Sept. 9, 1941. R. E. ALLISON 2,255,727

SIGNAL GENERATOR OUTPUT EQUALIZER

Filed Feb. 23, 1939

Fig. 1

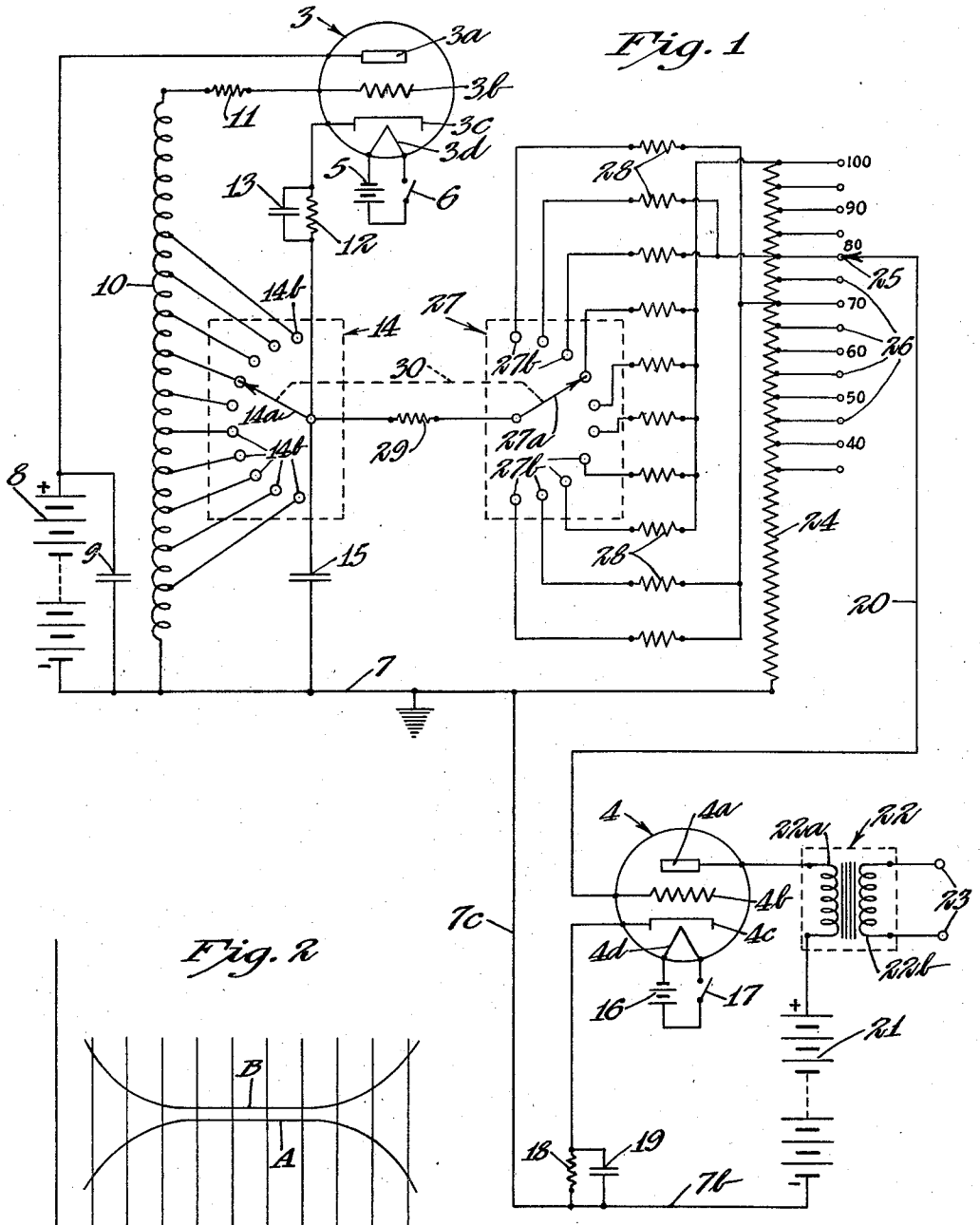


Fig. 2

Inventor
Ralph E. Allison
By Williamson & Williamson
Attorneys

Patented Sept. 9, 1941 2,255,727

UNITED STATES PATENT OFFICE

2,255,727

SIGNAL GENERATOR OUTPUT EQUALIZER

Ralph E. Allison, Minneapolis, Minn., assignor of one-half to W. E. Lehnert, Minneapolis, Minn.

Application February 23, 1939, Serial No. 258,118

3 Claims. (Cl. 250—36)

My invention relates to generators of oscillatory electrical signals and particularly to a system for equalizing the output voltages of variable frequency signal generators. My invention is particularly applicable to commercial audiometers used in the testing of human ears.

Ordinarily, signal generators which are arranged to be adjustable as to the frequency of the energy produced thereby will develop different output voltages at respective ones of the available operating frequencies. For many kinds of measurement work involving such a signal generator it is necessary to provide an attenuator in the output circuit thereof for adjusting the magnitude of the signal delivered to signal-utilizing means. It is considered very desirable and highly useful to calibrate an attenuator so used in terms of the magnitude or level of the delivered signal. However, since the energy produced by the source of signal energy is usually of different magnitudes at respective operating frequencies, it is usually necessary to feed the output of the signal generator into the attenuator at points corresponding to higher signal levels than the points from which signal-utilizing apparatus is fed.

Furthermore, where the signal strength of a signal generator falls off near the upper and lower limits of its frequency range and the signal transmission ability of signal-handling equipment fed by the generator does likewise, it is necessary to provide a more powerful signal generator than would be required in the intermediate portion of said range if it is desired to provide full output near said limits. However, in signal generators for some uses, full output is not required at frequencies near the limits of the frequency range and hence a relatively low power signal generator of only sufficient capacity to enable full output in the intermediate portion of its frequency range would be advantageous from the standpoint of economy. Use of such a low power generator, however, brings about certain problems in regard to an attenuator having signal level calibration which is correct for frequencies near the limits of the frequency range of the generator as well as at intermediate frequencies.

An object of my invention is to provide an output-equalizing attenuation system for signal generators which are operable at more than one frequency, including a directly calibrated output signal level-selecting means and wherein the calibration is equally correct at all operating frequencies.

Still another object is to provide such a system wherein signal strength compensating means is automatically operated responsive to and in unison with shifting of a frequency-selecting control element.

Yet another object is to provide such output equalizing attenuation equipment calibrated in terms of signal output level for use following a variable frequency signal generator having less output at frequencies whereat only small outputs are required than the required maximum outputs beyond said attenuation equipment at other frequencies.

A more specific object is to provide, in an audiometer, signal intensity compensating means enabling the combination of an output intensity control and a calibration therefor which is correct at all operating frequencies and at the same time enabling use, in the audiometer, of an oscillator of particularly low power output whereby the audiometer is readily portable and of low cost.

A further object is to provide, in an audiometer, such signal intensity compensating means adapted for compensating not only for the different output powers of the oscillator at its respective operating frequencies but also the degrees of response of a reproducer served by the audiometer at the respective operating frequencies.

These and other objects and advantages will be more apparent from the following description made in connection with the accompanying drawing, wherein like reference characters refer to the same parts throughout the several views, and in which:

Fig. 1 is an electrical connection diagram of an electronic signal generator and amplifier wherein an embodiment of my invention is incorporated, and

Fig. 2 is a graph illustrative of certain characteristics of apparatus such as that diagrammatically represented in Fig. 1.

Referring to the drawing, I have therein illustrated, in simplified form, an embodiment of my invention particularly applicable to use in audiometers used in testing of human ears. In such audiometers the American Medical Association has set up the requirements as to the maximum available signal levels at respective frequencies relative to a reference level assumed to be the threshold of hearing in a normal human ear as follows:

Frequency in cycles per second	Maximum available signal level in decibels above reference level
128	70
256	80
512	80
1,024	100
2,048	100
2,896	100
4,096	100
5,792	100
8,192	70
11,584	70

Since the usual variable frequency electronic oscillator has less output near the respective limits of its range of frequency and it so happens that the above tabulated requirements call for lower maximum available signal strengths near said limits it is desirable, in the best interests of economy, to build audiometers having oscillators only of sufficient capacity to supply energy in accordance with the above tabulated requirements. It is in such low powered oscillator circuits that my output equalizer is of particular value.

The embodiment of my invention diagrammatically shown in the drawing is associated with an electronic tube 3 having circuit elements connected therewith to form an electronic oscillator or signal generator, and a second electronic tube 4 having circuit elements connected therewith to form an electronic amplifier for amplifying an oscillatory electrical signal such as would be generated by a signal generator or the like.

The tube 3 is of triode construction including a plate element 3*a*, a grid element 3*b*, a cathode element 3*c* and a heater element 3*d* associated with each other in the usual manner. Electrical energy for feeding the heater 3*d* may be supplied thereto by any suitable means such as the battery 5 which is connected to the heater through an electrical switch 6. A common conductor 7 is provided and may consist of a metallic frame, chassis or case on or in which the illustrated apparatus may be mounted. The conductor 7 may be grounded as indicated in the diagram of Fig. 1.

A plate battery 8 or its equivalent is provided for supply of plate voltage and current to the electronic tube 3. The negative terminal of the battery 8 is connected to the plate 3*a* of the tube 3. A by-pass condenser 9 is connected in shunt with the plate battery 8.

Circuit elements are associated with the electronic tube 3 to form an oscillator circuit of the well-known Hartley type. An inductance coil 10 is so connected to the tube 3 and other elements that the upper part of the coil 10 will function as a grid coil and the lower portion will function as a plate coil. The upper end of the coil 10 is connected through a grid-leak resistor 11 to the grid 3*b* of the tube 3 and the lower end is connected to the common conductor 7. The cathode 3*c* of the tube 3 is connected through a self-biasing resistor 12 shunted by a bypass condenser 13, electrical switching means to be described, and the lower or plate circuit portion of the coil 10 to the common conductor 7 whereby plate current of the tube 3 will return to the negative terminal of the plate battery through the lower portion of the coil 10. Since respective portions of the coil 10 are connected in the grid and plate circuits of the tube 2 the necessary feedback from the plate to the grid of the tube 3 will be provided and the above described circuit will function as a generator of an oscillatory electrical signal.

Means is provided for adjustively varying the frequency of the signal produced by the above described oscillator circuit. A frequency selector switch 14 is provided having a contact element 14*a* movable for engagement with any desired one of a series of stationary contact elements 14*b* which are connected to respective ones of a series of taps or points on the coil 10. The circuit from the cathode 3*c* through the self-biasing resistor 12 runs to the switch arm 14*a* so that the plate current of the tube 3 will be routed back to the negative terminal of the battery 8 through a portion of the coil 10 determined by the position of the switch arm 14*a*. It is apparent that the position of the movable contact element or switch arm 14*a* will determine the point of division between the grid circuit and plate circuit portions of the coil 10. To form a resonant circuit in conjunction with the plate circuit portion of the coil 10, a condenser 15 is connected between the switch arm 14*a* and the common conductor 7 so as to be in parallel with said plate circuit portion. In a circuit such as that described above different frequencies will be obtained with the switch arm in respective ones of its positions. Also, in accordance with the characteristics of the usual variable frequency electronic oscillator, it is to be expected that the signal strength will not be the same at all of the available frequencies. The output voltage of the above described oscillator appears on the switch arm 14*a* as a potential taken with reference to the common conductor 7 considered as a zero potential reference point.

As previously mentioned, the electronic tube 4 has associated therewith suitable circuit elements to form an electronic amplifier. As shown, the tube 4 is of triode construction including a plate 4*a*, a grid 4*b*, a cathode 4c and a heater 4*d*. The heater 4*d* is supplied with electrical energy from a suitable source as, for example, the battery 16 which is shown connected to the heater 4*d* through a switch 17. A comon conductor 7*b* for the amplifier circuit is provided and is connected through a conductor 7*c* to the common conductor 7 previously described in connection with the oscillator circuit. The cathode 4*c* is connected to the common conductor 7*b* through a self-biasing resistor 18 shunted by a bypass condenser 19. The grid 4*b* is connected to an amplifier input conductor 20. A plate battery 21 is provided having its negative terminal connected to the common conductor 7*b* and its positive terminal connected through the primary winding 22*a* of an amplifier output transformer 22 to the plate 4*a* of the tube 4. A secondary winding 22*b* of the transformer 22 is connected to a pair of amplifier output terminals 23. Obviously some sort of a signal utilizing or translating device would ordinarily be connected to the amplifier output terminals 23 as a load. In audio-frequency applications of the circuit such load device may be in the nature of a telephone receiver for translating the signal energy from an electrical form to a corresponding form of sound energy. As well known in the art, the amplifier and whatever load device is fed therefrom will usually have what is known as a frequency discrimination characteristic.

The above described oscillator and amplifier are of conventional form and the equalizing system associated therewith and constituting an embodiment of my invention will now be described.

My equalizing equipment consists, in general, of attenuation means interposed at a suitable point in a system comprising a variable frequency signal source and signal-handling apparatus fed therefrom, with the attenuation means automatically so operated responsive to shifting of a frequency selector means as to compensate for variation in the signal strength of the source at respective frequencies and the frequency discrimination characteristics of the signal handling apparatus that the signal at a selected point in the system will be at the same level at all operating frequencies or, if desired, will be at predetermined respective different levels. In the system illustrated by the drawing, my equalizing

equipment is situated between the oscillator and the amplifier, but it is to be undertsood that my equalizing equipment may be interposed in a signal generating and handling system at any other suitable point.

In the illustrated embodiment of my invention I provide a voltage divider resistor 24 of which the lower end is connected to the common conductor 7. To provide for supplying signal energy at known levels I provide a signal level-selecting switch or voltage divider output switch comprising a contact 25 movable over a series of stationary contacts 26 to engage any desired one thereof. The stationary contacts 26 are connected to a series of respective points on the voltage divider resistor 24 and are calibrated in terms of signal level expressed in decibels above a reference level as indicated by the numerals 40, 50, 60, 70, 80, 90 and 100 shown in the drawing beside respective ones of the stationary contacts 26. The movable contact 25 is connected to the amplifier input conductor 20 previously described.

In accordance with my invention I provide means working automatically responsive to operation of the frequency selector switch 14 for attenuating the signal of the oscillator delivered to the voltage divider to various respective degrees so that the calibration of the signal level selector switch comprising the contact 25 and contacts 26 will be equally correct at all operating frequencies of the illustrated system. I provide a voltage divider input selector switch or attenuation control switch 27 having a contact 27*a* movable for engagement with any desired one of a series of stationary contact elements 27*b* which are connected through respective resistors 28 to selected points on the voltage divider resistor 24. The movable contact 27*a* of the switch 27 is connected through a resistor 29 to the movable contact 14*a* of the frequency selector switch 14 which, as was previously explained, is the point at which the output signal voltage of the oscillator circuit appears. The resistor 29 is inserted in the circuit to minimize reaction on the oscillator which may otherwise be produced to an undesirable degree due to changes in load fed from the voltage divider resistor 24. As indicated by the dotted line 30 the movable contact 14*a* of the frequency selector switch 14 is mechanically connected to the movable contact 27*a* of the voltage divider input selector switch 27 so that the two movable contacts 14*a* and 27*a* will move in unison and the movable contact 27*a* will be in engagement with a different one of the stationary contact elements 27*b* for each respective position of the frequency selector switch 14. The points on the voltage divider resistor to which the contact elements 27*b* are connected are selected to effect compensation for differences in the output voltage of the oscillator at the respective operating frequencies thereof so that the signal voltage at any given one of the contact elements 26 will be the same for each and every one of the operating frequencies of the oscillator. The resistors 28 are provided for purposes of adjustment of my device at the factory. These resistors are fixed resistors and are of respective resistance values chosen to bring about correct calibration of the signal level-selecting switch at all operating frequencies of the signal generator.

It is to be noted that some of the resistors 28 may be of very low resistance value or may be of zero resistance value, that is, omitted entirely.

As described in the preceding paragraph the selection of taps on the voltage divider resistor for connection to the voltage divider input selector switch 27 and the selection of resistance values of the resistors 28 may be made to compensate for differences in the output voltages of the oscillator at the respective operating frequencies thereof. If desired the calibration of the signal level switch contact elements 26 may be made in terms of signal level at the output terminals 23 of the amplifier. In this case the frequency discrimination characteristic of the amplifier circuit will become a factor and the choice of input tap locations on the voltage divider resistor 24 and the resistance values of the resistors 28 may be so made as to compensate for the frequency discrimination characteristics of the amplifier in addition to the output voltage characteristics of the oscillator so that changing the operating frequency will not change the voltage or energy level at the amplifier output terminals 23 and the calibration of the signal level switch will be equally correct at all operating frequencies. Adjustments may, of course, be made to compensate for frequency discrimination in signal-handling equipment receiving energy from the output terminals 23 of the amplifier. As an example, when the system is operated at audio frequencies and feeds a telephone unit wherein the ratio of sound output energy to electrical input energy is not the same for all of the operating frequencies, the signal level switch may be calibrated in terms of sound output intensity and my equalizing means may be adjusted to compensate for the frequency discrimination characteristics of the telephone unit in addition to the characteristics of the other parts of the complete system.

It is to be particularly noted that certain contact elements 27*b* of the attenuator input switch 27 are connected through corresponding ones of the resistors 28 to 70 and 80 decibel levels on the voltage divider resistor 24. These certain contact elements 27*b* are engaged by the movable contact 27*a* when the signal generator is operating at those frequencies where output signals of respectively only 70 or 80 decibels is required and the oscillator is capable of delivering energy to the attenuator at only 70 or 80 decibels. It should be apparent that the calibration of the signal level selector switch at such frequencies may be made to be correct through the range of signal levels required to be available at such frequencies. By such an arrangement I am able to provide a calibrated signal level-selecting element of which the calibration is correct at all operating frequencies in the portions of the range of calibration to be used during operation at the respective operating frequencies in signal generating equipment capable of less output at some operating frequencies than the required maximum available output from the attenuator at other operating frequencies. Accordingly, my equalizer equipment enables the use of an oscillator of less capacity in a system meeting requirements such as those previously tabulated than in the case of attenuation equipment wherein the oscillator output is always delivered, regardless of operating frequency, to points on an attenuator (such as the voltage divider resistor 24) at or above the maximum output level (corresponding to the 100 decibel level on the resistor 24) thereof.

Fig. 2 is a graph wherein curve A illustrates the relation between operating frequencies and the output signal level of a point in an attenuation system, such as, for example, the 50 decibel level

on my resistor 24, not including my equalizing means and curve B illustrates the corresponding variation in the degree of attenuation to be imposed on the system by my equalizing means when my equalizing means is incorporated in the system and adjusted to obtain equal output voltages or energy levels at all of the operating frequencies of the system at a point such as the 50 decibel level on the resistor 24.

It is also readily feasible, when other than equal output voltages are desired at respective operating frequencies, as for special purposes, to adjust the voltage divider taps and resistor values of my equalizing equipment to obtain signal output voltages at respective operating frequencies in accordance with predetermined ratios between output voltages at the respective frequencies.

While I have illustrated my equalizing equipment in operative relation with a signal generator of a specific type and signal handling equipment consisting of an amplifier of a specific type it is to be understood that my equalizing equipment is readily adapted for use with many types of generators of oscillatory electrical signal energy and many types of signal-handling equipment. Also, my equalizing equipment is readily adapted for use in systems operating in all frequency ranges in the audio frequency and radio frequency spectrums.

From the above it should be seen that my equalizing apparatus enables use of directly calibrated output signal level controls in variable frequency signal generating systems of particularly economical design meeting requirements such as those previously tabulated and, in many kinds of work involving use of such systems, eliminates the need for making use of output voltage measurements for purposes of adjusting attenuators or reference to charts or graphs for the purpose of correlating attenuator adjustments with frequency selector adjustments.

It should be apparent that I have invented a novel, effective, accurate and inexpensive form of equalizer capable of automatic compensation for frequency discrimination characteristics in variable frequency signal generating systems.

It will, of course, be understood that various changes may be made in the form, details, proportions and arrangement of parts without departing from the scope of my invention.

What is claimed is:

1. In an audiometer, the combination of a source of audio frequency signal energy consisting of, an electronic oscillator which is adjustable as to operating frequency and which is relatively deficient in energy output in some portions of its frequency range with a signal output attenuator device comprising, a main resistance element having respective ends constituting fixed zero and maximum signal voltage level points thereon, said main resistance element consisting of a plurality of resistors connected in series and having junctions therebetween constituting respective intermediate signal voltage level points on said main resistance element, electrical switching means for selectively connecting a load circuit to any one of said maximum and intermediate voltage level points, a plurality of electrical conductors of which at least one is connected to said maximum voltage level point and the remainder are respectively connected to selected ones of said intermediate voltage level points, electrical switching means for selectively connecting said source to any one of said conductors, and respective resistors interposed in series with at least some of said conductors.

2. In an audiometer, the combination of a source of audio frequency signal energy consisting of, an electronic oscillator which is adjustable as to operating frequency and which is relatively deficient in energy output in some portions of its frequency range with a signal output attenuator device comprising, a main resistance element having respective ends constituting fixed zero and maximum energy level points thereon and points thereon intermediate of said ends constituting respective intermediate energy level points, means identifying said maximum and intermediate energy level points in terms of respective relative energy levels thereat, said maximum and intermediate energy level points being accessible for selective connection of a load circuit to any one thereof, a series of electri-conductors connected to various selected ones of said identified points and at least one of which is connected to said maximum energy level point, electrical circuit-transferring means for selectively connecting said source to any one of said conductors whereby said source may be connected to one of said points having an energy level identification close to and not exceeding the energy level of the signal generated by said source, and resistors interposed in series with at least some of said respective conductors to introduce attenuation to compensate for the differences between the energy levels of the signal output of said source and the energy levels with which approximately corresponding respective ones of said points are identified.

3. In an audiometer, the combination of a source of audio frequency signal energy consisting of an electronic oscillator which is adjustable as to operating frequency and which is relatively deficient in energy output in some portions of its frequency range with a signal output attenuator device comprising, a resistance element having respective ends constituting fixed zero and maximum signal voltage level points thereon, said maximum voltage level point and a series of intermediate points on said resistance element being accessible for selective connection of a load circuit to any one thereof, electrical circuit-connecting means consisting of an electrical contact adapted to be connected to said source and a series of stationary contacts over which said first-mentioned contact is movable for successive engagement with respective ones thereof, electrical conductors connecting contacts in the respective end portions of said series to selected ones of said intermediate points and remaining contacts which are situated in the middle portion of said series to said maximum voltage level point, and voltage dropping resistors of selected relatively small respective ohmic values interposed in series with selected respective ones of said conductors.

RALPH E. ALLISON.