

Dec. 11, 1945.

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2,390,794

FREQUENCY RESPONSE CONTROL

Filed Feb. 21, 1944

2 Sheets-Sheet 1

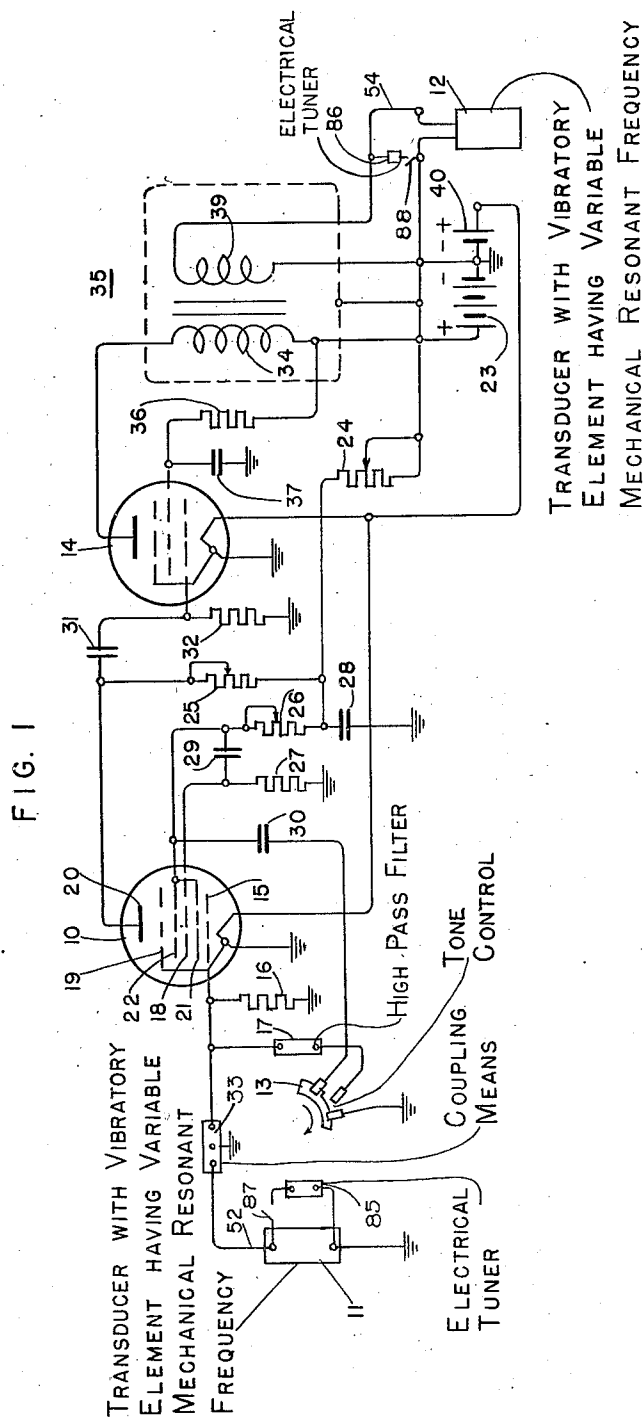


FIG. 4

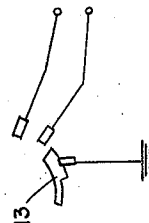


FIG. 2

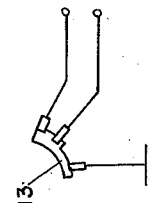
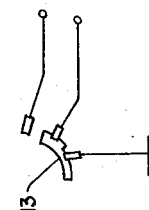


FIG. 3



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FIG. 6

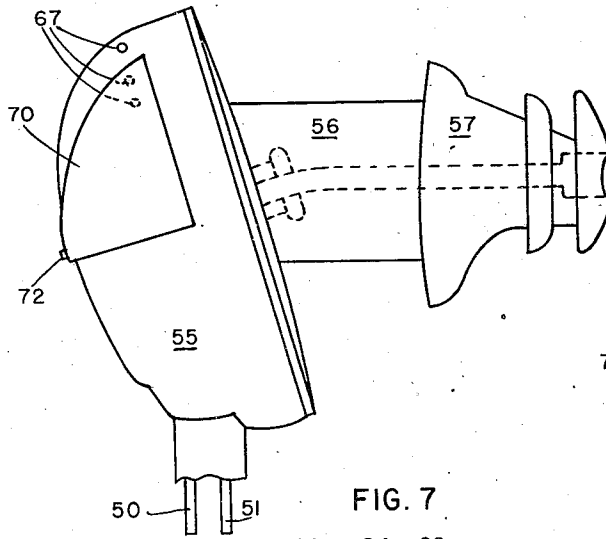


FIG. 7

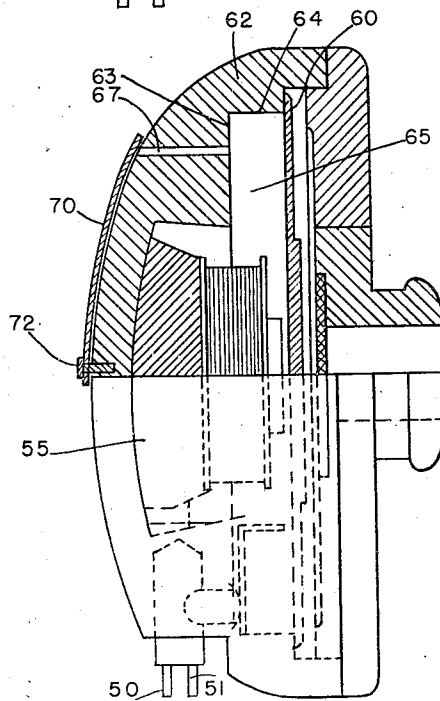


FIG. 5

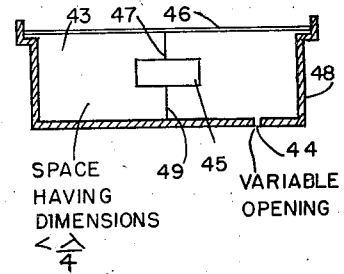


FIG. 8

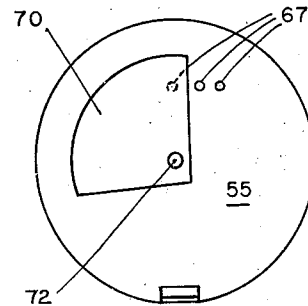
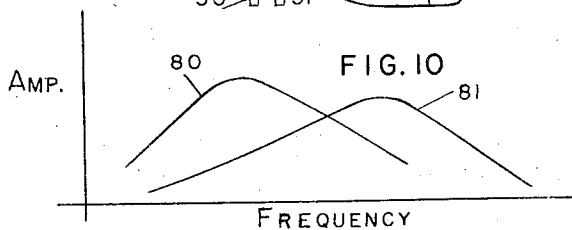
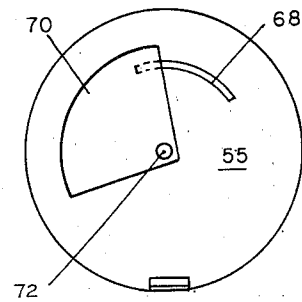


FIG. 9



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2,390,794

FREQUENCY RESPONSE CONTROL

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Application February 21, 1944, Serial No. 523,379

17 Claims. (Cl. 179-1)

This invention relates to tone controls for electro-acoustic apparatus and particularly to tone controls in hearing aid apparatus.

In present day hearing aid apparatus, there is supplied an electro-acoustical transducer for converting sound energy into electrical energy, an amplifier for amplifying such electrical energy, and a second electro-acoustical transducer for converting the amplified electrical energy into sound energy. The "over-all frequency response characteristic" of such apparatus is determined to a large extent by the frequency response characteristic of each one of the transducers and accordingly such "over-all frequency response characteristic" is altered in a relatively small degree by providing a so-called tone or tuning control in the amplifying circuit.

By the term "over-all frequency response characteristic" of acoustical apparatus it is understood that reference is made to the variation of the intensity of sound energy delivered at the output circuit of the apparatus as a function of frequency over the range of frequencies in the audible range when a constant intensity signal of corresponding frequencies in such range is applied to the input circuit of the apparatus.

Also, by the term "electro-acoustical transducer," it is understood that reference is made to electro-acoustical apparatus having as its function the conversion of sound energy into electrical energy, as in a microphone of the carbon, magnetic or piezoelectric type, or apparatus having as its function the conversion of electrical energy into sound energy as in a reproducer of the carbon, magnetic or piezoelectric type, such reproducer being, in hearing aid apparatus, either of the bone conduction or air conduction type.

The frequency response characteristics of such transducers having mechanical vibratory elements are determined largely by the mechanical resonance, as distinguished from electrical resonance, properties of the vibratory elements whereby the over-all frequency response characteristic of the composite hearing aid apparatus is determined largely by the mechanical properties of the vibratory elements in the two transducers.

When an attempt is made to match the over-all frequency response characteristic of such hearing aid apparatus to the frequency response characteristic of ears of persons having different types and forms of hearing deficiencies, the frequency at which the individual vibratory element in the transducer is resonant, mechanically speaking, assumes paramount importance, and which no means are present to vary the frequency at which

such vibratory elements are mechanically resonant. The matching operation is accomplished, but usually unsatisfactorily, by electrical means such as by the use of electric filter means or by tuning electrically the vibratory elements which might be piezoelectric or magnetic members.

It is accordingly an object of the present invention to provide in apparatus, such as hearing aid apparatus, a simple control preferably operable by the user, for variably controlling the mechanical resonant frequency of vibratory elements in such apparatus whereby the over-all frequency characteristic of such apparatus may be adjusted to supply accurately those deficiencies needed by the user for satisfactory hearing or sound reproduction.

It is understood that the tone quality of transducers has been varied in the past by enclosing a vibratory element within a closed space with variable size openings in the enclosing member. In such cases, the air space within which such vibratory elements move was defined by dimensions one or more of which was greater than one-quarter of the wave length of sound waves in the audible range. With this thought in mind, it is understood that the present invention has special reference to tone controls for transducers having vibratory elements confined within a space whose linear dimensions are less than one-quarter of the wave length of sound in the audible range.

It is realized that ordinarily change of size of known elements accompanied only by a change in degree and not of kind is not the basis of invention. A transducer constructed in accordance with the teachings of the present invention has as its function to change the mechanical resonant frequency of the vibratory element and not, as in the prior art, to adapt a space surrounding a vibratory element for accentuation of relatively unchanged characteristics in the resonant frequency of such vibratory element.

Another object of the present invention is to provide in electro-acoustic apparatus an improved tone control characterized by its simplicity, which is essentially of a mechanical nature.

Another object of the present invention is to provide an improved electro-acoustical transducer having a vibratory member whose mechanical resonant frequency may be varied to control the frequency response characteristic of such transducer.

A further object of the present invention is to provide hearing aid equipment which is readily

adjusted for satisfactory understanding of sounds by persons having many different types of hearing deficiency, such as a deficiency in hearing low, medium and/or high frequency audible sounds.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. This invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which:

Figure 1 shows generalized apparatus embodying the present invention;

Figs. 2-4 show means for controlling a characteristic of the apparatus shown in Fig. 1;

Figs. 5-8 show apparatus embodying the present invention, Fig. 8 showing the apparatus adjusted differently;

Fig. 9 shows modified apparatus embodying the present invention;

Fig. 10 shows frequency response characteristics of apparatus embodying the present invention.

The present invention has applicability to radio, television or audio-frequency translating systems incorporating a vibratory member whose mechanical resonant frequency affects the frequency response characteristics of such systems and has particular applicability to a hearing aid system shown for purposes of illustration in Fig. 1.

The hearing aid circuit in Fig 1 includes a first electro-acoustical transducer 11 having a vibratory element whose mechanical resonant frequency may be varied for converting selectively sound energy into electrical energy, a two-stage amplifier 10, 14 for amplifying such electrical energy, and a second electro-acoustical transducer 12 for converting the amplified electrical energy into sound waves.

The first transducer 11 and second transducer 12 may be of the carbon, magnetic or piezoelectric type having a vibratory element. The amplifying circuit including device 10 connecting the two transducers is described and the patentable features thereof claimed in the copending patent application, Serial No. 504,958, filed October 4, 1943, of John G. Prentiss and assigned to the same assignee as this present application.

The transducers 11 and 12 are characterized by the fact that the mechanical resonant frequency of a vibratory element in each one of the transducers may be variably controlled by means shown in Figs. 5-8 and described later. By the term "mechanical resonant frequency" of a vibratory element, it is understood that reference is made to one of a plurality of frequencies at which a vibratory member, due to particular combinations of compliant and inertia forces acting thereon, vibrates at larger amplitudes at those frequencies than at other frequencies, even though the same energy but of corresponding different frequency is applied in the same manner to such vibratory member. As is well understood and known by those skilled in the electro-acoustical transducer art, such vibratory elements may not only exhibit a relatively large amplitude of vibration at which is termed a fundamental frequency, but also at harmonics or sub-harmonics of such fundamental frequency, or in certain cases, noticed particularly in piezoelectric crystals, at different modes of vibration.

In Fig. 1, the hearing aid circuit incorporates

a high gain amplifier including electron discharge device 10 and a second amplifier including electron discharge device 14. The two amplifiers successively amplify signals from transducer 11 and impress such amplified signals on transducer 12. A switch 13 for effecting tone control of one particular type is inter-connected with the device 10.

Sound waves impinging on transducer 11 are transformed into electrical variations in the main control electrode circuit of discharge device 10. The device 10 greatly amplifies electrical variations produced by transducer 11 and the amplified electrical variations are further amplified by electron discharge device 14 before being applied to the transducer 12.

Transducer 11, which produces electrical variations in response to sound waves impinging thereon, is effectively connected through conductor 52 and through coupling means 33 between the main control grid 15 and the grounded filamentary cathode of discharge device 10. A grid leak resistance 16 is connected between input grid 15 and ground to by-pass continuous current flowing around transducer 11 between control grid 15 and the cathode of discharge device 10. It is noted that substantially no grid current flows through resistance 16 since grid 15 is at negative potential with respect to the cathode of device 10, such negative bias potential being provided by connecting grid 15 through resistance 16 to the grounded negative terminal of source 40 having its terminals connected to opposite terminals of the cathode of device 10.

Electron discharge device 10 is of the pentagrid type in commercial use and may be, for example, of the type commonly known as the 1R5. The particular elements of this device 10, however, are connected in a linear high gain amplifier circuit. Large gain is realized when device 10 is connected in the manner hereinafter described and such large gain is substantially independent of the amplitude of a signal applied between the main control grid 15 and the cathode of discharge device 10.

In general, device 10 is connected so as to be effectively two amplifiers in cascade with regeneration between the two amplifiers. In addition to the main control grid 15, discharge device 10 has what is termed a second control grid 18, a suppressor grid 19 connected to the cathode, a main anode 20, and a pair of screen electrodes 21 and 22 on opposite sides of the second control grid 18.

Operating continuous potentials for device 10 are supplied from a voltage source 23 whose negative terminal is grounded and whose positive terminal is connected to the main anode 20 of discharge device 10 through a series circuit including adjustable voltage dropping and gain control resistance 24 and output coupling resistance 25. Electrodes 21 and 22 are connected together and are maintained positive with respect to the cathode of device 10 by connection to the positive terminal of voltage source 23 through the series circuit including voltage dropping and gain control resistance 24 and coupling resistance 26. The continuous operating potential of the second control grid 18 is established by connecting it to ground and the cathode of discharge device 10 through resistance 27.

When alternating current signals are impressed between the main control grid 15 and cathode of discharge device 10, substantially all of the alternating output voltage appears across

the output coupling resistance 25, a by-pass capacitance 28 of low reactance being connected between the grounded cathode of discharge device 10 and the lower terminal of resistance 25 removed from the main anode 20. Also, potential variations on electrodes 21 and 22, due to an alternating voltage applied between main control grid 15 and cathode of discharge device 10 are impressed on the second control grid 18 through a coupling capacitance 29 connected therebetween.

Therefore, alternating voltages applied directly to control grid 15 and indirectly to control grid 18 cause alternating output signals to appear across resistance 25, which amplified signals are then applied to the grid circuit of another linearly amplifying discharge device 14. Coupling capacitance 31 and input resistance 32 are connected in series and the series circuit formed thereby is connected in parallel circuit relationship to the series circuit formed by output coupling resistance 25 and low reactance by-pass capacitance 28. Capacitance 31 is of relatively low reactance and serves essentially as a means for blocking the flow of continuous current from source 23 to resistance 32. The alternating voltage developed across resistance 32 through condenser 31 is applied between the grid and cathode of discharge device 14 so as to control the space current therein, which current normally flows due to the fact that voltage source 23 is connected between the plate and cathode of discharge device 14 through the primary winding 34 of an output transformer 35.

Discharge device 14 is preferably of the pentode type having its suppressor grid connected to the cathode and with the voltage source 23 connected between its screen grid and cathode through a voltage dropping resistance 36. The screen grid is maintained at constant potential in the presence of signals of frequency corresponding to audio-frequencies by means of low reactance by-pass capacitance 37, which is connected between the screen grid and grounded cathode of device 14.

Alternating voltages developed across resistance 32 are amplified linearly by discharge device 14 and appear across the secondary winding 39 of transformer 35 which is connected to impress those amplified voltages on the transducer 12 which is connected across the terminals of a secondary winding 39.

The filamentary cathodes of discharge devices 10 and 14 are preferably heated by current flowing therethrough as shown in Fig. 1. In such case the cathodes of discharge devices 10 and 14 are connected in parallel circuit relationship to voltage source 40.

The circuit thus far described is especially useful as a hearing aid circuit and, because of the high gain obtained by the use of discharge device 10, only two discharge devices requiring small space current are necessary for a good performance. The volume of signals reproduced by transducer 12 may be controlled by adjusting volume control resistance 24. An adjustment of resistance 24 causes no substantial non-linearity between the intensity of input signals applied to grid 15 and the intensity of signals developed across resistance 25 over a large range of input signals.

In addition to the simple means described hereinafter for changing the mechanical resonant frequency of the vibratory elements in transducers 11 and 12, the tone of signals repro-

duced by transducer 12 may be controlled also by connecting high pass filter 17 and capacitance 30 in the hearing aid circuits thus far described.

In general, high pass filter 17, which comprises a resistance when transducer 11 is a piezoelectric crystal, may be connected in parallel circuit relationship to transducer 11, to reduce the intensity of the low notes. Capacitance 30, which may be connected between the electrode 21 and cathode of discharge device, tends to reduce the intensity of high notes. Different types of tones may be reproduced corresponding to the four positions of the tone control member 13 shown in Figs. 2-4. That is, tone control member 13 is a short-circuiting member of such shape that in its clockwise movement it assumes positions whereby: (1) As in Fig. 1, the capacitance 30 alone is connected in the hearing aid circuit and high notes only are suppressed, and (2) as in Fig. 2, when both filter 17 and capacitance 30 are connected in the hearing aid circuit, both some of the high and some of the low notes are suppressed, and (3) as in Fig. 3, when the filter 17 alone is connected in the hearing aid circuit only some of the low notes are suppressed, and (4) as in Fig. 4, when neither the filter 17 nor the capacitance 30 is connected in the hearing aid circuit neither the low notes nor the high notes are affected. It is noted that lead 52 is connected directly to grid 15 when transducer 11 comprises a piezoelectric crystal.

As mentioned previously, discharge device 10 operates as two amplifying stages combined in the envelope of one discharge device with regeneration between the two amplifying stages. The first stage may be considered to comprise a triode section including the cathode of discharge device 10, main control grid 15 and electrode 21, which electrode operates through the anode of conventional triode. The second amplifying stage operates like a pentode and includes control electrode 18, screen electrode 22, suppressor electrode 19 and anode 20.

Fig. 5 shows in generalized form a structure embodying features of the present invention, for purposes of controlling frequency response or tone. This structure, an electro-acoustical device, for converting sound energy into electrical energy as in a microphone or for converting electrical energy into sound energy as in a speaker, comprises an electro-mechanical or mechanical-electro transducer 45 mechanically coupled to an acoustical-mechanical or mechanical-acoustical device 46 through a coupling 47, the transducer 45 being supported in casing 48 by coupling 49. The space 43 within and defined by transducer 46 and casing 48 has dimensions smaller than a quarter of a wave length ($<\lambda/4$) of sound energy in the audible range. A variable opening 44 is provided through casing 48 for placing the space exterior of casing 48 in communication with the space 43 for affecting the frequency response of one or more components of the composite transducer.

It is understood that Fig. 5 is representative in showing elements of well known electro-acoustical transducers controlled in a novel manner. Such transducers may be of the magnetic, condenser, piezoelectric or carbon types, as is well understood in the art.

The transducers 11, 12 are illustrated herein as being of the magnetic type, it being well known that a transducer of the type shown in Figs. 6 and 7 may be used interchangeably as a microphone or as a sound reproducer or speaker.

When a transducer of the type shown in Figs. 5-7 is used as a microphone in the hearing aid circuit of Fig. 1, the electrical terminals 50 and 51 of the transducer are connected respectively to lead 52 and ground in Fig. 1. And, when the transducer shown in Figs. 5-7 is used as a sound reproducer, receiver or speaker in the circuit of Fig. 1, the transducer terminals 50 and 51 are connected, respectively, to lead 54 and ground (Fig. 1).

The transducer 55 shown in Figs. 6 and 7, which may be used either as a microphone (Fig. 7) or speaker (Fig. 6) for achieving the purposes of the present invention, is of the type shown and claimed in the copending application, Serial No. 484,153, filed April 23, 1943, now Patent No. 2,371,819, of Gilbert E. Gustafson, and assigned to the same assignee as the present invention, but modified in accordance with the teachings of the present invention.

When used as a sound reproducer in a hearing aid circuit, as shown in Figs. 1 and 6, the transducer 55 has a stud 56 and a resilient earpiece 57 assembled thereon in the manner described and claimed in the copending application, Serial No. 507,438, filed October 23, 1943, of Elizabeth Kelsey, and assigned to the same assignee as the present invention. However, the stud 56 and earpiece 57 may be replaced by a molded earpiece. Also, coupling means 33 (Fig. 1) comprises an impedance matching transformer having one of its primary and secondary terminals grounded and the other terminals connected respectively to lead 52 and grid 15.

When the transducer 55 is used as a microphone in a hearing aid circuit, as shown in Figs. 1 and 7, sound impinging on movable pressure responsive diaphragm or vibratory element 60 causes a change in current flow through leads 50 and 51 from voltage source connected thereto and also causes a change in current flow through resistance 16.

One of the important features of the present invention is that when the transducer shown in Figs. 6 and 7 is used either as a sound reproducer or microphone, the mechanical resonant frequency of the vibratory element or diaphragm 60 may be controlled so as not only to impart a controllable frequency characteristic to the transducer but also to impart a controllable over-all frequency response characteristic to the composite hearing aid apparatus of which such transducer or transducers form a part.

The vibratory element or diaphragm 60, of circular shape, is housed within casing 62 and defines with the inner faces 63 and 64 an air space 65 of relatively small volume defined by linear dimensions less than one-quarter of the wave length of audible sound signals. This air space 65, contiguous to the diaphragm 60, is enclosed by casing 62 and diaphragm 60, but may be placed in communication with the space outside of casing 62 by means of one or more of a series of ports, channels or openings 67 of the same size or of differing sizes and extending from space 65 to the exterior of casing 62 through such casing. The cross-sectional area of the communication or passageway formed by channels, openings or ports 67 may be selectively controlled by positioning a pivoted plate 70 with respect to such openings.

The cover or channel closure member 70 is movably and adjustably supported on casing 62 by providing a pivot pin 72 which has an enlarged portion on one end, passes through an

enlarged opening in cover 70, and has its other end supported in casing 62, the cover 70 being of resilient material and being so shaped as to be held in adjusted position on casing 62, due to contact pressure and the frictional forces existing therebetween. It is thus seen that means are provided for increasing, diminishing or closing off entirely the cross-sectional area of the communication or passageway extending between space 65 and the outside space surrounding casing 62. And it is readily seen that the series of openings shown in Figs. 6 and 8 may comprise one large opening, a slotted opening 68 as shown in Fig. 9, or such openings may assume other sizes and shapes.

The purpose of the movable cover 70 and the variable size openings 67 comprising a passageway extending through the casing 62 from space 65 into the space surrounding casing 62 is to allow a change in mechanical resonant frequency of the vibratory element or diaphragm 60. That is, in a practical embodiment of the present invention, it has been found that the mechanical resonant frequency of vibratory element or diaphragm 60 is increased when the open cross-sectional area of the passageway comprising channels 67 is decreased, and that the resonant frequency of such vibratory element or diaphragm 60 is decreased when the open cross-sectional area of the passageway is increased. It has been found also that the length of port 67 influences the frequency response characteristic of the vibratory element.

The mechanical resonant frequency of the vibratory element 60 is determined by the compliance and inertia of such element, and is adjusted in accordance with the teachings of this invention preferably by varying the compliance of such vibratory element by varying the cross-sectional area of the passageway extending from space 65 to the exterior portion of casing 62. It has been observed, also, that the amplitude of vibration of vibratory element 60 increases with an increase in the cross-sectional area of the passageway comprising ports 67. It can be thus said that increasing the cross-sectional area of the passageway not only causes a change in damping of or resistance to movement of vibratory element 60, but also that a mechanical impedance or compliance is correspondingly varied, the space 65 and area of passageway comprising ports 67 determining to some extent the effective compliance of vibratory element 60.

A vibratory element movable contiguous to an air space defined by dimensions smaller, for example, than one-quarter of a wave length in the audible range can be considered to have lumped reactance elements, as distinguished from distributed reactance elements, with no undesirable resonant and anti-resonant frequencies in the transmitted range, such lumped reactance elements being of a nature to effectively change the resonant frequency of the vibratory element. Furthermore, in the transducer 55, Fig. 7, the space within which the vibratory element 60 moves is a small fractional part of the wave length of sound frequencies in the audible range, and low frequency radial nodes in the diaphragm and back cavity are not present.

The mechanical resonant frequency of the vibrating elements in the transducers 11 and 12 may thus be varied by varying the position of plate 70 on casing 62. Fig. 10 shows two frequency response characteristics 80 and 81 of a transducer having communications of different

cross-sectional area extending from space 55 to the space exterior of casing 52. Characteristic 80 is obtained when the area of the communication is relatively large and characteristic 81 is obtained when the area of such communication is relatively small. It is noted that the maximum amplitude of characteristic 80 is somewhat greater than the maximum amplitude of characteristic 81. This difference is perhaps due to increased damping of or resistance to movement of diaphragm 60 when the area of the communication is relatively small.

It is further seen that means are provided for shifting the frequency at which the amplitude response of a transducer occurs. This shifting of the frequency at which the maximum amplitude occurs is, of course, reflected in the shape of the over-all frequency response characteristic of the composite hearing aid or other audio circuit. In fact, such over-all frequency response characteristic may be controlled by shifting the frequency at which such maximum amplitude of the characteristic of one or both of the transducers 11 and 12 occurs. By this means, persons having different types of hearing deficiency and using hearing aid equipment incorporating such controllable transducers may readily adjust the cover 70 so as to select that over-all frequency response characteristic which they consider best for hearing.

Although the position of cover 70 determines the frequency at which the maximum amplitude on the frequency response characteristic of the associated transducer occurs and also affects the over-all frequency response characteristic of the associated apparatus, the position of tone control 13 produces an additional effect, of a filtering type, on the over-all frequency response characteristic of such apparatus.

That is, it can be said categorically that the position of cover 70 determines the position of maximum peaks on the over-all frequency response characteristic of the apparatus shown in Fig. 1 and that the position of tone control member 13 affects the shape of the over-all frequency response characteristic by affecting the degree to which signals are amplified over a band of frequencies.

It is understood that other types of tone control than one including element 13 may be used in conjunction with the adjustable cover 70 for controlling tone or frequency response. That is, the additional tone control instead of being of the filter type, as is the one including element 13, may be of the peak or resonant type by providing one or more variable tuners 85, 86 for tuning transducers 11 and 12 where such transducers are of the impedance or piezoelectric type. When such electrical tuners 85 and/or 86 are used for effecting tone control, corresponding switches 87 and/or 88 are closed and the corresponding transducers 11 and/or 12 may be tuned electrically.

When the transducers 11 and 12 are of the condenser or piezoelectric type, it is readily apparent to one skilled in the art that tuners 85 and 86 should be variable inductances for tuning the transducer circuit and that when the transducers 11 and 12 are of the magnetic type such tuners should be variable condensers.

It is readily seen that means are provided not only for tuning the transducers 11 and 12 mechanically to a desired frequency, but also means are provided for tuning such transducers 11 and 12 electrically to the same, or preferably to another, frequency by varying tuners 85 and 86. It

is also apparent that the over-all frequency response characteristic of the hearing aid circuit shown in Fig. 1 may be controlled separately or simultaneously in five different ways, namely, (1) by mechanically tuning transducer 11, (2) by mechanically tuning transducer 12, (3) by adjusting tone control element 13, (4) by electrically tuning transducer 11, and (5) by electrically tuning transducer 12. It is further apparent that, with the means shown herein, persons having hearing deficiencies of variously different types are provided with means or a combination of means allowing them to adjust the over-all frequency response characteristic of hearing aid apparatus for suitable amplified understandable hearing.

While the particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. In combination, an electro-acoustical transducer having dimensions suitably small for inconspicuous wear and a wall, said transducer having a movable diaphragm with a face thereof enclosed by the wall, and means for altering a physical parameter of said transducer in such an amount that the mechanical frequency response is substantially affected, said means including a sound channel extending through said wall in such a direction that movement of the air produced by movement of said face toward said wall is away from the diaphragm.

2. In a hearing aid apparatus operable in a band of frequencies, an input transducer and an output transducer, each of said transducers having a vibratory member with an inherent mechanical resonant frequency in said band of frequencies whose effect is reflected in selectively reproducing vibratory energy of a frequency within said band of frequencies, and means for altering the mechanical resonant frequencies of each of said vibratory members whereby the shape of the over-all frequency response characteristic of said apparatus may be controlled.

3. In electrical apparatus operable over a range of audible frequencies and having a variable frequency response characteristic, a vibratory member, a housing for said vibratory member enclosing a face of the vibratory member, said housing enclosing a space determined by linear dimensions smaller than one-quarter of the wave length of signals in said audible range, and means for altering a characteristic of said housing whereby the frequency response characteristic of said apparatus is controlled, said means including an air channel extending through said housing in such a direction that movement of the air produced by movement of said face toward said housing is away from the vibratory member.

4. In signal translating apparatus having an over-all frequency response characteristic and including an input circuit, an electro-acoustical transducer in said input circuit, said transducer including a vibratory member having a mechanical characteristic which causes said transducer to have a peaked frequency characteristic within the range of frequencies translated by said apparatus, a casing enclosing a face of said vibratory member, and mechanical means for controlling the

position of said peaked frequency characteristic in said frequency range, said means including a sound opening extending through said casing in such a direction that movement of the air produced by movement of said face toward said casing is away from the vibratory member, whereby the over-all frequency characteristic of said apparatus is affected.

5. In signal translating apparatus having an over-all frequency response characteristic and including an energy output circuit, an electro-acoustical transducer in said output circuit, said transducer including a vibratory member having a mechanical characteristic which causes said transducer to have a peaked frequency characteristic within the range of frequencies translated by said apparatus, a casing enclosing a face of said vibratory member, and mechanical means for controlling the position of said peaked frequency characteristic in said frequency range, said means including a sound opening extending through said casing in such a direction that movement of the air produced by movement of said face toward said casing is away from the vibratory member, whereby the over-all frequency characteristic of said apparatus is affected.

6. In signal translating apparatus having an over-all frequency response characteristic and including an input circuit and an energy output circuit, an electro-acoustical transducer in said input circuit, said transducer including a vibratory member having a mechanical characteristic which causes said transducer to have a peaked frequency characteristic within the range of frequencies translated by said apparatus, a casing enclosing a face of said vibratory member, mechanical means for controlling the position of said peaked frequency characteristic in said frequency range, said means including a sound opening extending through said casing in such a direction that movement of the air produced by movement of said face toward said casing is away from the vibratory member, whereby the over-all frequency characteristic of said apparatus is affected, a second electro-acoustical transducer in said output circuit, said second transducer including a second vibratory member having a mechanical characteristic which causes said second transducer to have a peaked frequency characteristic within the range of frequency translated by said apparatus, a second casing enclosing a face of said second vibratory member and mechanical means for controlling the position of said last mentioned peaked frequency characteristic in said frequency range, said means including a sound opening extending through said second casing in such a direction that movement of air produced by movement of said face toward said second casing is away from the vibratory member, whereby the over-all frequency characteristic of said apparatus is additionally affected.

7. In electro-acoustic apparatus operable over a range of frequencies, a transducer having an electrical impedance and a vibratory element having an adjustable mechanical resonant frequency, means for tuning said transducer electrically over at least a portion of said range of frequencies, and means for tuning said vibratory element mechanically over at least a portion of said range of frequencies whereby the frequency response characteristic of said apparatus is controlled.

8. In electro-acoustical apparatus having a desired frequency response characteristic over a range of frequencies, an audio-frequency trans-

lating device operable over a band of audible frequencies and having an input and an output circuit, a first electro-acoustical transducer connected to said input circuit, a second electro-acoustical transducer connected to said output terminals, at least one of said transducers having a vibratile element tunable to a plurality of mechanical resonant frequencies within said range of frequencies, a housing enclosing a face of said vibratile element the mechanical resonant frequencies of said vibratile elements producing a substantial effect on the frequency response characteristic of said apparatus, means for mechanically tuning said vibratile member for controlling said characteristic, said means including an air channel extending through said wall in such a direction that movement of air produced by movement of said face toward said wall is away from the vibratile element and additional means in said translating device for controlling said characteristic.

9. In combination, electrical apparatus including an electro-acoustical transducer and having a controllable over-all frequency response characteristic, said transducer having a vibratile element whose resonant frequency affects substantially said over-all frequency response characteristic of said apparatus, a housing enclosing a face of said vibratile element, and means for variably and mechanically tuning said vibratile element, said means including an air channel extending through said wall in such a direction that movement of air produced by movement of said face toward said wall is away from the vibratile element, whereby a selective control effect may be exerted on said characteristic.

10. In an electro-acoustical transducer having a variable frequency response characteristic, a member movable in response to energy imparted thereto of a wave length within an audible frequency range, a housing enclosing a face of said member and defining with said member a space within which said member vibrates in response to said energy, said space being defined by linear dimensions each smaller than one-fourth of the wave length of sound vibrations in said audible range, and a variable opening extending through said casing in such a direction that movement of air produced by movement of said face toward said housing is away from the member, whereby the frequency response characteristic of said transducer is controlled.

11. In an electro-acoustical transducer having variable frequency response characteristics, a member movable in response to vibratory energy of frequencies within an audible range, said member having a definite pronounced peaked amplitude variation as a function of applied vibratory energy applied thereto within said audible range, a closure member for one face of said movable member, said closure member enclosing a volume defined by linear dimensions smaller than one-quarter of the wave length of said vibratory energy within said audible range, and a variable opening extending through said closure member in such a direction that movement of air produced by movement of said face toward said closure member is away from the movable member whereby the frequency response of said transducer is varied in accordance with the size of said opening.

12. In electrical apparatus operable in a band of frequencies, an input transducer, an output transducer, a translating means connected between said input and output transducers, each of

said transducers having a vibratory member with an inherent mechanical resonant frequency in said band of frequencies whose effect is reflected in selectively reproducing vibratory energy of a frequency within said band of frequencies, means for altering the mechanical resonant frequencies of each of said vibratory members whereby the shape of the over-all frequency response characteristic of said apparatus may be controlled, and additional means in said translating means for controlling said characteristic.

13. In electrical apparatus operable in a band of frequencies, an input transducer and an output transducer, each of said transducers having a vibratory member with an inherent mechanical resonant frequency in said band of frequencies whose effect is reflected in selectively reproducing vibratory energy of a frequency within said band of frequencies, means for altering the mechanical resonant frequencies of each of said vibratory members whereby the shape of the over-all frequency response characteristic may be controlled, and means for tuning at least one of said transducers electrically over at least a portion of said range of frequencies to additionally control said characteristic.

14. In electro-acoustic apparatus operable over a range of frequencies, a transducer having an electrical impedance and a vibratory element having an adjustable mechanical resonant frequency, said apparatus including a translating means connected to said transducer, means for tuning said transducer electrically over at least a portion of said range of frequencies, means for tuning said vibratory element mechanically over at least a portion of said range of frequencies, whereby the frequency response characteristic of said apparatus is controlled, and additional means in said translating means for controlling said characteristic.

15. The invention defined by claim 8 characterized by means for tuning electrically at least one of said transducers to a frequency within said range of frequencies.

16. In electro-acoustic apparatus operable over a range of frequencies, a transducer having an electrical impedance and a vibratory element having an adjustable mechanical resonant frequency, said apparatus including a translating means connected to said transducer, frequency selective means in said translating means for controlling the frequency response characteristic of said translating means, and means for tuning said vibratory element mechanically over at least a portion of said range of frequencies whereby the frequency response characteristic of said apparatus is controlled.

17. In combination, an electro-acoustical transducer having dimensions suitably small for inconspicuous wear and a housing, a movable diaphragm arranged within said housing to divide the space within said housing into two parts, one part of said space being substantially entirely enclosed by said diaphragm and said housing, said housing being arranged to form a communication between the other part of said space and the outer ear of a person wearing said transducer in which case said other part of said space is entirely enclosed by said diaphragm, housing and outer ear of the user and out of air communication with said one part of said space, and means for altering a physical parameter of said transducer in such an amount that the mechanical frequency response is substantially effected, said means including a sound channel extending through said housing to place said one space in communication with the atmosphere surrounding said housing whereby when said transducer is worn by a user no air communication exists between the two sides of said diaphragm and the mechanical frequency response characteristic is substantially effected by the presence of said sound channel extending through said housing to place only said one part of said space in communication with the atmosphere.

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