

Jan. 31, 1950

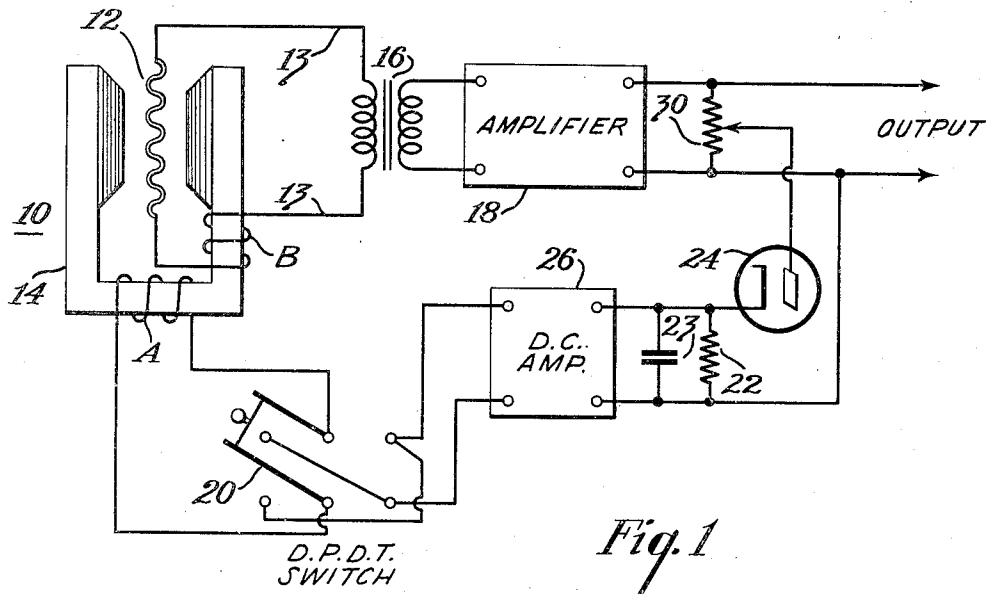
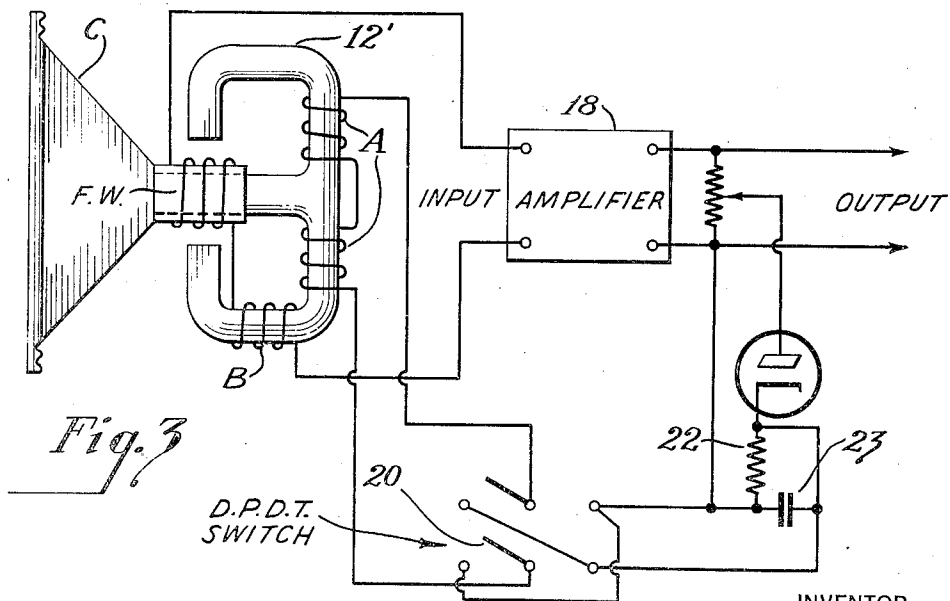
G. K. GRAHAM

2,495,809

SIGNAL EXPANSION OR COMPRESSION

Filed Sept. 6, 1945

3 Sheets-Sheet 1



INVENTOR
George K. Graham
BY
H. S. Brown
ATTORNEY

Jan. 31, 1950

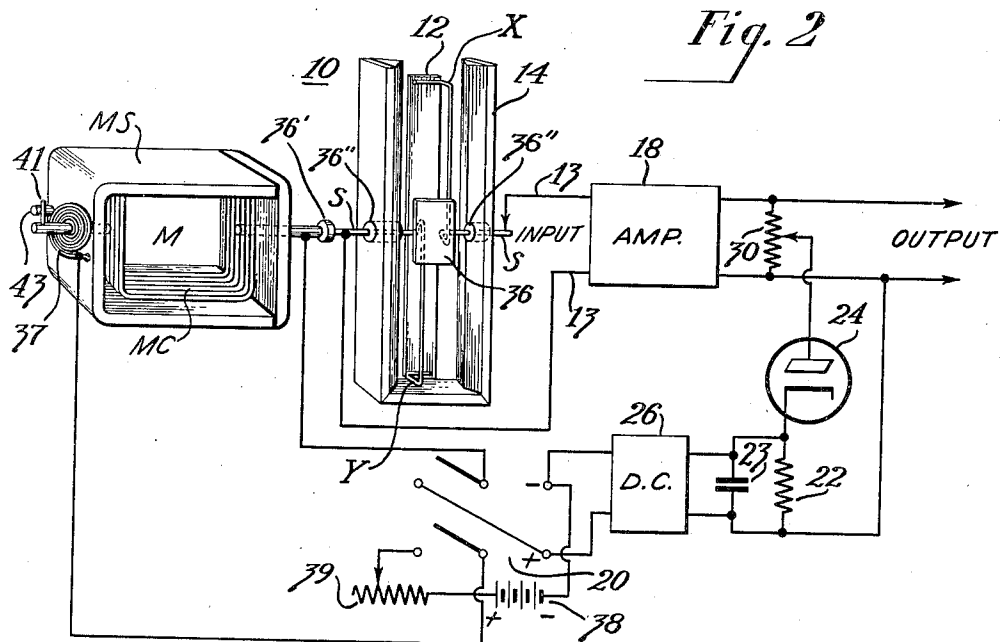
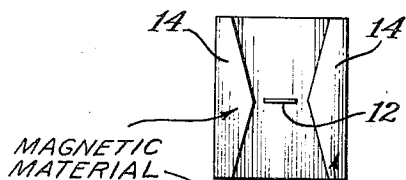
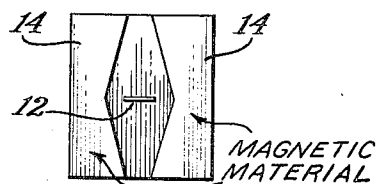
G. K. GRAHAM

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3 Sheets—Sheet 2



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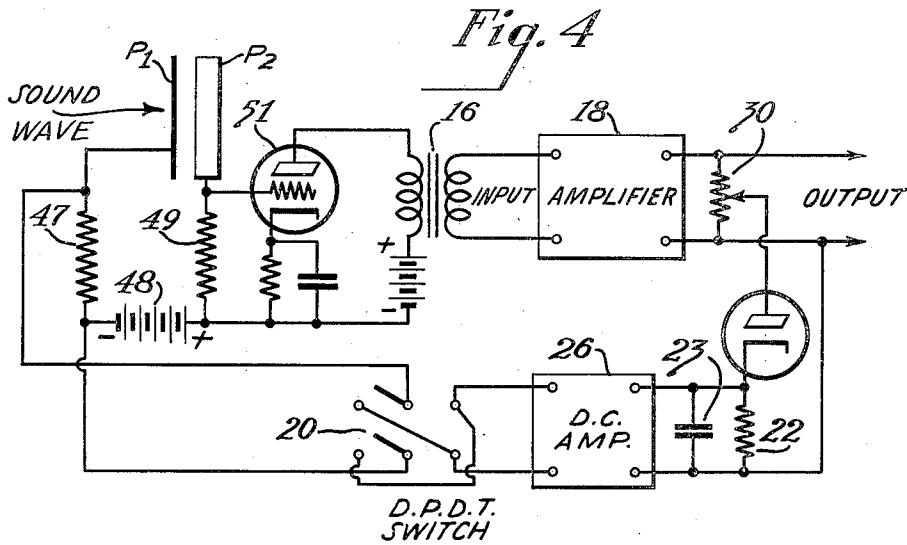
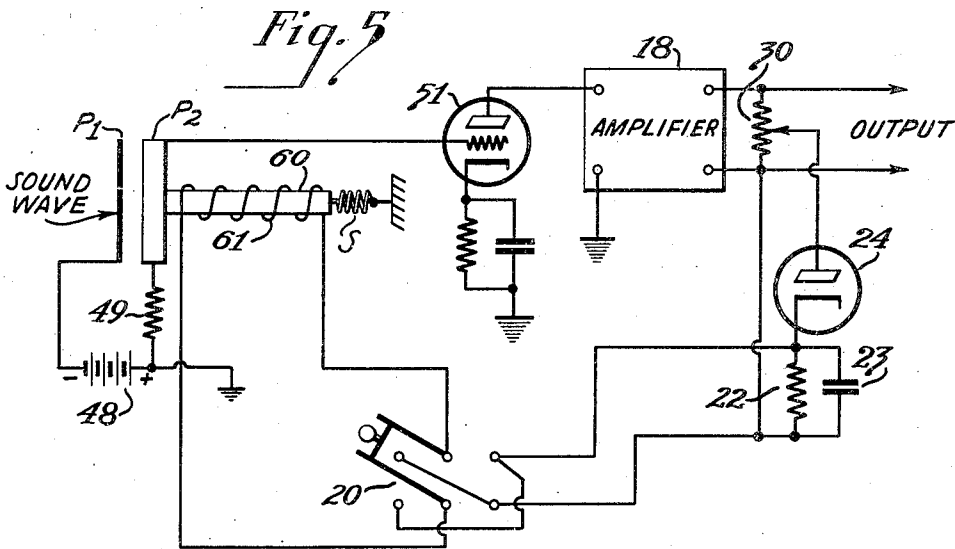
G. K. GRAHAM

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SIGNAL EXPANSION OR COMPRESSION

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3 Sheets-Sheet 3



INVENTOR
George K. Graham
BY *W. S. Grover*
ATTORNEY

UNITED STATES PATENT OFFICE

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SIGNAL EXPANSION OR COMPRESSION

George K. Graham, Oceanside, N. Y., assignor to
Radio Corporation of America, a corporation
of Delaware

Application September 6, 1945, Serial No. 614,736

8 Claims. (Cl. 179—1)

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This application relates to an improved method of and means for regulating the sensitivity of a transducer such as, for instance, a microphone or phonograph pick-up element. By means of my invention the transducer's sensitivity is regulated inversely or directly in accordance with the amplitude of the stimulus to which the transducer is subjected, so that compression or expansion of the currents representing the sound wave is accomplished.

In many radio systems sound waves are converted into electrical currents and transmitted from one point to another by way of conductors such as lines or by radiation. The transmitted material may represent voice or music or television or as a matter of fact intelligence of any type and may be put to various uses. In one particular application of my invention sound waves are converted to electrical currents, amplified, and supplied as output to be used as desired. This use may include modulation of a radiant energy transmitter or distribution to listening points, etc.

In the transmission of program material the volume level range which is transmitted must lie between two extremes, the upper limit established by the maximum handling capacity of the transmission medium and the lower limit by the level of noise present. In the present art it is customary to reduce the level of the higher level passages to a safe value and to increase the level of the lower level passages to overcome the effect of noise.

An object of my invention is to regulate the level of program material within predetermined limits. This object is attained by providing a new method of and means for regulating the sensitivity of the microphone, phonograph pick-up or other transducer supplying the material for transmission.

Some present day compression and expansion amplifiers depend for their operation on the change in grid bias of a variable mu type of tube which is provided by a rectified portion of the output of the compression type amplifier. Using such a method, wide variations in grid bias due to large output level changes tend to shift the operating point of the tube in such a way as to cause serious distortion.

A further object of my invention is a better method of and means for compressing or expanding the range of program material.

This improved regulation or control by compression or expansion is accomplished in accordance with my invention by regulating the sensitivity of the transducer per se rather than of a

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network and/or amplifier to which the current, resulting from the conversion from sound waves to electrical current, is supplied.

A further object of my invention is improved sensitivity control of a transducer of the nature described above.

An additional object of my invention is improved automatic control of the sensitivity of a transducer of the nature described above.

The above objects and others which appear hereinafter are attained in accordance with my invention by utilizing some of the converted energy after, if desired, amplification to regulate the sensitivity of the microphone, phonograph pick-up, or transducer or other means for converting from sound waves to electrical currents. Where compression is desired, if the program level is low the control is such as to increase the sensitivity of the transducer, while if the program level is high the sensitivity of the transducer is reduced. Where expansion is desired, if the program level is low the control is such as to decrease the sensitivity of the transducer, while if the program level is high the sensitivity of the transducer is increased. In an embodiment the field strength is made non-uniform, with an intensity pattern such that compression or expansion as desired may be obtained.

My invention is applicable to transducers of various types, including microphones and phonograph pick-up devices. In the detailed description which follows, I have disclosed application of my invention to transducers of the electromagnetic type and of the electrostatic type.

In disclosing my invention in detail reference will be made to the attached drawings, wherein—

Fig. 1 illustrates schematically an embodiment of my invention wherein the sensitivity of a transducer of the electromagnetic type is controlled. The transducer in the embodiment is a ribbon microphone.

Fig. 2 illustrates schematically a modification of the arrangement of Fig. 1. In Fig. 1 the sensitivity control is carried out by control of the field strength. In Fig. 2 the position of the pick-up element in the field is controlled.

Figs. 2a and 2b are modifications of the arrangement of Fig. 1.

Fig. 3 illustrates schematically the application of my invention to a different type electromagnetic microphone. In this embodiment the microphone is of the dynamic type, having a diaphragm operated coil moving in a magnetic field.

Fig. 4 shows my improved compression and expansion means as applied to an electrostatic

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transducer, while Fig. 5 is a modification of the arrangement of Fig. 4.

In the embodiments of Figs. 1 and 2, I have applied my invention to an electromagnetic microphone wherein sound pressure is converted to electrical energy by means of a moving sound pressure operated conductor which is caused to cut the magnetic field. In such a microphone the E. M. F. induced in the conductor is roughly proportional to the displacement of the conductor and to the strength of the magnetic field. The induced E. M. F. for a given displacement of the conductor is greatest when the moving conductor cuts the greatest number of lines of magnetic flux, and is diminished as the conductor assumes a position in which it cuts a smaller number of lines of magnetic flux.

In Fig. 1, the conductor or microphone ribbon 12 is located in the field of a magnet 14. The magnet 14 may be of the field winding type or of the permanent magnet type, the latter type being shown. Current induced in the ribbon 12 is used to excite winding A to control the effectiveness (strength) of the magnetic field, thereby to control the transducer's sensitivity. A compensating winding B, the operation of which will be described later, is also mounted on the magnet. In the embodiment of Fig. 2 I control the position of the ribbon 12 in the magnetic field to control the sensitivity of the transducer.

In Fig. 1, 10 designates a transducer or microphone of the ribbon type. In this microphone a conductor in the form of a ribbon 12, acted on by sound waves, is located between the poles of a magnet 14, which may be permanent or may be of the type having a field producing winding. The ribbon 12, as stated above, is located between the pole pieces and connected in series with the primary wiring of a transformer 16 whereby the E. M. F. induced in the ribbon 12 during its movement by the sound waves is fed by lines 13 to unit 18. The ribbon conductor 12 is also in series with a winding B, the purpose of which appears hereinafter. The unit 18 may include an amplifier if desired and the amplifier output may be put to any use, such as being fed to a loudspeaker or transmitter. The magnet 10 also has mounted thereon a second coil A which when energized varies the magnetic field, thereby controlling the sensitivity of the transducer. Coil A is connected by a polarity reversing switch 20 to the load impedance 22 of a diode rectifier 24. This coupling may, if desired, include a direct current amplifier 26. The diode 24 has its anode tapped to a potentiometer 30 across the output of the amplifier 18. The cathode of the diode is connected to the low potential end of the potentiometer resistance 30, so that a portion of the potentiometer is included in series with the load resistor 22 and the cathode to anode impedance of the diode 24. The potential across the load impedance 22 is proportional to the magnitude of the program at the output of the amplifier 18, so that the current passed through coil A is proportional to the output voltage of the amplifier 18. Under these conditions, the sound energy or waves impinging on the microphone ribbon 12 will cause variations in the current passed through to coil A. The switch 20 will determine the direction of the current through coil A. Assume that the switch 20 is in such a position that an increase in current through the coil causes a magnetic flux to be set up which opposes the normal flux in the magnet 14. Then any increase in sound pressure will cause a decrease in magnetic flux in which the

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conductor moves. This decrease in magnetic flux will cause a reduction in the E. M. F. impressed on the input of the amplifier 18. Conversely, a decrease in sound pressure will cause an increase in the magnetic flux. Under these circumstances, the electrical output of the microphone will be proportionately greater for low level sounds than for high level sounds. This will cause the louder passages of sound to be compressed. Reversing the switch 20 will reverse the above and cause expansion of the loud passages. The diode circuit may have suitable electrical networks including, for example, a condenser 23 so that the voltage impressed on the coil A will follow the average level of energy or be responsive to the peaks of energy, so that by a suitable combination of circuit elements, the required degree of expansion or compression can be achieved. If it is desired that the sensitivity be controlled in accordance with the average level, then the condenser 23 is large so that the network has a time constant which is relatively large with respect to the average variations in volume intensity. If the sensitivity is to be controlled by peaks only, then the time constant is made relatively small and condenser 23 would have less capacity.

Coil B is in series with the moving conductor and is so arranged in position and number of turns that any E. M. F. induced in the moving conductor, due to the variations in the magnetic field under the influence of the current in coil A, will be opposed by an equal E. M. F. induced in coil B. This will minimize the effect of any voltage which might be induced in the moving conductor due to a change in magnetic flux. Complete cancellation of the effect of the potential set up in A appears possible.

In practice in many cases, my invention will be applied where compression only or expansion only is desired. For example, in broadcast program distribution, compression would be used in order to restrict the dynamic range to suit the transmission facilities. If the transducer control of my invention is to be used where the noise level is high, then expansion may be used. If used on phonograph pickups expansion may be used to compensate for the intentional compression used in the recording art. When applied as described above the switch 20 is omitted and the winding A is then coupled directly to the amplifier 26 in the proper polarity. The apparatus is then otherwise as described hereinbefore.

In the embodiment of Fig. 1 the sensitivity of the transducer is controlled by controlling the magnetic field intensity. Means is also provided to eliminate any effect due to the change in the magnetic field intensity. In the embodiment of Fig. 2 now to be described, the sensitivity of the transducer is controlled by controlling the effectiveness of the field on the element cutting the field. This is done by moving the static or mean position of the moving element in the field. Means are also provided to eliminate any effects due to changes in static position of the moving element.

In Fig. 2, to simplify the description, reference numerals corresponding to those used in Fig. 1 are used in so far as possible. The sound responsive element 12 again is shown as the ribbon of the microphone.

The ribbon element 12 is acted on by sound waves as before and is connected by leads 13 to the input of an amplifier 18 as before. It is noted that transformer coupling is not shown in this embodiment, but may be used if desired. As a

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matter of fact, the transformer coupling may be included in the amplifier 18. The diode 24 and its connections to the amplifier 18 may be as described hereinbefore, so that across diode load 22 a potential proportional to the magnitude of the current at the output of 18 is developed. This potential is supplied by the reversible switch 20 to the winding of the driving means M which may be considered a motor. The motor M has a shaft S connected to the mounting element for the ribbon 12. In the embodiment illustrated, the shaft S is shown as being passed through the magnet 10 in a manner so that its axis is at right angles to the plane of motion of the ribbon 12 as acted on by the sound.

In this arrangement, the E. M. F. induced in the ribbon 12 by cutting the magnetic field is proportional to the extent of motion. The induced E. M. F. is greatest when the conductor moves in the entire magnetic field at right angles to the direction of the magnetic flux and is diminished as the conductor assumes the position in which it moves in a reduced magnetic field. The ribbon 12 is mounted on supports X and Y which extend in to the axis of rotation and are connected to shaft S separated by insulator 36, which also supports and strengthens the ribbon 12. The shafts S may pass through insulators 36' in the magnet 14. The ribbon is rotated in one direction or the other by the motor M depending upon the position of switch 20, to an extent proportional to the magnitude of the potential across impedance 22. The motor M may be a device similar to the moving element in a direct current meter, actuated by the potential drop across 22. As illustrated the motor M comprises a magnetic structure MS and a coil MC free to move in the magnetic field. The coil MC is connected by an insulator 36' and shaft to the shaft S on which the ribbon 12 is mounted for rotation in the field of magnet 14. The ribbon 12 may be further supported by the insulator 36. The motor M rotates the ribbon 12 from its position at which the maximum current is induced in ribbon 12 to a position at which less current is induced in ribbon 12 when the magnitude (peak or average) of the current at the output of 18 is high and compression or reduction of sensitivity is desired. The ribbon 12 is then at an angle with respect to the magnetic pole pieces and the conductor moves in a smaller magnetic field and the output is reduced. Thus, when the switch 20 is adjusted for compression, the conductor 12 is caused by the spring 37 to assume a position parallel to the magnetic pole pieces in the absence of applied sound waves. When sound wave energy is applied, the amplified output of the microphone is rectified by the diode 24, causes a current to flow through the motor winding MC and rotate the conductor 12 so that its motion causes it to cut a reduced magnetic field, and the electrical output of the system and the sensitivity of the transducer is reduced.

If the switch 20 is reversed, a source 38 and an adjustable resistance 39 is included in the motor driving circuit wherein the direction of current flow has been reversed. The source 38 and resistance 39 is such as to cause the motor MC to rotate the ribbon 12 on its axis to a position whereat it is nearly at right angles to the magnetic pole pieces in the absence of output from the amplifier 18 (i. e., no sound waves on the ribbon). The source 38 polarity opposes the polarity of the potential developed across impedance 22 when sound waves are applied. How-

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ever, it will be understood that the magnitude of this opposing voltage is adjustable.

Now when sound waves strike the ribbon 12 the voltage developed across impedance 22 increases. The motor MC, actuated by the potential across 22, is caused to move the ribbon 12 to a position at which it becomes nearly parallel to the magnetic pole pieces, and the output of the system is expanded. Thus, under expansion condition the ribbon 12, the motor M, and so forth, are set so that the conductor normally assumes a position nearly at right angles to the pole pieces in the absence of sound waves and little electrical output results. This is accomplished by arranging bias voltage at 38 to position the conductor 12 at an angle approaching 90° with respect to the pole pieces, or by supplying a member 41 attached to MC and arranged to strike a mechanical stop 43 so that the motion of the conductor is restricted to a position at right angles to the magnetic pole pieces in case the voltage supplied at 38 is more than required to move MC to said position at which it approaches 90° with respect to the magnetic pole pieces. The source 38 and resistance 39 are means for selecting signal magnitudes below which there is substantially no output from the system. This will be clear when it is kept in mind that the current to MC results from the difference in the magnitudes of the opposing potentials at 22 and 38 and that the ribbon cannot be made parallel to the magnetic pole pieces until the two potentials are about equal so that the spring 37 can move the coil MC and ribbon 12 into said position. Such operation is useful on transducers used, for example, in a noisy location. Then the sensitivity of the system will be greater for desired high level sounds.

The compensation for the effect of the motion of the ribbon 12 and its mounting means in Fig. 2 is inherent, in that movement of the ribbon by the motor MC as described above does not produce distortion by changing the current output. This is because the mounting X, Y is symmetrical and the current induced by the movement in the two halves of the ribbon mounting are of opposed polarity and balance out in the transducer output. This will be apparent by inspection of the ribbon 12 of Fig. 2. When the same is rotated both halves move away from the 90° relation, but in opposite directions.

The flux producing field may be of irregular shape, so that the effectiveness thereof on the moving member 12 increases or decreases with movement of the member 12 from the no sound wave position. This non-uniform flux field may be arranged to have either a decreasing flux, as shown in Fig. 2a, or an increasing flux, as shown in Fig. 2b, at points removed from the conductor. Then the potentiometer 30, diode 24, impedance 22, amplifier 26, switch 20 and windings A and B, all as shown in Fig. 1, are omitted. The magnet 10 has a cross section as shown in Figs. 2a or 2b. Where the field decreases in intensity, as in Fig. 2a, the sensitivity of the transducer is reduced for higher level signals and compression takes place. Where the field increases in intensity, as in Fig. 2b, the sensitivity of the transducer is increased for higher level signals and expansion takes place.

As stated hereinbefore, my invention is applicable to transducers of any type, and a further application thereof is illustrated in Fig. 3 of the drawings. In this figure a transducer or microphone of the cone and voice winding type is used. In describing this embodiment reference char-

acters and letters corresponding to those used in the prior figures are used in order to simplify the description. The microphone or transducer has a cone C responsive to the sound waves. The cone C carries a field winding FW mounted between the poles of a magnet 12'. The moving winding FW cutting the flux field has induced therein a current responding to the sound waves, which is fed to the amplifier 18 as in the prior embodiment. As in the prior embodiment, a potential which varies in a manner corresponding to the variations in the output of 18 appears in the impedance 22 and is applied through switch 26 to windings A mounted on the flux field producing magnet 12'. The operation of this winding A as excited by current from 22 is similar to the operation of the winding coil A in Fig. 1. The current in the winding A is in a direction to increase the strength of the magnet with increases in amplitude of the current output of 18 to accomplish expansion of the said currents, to increase the sensitivity of the microphone, or the current in the winding A may be in the opposite direction to decrease the flux field and the strength of the magnet, to decrease the current at the input of 18 when the current intensity at the output thereof goes up and to thereby compress the signalling thereof by decreasing the sensitivity of the microphone. A winding B in series with the winding FW serves the same purpose as the winding B of Fig. 1.

In Fig. 4, I have illustrated my improved sensitivity control as applied to transducers or microphones of the electrostatic type. In Fig. 4, the microphone comprises two plates P1 and P2 spaced from each other to form the plates of a variable condenser across impedances 47 and 49. The impedance 49 is across the input of the amplifier tube 51. The potential drop across resistance 49 is a function of the capacity of the condenser P1, P2 and of the voltage across the condenser plates. The latter voltage is made up of the voltage of source 48 and the potential drop across the output of D. C. amplifier 26. The amplifier 51 may comprise the first stage of the amplifier 18 of the prior figures. The condenser microphone P1 and P2 has a fixed plate P2 and a movable plate P1. Sound waves impinging on plate P1 vary the capacity of the condenser to correspondingly vary its rate of charge and the voltage on the grid of tube 51 and at the output of amplifier 18 and across the impedance 22. To decrease the sensitivity, the voltage appearing across the output of D. C. amplifier 26 is so connected to impedance 47 as to oppose the voltage of source 48, with the result that the voltage appearing across the plates of the condenser P1 and P2 is reduced. To increase the sensitivity of the transducer, the polarity of the potential developed across impedance 22 is reversed and adds to the voltage at 48. The values of these voltages are adjustable at potentiometer 30 and at source 48.

In the embodiment of Fig. 5, the plate P2 is mounted on a core 60 of an electromagnetic solenoid having a winding 61 connected to the output terminals of the switch 20. In this arrangement, as the sound waves impinge on the microphone plate P1 its position with respect to P2 is changed and the voltage on plate P2 is varied and this voltage variation across the grid resistor 49 is applied to the grid of the amplifier tube 51. The potentials developed in the impedance 22 are fed

to the magnet winding 61 to move the plate P2 toward or from the plate P1 to increase or decrease the capacity between the plates. If the current in the winding 61 is in a direction to move plate P2 away from P1 and reduce the capacity when the signal strength increases, compression of the signal takes place, so that the transducer's sensitivity is reduced. If the current through the winding 61 is in a direction to move the plate P2 closer to the plate P1 to increase the capacity when the magnitude of the voltage appearing at the output of the amplifier 18 increases, the sensitivity of the microphone is increased.

The core 60 for the winding 61 may be mounted in any manner, and the mounting of the same is shown schematically in Fig. 5. The core 60 is held by a spring S in such a position that the desired relationship between plates P1 and P2 is maintained. Current through the winding 61 compresses or expands the spring S to change the position of the core 60 and plate P2.

What is claimed is:

1. In signalling apparatus, a ribbon-type microphone, having its ribbon in a magnetic field, for converting motion representing signals to electrical currents, an electrical circuit connected to the ribbon, and means responsive to currents in said circuit for changing the static position of the ribbon in the magnetic field.

2. A transducer including a movable element in a magnetic field and in a circuit wherein current is produced by said movement, and apparatus including a rectifier responsive to the produced currents for producing a control potential, and a driving element for said movable element controlled by said control potential for changing the static position of said element in the field to change the sensitivity of said transducer.

3. A transducer including a movable element in a magnetic field and in a circuit wherein current is produced by said movement, and a motor controlled by said produced current for automatically changing the static position of said element in the field in accordance with the strength of the produced current to change the sensitivity of said transducer.

4. A transducer including a movable element in a magnetic field and in a circuit wherein current is produced by said movement and means for changing the static position of said element in the field to change the sensitivity of said transducer comprising a movable support for said element, and means actuated by the produced current for controlling the position of the support.

5. In signalling apparatus, in combination, means for converting sound waves to electrical variations comprising a movable element on which the sound waves impinge, a circuit associated with said movable element wherein a voltage is produced of an amplitude which varies with movement of said element, an amplifier coupled with said circuit, said amplifier having an output wherein amplified electrical variations corresponding to the variations in the sound waves appear, a rectifier in a circuit including an impedance wherein a voltage is developed proportional to the magnitude of the signal in the output of the amplifier, and electrical or mechanical means excited by said last named voltage for regulating the sensitivity of the converting means.

6. In signalling apparatus, in combination, means for converting sound waves to electrical

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variations comprising means for producing a magnetic field, a movable element in said field on which the sound waves impinge, a circuit associated with said movable element wherein a voltage is produced of an amplitude which varies with movement of said element, and an amplifier coupled with said circuit, said amplifier having an output wherein amplified electrical variations corresponding to the variations in the sound waves appear, the said magnetic field being irregular so that the intensity thereof changes with movement of said element.

7. In signalling apparatus, in combination, means for converting sound waves to electrical variations comprising a movable element on which the sound waves impinge, a circuit associated with said movable element wherein a voltage is produced of an amplitude which varies with movement of said element, an amplifier coupled with said circuit, said amplifier having an output wherein amplified electrical variations corresponding to the variations in the sound waves appear, a diode having an anode and a cathode, means including an impedance connecting the cathode and anode in shunt to a part at least of the output of said amplifier whereby a voltage is developed in the impedance propor-

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tional to the magnitude of the signal in the output of the amplifier, and electrical or mechanical means excited by said last named voltage for regulating the sensitivity of the converting means.

8. A transducer including a movable element in a magnetic field and in a circuit wherein current is produced by said movement, means for automatically changing the static position of said element in the field in accordance with the strength of the produced currents to change the sensitivity of said transducer, and means for compensating the effect of changes in the static position of said element on the produced current.

GEORGE K. GRAHAM.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,519,211	Martin	Dec. 16, 1924
1,565,548	Clark	Dec. 15, 1925
1,967,125	Miller	July 17, 1934
2,113,219	Olson et al.	Apr. 5, 1938
2,309,109	Hathaway	Jan. 26, 1943