Feb. 27, 1945. G. MUFFLY 2,370,483

AMPLIFIER

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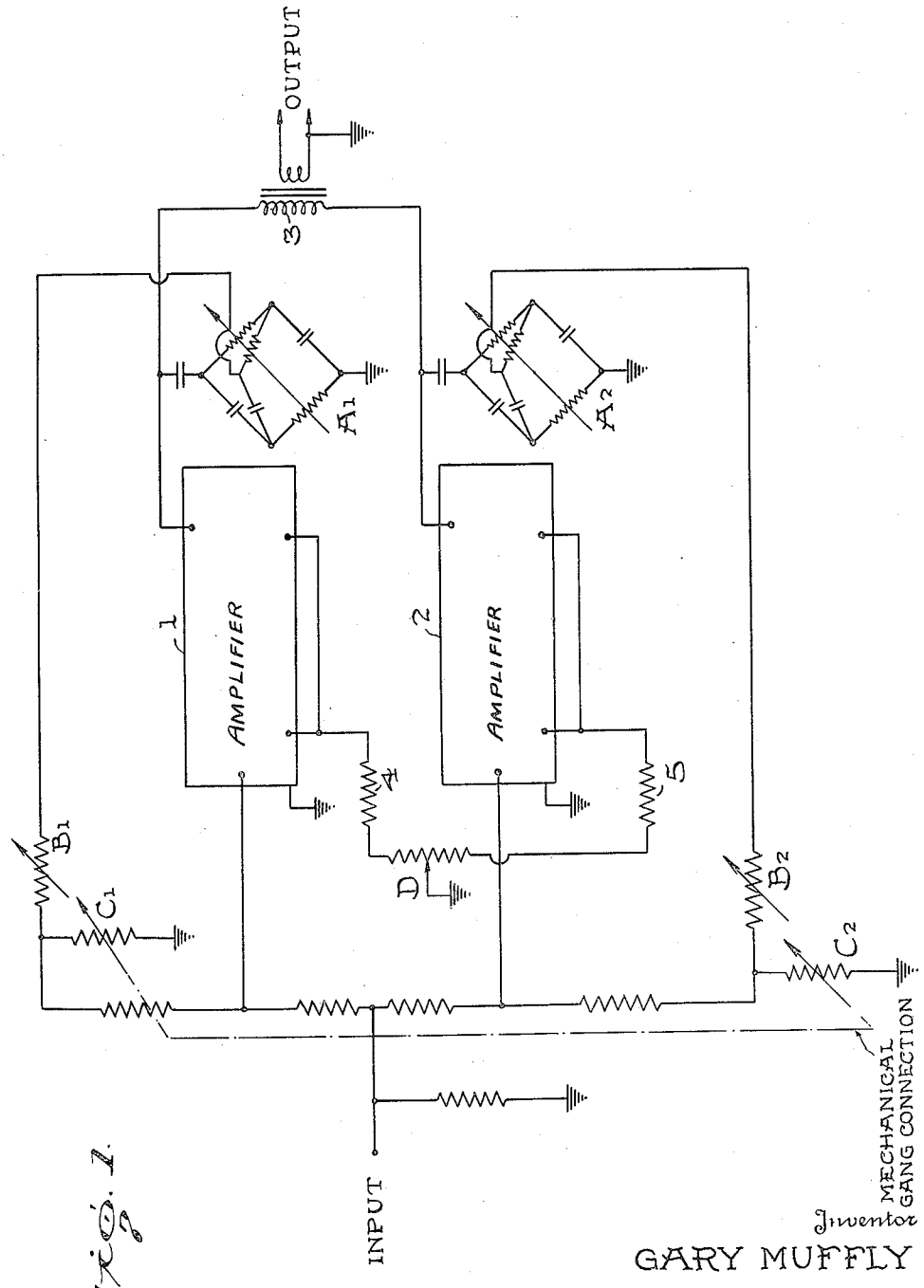


Fig. 1.

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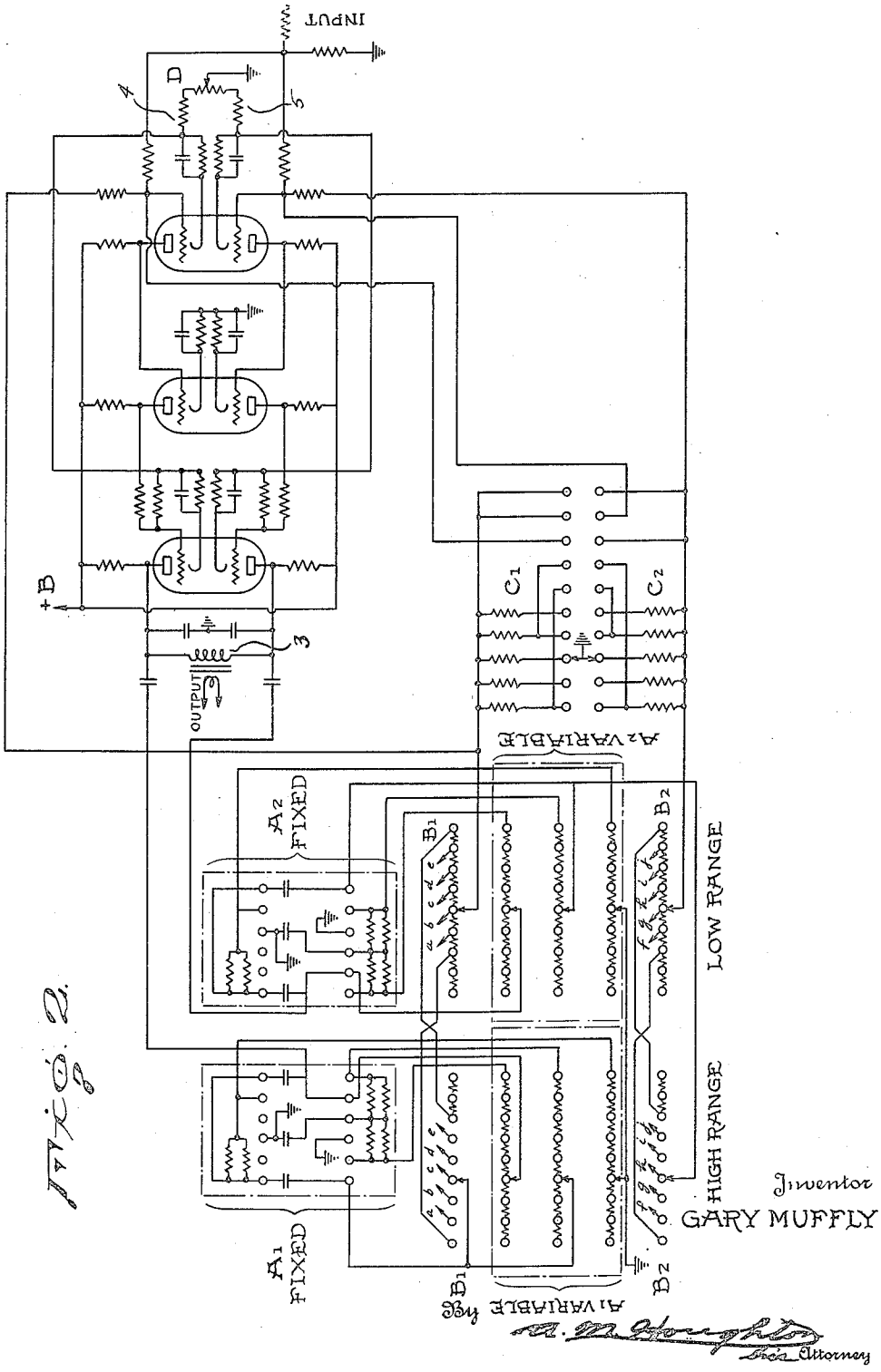


Fig. 2.

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Fig. 3.

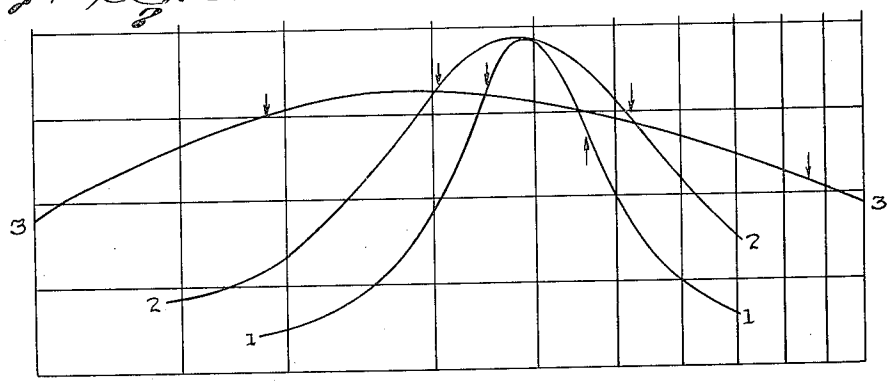


Fig. 4.

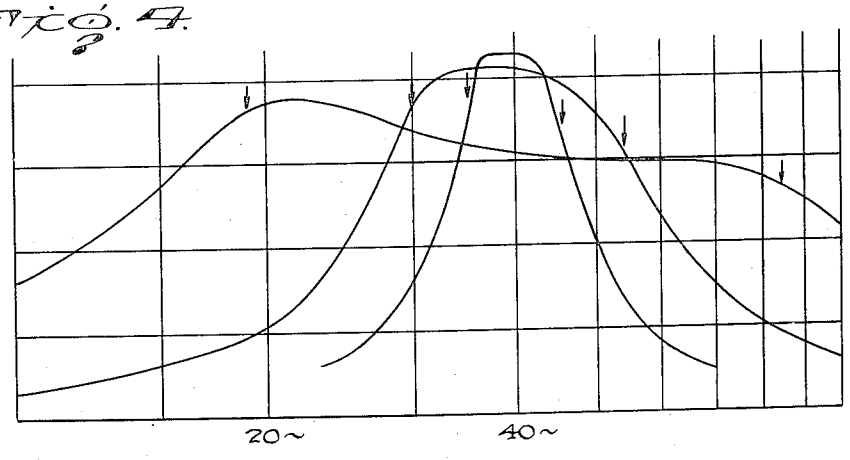
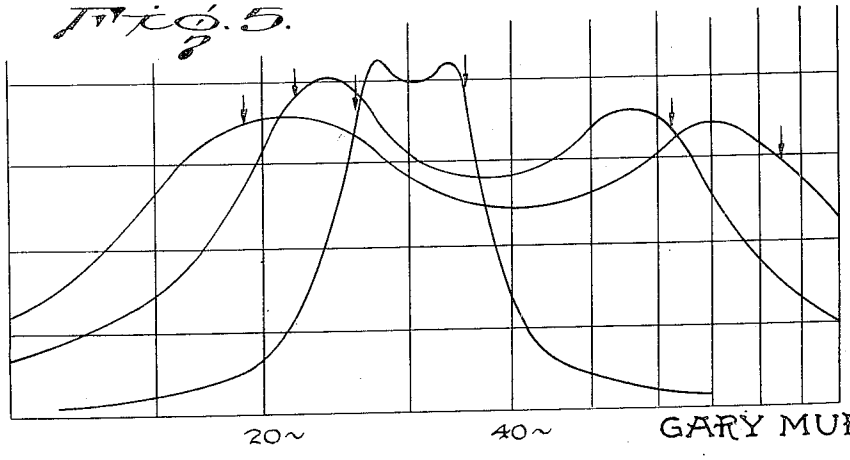


Fig. 5.



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Fig. 6.

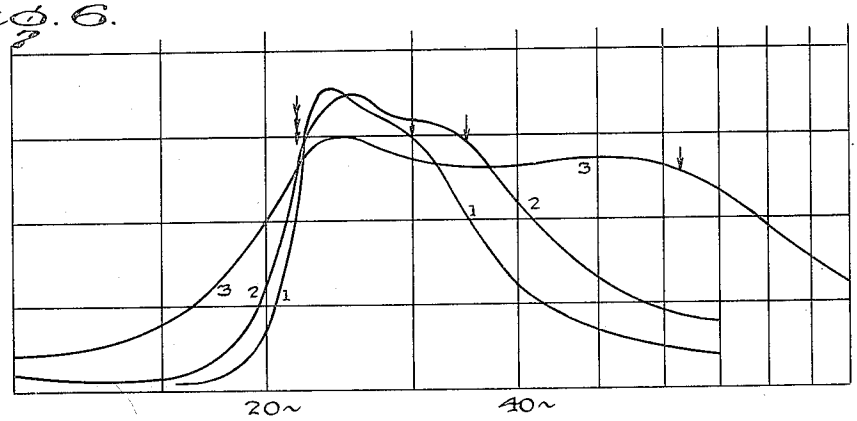


Fig. 7.

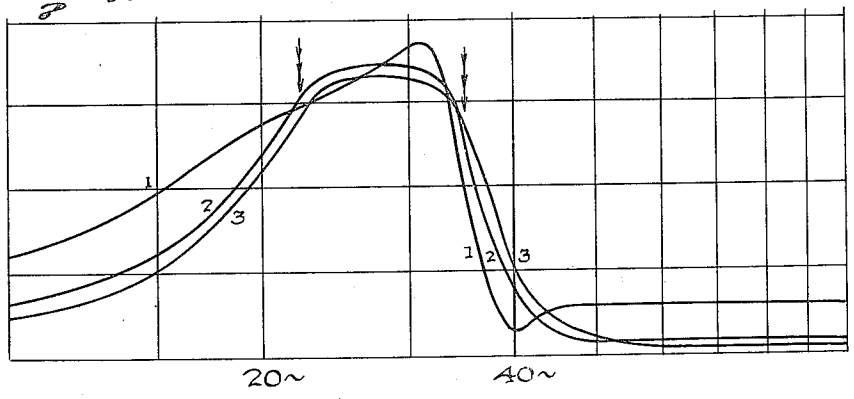
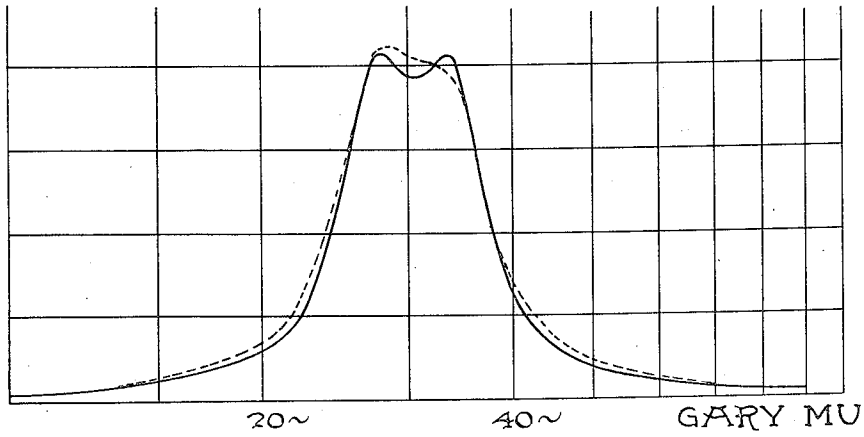


Fig. 8.



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Patented Feb. 27, 1945 2,370,483

UNITED STATES PATENT OFFICE

2,370,483

AMPLIFIER

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Application August 14, 1942, Serial No. 454,842

10 Claims. (Cl. 179—171)

This invention relates to improvements in amplifiers.

In seismograph prospecting artificially created seismic waves are picked up at one or more positions in the earth by electro-mechanical detectors, and the corresponding electrical waves developed by the detectors are amplified and recorded. The received waves include a wide range of frequencies, some of which it is desired to record to the exclusion of others.

The requirements to be met in amplifiers for such use are rather severe. A seismograph amplifier should be sensitive to the desired range of frequencies although highly insensitive to frequencies outside of that range. It is sometimes difficult to exclude powerful undesired frequencies which are close to the desired band. Further, the frequency response function of the amplifier should be adjustable both as to the range of frequencies passed and suppressed and, independently of such adjustment, as to the relative sensitivity for the several frequencies. In other words, the shape of frequency response function should, in an ideal amplifier, be readily adjustable.

It is accordingly an object of the present invention to provide an amplifier which closely approaches the ideal above described, being readily adjustable to band width and, independently, to shape of the frequency response curve.

Another object of the invention is the provision of a resistance-tuned amplifier in which variation of the frequency response function is accompanied by varying resistance only.

Other objects are the provision of an amplifier of the type described making use of the inverse feedback principle, and of extraordinary stability as to gain and frequency characteristics even with large variations in battery voltage and in tube aging.

Further objects and advantages of this invention will be apparent from the following description and drawings in which:

Fig. 1 is a schematic diagram of the resistance-tuned amplifier circuit;

Fig. 2 is a diagram of the amplifier circuit showing in greater detail the feedback circuits and tunable bridge adjustments;

Figs. 3, 4 and 5 show curves resulting from the adjustment of various circuit resistances;

Fig. 6 shows typical curves produced by the use of unequal resistances in certain parts of the circuit;

Fig. 7 shows a series of asymmetrical curves obtained by varying the sharpness of the high frequency side while keeping the low frequency on broad settings;

Fig. 8 shows the effect of extreme mismatching of tubes.

The invention applies the principle of inverse feedback to amplifiers 1 and 2 which consist of electron discharge tubes coupled in stages and arranged in back-to-back relation so to speak with their inputs in parallel and their outputs opposed in the primary of a transformer 3.

Each of the tunable bridges A_1 and A_2 in the respective amplifier networks feeds back all but a selected frequency to the input of the corresponding amplifier circuit through resistors B_1—C_1 or B_2—C_2 which will be described hereinafter in more detail. Each side is tuned to its own individual frequency, differing from that of the other side by an adjustable amount. Bridges A_1 and A_2 each contain three fixed condensers and three variable resistors. Each variable resistor contains a fixed part made up of two resistors of selected values connected in parallel to give the desired resistance within about one-half per cent. The fixed condensers of the bridge circuits are similarly built-up of measured units paralleled to give the desired capacity with accuracy.

High gain inverse feedback amplifiers tend to oscillate above and below the range of operation. This is due to phase shifts in the feedback and amplifier circuits which inevitably accompany frequency cutoff and which usually add up to 180 degrees or more at high and low frequencies, thereby reversing the direction of the vectorial quantity MB (where M is the gain and B is the fraction of output applied to input) and causing oscillation. These objectionable phase shifts can be minimized by employing a D. S. amplifier, but such amplifiers are inherently unstable and require too many batteries. The amplifier in the present invention is a sort of hybrid A. C.-D. C. amplifier that has small phase shifts and operates on a single B battery. In addition, it is self-adjusting with respect to D. C. electrode potentials. Tubes of widely different characteristics may be employed in the circuit and will automatically adjust themselves to optimum operating conditions.

If the feedback is in phase with the input of the amplifier, gain is increased, sometimes to an extent causing continuous oscillation. If the feedback is opposed in phase to the input, the gain is reduced and the tendency to oscillate is likewise reduced. The gain of the amplifier is roughly the inverse of the transmission of the feedback circuit since the total gain available is

high. By utilizing a tuned bridge circuit which will not provide a feedback at a selected frequency the equivalent of a resonant tuned circuit is produced, and the amplifier thus eliminates the extraneous frequencies which are passed by the feedback circuit. Such a system is shown in Scott Patent No. 2,173,426. It has certain advantages over conventional tuned amplifiers and is useful where transmission curves of gradual cutoff are acceptable.

The present invention in one aspect can be regarded as an improvement upon systems of the above type, to provide band-pass characteristics, to achieve a greater range of adjustability, and to afford very sharp cutoff at the end or ends of a desired frequency band.

Voltages from the bridges A_1 and A_2 pass back through the resistors B_1—C_1, B_2—C_2 to the amplifier inputs. In operation the two bridges are tuned to different selected frequencies, namely the upper and lower frequencies at which drop-off of response is desired. Although it would seem that the two outputs would cancel for a frequency midway between the two frequencies where the outputs were equal, this does not occur because of opposite phase shifts accompanying the high and low frequency resonance. Above and below the selected frequencies the outputs of both sides drop and soon have similar phase shifts and amplitudes so that low net output is rapidly reached. Band pass characteristics are thus achieved.

The shapes of the resulting response curves depend upon the adjustments of resistors B_1—B_2 and C_1—C_2 as well as on the gain of amplifiers 1 and 2.

The sharpness of resonance of each side of the unit must be adjustable. If the two sides are separated by large frequency differences, the breadth of resonance of each side should be made proportionally large to maintain the same relative shape of curve. This is done automatically by varying each resistor B_1—B_2 in accordance with the displacements between the frequencies of bridges A_1 and A_2. Figs. 3 to 6 inclusive show how curves of similar characteristics are automatically obtained. In each of these figures only the frequency setting knobs were adjusted to the frequencies indicated by the small arrows.

It is also desirable to provide for varying the sharpness of tuning of the two sides independently of frequency adjustments in order to change the shape of the response curves. This is done by means of resistors C_1 and C_2 which are ganged together for operation by a single control means. By providing a variety of values of the resistors C_1 and C_2 various curve shapes are made available, including round-topped, flat-topped, double-peaked and intermediate shapes, as well as asymmetrical curves with extraordinary high attenuation just above or below the desired pass band. The amplifier can also be made flat from about 5 to 200 cycles.

In Fig. 3 is shown the curve obtained when the resistances C_1 and C_2 are of small value. The tuned feedback is accordingly reduced and the resulting curves are broad and round-topped.

Increasing the resistances C_1 and C_2 first produces flattened curves of the shape shown in Fig. 4, and eventually of double-peaked shape shown in Fig. 5.

Where the resistances C_1 and C_2 are of unequal value, the shape of the curves is asymmetrical but remains practically the same in character, regardless of band width, as shown in Fig. 6. In the curves here represented, the low frequency side of the amplifier is kept to a fixed frequency and is sharply tuned, making the low frequency cutoff much sharper than normal. The high frequency side is broadly tuned but its frequency has been changed to illustrate the effect of varying the band width.

In Fig. 7 three asymmetrical curves are shown. These are obtained at fixed high and low frequencies by varying the sharpness of the high frequency side while keeping the low frequency side on a broad setting.

Amplifiers 1 and 2 are similar to ordinary resistance-coupled amplifiers but use no interstage coupling condensers. The first stage is normal, while the second stage grid is connected directly to the plate of the first stage. Ordinarily, the second stage grid would therefore become positive and draw a large current but this disastrous effect is avoided in the present invention by employing a self-biasing cathode resistor of about fifty times the normal value in the second stage. The cathode is thereby maintained at a potential slightly higher than that of the preceding plate and hence makes the grid slightly negative with respect to its cathode. This bias is self-adjusting even for abnormally large changes of circuit constants because a very slight deviation from normal plate current in the second stage makes a large shift in the cathode bias in a direction tending to restore the normal current.

The gain of each side is stabilized by providing fixed inverse-feedback resistors 4 and 5 which couple inverse feedback from the cathode circuit of the third stage into the cathode circuit of the first stage. This reduces the gain of the amplifier but stabilizes the gain with respect to tube, battery, and circuit variations by the same factor.

Fig. 8 shows the curves resulting from extreme mismatch of tubes. The solid curve was obtained with normal tubes and adjustments. The output and input tubes were then interchanged. Since these tubes differ by nearly a 3 to 1 ratio in plate impedance, drastically upset bias and gain would normally be expected to result from such change. However, due to the self-biasing and fixed inverse feedback features the peak gain dropped only 12 per cent. The dotted curve was corrected for this drop of gain to show the true relative shapes of the response curves. The amplifier was slightly unbalanced by the change and the curve was broadened so slightly as to have negligible effect on the appearance of the recorded waves.

Variable voltage divider D is provided to throw additional resistance from one side of the circuit to the other as required to equalize or balance the gains of the two sides. Each of the adjustments is almost entirely independent of the others with the result that tuning is relatively simple. There are only three adjustments which are normally used, two of which are calibrated directly in logarithmic frequency steps and are set to the upper and lower frequencies at which drop-off of response is desired, while the third control selects the desired shape of response curve. The response curves can, by manipulation of these controls be shifted to any part of the frequency spectrum without change of shape.

The new amplifier is exceptionally versatile; its use is not confined to seismograph prospecting, but it is susceptible of broader adaptation. It can duplicate the characteristics of any ordinary seismograph amplifier and at the same time pro-

vide some new types of response curves of desirable characteristics. Iron-cored inductances are eliminated along with their objectional characteristics, and no tuning inductances or adjustable condensers are needed. Tuning is effected by variable resistances only, and the inherent disadvantages of amplifiers which have objectionable phase shifts and inherent instability, are avoided.

What I claim is:

1. An amplifier of band-pass characteristics comprising a pair amplifier circuits, means in said circuits for passing selected adjacent overlapping bands of frequencies of similar band width and suppressing undesired frequencies, said circuits having their inputs in parallel and their outputs in opposition to produce a band-pass of desired characteristics.

2. An amplifier of band-pass characteristics comprising a pair of resistance-tuned amplifier circuits, resistance tuned bridges in said circuits for passing selected adjacent overlapping bands of frequencies of similar band width and suppressing undesired frequencies, said circuits having their inputs in parallel and their outputs in opposition to produce a band-pass of desired characteristics.

3. An amplifier of band-pass characteristics comprising a plurality of coupled electron discharge tubes in each of a pair of amplifier circuits, means in each circuit to feed back inversely all but a selected frequency to be passed through such circuit, thereby to eliminate extraneous frequencies the said selected frequencies being overlapping bands of similar width, said circuits having their inputs in parallel and their outputs in opposition to produce a band-pass of desired characteristics.

4. An amplifier of band-pass characteristics comprising a pair of amplifier circuits, a plurality of coupled electron discharge tubes in each such circuit, tuned bridges in said circuits with connections for feedback of all but selected frequencies to the inputs of the amplifiers, said selected frequencies being of similar band-width and overlapping, the outputs of said circuits being in opposition to produce a band-pass within the range of the selected upper and lower frequencies.

5. An amplifier comprising a pair of resistance-tuned circuits, the inputs of which are in parallel, a plurality of coupled electron discharge tubes in each circuit, a bridge in each circuit, connections from each bridge to the grid of the first of said coupled electron discharge tubes, means for tuning the bridges to desired upper and lower frequencies, respectively, at which drop-off of response is desired, said bridges and connections providing inverse feedback of all other frequencies, whereby extraneous frequencies are eliminated, the outputs of said amplifier circuits being in opposition, resulting in a band-pass of desired characteristics within the range of the selected upper and lower frequencies.

6. An amplifier comprising a pair of amplifier circuits, a plurality of coupled electron discharge tubes in each circuit, bridges in each circuit having connections for inverse feedback to the first stage of said coupled electron tubes, means for selectively tuning said bridges to two distinct desired frequencies so that each bridge will feed back all but one of said desired frequencies, whereby undesired frequencies will be suppressed in each circuit, a variable resistance in each amplifier circuit arranged to adjust the sharpness of tuning of said circuit, means for simultaneously adjusting said resistances when tuning said circuits, the inputs of said circuits being in parallel and their outputs in opposition, resulting in a band-pass of desired characteristics within the range of the selected upper and lower frequencies.

7. The combination of claim 1 wherein the amplifier circuits are adjusted in unison by ganging of the controls so that the breadth of resonance of each tuner is proportional to the frequency interval between them.

8. The combination of claim 3 wherein fixed feedback is provided in the cathode circuits of the electron discharge tubes and the feedback from plate to grid circuits is tuned to give balanced curves with minimum interaction between the various feedback paths.

9. The combination of claim 3 wherein the gain of each amplifier is stabilized by a fixed inverse feedback resistor coupling inverse feedback from the cathode circuit of the third stage into the cathode circuit of the first stage.

10. An amplifier of band-pass characteristics comprising a pair of amplifier networks having their inputs in parallel and their outputs in opposition, tunable bridges in said respective networks for inverse feedback to the input of each amplifier of all but an individual selected frequency whereby undesired frequencies are eliminated from the output of each amplifier, variable resistances in said respective networks for changing the sharpness of tuning of each network, the arrangement being such that the frequency response function of the amplifier is adjustable both as to range of frequencies passed and suppressed, and, independently of such adjustment, as to the relative sensitivity for the several frequencies.

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