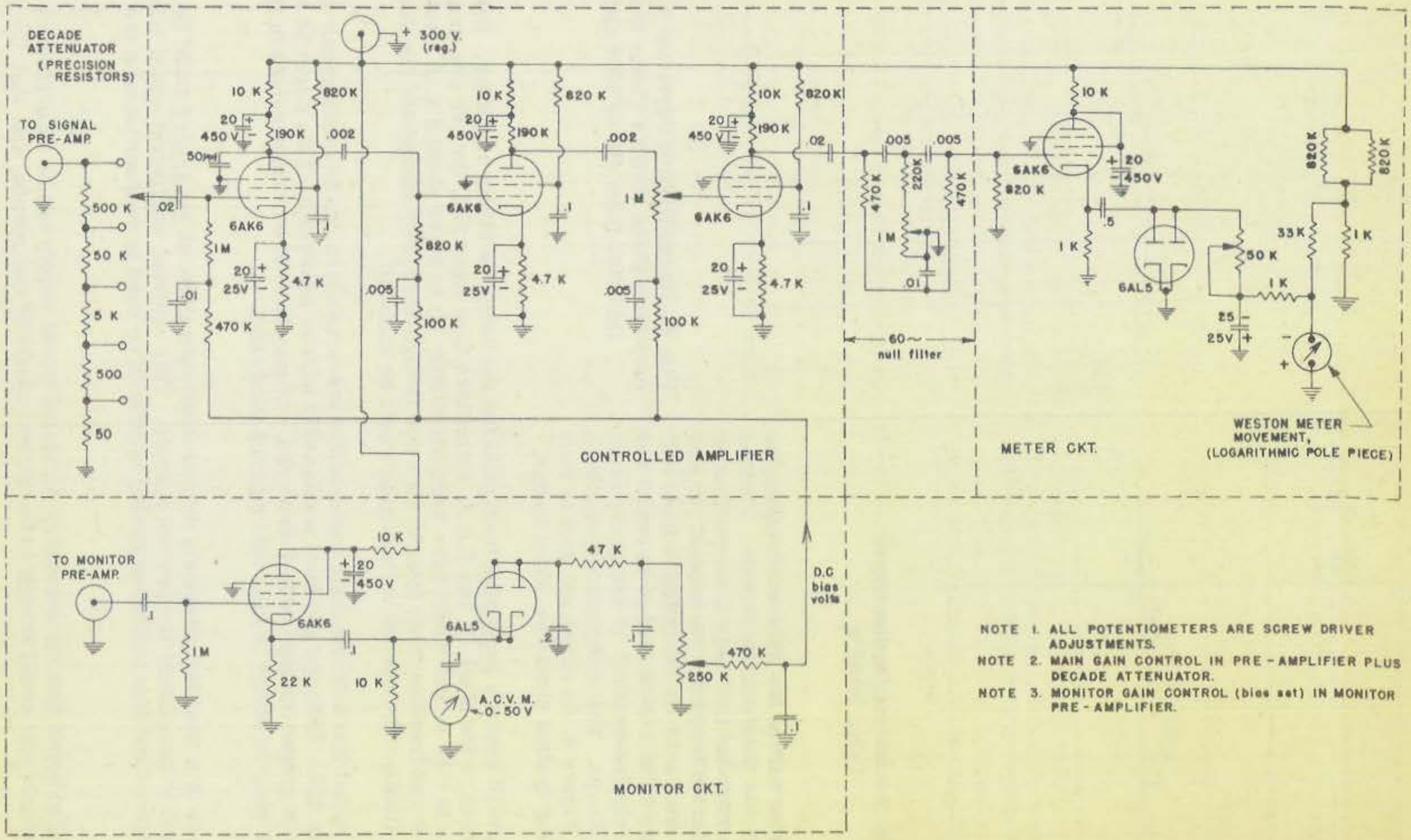
Fig. 8 - Normalization Curve for 3 Stage Amplifier Using 6AK6's (Less than 5% variation from 400 to 5000 cps)

Figure 10 shows a suggested front panel for the complete utility amplifier. Using the best features of the Mark IV and T.A.A. amplifiers (see appendix), the two pre-amplifiers necessary to this model would have good sensitivity (it is hoped about 5×10^{-8} volt) low noise level and freedom from interference due to high-frequency pickup and low-frequency induction fields. The overall voltage gain would be about 10^{8}.

It is hoped that both the main and monitor pre-amplifiers can be continuously gang-tuned from 400 - 5000 cps and have a relatively narrow bandwidth. This might be accomplished with ganged-tunable twin-T networks, but may have to be compromised in favor of adjustable plug-in filters to give the required bandwidth.

If there is a need for extremely narrow-band operation, an accessory could be used in order not to complicate the present scheme. This optional equipment could take the form of a pre-amplifier and heterodyning system to be used in conjunction with the present plan.

It is also hoped that the necessary regulated power supply can be incorporated in order to give a single unit small enough to be handled easily by one person, and that the output



NOTE 1. ALL POTENTIOMETERS ARE SCREW DRIVER ADJUSTMENTS.

NOTE 2. MAIN GAIN CONTROL IN PRE-AMPLIFIER PLUS DECADE ATTENUATOR.

NOTE 3. MONITOR GAIN CONTROL (bias set) IN MONITOR PRE-AMPLIFIER.

Fig. 9 - Final Laboratory Model of Normalized Amplifier

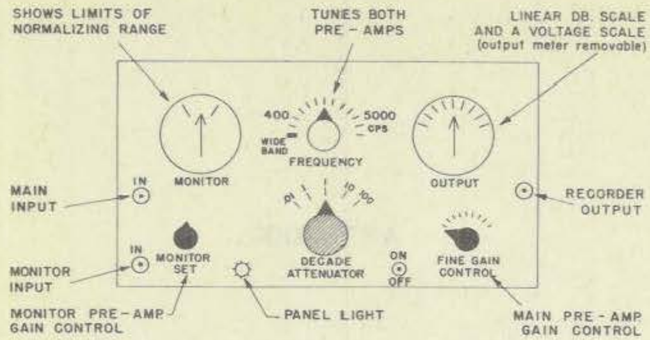


Fig. 10 - Proposed Front Panel Controls for All-Purpose Audio Amplifier

meter will be large enough to permit accurate S.W.R. readings. The input circuit should be able to match a Wollaston wire bolometer or a crystal, with provision to supply adjustable and metered current for a bolometer (Cf. Mark IV). The proposed development by the contractor should provide the answer to these problems.

* * *

APPENDIX

1. Features of the Mark IV that should be considered are the very satisfactory input circuit, good sensitivity, and low noise level. The twin-T feedback circuit could possibly be improved by using a non-symmetrical twin-T network to achieve a narrower bandwidth without sacrificing the symmetry of the response curve. If this filter is to be tunable, however, a narrow bandwidth may have to be compromised. The methods of shielding and construction should be noted.

2. Notable features of the T.A.A. are its portability (one unit) and tunability (400 to 4000 cycles).

3. Two other avenues of research were examined. One, a lock-in scheme, was abandoned because of the critical adjustment, added bulk and the fact that a very narrow bandwidth is not necessary for general laboratory work. The second possibility investigated was use of the d-c output of the crystal or bolometer, by putting it through a chopper and narrow-band amplifier. The gain in bandwidth and other advantages over the present method once more judged to be insufficient for practical use. The chopper method works well on c-w, but pulsed transmissions are frequently necessary in order to obtain sufficient power in the critical frequency bands.

* * *

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