March 8, 1938. W. D. PENN 2,110,817

HEARING AID APPARATUS AND METHOD

Filed April 16, 1936

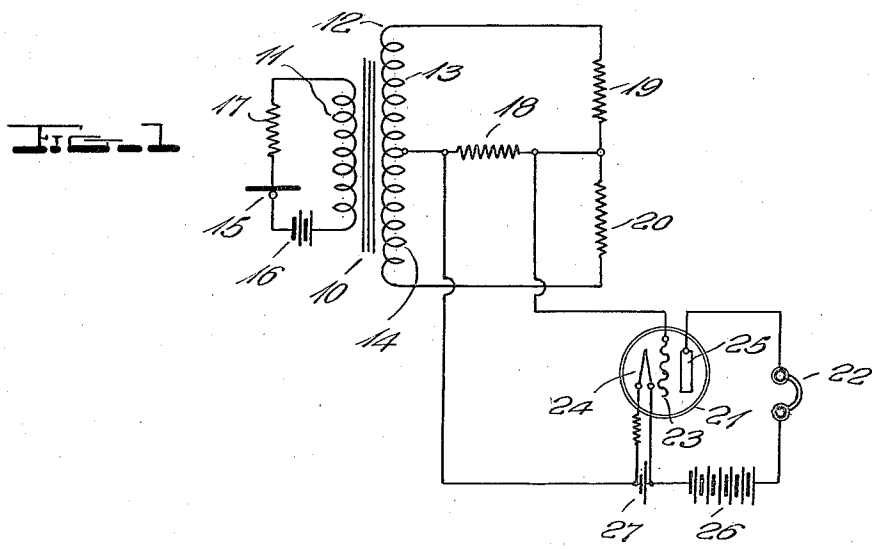

FIG. 1

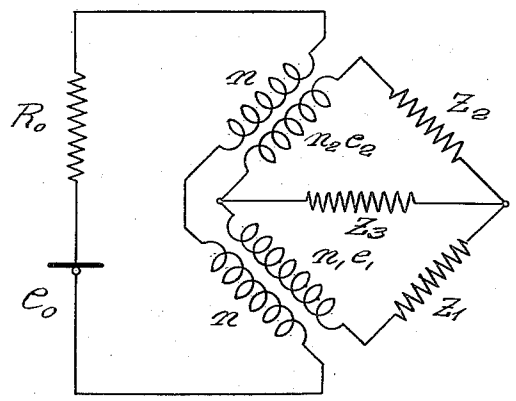

FIG. 2

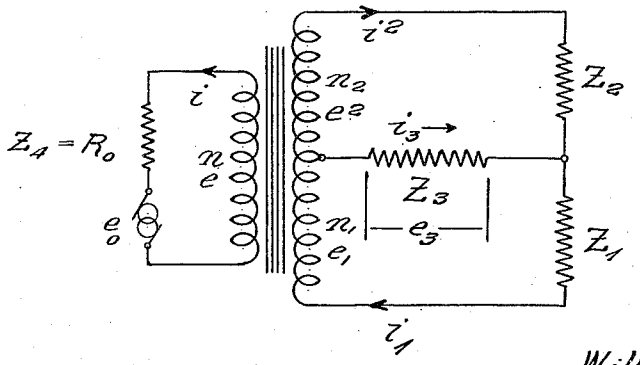

FIG. 3

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Patented Mar. 8, 1938

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UNITED STATES PATENT OFFICE

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HEARING AID APPARATUS AND METHOD

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Application April 16, 1936, Serial No. 74,754

12 Claims. (Cl. 179—1)

This invention relates to a new and improved method and apparatus to be used in aiding hearing and more particularly, to a method and apparatus for selectively accentuating the frequencies to which a particular user is less sensitive than normal.

An object of this invention is to provide an apparatus that may be used in aiding hearing and which is adapted to amplify selected frequencies.

Another object of this invention is to provide an apparatus adapted to be used in aiding hearing, said apparatus being adapted to be adjusted to amplify selected frequencies more than others.

Still another object of this invention is to provide a frequency selective apparatus adapted to be used in aiding hearing, which may be connected between the hearing aid microphone and reproducing device to select the frequencies to be accentuated.

A further object of this invention is to provide a simple and easily constructed hearing aid amplifying apparatus adapted to accentuate certain frequencies to which a particular user is less sensitive than normal.

Other and further objects of this invention will be apparent from the following specification and the claims.

In accordance with this invention I provide a hearing aid apparatus that may be adapted to meet the needs of different users troubled with impaired hearing on different frequencies or bands of frequencies. The apparatus of my invention may be easily made and adjusted very readily to meet special cases. This is especially important because persons afflicted with impaired hearing vary in the extent to which they are afflicted.

Different persons may be sensitive to different frequencies, that is, certain persons may have their hearing impaired on a certain high frequency band whereas others may have their hearing impaired to a greater extent on a lower frequency band. Still others may have their hearing impaired over a wider band of frequencies. Thus, in order to satisfy the need for a useful hearing aid apparatus, the apparatus must be either adjustable to the individual person or it must be custom built to satisfy that person's requirements. The apparatus of my invention is constructed in such a manner that it may be made to meet the requirements of individual persons very readily.

Briefly, my invention consists of a microphone connected to a transformer primary winding and a suitable reproducing device connected to the secondary winding of the transformer through suitable impedance or resistance devices, with or without suitable vacuum tube amplifying apparatus. The adjustment of these impedance or resistance devices, which will be described in greater detail in the following paragraphs, determines to a large extent which frequencies will be accentuated over other frequencies. Where desired, the transformer secondary and its associated impedance and resistance devices may be connected to the input of a suitable electric discharge device amplifier and the reproducing device may be connected to the output circuit of this electric discharge device amplifier.

Further details of this invention will be apparent to those skilled in the art to which it relates from the following specification and the drawing in which, briefly, Figure 1 illustrates schematically an embodiment of this invention and Figures 2 and 3 show details of this invention for the purpose of setting forth its operation more clearly.

Referring to Figure 1 of the drawing in detail, reference numeral 10 designates a transformer having a primary winding 11 and a secondary winding 12 which is divided into two sections, 13 and 14. The microphone 15 and battery 16 are connected to the primary 11. A resistance unit 17, which may be variable, may be connected in series with the microphone 15 and primary 11 particularly where the microphone 15 is of the carbon granule type. Where desired, the two-button type of microphone may be employed, and in that case the primary 11 should be provided with a central tap. Furthermore, the microphone 15 may be replaced by a suitable electrical pick-up device adapted to reproduce phonograph records so that this apparatus may be employed in conjunction with phonograph records, should the person using it desire to listen to recordings in that manner.

The secondary sections 13 and 14 which may be electrically equal or unequal, that is, if the secondary 12 is center tapped to divide it into two sections 13 and 14, these sections may be wound in such a way that electrically they have either substantially equal or materially unequal characteristics. The secondary 12 may be composed of two distinct windings in which case one of the windings will function as the section 13 and the other winding will function as the section 14. These two windings or sections are connected to the impedances or resistances 18, 19, and 20 to form a bridge circuit of the Wheatstone type as shown in Figures 2 and 3 of the drawing.

The elements 19 and 20 are connected together in series and this series arrangement is connected across the secondary 12. The element 18 is connected between the units 19 and 20 and to the secondary 12 between the sections 13 and 14. The electric discharge device 21, which is adapted to act as an amplifier, is provided with a grid electrode 23 and a cathode 24 connected across impedance device 18. The anode 25 of the device 21 is connected to the reproducing device 22 which may be of any convenient and useful type or form, such as, a telephone receiver or a bone-conduction type reproducer. Where desired, a loud-speaking reproducer employing a diaphragm may be employed.

Sources of current supply 26 and 27 for energizing the anode and cathode heating circuits, respectively, are connected to the tube or electric discharge device 21. It is, of course, apparent that various forms of current supply sources, such as, batteries, direct current from lighting circuits and rectified and filtered alternating current from the light-power supply mains may be used as the source 26. Likewise the cathode may be heated by an electric current derived from various sources and an indirectly heated cathode may be used conveniently.

Various types of vacuum tubes having three or more electrodes also may be used as the device 21 and it is, of course, understood that I do not desire to limit this invention to the use of three element type vacuum tubes.

Considering only the transformer 10 by itself, it will be seen that due to the manner in which it is connected, it acts in the same manner as a Wheatstone bridge circuit. This may be more clearly shown by reference to Fig. 2, in which the windings N comprise the primary 11 and the windings N_1 and N_2, the secondary.

If the windings N_1 and N_2 are equal, then for a given voltage, e_0, impressed in the primary circuit, the secondary voltages e_1 and e_2 will be equal. Now, if the impedances Z_1 and Z_2, corresponding to 20 and 19 of Fig. 1, are equal, the circuit will be balanced and no current will flow through Z_3, which corresponds to 18 of Fig. 1, and hence there will be no difference of potential across Z_3, Z_3 being the input impedance of the amplifier or headpiece.

If the impedances Z_1 and Z_2 are equal resistances, then no voltage will appear across Z_3 at any frequency throughout the audible range provided the transformer capacities are small enough not to upset the balance. The capacities existing in ordinary transformers are such that practically a perfect balance is obtained until frequencies of the order of 15,000 cycles are reached.

I prefer to use a transformer of small physical dimensions, for example, a transformer approximately 1.2 inches wide, 1.1 inches high, and 1 inch thick, is a convenient size. However, these dimensions may be departed from if desired, and transformers of various dimensions used.

If the impedances Z_1 and Z_2 are not equal, current will flow through the impedance Z_3 and a voltage will be set up across it. The magnitude of the current flowing will depend upon the degree of unbalance between Z_1 and Z_2 and will be different at different frequencies. For example, if Z_1 consists of an inductance L_1 and Z_2 is a resistance, the higher frequencies will be amplified more than the low frequencies. If Z_1 consists of a condenser, and Z_2 a resistance, the low frequencies will be amplified more than the high frequencies. The magnitude of the variations in amplification as well as the range over which they are operative can be varied by suitably choosing the various impedances. Z_1 and Z_2 can both be impedances which vary with frequency. Additional effects can be obtained by making Z_3 also vary with frequency.

In accordance with this invention I may use inductances in the impedances Z_1 and/or Z_2, capacitances in Z_1 and/or Z_2, series resonant circuit in Z_1 and/or Z_2, parallel resonant circuit in Z_1 and/or Z_2 and various other impedances or impedance combinations to obtain the desired effect.

The greatest selective effect is obtained when the resistances in the two branches are equal and one or both branches contains a reactance.

The equations for the transformer, assuming an ideal transformer, are obtained as follows:

$$e=e_0-R_0i,$$

$$e_1=Z_3i_2-(Z_1+Z_3)i_1,$$

$$e_2=Z_3i_1-(Z_2+Z_3)i_2,$$

$$i/i_1=N_1/N,\ i/i_2=N_2/N,$$

$$Ni+N_1i_1+N_2i_2=0,$$

$$e/N=e_1/N_1=e_2/N_2$$

Let $r=N/N_1=N/N_2$,

$$i_3=i_1-i_2=\frac{E(Z_1-Z_2)}{r(Z_2Z_3+Z_3Z_1+Z_1Z_2)+\frac{Z_4(Z_1+Z_2+4Z_3)}{r}}$$

$$E_3/E=i_3Z_3/E=\frac{Z_3(Z_1-Z_2)}{r(Z_2Z_3+Z_3Z_1+Z_1Z_2)+\frac{Z_4(Z_1+Z_2+4Z_3)}{r}}$$

Let $Z_4=R_0$

$Z_3=R_3$

$Z_2=R_2$

$Z_1=R_1+jwL_1$

The expression for the voltage stepup of the transformer 10 may be rearranged into the following form:

$$E_3/E=\frac{\frac{R_3R_1-R_2R_3}{jwL_1}+R_3}{r\left[\frac{R_2R_3}{jwL_1}+\frac{R_1R_3}{jwL_1}+\frac{R_1R_2}{jwL_1}+(R_2+R_3)\right]+\frac{R_0}{r}\left[\frac{R_1}{jwL_1}+\frac{R_2}{jwL_1}+\frac{4R_3}{jwL_1}+1\right]}$$

The limit of this expression as the frequency increases is:

$$\lim_{W\to\infty} E_3/E=\frac{R_3}{r(R_2+R_3)+\frac{R_0}{r}}=\frac{1}{r\left(\frac{R_2}{R_3}+1\right)+\frac{R_0}{R_3r}}$$

R_0/R_3r will be small compared to

$$r\left(\frac{R_2}{R_3}+1\right)$$

so

$$\lim_{W\to\infty} E_3/E=\frac{1}{r\left(\frac{R_2}{R_3}+1\right)}$$

if $r=1/20$, $R_2=100{,}000$ ohms, $R_3=500{,}000$ ohms

$$\lim_{W\to\infty} E_3/E=20/1.2=16.7\doteq 0.8/r.$$

By using a condenser in place of an inductance in one arm of the bridge, that is, in one of the arms 19 or 20, exactly the opposite effect can be

obtained, that is, the low frequencies will be amplified more than the high frequencies.

While I have described this invention in one of its embodiments in detail, it is apparent that modifications thereof may be made without departing from the spirit and scope of this invention and, therefore, I do not desire to limit this invention to the exact details described except insofar as they are defined by the claims.

What I claim and desire to secure by Letters Patent of the United States is as follows:

1. In hearing aid apparatus the combination of a transformer having a primary winding and a pair of secondary windings, a microphone connected to said primary winding, a plurality of impedance elements connected to said secondary windings to form a Wheatstone bridge circuit with said secondary windings, the characteristics of said bridge circuit being such that said bridge circuit is balanced at predetermined frequencies, and a reproducing device coupled to said bridge circuit to be energized over a range of frequencies for which said bridge circuit is not balanced.

2. In hearing aid apparatus the combination of a transformer having a primary winding and a secondary composed of two sections, connected together in series so that the voltages thereof are substantially in phase, a microphone connected to said primary winding, a pair of impedance elements connected across said secondary sections to form a bridge circuit therewith, said bridge circuit being substantially balanced at predetermined frequencies, and a reproducing device connected across said bridge circuit between said secondary sections and said pair of impedance elements to receive substantially no energization at the frequencies at which said bridge circuit is balanced.

3. Hearing aid amplifying apparatus adapted to accentuate certain frequencies, the combination of a transformer having a primary winding and a pair of secondary windings connected together, a microphone connected to said primary winding, a plurality of impedance elements the impedances of which vary with frequency, said impedance elements being connected to said secondary windings to form a bridge circuit with said secondary windings, said secondary windings being connected together in series so that the voltages thereof are substantially in phase to energize the bridge circuit, and a reproducing device coupled to said bridge circuit to be energized over a range of frequencies for which said bridge circuit is not balanced.

4. Hearing aid amplifying apparatus adapted to accentuate certain frequencies, the combination of a transformer having a primary winding and a secondary composed of two sections connected together in series so that the voltages thereof are substantially in phase, a microphone connected to said primary winding, a pair of impedance elements the impedances of which vary with frequency, said impedance elements being connected across said secondary sections to form a bridge circuit therewith, said bridge circuit being substantially balanced at predetermined frequencies, and a reproducing device connected across said bridge circuit to receive substantially no energization at the frequencies at which said bridge circuit is balanced.

5. In hearing aid apparatus the combination of a transformer having a primary winding and a pair of secondary windings, a microphone connected to said primary winding, a resistance and an inductive impedance element connected to said secondary windings to form a bridge circuit with said secondary windings and a reproducing device coupled to said bridge circuit to be energized over a range of high audio frequencies for which said bridge circuit is not balanced.

6. In hearing aid apparatus the combination of a transformer having a primary winding and a secondary composed of two sections connected together, a microphone connected to said primary winding, a pair of impedance elements including a resistance and a capacity connected across said secondary sections to form a bridge circuit therewith, said bridge circuit being substantially balanced at predetermined frequencies, and a reproducing device connected across said bridge circuit to receive substantially no energization at the frequencies at which said bridge circuit is balanced.

7. In hearing aid apparatus the combination of a transformer having a primary winding and a pair of secondary windings, a microphone connected to said primary winding, impedance elements resonant to a predetermined frequency connected to said secondary windings to form a bridge circuit with said secondary windings and a reproducing device coupled to said bridge circuit to be energized over a range of frequencies for which said bridge circuit is not balanced.

8. In hearing aid apparatus the combination of a transformer having a primary winding and a secondary composed of two sections connected together, a microphone connected to said primary winding, a pair of impedance elements connected across said secondary sections to form a bridge circuit therewith, said bridge circuit being substantially balanced at predetermined frequencies, at least one of said elements being resonant to a predetermined frequency at which it is desired to unbalance said bridge circuit, and a reproducing device connected across said bridge circuit to receive substantially no energization at the frequencies at which said bridge circuit is balanced.

9. In hearing aid apparatus the combination of a transformer having a primary winding and a pair of secondary windings, said secondary windings being connected together to form two legs of a bridge circuit, a pair of impedance elements connected together and to said secondary windings to form the other two legs of said bridge circuit, an additional impedance element connected between said secondary windings and said pair of impedance elements, an electric discharge device amplifier having an input circuit connected across said additional impedance element, and a reproducing device connected to the output of said amplifier.

10. In hearing aid apparatus the combination of a transformer having a primary winding and a secondary composed of two sections connected together to form two legs of a bridge circuit, a microphone connected to said primary winding, a pair of impedance elements connected across said secondary sections to form the other two legs of said bridge circuit therewith, said bridge circuit being substantially balanced at predetermined frequencies, an additional impedance comprising an inductive reactance connected between said secondary sections and said pair of impedance elements, an amplifier connected to said inductive reactance, and a reproducing device connected to said amplifier to be energized over a range of frequencies for which said bridge circuit is not balanced.

11. In hearing aid apparatus the combination of a transformer having a primary winding and

a secondary composed of two sections connected together, a microphone connected to said primary winding, a pair of impedance elements connected across said secondary sections to form a bridge circuit therewith, said bridge circuit being substantially balanced at predetermined frequencies, and an additional impedance comprising a capacitative reactance connected between said secondary sections and said pair of impedance elements, an amplifier connected to said reactance, and a reproducing device connected to said amplifier to be energized over a range of frequencies for which said bridge circuit is not balanced.

12. Hearing aid amplifying apparatus adapted to accentuate certain audio frequencies comprising: a bridge circuit having four legs, a transformer having a primary and a secondary, means for energizing said primary, said secondary being connected into said bridge circuit and forming two legs thereof whereby the electromotive force induced into said secondary is impressed across said bridge circuit, a pair of impedance elements connected into said bridge circuit across said secondary to form the other two legs of said bridge circuit the balanced or unbalanced condition of which is determined by the frequency characteristics of said impedance elements and signal reproducing means connected across said bridge circuit to be energized substantially only at the audio frequencies at which said bridge circuit is not balanced.

WILLIAM D. PENN.