Sept. 9, 1941. F. W. NICKERSON ET AL 2,255,517

TALK-BACK COMMUNICATION SYSTEM

Filed Oct. 27, 1939 6 Sheets-Sheet 1

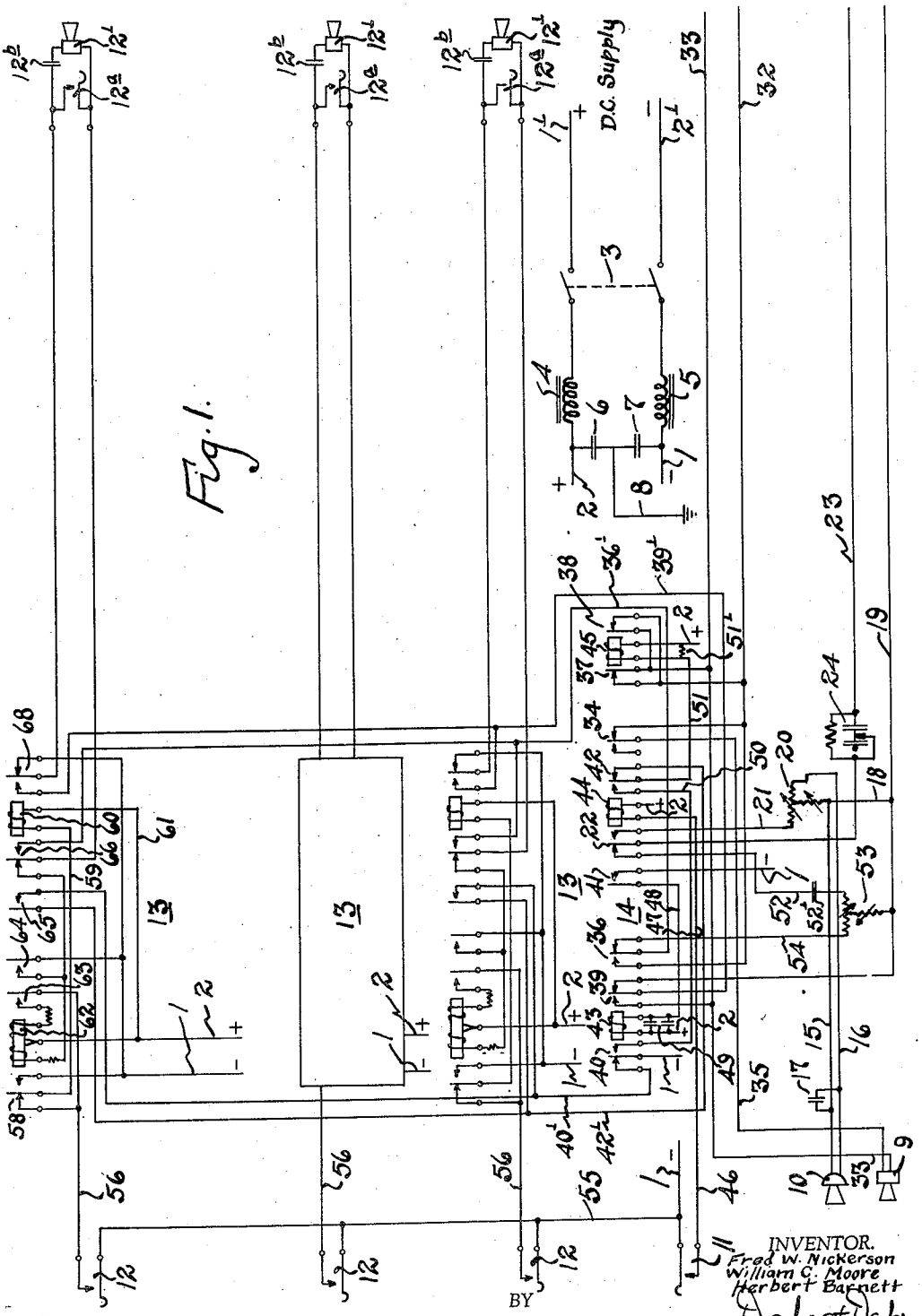

Fig. 1.

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TALK-BACK COMMUNICATION SYSTEM

Filed Oct. 27, 1939 6 Sheets-Sheet 2

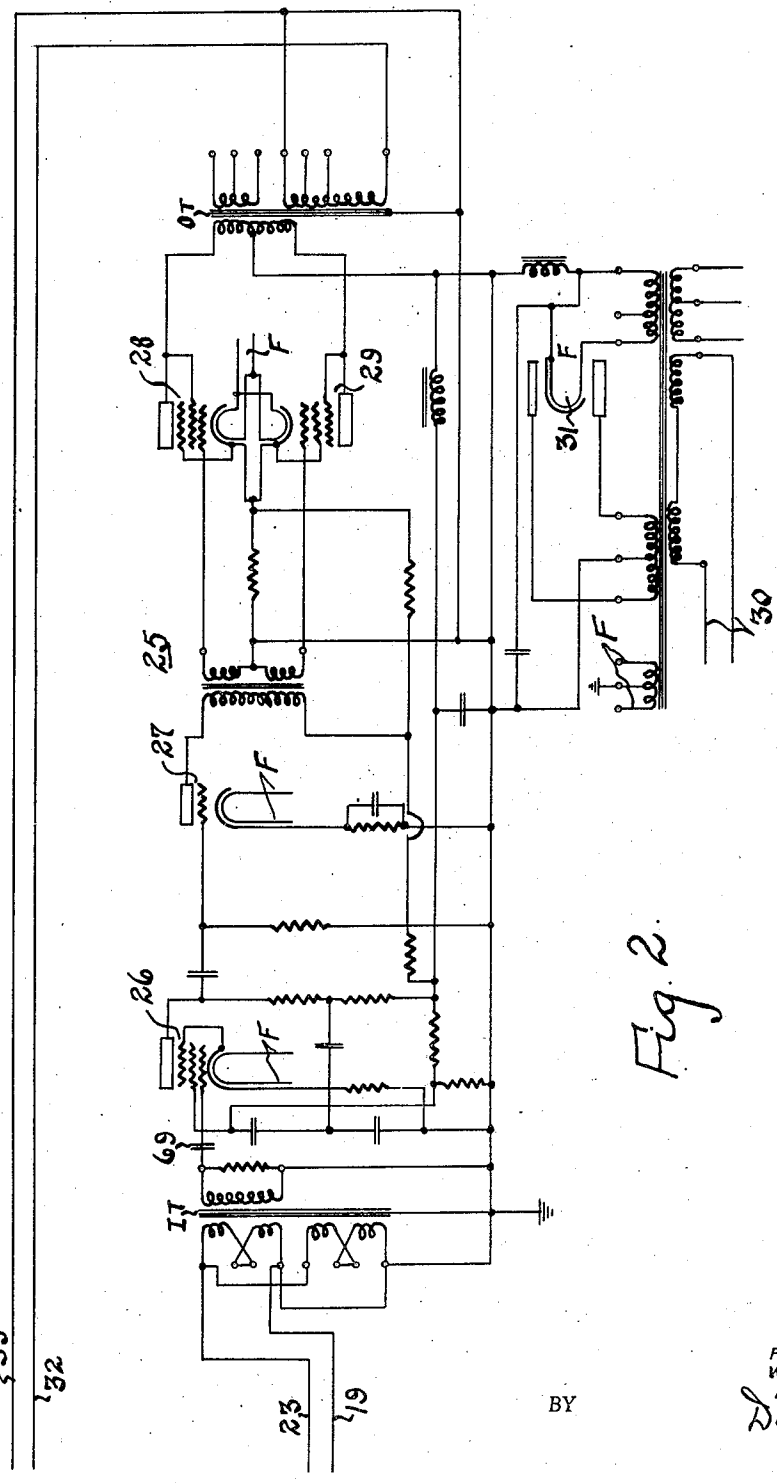

Fig. 2.

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TALK-BACK COMMUNICATION SYSTEM

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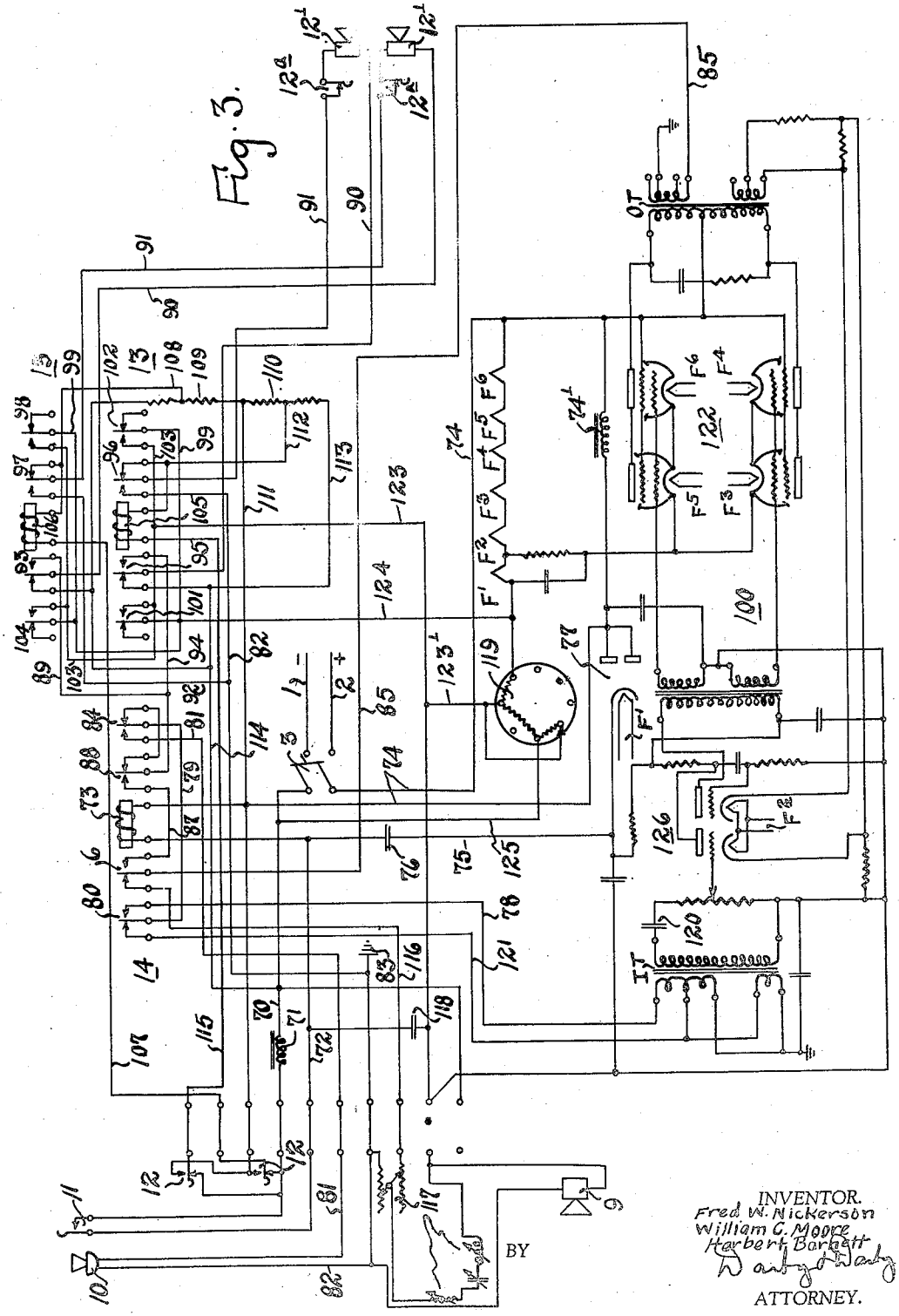
Fig. 3.



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TALK-BACK COMMUNICATION SYSTEM

Filed Oct. 27, 1939 6 Sheets-Sheet 4

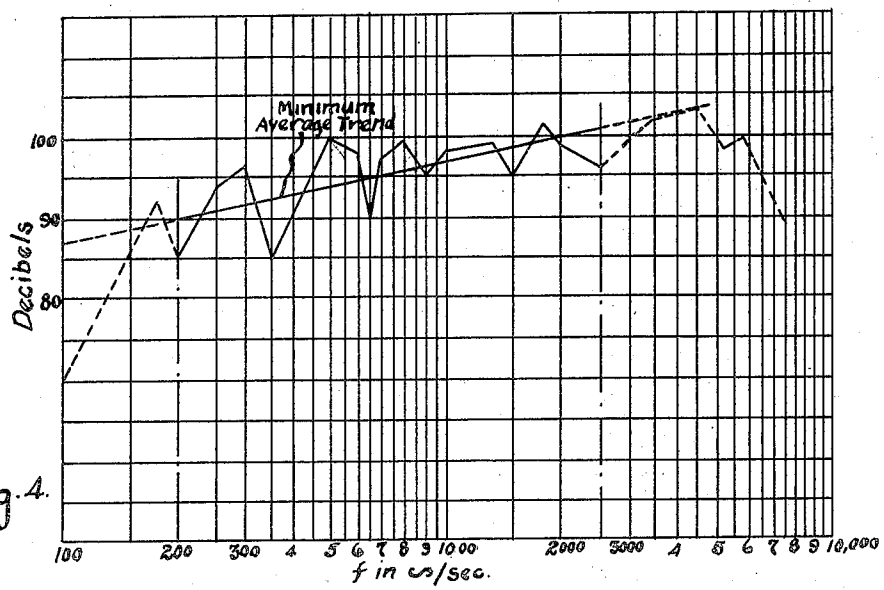

Fig. 4.

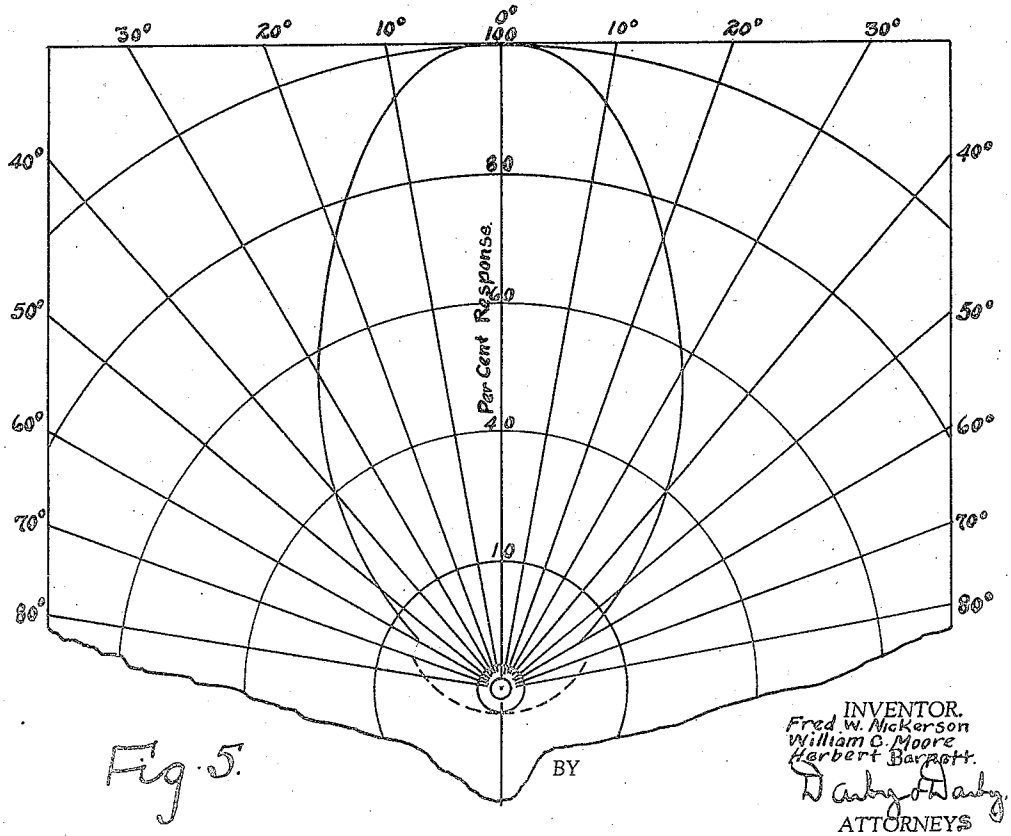

Fig. 5.

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TALK-BACK COMMUNICATION SYSTEM

Filed Oct. 27, 1939 6 Sheets-Sheet 5

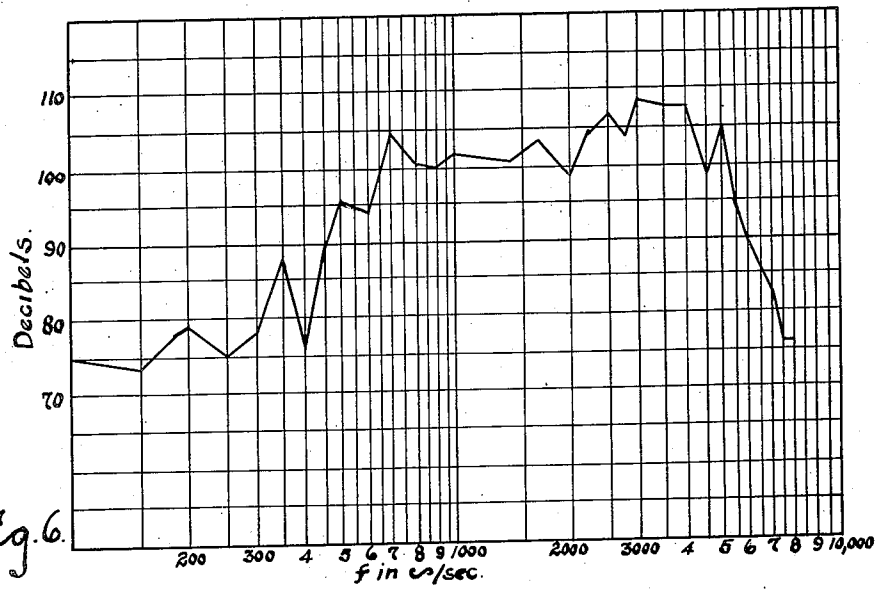

Fig. 6.

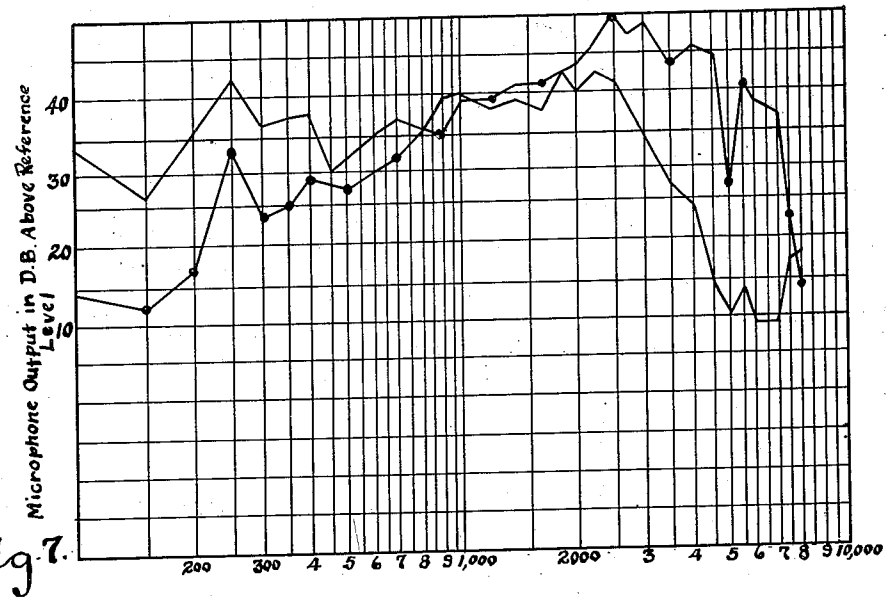

Fig. 7.

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TALK-BACK COMMUNICATION SYSTEM

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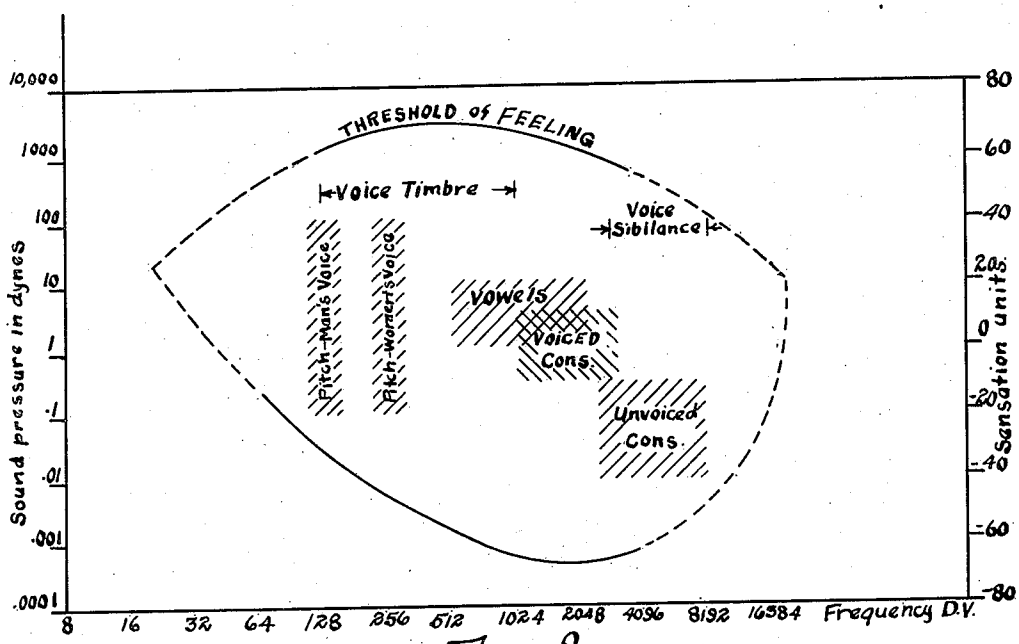

Fig. 8.

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UNITED STATES PATENT OFFICE

2,255,517

TALK-BACK COMMUNICATION SYSTEM

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Application October 27, 1939, Serial No. 301,546

16 Claims. (Cl. 179—1)

This invention comprises a combination of instrumentalities associated to form an audio-frequency communication system capable of sound transmission in either direction.

In a broad sense, the invention consists of a combination of electrical instrumentalities of such characteristics and so associated that at one end of the system there is provided a transmitter or microphone and a receiver or loudspeaker, while at the other end of the system there are provided a plurality of spatially distributed combined microphones and loudspeakers or transmitters and receivers so that at the latter end talk-out as well as talk-back can be accomplished.

An important object of this invention is to provide a system of the above nature having characteristics such that the combined loudspeaker and microphone, which hereinafter may be termed transducers, are capable of picking up and transmitting intelligible sounds from substantial distances.

Another object of this invention is to provide a system of the above type which may be turned on from either end so that speech may be transmitted from either end to the other under controls at one end.

These and many other objects which will become apparent from the following detailed description of several forms of the invention are successfully secured.

This invention resides substantially in the combination, construction, arrangement and relative location of parts, all in accordance with this disclosure.

In the accompanying drawings,

Figures 1 and 2 together comprise a diagrammatic illustration of one form of system in accordance with the objects and principles of this invention;

Figure 3 is a diagrammatic view of a modified form of system likewise in accordance with the objects and principles of this invention;

Figure 4 is a graph illustrating the response curve of the transducers showing a rising response with increasing frequency;

Figure 5 is another chart illustrating the directional characteristics of the transducers;

Figure 6 is a chart of the response of the electrical transmission network and transducer in combination illustrating its non-linear response;

Figure 7 is a chart illustrating the response of the transducers as loudspeakers, upper curve, and microphones, lower curve; and

Figure 8 is a chart illustrating the sensitivity of the human ear at various frequencies.

In order to fully appreciate the nature of this invention and the manner in which the objects thereof are accomplished, a brief discussion of the principles thereof is desirable before describing examples of the forms which the complete system may take. The system herein described will effect two-way long distance audio communication with intelligible signal pickup over distances heretofore unattained using the same electro-acoustic device as a microphone for speech pickup as is used for reproducing speech as a loudspeaker. In this two-way audio-frequency communication system, amplifier units are employed which are controlled from one end of the system so that when the transducer is acting as a microphone it is connected to the input of the amplifying system and when it is acting as a loudspeaker it is connected to the output of the amplifier.

The system of this invention utilizes a combination of acoustic transducers, transmission networks and amplifiers having electrical and acoustical characteristics that would be normally avoided in designing any loudspeaker system as commonly known in that each is intentionally made to have a non-linear amplitude-frequency response and a limited frequency range. In addition, there is provided in the system a so-called talk-back volume control to permit reduction of volume to increase the effectiveness of sound pickup at long distances.

These apparently "low fidelity" components referred to are combined in a system in ways which will be hereinafter described to effect unusually long distance pickup of voice and other sound signals by the electro-acoustic transducers which are so designed as to operate efficiently as high power loudspeakers. By high power is meant in this disclosure the capability of handling energy in amounts of the order of ten watts or more of electrical power input. To illustrate the effectiveness of systems in accordance with this invention, it is noted that the transducers when used as microphones are capable of picking up intelligible speech in a range from 700 to 2500 feet. In other words, a person separated a distance of 700 feet from the transducers may, under ordinary conditions, such as would be encountered for example on shipboard, talk at an ordinary sound level and operate the transducers to transmit intelligible speech. Thus talk-back has been accomplished up to as much as 2500 feet, that is to say, the speaker

may stand that far from the transducer and talk with a person at the other end of the system. It will, of course, be recognized at once that no system heretofore known has been capable of such operation, it being necessary, especially where the loudspeakers are also used as microphones, to stand directly in front of them in order to transmit intelligible speech. The result is that systems of this type may be installed, for example, on shipboard with the main station on the bridge of the ship and the various transducer stations distributed at desired points over the ship. An officer on the bridge may with such a system communicate with any member of the crew, who need not be anywhere near the transducers in order to reply. This result is the more remarkable because intelligible speech can be transmitted through a substantial background of undesired sounds.

As will appear as the disclosure proceeds, the combination into a communication system of the audio-frequency type of components having non-linear response and limited frequency range would be intentionally avoided by skilled designers of conventional loudspeaker communication systems for the reason that a result exactly contrary to applicant's is normally striven for, that is, high fidelity of sound transmission and reproduction.

It is, of course, recognized that a loudspeaker as a talk-back microphone is in itself not new, such use thereof having been heretofore suggested. When used, however, as a microphone such loudspeakers are only capable of reproducing intelligibly sounds picked up in the immediate vicinity thereof. The practical distinguishing feature in over-all result of applicant's system is its ability to intelligibly reproduce sounds from unusually long distances.

Referring more in detail to the components of applicant's system, reference is first made to the talk-back loudspeaker, i. e., the transducer. In accordance with this invention, the transducer must have inherent low frequency discrimination and high sensitivity in the region of optimum ear sensitivity. To obtain such results the average trend of the frequency response curve of this device must rise with increasing frequency, and between, for example, 200 and 2500 cycles the rate of rise must not be less than three decibels per octave. Such a response curve is illustrated in Figure 4. The straight line of this curve indicates the minimum average rising trend required for effective operation while the other curve is a sample loudspeaker curve that meets this limit. Such a device when used as a loudspeaker permits efficient reproduction of sound and when used as a microphone provides the best operation as a pickup device. As illustrated in Figure 4, the frequencies below the important speech region, that is, below about 200 cycles, are rapidly attenuated. This is desirable because the low frequencies apparently produce a secondary effect which has a tendency to mask the higher and more important speech frequencies and thus operate to reduce the intelligibility.

This device in accordance with this invention is also designed to have strong spatial discrimination. In other words, the device when used both as a talk-out and a long distance talk-back unit must have a sharp directional effect in a dimensional sense. The directional discrimination of a suitable transducer is illustrated in Figure 5. The transducers should have a directional characteristic not greater than that illustrated in Figure 5 at a frequency of 1000 cycles and should be so designed so as to have an increasing directional effect up to at least a frequency of 3000 cycles. Such a device when operating either as a talk-out or a talk-back unit permits the collection of sound in a narrow cone along the axis in which the horn thereof is directed with a much greater sensitivity to sounds within that region than to sounds and noises outside of it.

The transmission circuits which receive the electrical currents generated by the pickup devices feed into an amplifier. The circuits just ahead of the amplifier are designed to electrically discriminate so as to attenuate the low and other undesirable frequencies while increasing or emphasizing those frequencies which include the vowel sounds, voiced consonants and such sibilant sounds as are desired for good intelligibility of speech. Like the transducers, the frequency response of transmission circuits and amplifiers must have a trend which rises with increasing frequency between the lowest frequency transmitted by the talk-back speaker and a frequency not lower than 1000 cycles, and desirably must transmit frequencies efficiently up to at least 3000 cycles.

In accordance with this invention, in order to obtain the proper emphasis when the talk-back unit is used as a loudspeaker, the circuits are arranged so that the response curve of the electrical system may be automatically changed in any predetermined manner but preferably so that frequencies below 200 cycles per second are rapidly attenuated.

The sounds that the talk-back loudspeaker or transducer pick up are fed through the amplifier and reproduced by a receiving loudspeaker. This loudspeaker, which would be the one on the bridge in the case of ship installation, is not used in the system shown, as a microphone. It must, however, be so designed that its response is greatest in the higher vowel voiced consonant and sibilant regions, thereby having its greatest efficiency in a band of frequencies starting not higher than 1000 cycles up to not lower than 4000 cycles, and so constructed that frequencies below 500 cycles are markedly attenuated. The response curve of such a loudspeaker is illustrated in Figure 6. When desired, a receiving loudspeaker of the conventional type may be employed if used in conjunction with an electrical network having transmission characteristics such that the response curve of the combination is substantially like that of Figure 6.

Experience has demonstrated that an adjustment is desirably provided so that the gain of the amplifier can be reduced for talk-back operation as against talk-out operation. The ear is more sensitive in the higher vowel, voiced consonant, and sibilant regions at low intensities so that it is important to keep the total volume of speech and noise low enough so that the ear operates at a maximum sensitivity, as is illustrated as being necessary by the chart of Figure 8.

It is a well known fact that the sensitivity of the ear varies with the amplitude of the sound impinging thereupon, and such a marked decrease in the ear sensitivity occurs if the volume is too greatly increased, as when an appreciable amount of extraneous noise is amplified, that the effectiveness of the talk-back reception is seriously impaired. This result is normally un-

derstood to be just opposite to what would be expected for when reproduced speech is difficult to understand the natural tendency is to increase the reproduced volume in order to hear it. Such a procedure with this system, however, is improper.

With components incorporated into a system, as will be described in detail later, it is possible to accomplish the unusually long distance talk-back operation referred to above which, it is believed, has not heretofore been possible. One of the novel features of the invention is present in the combination of the two properties of the talk-back loudspeaker as emphasized above. Not only does it have a directional discrimination but this directional effect increases markedly as the frequency increases. This property combined with the low frequency discrimination of the talk-back loudspeaker increases the effect of higher sensitivity in the region of best ear sensitivity over what would be obtained if the increased directional effect with frequency were not present.

Referring to Figures 1 and 2, a description will be provided of a system in accordance with the objects and principles of this invention. These two figures are to be read together, representing a single complete system. It may be noted that one of the more suitable fields of use for this invention is on shipboard. The power supply for the system of the invention is from the 110 volt direct current circuit of the ship, represented by the reference numerals 1' and 2'. They are connected through a main switch 3 and a pair of choke coils 4 and 5 to the supply leads 1 and 2 for the apparatus of this invention. These leads are bridged by a pair of condensers 6 and 7 in series having their common tap grounded, as indicated at 8. The combination of choke coils and condensers provides a filter circuit for keeping out any undesired current fluctuations which may be present in the power circuit feeding the apparatus.

In the various figures the power supply leads 1 and 2 are not extended to all of the various instrumentalities receiving energy therefrom for purposes of simplifying the drawing. However, the corresponding leads of the various instrumentalities are provided with the same reference numerals 1 and 2, from which it will be apparent to those skilled in the art that all of the leads marked 1 are connected to the power lead 1 and all of the leads 2 are connected to the power lead 2.

At 9 and 10 are illustrated the loudspeaker and microphone, which in the case of a ship installation would normally be on the bridge of a ship under the control of an officer. As noted in the description above, the loudspeaker 9 is used only as a loudspeaker and the microphone 10 is used only as a microphone. At 11 is a push button or equivalent switch which is of the type which only remains closed so long as pressure is applied thereto, that is, it is not of the locking type. This switch is likewise on the bridge adjacent to the microphone 10 so that when the bridge officer wishes to use the system to talk-out he closes this switch. At 12 are shown a plurality of switches which are preferably of a locking type, that is, they remain closed when operated until again operated for opening. There is one of these switches provided for each transducer station on the ship. As each is closed a corresponding transducer is placed in circuit so that the bridge officer may control from the bridge those transducers which are to be operated. The transducers are indicated by the reference numerals 12', there being one illustrated for each switch 12. While, of course, only three transducers are shown, it is apparent that any desired number as required may be employed.

The reference numeral 13 is used to indicate generally the control units, one of which is provided for each transducer and is controlled at least in part by the respective switches 12. Each of these control units consists of two relays 62 and 60. The reference numeral 14 indicates generally the control unit under the influence of the switch 11 by means of which the apparatus is controlled at the bridge for operation either for talk-out over the microphone 10 or for talk-back over the transducers and the loudspeaker 9. This control unit consists of three relays 43, 44 and 45. It may be noted that the apparatus within the square 13 for the middle transducer is the same as that illustrated directly above and below it and has merely been shown in this form to further simplify the drawing.

One terminal of the microphone 10 is connected by wire 15 to the grounded terminal of the volume control 20, which is illustrated as comprising variable resistors and is also connected by wire 18 to the input lead 19 of the amplifier 25. The other terminal of the microphone 10 is connected by wire 16 to the input terminal of the volume control 20 as shown. The output terminal of this volume control is connected by wire 21 to the normally open fixed contact of switch 22, which is a part of relay 44. The leads 15 and 16 are bridged by a condenser 17, for the purpose of properly equalizing the talk-out frequency characteristic of this particular circuit. The movable contact of switch 22 is connected by wire 23 to the other input terminal of the amplifier 25, through variable impedance network 24.

The amplifier 25 is illustrated as an ordinary audio-frequency vacuum tube amplifier, which, as those skilled in the art will appreciate, may take other forms. Referring to the amplifier generally, it is noted that the input transformer is indicated at IT. The lead from one terminal of the output of this transformer to the control grid of the vacuum tube 26 includes a condenser 69, which will be referred to later. The circuits of the first amplifier tube 26 are resistance-coupled to the circuits of the second amplifier tube 27, the output of which tube is coupled by a transformer to a pair of multi-electrode vacuum tubes 28 and 29 connected in the well known push-pull circuit. The reference numeral F in all cases indicates the filament or heater leads of the vacuum tubes which would be connected to the terminals F of the winding of the power pack transformer, all in accordance with well known practice. These connections have not been completed for sake of simplicity. The output of the amplifier is supplied to the output transformer OT, which is provided with the leads 32 and 33. At 31 is indicated a full wave vacuum tube rectifier, which is used in conjunction with the usual power supply filter arrangements, etc., as is well known in the art. The leads 30 are to be connected to a suitable alternating current supply source which may be from an inverted rotary converter operating from the power line of a ship. For emphasis, it is again noted that this amplifier may take any one of a number of well known forms and is

only to be differentiated therefrom by the features which will be referred to later.

The output of the amplifier appears between ground (wire 33) and wire 32 which is connected to the normally open fixed contact of switch 36, which is a part of relay 43. This wire is also connected to the normally closed fixed contacts of switch 34 which is a part of relay 44 and switches 37 and 38 which are parts of relay 45. The movable contact of switch 34 is connected by wire 35 to one terminal of the receiving or bridge loudspeaker 9. The other terminal of this loudspeaker is grounded by wire 33, which is also connected to both of the movable contacts of switches 37 and 38 (relay 45) and to the normally open fixed contact of switch 39 which is a part of relay 43. The movable contact of switch 39 (relay 43) is connected by a wire 39' to the normally open fixed contacts of each of the switches 68 which are a part of relays 60 in the control units 13. The movable contact of switch 36 (relay 43) is connected by wire 36' to the normally open fixed contacts of each of the switches 66 which are also a part of relays 60 in each of the control units 13. The normally closed fixed contact of switch 36 (relay 43) is connected by wire 54 to the input terminal of the constant impedance volume control 53 shown as composed of variable resistors. The ground terminal of the volume control is connected to wire 19, and the output terminal of the volume control is connected through the condenser 52' by wire 52 to the normally closed fixed contact of switch 22 which is a part of relay 44. The normally open fixed contact of switch 42 (relay 44) is connected by wire 50 to the normally open fixed contacts of switch 40 which is a part of relay 43. The movable contact of switch 40 (relay 43) is connected to the lead 1 of the direct current power source. The movable contact of switch 42 (relay 44) is connected by wire 51 to one terminal of the winding of the relay 45, which includes switches 37 and 38. The other terminal of this winding is connected by wire 2 to the power source and wires 51 and 2 are bridged by a suitable current reducing resistor, as indicated at 51'. The normally closed contact of switch 42 (relay 44) is connected by wire 42' to each of the movable contacts of switches 65 which are a part of relays 60 in the control units 13. One of the fixed contacts of switch 40 (relay 43) is connected by wire 40' to each of the normally open fixed contacts of the switches 65 (relays 60). The normally open fixed contact of switch 41 (relay 44) is connected to the lead 1 of the power source and the movable contact is connected by wire 48 to one terminal of the winding of the relay 43, which includes switches 36, 39 and 40. The other terminal of this winding connects to the positive lead 2 of the current source.

Leads 48 and 2 are bridged by condensers 49 which act as time delay devices to delay the release of the relay 43. One terminal of the winding of the relay 44, which includes switches 22, 34, 41 and 42 is connected to the positive terminal 2 of the current source, and the other terminal is connected by wire 47 to one terminal of push button switch 11. The other terminal of switch 11 is connected to wire 1 of the direct current power source. One contact of each of the switches 12 is connected by wire 55 to wire 1 of the direct current power source. The other contact of each of these switches is connected by wires 56 respectively to the movable contact of switch 63 which is a part of relay 62 and to the normally closed fixed contact of switch 58. The normally open fixed contact of switch 58 is connected to the direct current power source wire 1, which is also connected to the movable contact of switch 64, which is a part of relay 62 and to the normally closed fixed contacts of switch 68 which is a part of relay 60. The power lead 2 is connected to the common terminal of two opposing windings of the relay 62 and by wire 61 to one terminal of the winding of the relay 60. The other terminal of the winding of the relay 60 is connected by wire 59 to the movable contact of switch 58 which is a part of relay 62. The normally open fixed contact of switch 63 (relay 62) is connected through a resistor as shown to the remaining terminal of the right hand winding of relay 62 while the remaining terminal of the left hand winding of this relay is connected through a resistor to the normally open fixed contact of switch 64 (relay 62) and to the normally closed fixed contact of switch 66 which is a part of relay 60. The movable contact of switch 66 (relay 60) is connected by wire 66' to one terminal of the transducer 12'. The movable contact of switch 68 (relay 60) is connected by wire 68' to the other terminal of the transducer 12' through a condenser 12b which acts as a blocking condenser for direct current. A push-button switch 12a is provided for connecting the leads 66' and 68' of the transducers together for turning the station on from the outside. It may be noted that the connections in each of the control units 13 are the same as those just described.

The network 24 connected in the lead 23 consisting of a condenser adjustable to three values of capacitance, shunted with a resistor, and the condenser 69, Figure 2, are provided so that the over-all response of the network and amplifier in combination with the transducers as previously described will be non-linear but having a rising trend with increasing frequency and rapid attenuation below about 200 cycles per second and an operating range up to about 3,000 cycles per second. It is to be noted that the volume controls 20 and 53 are used alternately, the volume control 20 being used for talk-out and the volume control 53 being used for talk-back. The circuit connections as will be described in connection with the operation are such that the change over from one volume control to the other is accomplished automatically to provide the proper volume level or to accomplish good speech intelligibility when the transducers are used as talk-back units. The talk-back volume control is adjustable to control the talk-back signal level in order to secure the proper signal strength for maximum ear sensitivity under the operating conditions likely to be encountered. The condenser 52' in series with the talk-back volume control 53 reduces the low frequencies further for talk-back.

In describing the operation of this system, it is first to be noted that all switches and connections are shown in their normal positions, that is, when the system is not in use, although the switch 3 is closed so that energy is available to put the system in use. If it be assumed that a bridge officer wishes to talk-out through one or more of the transducer stations, he first closes switch 12 corresponding to those stations he desires to operate. He then closes switch 11, with the result that current flows from wire 1 through switch 11, wire 46, relay 44, back to wire 2. The result is that relay 44 is operated and the movable con-

tacts of switches 22, 34, 41 and 42 are moved over into engagement with the normally open contacts of those switches. This operation of switch 22 connects leads 23 with lead 21, placing the talk-out volume control 20 in circuit between the microphone 10 and the amplifier 25. The common lead 19 is already connected to the other terminal of this microphone. The closing of switch 41 supplies current through wire 1, switch 41, wire 48, to relay 43, and from there through wire 2 back to the direct current power source. Since there is very little resistance in series with the parallel circuit of relay coil 43 and condensers 49, the relay operates immediately and switches 40, 39 and 36 are operated. The operation of switch 34 disconnects wire 35 from wire 32 so that the bridge loudspeaker is out of circuit.

As soon as switch 40 is operated current flows from wire 1, through the normally open contact of switch 40 (relay 43), wire 50, normally open contact of switch 42 (relay 44), the movable contact wire 51, relay 45, and back to direct current power source through the lead 2. The energization of the winding of relay 45 opens switches 37 and 38, which are simply in parallel. The opening of these circuits removes a short-circuit across the output terminals 32 and 33 of the amplifier. The operation of switch 36 which is a part of relay 43 connects the output lead 32 of the amplifier to wire 36' and switch 39 also a part of relay 43 connects the other output lead 33 to wire 39'. Wires 36' and 39' run respectively to the normally open contacts of the switches 66 and 68 of each of the relays 60.

It will be recalled that one or more of the switches 12 have been closed. Assuming that the uppermost switch 12 has been closed, current flows from lead 1, through lead 55, upper switch 12, wire 56, switch 58 (relay 63), the winding of relay 60, and back to the lead 2 through wire 61. This operates relay 60, closing switch 65 and operating switches 66 and 68. The operation of switches 66 and 68 connects the corresponding transducer 12' to the leads 36' and 39', as is clear from Figure 1. The same operation occurs in each control unit 13 for which the corresponding switch 12 has been closed.

The system is now set up for operation for talk-out, that is, the bridge officer speaking over the microphone 10 supplies speech energy to the amplifier, the output of which is supplied to the transducers 12' whose switches 12 are closed. During all the time the bridge officer talks he holds switch 11 closed. In order to be talked to, that is, in order for talk-back operation to occur, as soon as he finishes speaking or issuing a command, he releases switch 11. The opening of switch 11 breaks the circuit to relay 44 with the result that all the switches controlled by it move to the position shown in Figure 1. Thus the bridge loud-speaker 9 is connected through switch 34 which is a part of relay 44 to output lead 32 and, since it is always connected to output lead 33, it is ready to be operated, except that the release of relay 44 also caused relay 45 to release and short-circuit the output of the amplifier temporarily.

Input lead 19 is connected through switch 39 (relay 43) to lead 39' and input lead 23 is connected through switches 22 and 36 to lead 36'. At this time the network 53 is in circuit and network 20 is out of circuit, switch 22 being in the position shown.

The release of relay 44 also breaks the circuit to relay 45 at switch 42 and the circuit to relay 43 at switch 41. Thus switches 37 and 38 of relay 45 close and momentarily short-circuit the loudspeaker 9, preventing the emission from the loudspeaker of the various noises incident to the change-over, which has been found important in that the elimination of these noises is desirable. It has been found that if these noises are permitted to reach the loudspeaker 9 the person thereat is initially distracted as the speech comes over the loudspeaker. Practice indicates that the elimination of this distraction serves for more accurate communication. The short-circuit across the speaker only exists momentarily, as will be explained later.

The release of relay 43 sufficiently to permit the switches controlled thereby to move back from operated position to the position shown in Figure 1 is momentarily delayed by reason of the time required for the condensers 49 to discharge through the relay winding and it is during this period that the short-circuit on the bridge loudspeaker at switches 37 and 38 of relay 45 occurs. However, as soon as switch 40 moves back to the position shown, current flows from wire 1, through wire 40', through closed switch 65, wire 42', the normally closed contacts of switch 42, wire 51, relay 45, and back to the direct current power source through the wire 2. This causes switches 37 and 38 of relay 45 to open and break the short-circuit. Relay 60 remains operated, holding switch 65 closed and the transducer connected to the leads 36' and 39'.

In addition to connecting the loudspeaker 9 to the output leads of the amplifier, the release of the relay 44 causes the transducers to be connected to the input of the amplifier at switches 36 and 39 of relay 43. The system is now ready for talk-back in a manner which it is believed will be apparent. This change in connections substitutes the talk-back volume control 53 for the talk-out volume control 20 so that the gain of the amplifier system is changed for talk-back in accordance with the description previously provided. The condensers 12b in addition to acting as blocking condensers assist in providing the proper amount of equalization for the transducers for maximum speech intelligibility both for talk-out and talk-back. These condensers, if desired, may be variable as may be the other modifying elements of the circuits to adapt them for operation under varying conditions.

The operation of the system will now be described for a case where talk-back is desired to the bridge, the conversation to initiate at the talk-back end. Assuming switches 12 are open, as they would normally be, the person desiring to talk-back to the bridge, at one of the transducer stations, momentarily closes the corresponding switch 12a. It may be noted, as those skilled in the art will appreciate, that the switch 12a need not be right at the transducer itself but will be located at a convenient point spaced therefrom, and if desired there may be a number of them in parallel distributed about the regions from which talk-back can be effected over that particular transducer.

The closing of switch 12a, say for the upper transducer station in Figure 1, causes current to flow from wire 1, through the normally closed contacts of switch 68 which is a part of relay 60, switch 12a, back through the normally closed contacts of switch 66, also of relay 60, to and through the left hand winding of relay 62 and back to lead 2. The energization of the left

hand winding of relay 62 is sufficient to cause operation of the three switches 58, 63 and 64 controlled thereby. Current flows through lead 1, the normally open contacts of switch 58, wire 59, relay 60, and wire 61, back to wire 2. The closing of switch 64 completes a holding circuit for this winding from wire 1, through switch 64 to the left hand winding of magnet 62 and back to the direct current power lead 2 so that even though switch 12a is immediately opened the left hand winding of relay 62 remains energized.

The operation relay 60 connects the transducer with the wires 36' and 39' as before through the normally open contacts of switches 66 and 68. The closing of switch 65 causes current to flow from lead 1 through the normally closed contact of switch 40, which is a part of relay 43, wire 40', switch 65 (relay 60), wire 42', normally closed contacts of switch 42, wire 51, relay 45, and back to the lead 2. Thus the short-circuit is taken off the bridge loudspeaker at switches 37 and 38 of relay 45.

The system is now ready for talk-back. The bridge officer, in order to talk-out, closes the corresponding station switch 12 and as he talks holds switch 11 closed, which of course operates the control unit 14, as previously described. The closing of switch 11 also supplies current from the lead 1, wire 55, switch 12, wire 56, closed switch 63 of relay 62 and the right hand winding of relay 62, back to the power lead 2. Thus the right hand winding of the relay 62 is energized in the opposite direction to the other winding so that the relay releases and switches 58, 63 and 64 assume their normal positions. Relay 60 remains operated as long as switch 12 is closed however as previously described. It is therefore obvious to those skilled in the art that when the system has been put in operation by pressing the outside push button 12a, it may be shut off by the bridge officer by operating and then releasing his switch 12.

Figure 3 shows diagrammatically a modified circuit which differs in the main from that of the circuit of Figures 1 and 2 in that part of the equalization or control means by which good intelligibility of speech is secured and the volume thereof controlled is shown inserted in the receiving speaker circuit in place of the input circuit of the amplifier, as in the former circuit.

In Figure 3 some of the reference numerals used in the previous figures are employed to designate the same or substantially similar parts for the purpose of aiding in interpreting the disclosure. In this case the direct current power supply circuit is represented by the negative lead 1 and the positive lead 2 and controlled by the main switch 3. The negative side of the circuit is connected by wire 70 through a choke coil 71 to one side of the push button switch 11. The other side is connected by wire 72 to the winding of relay 73, the other terminal of which is connected by wire 74, back through the choke coil 74' to the other side of the main switch 3. Thus when switch 11 is closed, relay 73 is operated and the switches 6, 80, 84 and 88 move from their positions shown to their other positions.

At this point it may be noted that the heaters or filaments F—1 to F—6, inclusive, for the rectifier tube 77 and amplifier tubes 122 and 126 are in series across the line through the tapped resistor 119 when switch 3 is closed. Thus current flows from wire 70 through wire 125, the whole of resistor 119, filaments F1 to F6, and wire 74 to the other side of the line. Thus when the system is in operation the heaters of all the tubes are at operating temperatures and floating across the line. Here it may be noted that the rectifier 77 is a half wave vacuum tube rectifier with a resistance-capacitance filter and vacuum tubes 122 and 126 are the usual amplifying tubes with their associated circuits coupled to form a cascade amplifier with which the tubes 122 are associated in a push-pull circuit. The choke coils 71 and 74' are simply for filtering purposes to keep the variations in screen and plate potential of the output tubes from reacting on the input. The filaments F—1 to F—6 are all shown associated together to simplify the circuit but they will, of course, occupy their respective positions in the vacuum tubes as represented by the same symbols and reference numerals with respect to each tube. The reference numeral 100 represents generally the audio-frequency amplifier employed in this system, which includes the input transformer IT and the output transformer OT.

The high impedance primary terminal of the input transformer is connected by wire 78 to the normally open fixed contact of switch 80 which is a part of relay 73. The movable contact of this switch is connected by wire 79 to the movable contact of switch 84, also on relay 73. The normally open fixed contact of switch 84 (relay 73) is connected by wire 81 to one terminal of the bridge microphone 10. The other terminal of this microphone is connected by wire 82 to ground, as shown at 83, as is one terminal of the bridge loudspeaker 9. The other terminal of this loudspeaker is connected through an adjustable impedance network shown comprising inductance, resistance and capacity, and a volume control 117 comprising variable resistance with wires 83 and 116. Wire 116 is connected to the normally closed fixed contact of switch 6 which is a part of relay 73. The movable contact of this switch is connected by wire 85 to one of the terminals of the output transformer OT of the amplifier. The other terminal of this transformer is grounded as is the other terminal of the input transformer as shown. The normally closed terminal of switch 80 (relay 73) is connected by wire 121 to the low impedance taps on the input transformer IT. The normally open fixed contact of switch 6 (relay 73) is connected by wire 87 to the normally open fixed contact of switch 88 which is also a part of relay 73. The normally closed fixed contacts of switches 88 and 84 on relay 73 are connected together. The movable contact of switch 88 (relay 73) is connected by wires 94 and 89 to the normally open fixed contacts of switches 95 and 93 on relays 105 and 106. The movable contacts of switches 93 and 95 of the relays 106 and 105 are connected respectively by the wires 90 to one terminal of each of the transducers 12'. The other terminal of each of the transducers is connected back through the normally closed switches 12a by wires 91 to the movable contacts of switches 96 and 97 of the same relays.

The normally open fixed contacts of switches 96 and 97 on relays 105 and 106 are connected by wires 82 and 92 to ground 83. The normally closed fixed contacts of switches 93 and 95 on relays 106 and 105 and one end of the tapped resistors 109 and 110 are all connected by the wire 114 to the negative side of the power supply through main switch 3. The movable contacts of switches 104 and 98 on relay 106 and switches 99 and 101 of relay 105 are connected by wire 124 to one end of the tapped resistor 119. The

normally open fixed contacts of each of the switches 104 and 98 on relay 106 are connected by wire 103 to the normally open fixed contacts of each of the switches 101 and 102 on relay 105, and by wires 123 and 123' to the tap on resistor 119. One terminal of the winding of relay 106 is connected by wire 107 to the movable contact of the lower station switch 12. The normally engaged contact of this switch is connected to wire 70. The normally disengaged contact of this switch and the other switch 12 are connected together, and to the positive terminal of the power supply through wires 74, choke 74', and main switch 3. The normally engaged contact of the upper switch 12 is also connected to wire 70. The other end of resistance 109 is connected by wire 111 to the normally disengaged contacts of the switches 12. Wire 111 is connected as shown to wire 74. A tap connection from resistance 109 is connected by wire 108 to the other terminal of the magnet 106. Wire 111 is also connected to a resistance 110, the other terminal of which is connected by wire 113 to wire 114 which is connected to one of the fixed contacts of switch 95. The other fixed contact of this switch is connected by wire 94 with the movable contact of switch 88. The movable contact of the upper switch 12 is connected by wire 115 to one terminal of the magnet 105. The other terminal of this magnet is connected to wire 112 which comprises a tap on resistance 110 and to one of the fixed contacts of switch 96.

In describing the operation of this circuit it will be assumed that all the switches are in their off position as shown, except switch 3 which must necessarily be on. Current flows through lead 2 from the power source through switch 3, wire 74, the heaters F6, F5, F4, F3, F2, F1 of the amplifier and rectifier tubes, one section of resistor 119, the other two sections of resistor 119 in parallel, wire 125, and back through switch 3 and wire 1 to the negative terminal of the power source. This heats the filaments or heaters of the vacuum tubes sufficiently so that they are ready for operation. It will be noted that the voltage drop across one section of resistor 119 is connected in series with the grid bias for the output tubes 122. The value of this voltage drop is sufficient to bias these tubes to cut-off so that no plate current flows; this is the normal or standby condition for this amplifier. Current also flows from the positive terminal of the power source through wire 2, switch 3, wire 74, choke coil 74', rectifier tube 77, to the first two stages of the amplifier comprised in the double tube 126. Current also flows as described above to and through the choke coil 74', then through wire 111 to one end of each of the tapped resistors 109 and 110. The current passing through resistor 109 flows through the normally closed contact of switch 97, which is a part of relay 106, to the movable contact of the same switch, through wire 91, normally closed push button switch 12a, transducer 12', wire 90, the movable contact of switch 93 on the same relay, the normally closed fixed contact of the same switch, and back through wire 114 and switch 3 to the negative terminal of the power supply 1. There is a parallel path around the transducer circuit through wire 108, the winding of relay 106, the movable arm of switch 12, the normally closed contact of the same switch, choke coil 71, wire 70, and back through switch 3, to the negative terminal of the power supply 1. The resistance of the winding of the relay is so much higher than the resistance of the transducer circuit that only a negligible portion of the total current flows through this circuit, so that the relay 106 is normally not operated. However, if a person at the transducer station pushes the button 12a momentarily, this will force the current to flow through the relay coil 106 causing the operation of the relay.

This relay is also operated when the lower station switch 12 is turned on. The circuit in this case is as before through the choke coil 74', wire 111, the normally open contact of switch 12, the movable contact of the same switch, wire 107, the winding of relay 106, wire 108, back to the tap on resistor 109. It will, of course, be apparent to those skilled in the art that relay 105 may be operated in the same way as relay 106. The operation of either or both of these relays short circuits one part of resistor 119 through wires 123', 123, switches 101 and 102 in parallel or 104 and 98 in parallel, wires 99 and 124. The short circuiting of this part of resistor 119 removes the cut-off bias from the grid circuit of the power amplifier tubes 122 and simultaneously increases the filament current to the normal value, this transferring the amplifier from the standby to the operating position.

When either relay 106 or 105 is operated, its transducer 12' is connected through wires 91 and 90, switches 93 and 97 of relay 106 or switches 95 and 96 of relay 105 through wire 89 to switch 88 of relay 73 and through wire 92 to ground 83. When relay 73 is in the released position as shown, the circuits are set up for talk-back as follows: The low impedance tap on the input transformer IT of the amplifier 100 is connected by wire 121, the normally closed fixed contact of switch 80, the movable contact of the same switch, wire 79, the movable contact of switch 84, the normally closed fixed contact of the same switch, the normally closed fixed contact of switch 88, the movable contact of switch 88, and wire 89, to whichever of the transducers 12' is connected as described above. The output transformer 85 of the amplifier 100 is connected through the movable contact of the switch 6, the normally closed fixed contact of the same switch, wire 116, volume control and adjustable impedance network 117 to the bridge loudspeaker 9.

As will be seen from the diagram, one end each of the input transformer IT, the output transformer OT, the transducer 12', and the bridge speaker 9 is grounded. Thus the necessary circuits for talk-back operation are set up.

When the push button 11 associated with the microphone 10 is operated, current flows as above described, to and through the choke coil 74', wire 111, the winding of relay 73, wire 72, the contacts of switch 11, choke coil 71, wire 70, and back to the negative side of the power supply through switch 3 and wire 1. This causes relay 73 to operate and the switches 6, 80, 84, and 88 to move to the positions opposite from those shown in the diagram. The circuits for talking out are now set up as follows: The microphone 10 is connected by wire 81, the normally open fixed contact of switch 84, the movable contact of the same switch, wire 79, the movable contact of switch 80, the normally open fixed contact of the same switch, and wire 78 to the high impedance tap on the primary of the input transformer IT. From the output transformer OT, wire 85, the movable contact of switch 6, the normally open fixed contact of the same switch, wire 87, the normally open fixed contact of switch 88, the movable contact of the same switch, wire 89, to either or both of the transducers 12' as described above.

The condenser 76 has its positive side connected through rectifier 77 and wire 111 to one side of the relay coil 73, and its negative side connected directly to the other side of said relay coil. This condenser has a value of capacity sufficiently large to delay the release of the relay 73 when the push button 11 is released. This slowing up of the release of relay 73 minimizes undesired clicks or thumps in the bridge loudspeaker which would otherwise have a distracting effect.

The condenser 120 in combination with the volume control shown connected to the tube 126, attenuates the undesired low frequency components of speech and extraneous noises in order to increase the emphasis in the higher vowel, voiced consonants and sibilant regions. In the talk-back circuit, additional control over the frequency response of the amplifier, as well as its gain, is provided by the volume control and adjustable impedance network 117, the controls of which are mounted on the bridge so that the bridge officer may adjust the talk-back gain and frequency response to suit operating conditions.

What we seek to secure by United States Letters Patent is:

1. An audio-frequency signaling system including a microphone, a loudspeaker, a transducer, a multi-tube vacuum tube amplifier, means for alternately connecting the microphone to the input of the amplifier and the transducer to the output thereof, or the transducer to the input of the amplifier and the loudspeaker to the output of the amplifier, and control means adjacent the microphone and the transducer whereby two-way audio-frequency communication may be initiated from either point.

2. In an audio-frequency communication system the combination including a microphone and a loudspeaker at a central station, a transducer at a receiving station, an amplifier, and means controlled from either the central station or the receiving station for connecting the microphone to the input of the amplifier and the transducer to the output of the amplifier, or the transducer to the input of the amplifier and the loudspeaker to the output of the amplifier.

3. In an audio-frequency communication system, the combination including a microphone and a loudspeaker at a central station, a transducer at a receiving station, an amplifier, means controlled from either the central station or the receiving station for connecting the microphone to the input of the amplifier and the transducer to the output of the amplifier, or the transducer to the input of the amplifier and the loudspeaker to the output of the amplifier, and an impedance network connected in the input of the amplifier whereby the over-all response of the system is non-linear and has a rising frequency response with increasing frequency.

4. In a two-way audio-frequency communication system, the combination including a microphone and loudspeaker situated at a central station, a transducer situated at a receiving station, an amplifier, an impedance network connected to the input of the amplifier, and means at the central station for connecting the microphone to said network and the transducer to the output of the amplifier, and means at the receiving station for connecting the transducer to the network and the loudspeaker to the output of the amplifier, said network and amplifier in combination having a non-linear response and the response having a rising trend with increasing frequency.

5. In a two-way audio-frequency communication system the combination including a microphone and loud-speaker situated at a central station, a transducer situated at a receiving station, an amplifier, an impedance network connected to the input of the amplifier, means at the central station for connecting the microphone to said network and transducer to the input of the amplifier, means at the receiving station for connecting the transducer to the network and the loudspeaker to the output of the amplifier, said network and amplifier in combination having a non-linear response and the response having a rising trend with increasing frequency, and means for short-circuiting the transducers during change-over.

6. In a two-way audio-frequency transmission system, the combination including a microphone and a loudspeaker, a transducer, an amplifier, a pair of volume controls, means for connecting the microphone to the input of the amplifier, the transducer to the output of the amplifier, and one of said volume controls in circuit for speech transmission in one direction, and means for connecting the transducer to the input of the amplifier, the loudspeaker to the output of the amplifier, and the other volume control in circuit for speech transmission in the opposite direction.

7. In a two-way audio-frequency transmission system, the combination including a microphone and a loudspeaker, a transducer, an amplifier, a pair of volume controls, means for connecting the microphone to the input of the amplifier, the transducer to the output of the amplifier, and one of said volume controls in circuit for speech transmission in one direction, means for connecting the transducer to the input of the amplifier, the loudspeaker to the output of the amplifier, and the other volume control in circuit for speech transmission in the opposite direction, and means for short-circuiting the transducer during change-over.

8. A two-way audio-frequency communication system including a central station having a microphone and a loudspeaker, a remote station having a transducer, an amplifier, input and output circuits for the amplifier, a volume control in the output of the amplifier, and means at the central and remote stations for connecting at will either the microphone or the transducer to the input of the amplifier and the transducer and loudspeaker to the output of the amplifier respectively.

9. A two-way audio-frequency communication system including a microphone and a loudspeaker, a transducer, an amplifier, input and output circuits for the amplifier, a volume control in the output of the amplifier, means for connecting at will either the microphone or the transducer to the input of the amplifier and the transducer and loudspeaker to the output of the amplifier respectively, and impedance means in the amplifier circuit for imparting thereto a limited frequency range of non-linear characteristics.

10. A two-way audio-frequency communication system including a microphone and a loudspeaker, a transducer, an amplifier, input and output circuits for said amplifier, means at one point for connecting either the microphone or the transducer to the input circuit of the amplifier and the loudspeaker or the transducer to the output of the amplifier, whereby two-way communi-

cation may be accomplished and controlled from one point, and means at the transducer station for initiating two-way conversation.

11. A two-way audio-frequency communication system including a microphone and a loudspeaker, a transducer, an amplifier, input and output circuits for said amplifier, and means at one point for connecting either the microphone or the transducer to the input circuit of the amplifier and the loudspeaker or the transducer to the output of the amplifier, whereby two-way communication may be accomplished and controlled from one point, and a pair of volume controls alternatively and automatically connected to the input circuit of the amplifier for either direction of communication.

12. A two-station long distance two-way audio-frequency communication system including a microphone and an amplifier, a transducer having directional characteristics in a dimensional sense, with an increasing response with increasing frequency, a non-linear amplifier and input and output circuits for the amplifier, and control means at each station for connecting either the microphone or the transducer to the input circuit of the amplifier and the transducer or loudspeaker respectively to the output circuit of the amplifier.

13. A long distance two-way audio-frequency communication system including a microphone and an amplifier, a transducer having directional characteristics in a dimensional sense with an increasing response with increasing frequency, an amplifier and input and output circuits for the amplifier and control means for connecting either the microphone or the transducer to the input circuit of the amplifier and the transducer or loudspeaker respectively to the output circuit of the amplifier, said amplifier and input circuit having a non-linear response and a limited frequency range.

14. A long distance two-way audio-frequency communication system having talk-out and talk-back stations, a microphone and a loudspeaker at the talk-out station, a transducer at the talk-back station, an amplifier, talk-out and talk-back volume control networks, and means at the talk-out station for connecting the microphone to the input of the amplifier through the talk-out network and transducer to the output of the amplifier or the transducer to the input of the amplifier through the talk-back network and the loud-speaker to the output of the amplifier.

15. A long distance two-way audio-frequency communication system having talk-out and talk-back stations, a microphone and a loudspeaker at the talk-out station, a transducer at the talk-back station, an amplifier, talk-out and talk-back volume control networks, and means at the talk-out station for connecting the microphone to the input of the amplifier through the talk-out network and transducer to the output of the amplifier or the transducer to the input of the amplifier through the talk-back network and the loudspeaker to the output of the amplifier, and means for short-circuiting the transducer during change-over from talk-out to talk-back or talk-back to talk-out.

16. A long distance two-way audio-frequency communication system including a talk-out station having a microphone and loudspeaker thereat, a plurality of talk-back stations each having a transducer thereat, an amplifier, means at the talk-out station for connecting the microphone to the input of the amplifier and one or more of the transducers to the output of the amplifier, and means at each transducer station for connecting the transducer thereat to the input of the amplifier and the loudspeaker to the output thereof.

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