Feb. 22, 1949. D. S. RENNER 2,462,551

AMPLITUDE CONTROL

Filed Nov. 5, 1942

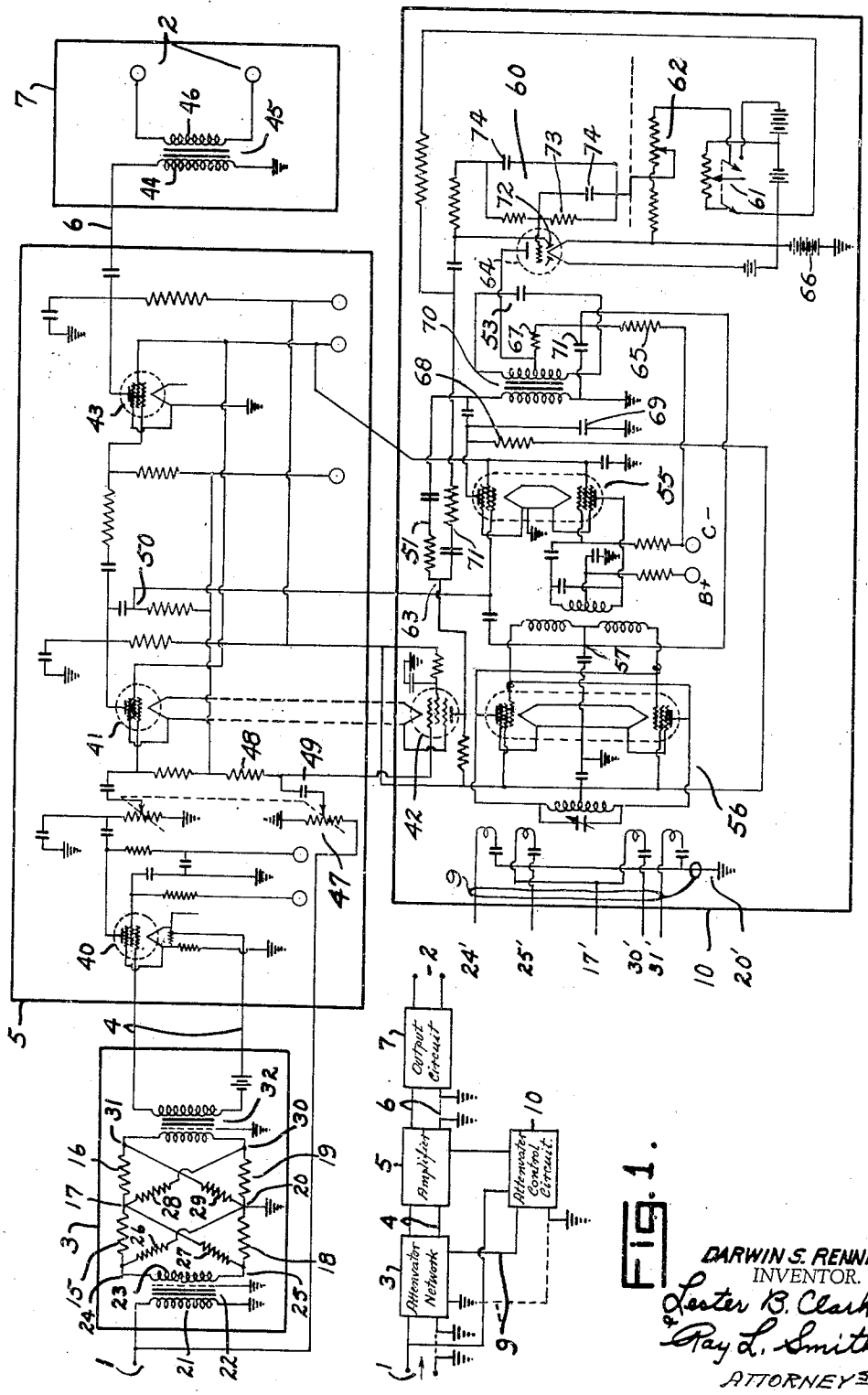

Fig. 2.

Fig. 1.

DARWIN S. RENNER
INVENTOR.
Lester B. Clark
Ray L. Smith
ATTORNEYS

Patented Feb. 22, 1949

2,462,551

UNITED STATES PATENT OFFICE

2,462,551

AMPLITUDE CONTROL

Darwin S. Renner, Dallas, Tex., assignor to Geophysical Service Incorporated, a corporation of Delaware

Application November 5, 1942, Serial No. 464,607

1 Claim. (Cl. 178—44)

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This invention relates to automatic gain or amplification control, and more particularly to an amplifier system including an electrically variable attenuator and control means therefor so that for a variable input a substantially constant output may be had with high fidelity.

It has been proposed to control amplitude automatically and within limits by altering tube bias so that gain control is effected by shifting the working point on the characteristic curve of the thermionic tube. Such mechanism for gain control produces amplitude distortion or, in other words, distortion in reproduction of amplitudes in the different phases of a vibratory event. This distortion is severe when high attenuation is attempted and tube operation occurs proximate the knee of a characteristic curve of the tube. Furthermore, spurious signals from bias ripple and the bias itself may be introduced, and in this manner fidelity in reproduction with desired gain control cannot be satisfactorily accomplished. This method of gain control also gives rise to both phase and frequency distortion in view of the fact that the alternating current resistance of tubes varies because of bias variations. It is also known that the tubes used in such a system lack in stability and ruggedness and, as well, are not permanent elements of the system. For these reasons, and others, the tube bias method of amplitude or gain control is unsatisfactory and in particular is this true in the fiield of seismic geophysics where large variations in amplitude are to be controlled.

In this particular field of utility of the present invention a frequency spectrum between 2.5 cycles per second and approximately 200 cycles per second is involved, and the frequency band of particular interest lies approximately between 18 cycles per second and 70 cycles per second. Additionally, a visual record is produced as distinguished from the reproduction of a vibratory event in the form of sound, and for best results there is required accurate and faithful reproduction of the vibratory event and also proper gain control over an extremely wide range of amplitudes. While the utility of the invention in the field of seismic geophysics is specifically referred to in the present disclosure, it is to be understood that the invention is not confined to this particular field inasmuch as the invention is of utility in gain control and faithful reproduction of vibratory events in any of the various fields.

The primary object of the invention is to overcome the difficulties to which reference has above been made.

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Another object is to provide faithful reproduction of a vibratory event and accurate control of the amplitude of the amplified vibrations of the event.

Still another object is to provide a device of the class described that will operate satisfactorily at any particular frequency or over a large band of frequencies.

Another object is to provide an amplitude control device having a large control range.

A further object is to provide an attenuator control network of which the attenuation is unaffected by the signal transmitted throughout the network.

A still further object is to provide an amplitude control device which is rugged and which is stable under operating conditions for and throughout the long life thereof.

Another object is to provide a device of the class described which is free from amplitude distortion.

A still further object is to provide a device which eliminates the introduction of spurious signals and which also avoids the introduction of phase and frequency distortion in the amplified signals.

A more specific object of the invention is to provide an automatic volume control system including a thermally controlled attenuator in which the control heating is effected by means of a heating current supplied at a frequency which is widely displaced from the frequency of the amplified signals.

Still another object is to provide a device for gain or amplitude control of particular utility in the field of seismic geophysics and operable to secure usable records of all phases of a seismic event.

Another object is to provide an automatic gain control system including a substantially constant gain amplifier and a cooperating variable attenuator network controlled thereby to, in turn, control the amplitude of the output of the amplifier.

The foregoing are primary objects and will, together with other objects, be more fully apparent from the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a schematic diagram showing the essential elements of an automatic gain control device or system constructed in accordance with the invention;

Fig. 2 is a circuit diagram showing in greater detail the various elements of Fig. 1.

Referring to Fig. 1 of the drawings which dia-

grammatically shows the essential elements of the device of the invention, there is fed into the system at 1 an input of varying amplitude which is to be transmitted to the output terminals 2 for use in a suitable reproducer (not shown) such as a recording mechanism or a sound reproducing device. In its transmission the signal or vibratory event is first utilized as the input to an attenuator network or net 3. As will more fully appear hereinafter, the attenuator net 3 comprises a network of resistors and is thermally controlled so that the output thereof through the conductors 4 to the amplifier 5 is controlled in a manner to accomplish the purposes of the invention. The output of the amplifier 5 is transmitted through conductors 6 to the output circuits 7 and thence to the output terminals 2 which, as above indicated, are connected to any suitable device such as a speaker, a transmission line or in the case of seismic prospecting, to the galvanometer or other recording equipment.

The system generally described above may be considered as a composite transmission line including an attenuator control circuit 10 connected therein at a suitable point between the input terminals 1 and the output terminals 2. Preferably this control circuit is connected to the amplifier 5 in a manner that the controlling current supplied through the conductors 9 to the network 3 provides such attenuation of the vibrations that the input to the amplifier 5 is such that the vibrations at the output terminals 2 are of a desired amplitude.

As already pointed out, the attenuator network 3 comprises a plurality of resistors which are shown more fully in Fig. 2 as comprising line resistors 15 and 16 interconnected at point 17 and resistors 18 and 19 in parallel therewith and interconnected at the point 20 which is also grounded inasmuch as a grounded return is utilized in the system. Input to the terminals 1 energizes the primary 21 of the transformer 22 of which the secondary 23 is connected to the respective above mentioned series resistors at the points 24 and 25.

The attenuator may comprise any suitable number of sections, and two such sections are shown for convenience. In addition to the resistors 15 and 18, the first section of the network also includes bridging resistors 26 and 27 of which the former is connected at points 20 and 24 and the latter is connected at points 17 and 25. In a similar manner the second section comprising resistors 16 and 19 includes bridging resistors 28 and 29 of which the former is connected to points 17 and 30 and the latter is connected between points 20 and 31.

The output of the attenuator from points 30 and 31 is connected to the primary terminals of the output transformer 32, and the output from the secondary terminals of the transformer is transmitted through the conductors 4 to the amplifier 5 as already explained.

To change the attenuation of the network 3, the value of one or more of the resistors thereof must be changed and such change must be made in a manner that the transmitted signal will not be undesirably affected. A convenient method of effecting the desired resistance change is that of controlling the temperature of certain of the resistors and hence taking advantage of the temperature coefficient of resistance of the resistors. Such temperature change may be effected by thermal conduction or by direct electrical conduction, but I prefer that electrical heating be utilized. The frequency of the source of heating of the selected resistors is immaterial so long as such frequency is sufficiently high to avoid cyclic variations in heating as, for example, 50 cycles per second or more.

If the band of frequencies to be transmitted lies between f_1 and f_2, the heating frequency f_h will be chosen well out of this band on either side but under most circumstances:

$$f_h > f_2$$

That is, the chosen frequency f_h is sufficiently removed from the signal band that its separation from the frequencies f_1 and f_2, both from the potential and circuit standpoints, is accomplished with little or no extra precaution.

Preferably, though not necessarily, all the resistors of the network 3 are in the form of tungsten lamps and the elements 26, 27, 28 and 29 are equally heated in a manner hereinafter described. When no heating power is supplied to the heated elements or resistors the network has a maximum attenuation. It seems apparent that the sections of an illustrated two-section network pass monotonically to lower attenuations as power is applied to the elements.

Regardless of the exact nature of the resistor elements 26 to 29 inclusive, the power necessary to effect heating thereof should be as small as possible. To this end these resistors are preferably filamentary and enclosed, as in an evacuated envelope, to avoid atmospheric convection. Inexpensive and readily available panel bulbs requiring only one-tenth of a watt, with straight line, low temperature tungsten filaments may be used and are practically indestructible. A resistance change of as much as 10 to 1 can be realized from such bulbs without energizing the bulbs to much more than one-half their rated power. It is to be understood that all of the resistors of the network 3 may take the suggested or similar form and heating may be supplied as hereinafter described to the selected resistors.

The resistors chosen will normally satisfy the requirement that the power to heat them at all will greatly exceed the maximum signal power present within them.

The manner of effecting desired heating of the selected resistors and for amplification of the signal output from the attenuator net 3 will now be described. The output from the terminals of the secondary of the transformer 32 constitutes the input to the tube 40 of the amplifier 5 which includes tube 41 and output tube 43 of which the plate current is supplied through conductor 6 to the primary 44 of transformer 45 in the output circuit 7. Energy induced in the secondary 46 of the transformer 45 is supplied to the terminals 2 and thence to the recorder, sound reproducer or other mechanism, depending upon the desired use of the amplified vibrations.

It is to be understood that while certain elements are shown as encompassed within the amplifier 5 or within the control unit 10, yet the invention is not confined to this unitized grouping since obviously the various elements may be grouped in any desired number of units and groupings without departing from the invention. For example, thermionic tube 42 shown as a part of the unit 10 cooperates with resistors 47, 48 and capacitance 49, shown as part of unit 5, to serve as an amplifier for the control of potential taken from the terminal 1. In a similar manner the vacuum tube 55 and its associated circuit serves

as an amplifier for the potential taken from the point 50 in amplifier unit 5.

The circuit indicated generally as 51 serves as a mixer for the amplified voltages which are supplied to diode 53 for conversion of the mixed potential to a direct potential. The operation of this mixer circuit comprehends the introduction of signals from the upper part of the tube 55 and hence from the point 50 in the amplifier unit 5 and from the tube 42. This signal is introduced to the common impedance comprising resistor 68, condenser 69 and transformer 70. Thus, the signals from the two sources are mixed in the common impedance and this mixed signal is presented to the diode 53 for rectification.

The magnitude of the rectified potential is directly proportional to the magnitude of the sum of the mixed signals, and such rectified potential exists across the resistors 67 and 65, of which the latter has the greater value. The condenser 71 acts as a filter condenser for the direct potential and also introduces a time constant into the circuit.

Due to the connection to the point 57 and thence to the grids of the amplifier tube 56, there is applied to these grids the rectified and filtered potential plus the relatively small fixed potential applied to the terminal C—. This rectified and filtered potential, which is proportional to the amplitude of the mixed signal, is of a negative polarity to the grids. Thus, the grid potential of the amplifier tube 56 is proportional to the amplitude of the mixed signal.

Tube 55 and the associated circuit comprises an oscillator with a constant output and frequency, and the output thereof is supplied to the amplifier 56, to which the above explained direct current control is supplied at the point 57 from the mixing circuit above described. Inasmuch as the control potential is of a negative polarity to the grid of the tube 56, the output from such tube is inversely proportional to the amplitude of the mixed signal. The output from the amplifier 56 is applied through the conductor cable 9 to the resistors of the attenuator network 3, such cable comprising conductors 24', 25', 17', 30', 31', and 20' which are connected to the respective, like, unprimed points of the resistors of the attenuator unit. Since the attenuation of the attenuator network rises as the control power is decreased, attenuation increases as the amplitude of the signal increases, as required.

The mechanisms thus far described desirably control the output at the terminals 2 during all phases of a usual vibratory event. In some cases, however, such as the production of a record of the seismic event in the art of geophysical prospecting, there may be a portion of the event which presents an extremely steep wave front. In order to effect desired signal control for this phase of the vibratory event, I provide an initial attenuation control circuit which is referred to generally as 60. This circuit is so constructed that manual operation of controls 61 and 62 supplies a desired potential to the direct current time constant section 53 at point 57.

In the operation of the attenuation control circuit 60, the plate current from tube 64, adjustable by the controls 61 and 62, flows through the resistors 67 and 65 and thus produces a negative voltage in the manner above explained in connection with the rectified mixed signal, except that adjustment of the controls 61 and 62 produces the effect in the absence of any signal. Thus, an attenuation can be set up in the attenuator network 3 by adjusting these controls. This manually set attenuation will be effective on the first impulses of signal.

After a signal is present it is impressed upon the diode 72 through the circuit 71 and the resultant direct potential on the resistor 73 biases the grid of the tube 64 beyond the cut-off and thus shuts off the plate current from the tube 64 through resistors 67 and 65. At the same time, the diode 53 takes over as already described and effects the desired control throughout the signal intervals.

After the signals have ceased to exist, there will obviously be no further rectification at the diode 72 and the charge on the condensers 74 will leak off and the tube 64 will once again pass the plate current as set by the controls 61 and 62, and the system will have returned to a condition of readiness for the next signal train.

It seems apparent that when the signal input at terminals 1 is substantially constant, the gain within the system is substantially constant and adjustments are such that the signal output at terminals 2 have a desired amplitude. When, however, a signal of high initial amplitude is to be received, as in seismic prospecting, the controls 61 and 62 are manually operated to control the high initial amplitude. When this initial control is discontinued, further control of gain is effected through potentials picked up at points 1 and 50. As above explained these potentials are mixed in the mixing circuit 51, rectified by means of the diode 53 and thence utilized to control the gain of amplifier 56, whereby the temperature of the respective linear passive resistors in the attenuator unit 3 is desirably controlled.

Broadly the invention comprehends an automatic gain or amplification control which comprehends the utilization of an automatically variable attenuator and control means therefor to maintain a substantially constant, high fidelity output.

What is claimed is:

In an automatic gain control system for a vibratory event in a seismic amplifier the combination of, an attentuation network having input and output terminals, a plurality of resistors interconnecting said terminals, at least some of said resistors being filamentary and adapted to adjust attenuation by heating thereof, and means including a source of alternating current of a frequency widely displaced from the frequencies of the vibratory event, said source being connected to said resistors for conductively varying the heating of the resistors in a predetermined manner to control the output of the network.

DARWIN S. RENNER.

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