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SOUND SYSTEM

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2 Sheets-Sheet 1

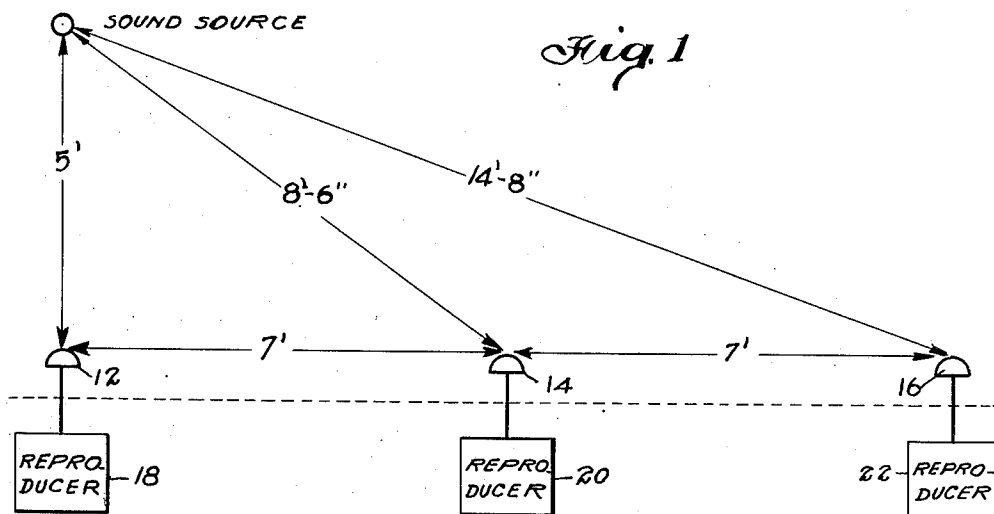
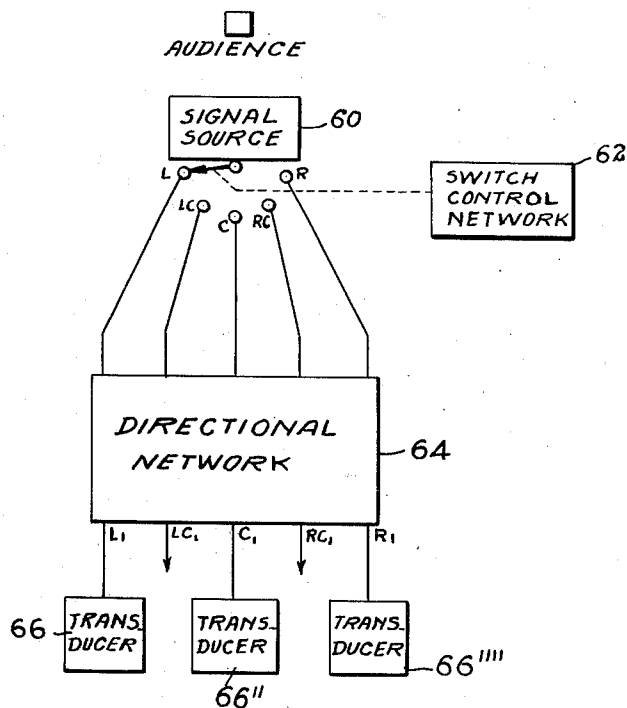


Fig. 3



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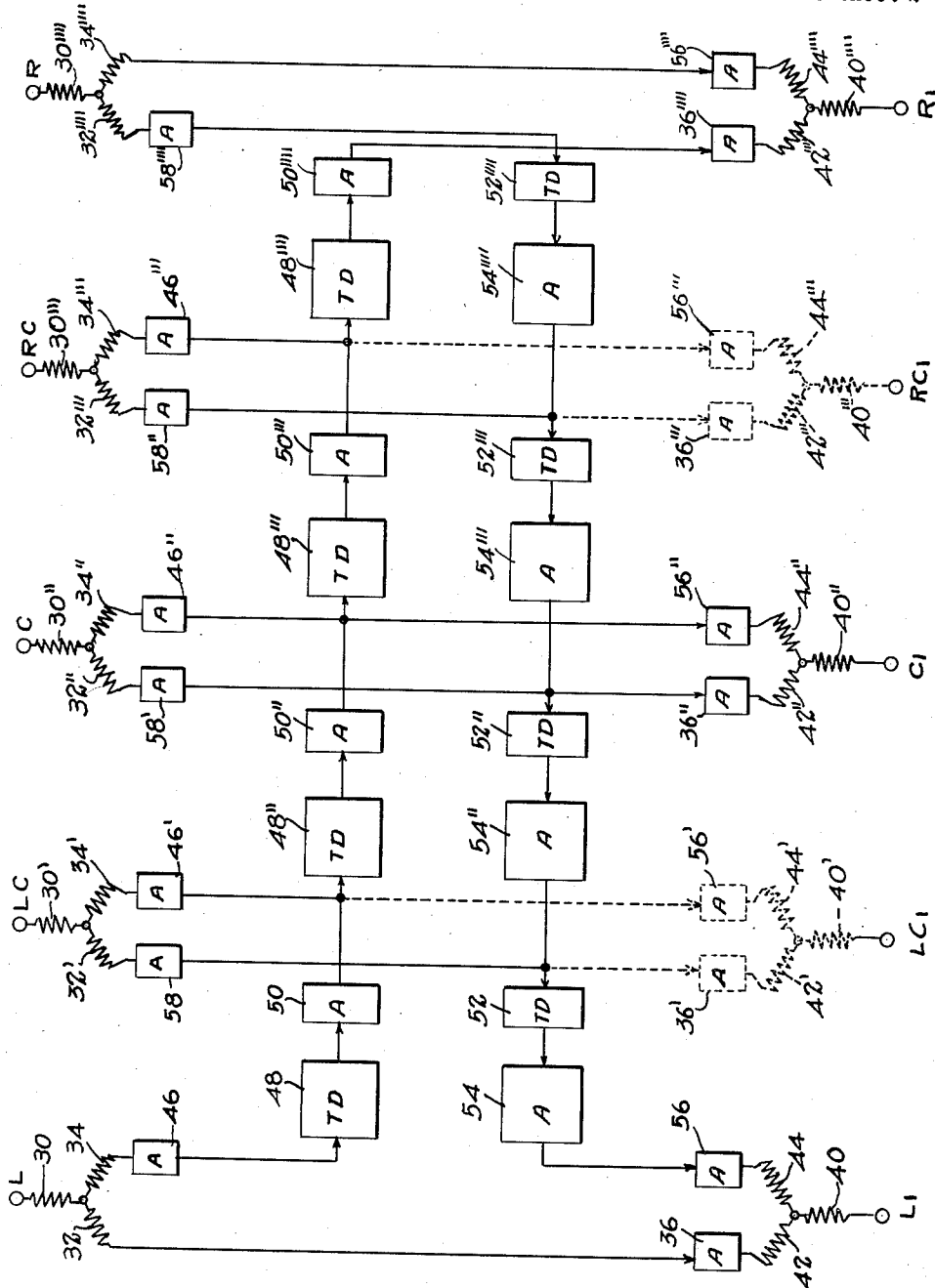


Fig. 2

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SOUND SYSTEM

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7 Claims. (Cl. 179—1)

This invention relates to sound systems and, more particularly, to improvements in stereophonic sound systems.

A presently favored arrangement for obtaining "three-dimensional" or directional sound in conjunction with motion pictures, for example, is to employ three or more speakers placed to provide a center, right, and left speaker position. Audio signals are fed to the three speakers in phase. In order to create the illusion of sound from the right, left, or center, the amplitude of the speaker which is on the side from which it is desired to simulate the source of sound is maintained at the maximum level for the particular sound and the other two are at successively lower levels. Different methods are employed to shift the volume control with the action on the screen. The speakers may each be fed from a separate track upon which the audio levels for obtaining the three-dimensional effect are recorded or they may all be fed from a single audio track with level control signals either being recorded on a separate track or being modulated on carriers which are not audible and which may be filtered out and then employed to control the various sound levels.

There are complexities not only in the reproduction of sound but more so in the making up of the sound tracks for three-dimensional reproduction since oftentimes these must be made up from a single track with the motion picture providing the cueing information for "placing" the sound. Furthermore, the phenomena of determining the direction of the source of a sound is not caused by differences in loudness so much as differences in time of the arrival of sound waves at the ears. Therefore, these "loudness" three-dimensional sound-reproduction systems are not as realistic as is desired.

The present invention has for an object the provision of a three-dimensional sound system which is simpler than the previously noted systems.

Another object of the present invention is the provision of a directional sound system which can be operated from a single track.

Still another object of the present invention is the provision of a novel, useful, and more faithful three-dimensional sound-reproduction system.

Yet another object is the provision of a novel network arrangement for enabling either the production of a recording for three-dimensional reproduction from a single sound source or three-directional reproduction directly from a single sound source.

These and other features of the invention are achieved in a system which includes a plurality of input signal terminals which are arranged in a sequence. Also provided are a plurality of output signal terminals which are arranged in a corresponding sequence. Means are provided for directly coupling each input-signal terminal to an output-signal terminal corresponding thereto in said sequence. There are also provided a plurality of network means. A different one of these network means are used to couple a signal-input terminal to a succeeding signal-output terminal. A different one of these network means are also used to couple a signal-input ter-

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minal to a preceding signal-output terminal. Each of these network means may include a time-delay network and an amplifier. If each one of these signal-output terminals is connected to a recording head or to a loudspeaker, then signals from a single-sound signal source may be applied to the one of the signal-input terminals which directly connects to the speaker which is placed in the direction from which it is desired the sound reproducers simulate the origin of the sound source. The sound signal will be fed directly to the signal output terminal and transducer at that position. The sound signals will be fed to the remaining loudspeakers at various later times in accordance with the delays provided by the interconnecting network. The resulting sound heard will appear to emanate from the desired direction. The sound signals may be switched to the other input terminals and the sound will appear to emanate from the direction of the location of the speaker to which the input terminal is directly connected. The embodiment of the invention may also be employed in conjunction with three magnetic-recording heads coupled to three signal-output terminals to produce three sound tracks. By switching the input signals between the three signal-input terminals directly coupled to the three signal-output terminals, the apparent direction of the sound which can be reproduced from the three track recordings will shift accordingly.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

Figure 1 is a drawing of an arrangement of microphones and reproducers shown to illustrate the principles involved in providing the three-directional reproduction of sound;

Figure 2 is a block diagram of an embodiment of the invention; and

Figure 3 is a block diagram of the embodiment of the invention being used to either reproduce or record directional sound signals from a single signal source.

Figure 1 illustrates an arrangement for a true directional reproduction. In Figure 1 there is shown a source of sound 10. Three microphones 12, 14, 16 pick up the sound emanating from the source 10 and furnish the signals to three reproducers 18, 20, 22. These reproducers may comprise the usual amplifier and loudspeaker which is required to reproduce the signals supplied from a microphone. By way of illustration, the distances between the sound source to each microphone and between each of the microphones is illustrated on the drawing. The reproducers are spaced a convenient distance apart, which may be determined by the width of a screen. Sound will be picked up by microphone 12 first, by microphone 14 second, and by microphone 16 third. A listener who can hear only what emanates from the reproducers will hear the sounds from the reproducers 18, 20, 22 in exactly the same sequence as the sounds are detected by the microphones. Since sound travels at the rate of 1100 feet per second, a foot of distance corresponds to approximately 1 millisecond in delay time. Therefore, in accordance with the distances indicated on the drawing, microphone 12, which is 5 feet from the source, receives the signal 5 milliseconds later; microphone 14, which is 8.6 feet from the source, receives the signal 8.6 milliseconds after it is originated; and microphone 16 receives the signal 14.8 milliseconds after the sound originates. As far as a listener is concerned, when sound reaches him first from reproducer 18, and sequentially later from the other reproducers, he places the sound source as emanat-

ing from the direction of reproducer 18. Reproducer 20 provides him with sound 3.6 milliseconds later than reproducer 18, and reproducer 22 provides him with sound 9.8 milliseconds after reproducer 18. Time differences, plus the decrease in sound-pressure level which occurs as a result of the travel of the sound, are the factors which simulate a directional result for the listener.

The same result would be achieved if instead of having the sound emanating from some distance behind the microphones it would be created at reproducer 18 first, 20 second, and 22 third. With this arrangement varying the amplitude of the sound would create the effect of distance. To simulate a sound source from the side of reproducer 22, sound would first emanate from reproducer 22, then from 20, then from 18. To simulate a sound source from the center of the arrangement then, sound is fed first to reproducer 20, then to both reproducers 18 and 22. It should be appreciated that the differences in sound amplitude between the reproducers when excited from a single-sound source are those due to attenuation caused by the longer paths of air travel. These contribute to but are not the chief factor in the directional effect.

A network for achieving such a three-dimensional sound simulation is an embodiment of the invention which is shown in block-diagram form in Figure 2. A plurality of input-signal terminals in a sequence which are designated as "L," "LC," "C," "RC," and "R" are shown. These may be associated with the placement of speakers in a theater and thus correspond to left, left center, center, right center, and right. First assume, however, that there are only three speakers or output transducers in the system. A plurality of output terminals in a sequence which corresponds to that of the input-signal terminals are respectively designated as L₁, C₁, and R₁. These are respectively connected to speakers or other transducers. Three isolation resistors, 30, 32, 34—30''', 32''', 34''' are connected in the form of a Y to provide two branches from each signal input terminal. Substantially direct coupling exists between the signal-input terminals L, C, and R and the respective signal-output terminals L₁, C₁, R₁. This may be followed from terminal L through resistors 30, 32, amplifier 36, resistors 42, 40 to terminal L₁. Terminal R connects to R₁ through resistors 30''', 34''', amplifier 56''', and resistors 44''', 40'''. Both branches from terminal C couple to C₁ via the resistors 30'', 32'', 34'', amplifiers 58'', 46''—36'', 56'', and resistors 42'', 44'', 40''. For a three-speaker or transducer system, signal-input terminals Lc and Rc are not directly coupled to any of the three speakers. These are used for placing sound sources between the L₁ and C₁ or the C₁ and R₁ speakers. However, if a five-speaker system is desired, the connections are made as shown in accordance with the dotted lines. The first and last input terminals of the sequence couple to the respective first and last output terminals of the sequence. The input terminals in between these also are coupled to the respective associated output terminal but through both branches of the Y made by the isolation resistors.

One branch of the Y connection from the respective signal-input terminals except for the last signal-input terminal is respectively connected to a succeeding signal-output terminal through an isolation amplifier 46—46''', a time delay network 48—48''', and an amplifier 50—50'''. Excellent results have been obtained by making the delay for the time-delay network 48 that which sound would have in traveling the distances between the positions of the input transducers which are in circuit with the signal-output terminals. In other words, if the distance from a microphone connected to L to a microphone connected to C is 7 feet, then each of the time-delay networks would have a delay time of 3.5 milliseconds. Thus a sound signal applied to terminal L

would reach terminal L₁ almost immediately, terminal C₁ seven milliseconds later, and terminal R₁ 14 milliseconds later. Terminal LC₁ receives the signal 3.5 milliseconds after terminal L₁ and terminal RC₁ 10.5 milliseconds after L₁, if a five-speaker system is desired.

For theatre reproduction, these time delays may be established from the size of the screen; one microphone can be considered as being at the center of the screen and the left and right microphones can be considered as being one-sixth of the distance in from the edge of the screen. The distances, and thus the time delays required, are readily determined. Time-delay networks for audio-frequency signals are well known in the art and need not be described here. The gain of each of the amplifiers 50—50''' is set at a value to replace the attenuation provided by the time-delay network except for an amount which the sound itself would be attenuated in traveling the distance between each of the input transducers, or traveling through air for the time of a delay network. Thus, if a signal is applied to signal-input terminal L, the signal would be reproduced first and with its maximum volume by the speaker connected to L₁ and would be reproduced last and with its minimum volume by the speaker connected to terminal R₁. The listener would then hear the sound as emanating from the left side. It should be noted here that the attenuation due to the delay network may be completely compensated for and the "directional" effect will still be present. However, the realism of the reproduction is heightened further by the slight attenuation being permitted in the system as described.

The remaining part of the time delay and amplification network is substantially the same as has been described except that the connections are made to allow signal flow in the opposite direction. The time-delay networks 52—52''' and the amplifiers 54—54''' are employed to connect a signal-input terminal to a preceding signal-output terminal except for the first input terminal. A signal which is applied to the signal-input terminal R will thus be heard first and with its maximum volume from a speaker connected to R₁ and will be heard last from L₁ with a time delay of approximately 14 milliseconds and an attenuation of approximately 9 db. The intermediate speakers will reproduce the signals at intermediate times and with intermediate attenuations. Thus the signal will appear to be emanating from the right. It will be appreciated that the sound signal can be reproduced and made to come from either right, left, or center, or left of center, or right of center. This is readily achievable by applying the signal to the proper signal input terminal.

Thus, as shown in Figure 3, the signals from a source 60 can be readily switched by a switch-control network 62 to desired ones of the signal-input terminals for determination of the direction from which the sound emanates. The network shown in Figure 2 is represented by the rectangle 64 in Figure 3, which is labeled "directional network." The outputs from the network are connected to transducers 66—66'''. The system shown in Figure 3 employs a selector switch. This is merely by way of representation. It will be well within the ability of those skilled in the art to employ suitable electronic switching apparatus or electromechanical switching to achieve the desired results. The signals emanating from the signal source are switched manually on cue or automatically to any one of the five signal-input terminals, and if the output apparatus consists of loudspeakers, the sound will be heard emanating from the direction selected by the switch-control network. The switch-control network 62 can be controlled by signals on a single track on tape or one film, whereas the sound-signal source 60 can be a second track, or a single track can contain both sound and switching signals with a filter being used to separate out the switching control signals. The output 75 of the directional network from a single switched sound

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source can also be applied to three or more recording heads or transducers, and the sound signals can be recorded on a medium such as tape or film in the three tracks. However, instead of each of the three tracks having the sound recorded in the same phase but with differing amplitudes, the sound is recorded with differing amplitudes but also delayed with respect to one another in accordance with the output of the directional network.

Accordingly, there has been shown and described hereinabove a novel, useful, and simple directional network arrangement which may be directly employed to create from a single-sound source a three-dimensional effect which heightens the realism of the reproduction or to provide a recording from such single source which represents three-dimensional sound.

I claim:

1. A directional sound-simulation system comprising a plurality of signal-input terminals in a sequence, a plurality of output terminals in a corresponding sequence, means directly coupling an input terminal with an output terminal which corresponds thereto in its sequence, a plurality of delay means, a first means including a different one of said delay means coupling each signal-input terminal with a succeeding signal-output terminal, and a second means including a different one of said delay means coupling each signal-input terminal with a preceding signal-output terminal.

2. A directional sound-simulation system comprising a plurality of signal-input terminals in a sequence, a plurality of signal-output terminals in a corresponding sequence, means directly coupling said input terminals in said sequence respectively to output terminals having a corresponding position in said sequence, a first plurality of delay networks a different one of which couples one of said input terminals to a succeeding one of said output terminals in its sequence, and a second plurality of delay networks a different one of which couples one of said input terminals with a preceding one of said output terminals in its sequence.

3. A three-dimensional sound-simulation system comprising a plurality of signal-input terminals in a sequence, a plurality of signal-output terminals in a corresponding sequence, means directly coupling each of said input terminals in said sequence to an output terminal having the corresponding position in its sequence, and a plurality of networks, a different one of said networks coupling a signal-input terminal to a succeeding signal-output terminal, a different one of said networks coupling a different signal-input terminal to a preceding signal-output terminal, each said networks including a time-delay network which attenuates signals passing therethrough, and an amplifier in series with said time-delay network, the gain of said amplifier being set to compensate for all of the losses due to said attenuation except for an amount of loss equivalent to that sustained when sound travels a distance in air during a time equal to that of said time delay.

4. A system for providing directional sound from a single-signal source to simulate a desired sound-reproduction layout having a plurality of spaced input transducers said system comprising a plurality of signal-input terminals in a sequence, a plurality of signal-output terminals in a corresponding sequence, a plurality of transducers a different one of which is coupled to a different one of said signal-output terminals, means directly coupling each signal-input terminal to an output terminal corresponding thereto in said sequence, a plurality of networks each of which includes a time-delay circuit, each signal-input terminal being coupled to a succeeding signal-output terminal through a different one of said networks, each signal-input terminal being coupled to a preceding signal-output terminal through a different one of said net-

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works, the delay of each of said networks being made substantially equal to the time required for sound to travel between said spaced input transducers in said desired sound reproduction layout, and means to selectively switch signals from said single-signal source to a desired one of said signal-input terminals.

5. A system as recited in claim 4 wherein each of said time-delay circuits attenuates a signal and each of said networks includes an amplifier having its gain adjusted to compensate for all the attenuation of a time-delay circuit except for an amount of attenuation substantially equivalent to that occurring when sound travels a distance in air between said spaced input transducers in said desired reproduction layout.

6. A system for providing stereophonic sound from a single-signal source to simulate a desired sound-reproduction layout having a plurality of spaced input transducers said system comprising a plurality of signal-input terminals in a sequence, a plurality of signal-output terminals in a sequence, a plurality of sound reproducers each of which is coupled to a different one of said signal-output terminals, each of said sound reproducers being spaced adjacent each other to extend over a desired distance, means coupling each signal-input terminal to the signal-output terminal corresponding thereto in said sequence, a plurality of time-delay networks, each signal-input terminal being coupled to a succeeding signal-output terminal through a different one of said networks, each signal-input terminal being coupled to a preceding signal-output terminal through a different one of said networks, the time delay of each of said networks being determined by the time required for sound to travel between adjacent ones of said spaced input transducers in said sound-reproduction layout, and means to selectively switch signals from said single source of signals to one of said plurality of signal-input terminals in accordance with the desired source location simulation for the reproduced signal.

7. A system for providing directional sound from a signal source to simulate a desired sound-reproduction layout having a plurality of spaced input transducers in a plane, said system comprising a plurality of signal-input terminals in a sequence, a plurality of signal-output terminals in a sequence, a plurality of sound reproducers each of which is coupled to a different one of said signal-output terminals, each of said sound reproducers being spaced from each other, means coupling each signal-input terminal to the signal-output terminal corresponding thereto in said sequence, a plurality of networks, a different one of said networks coupling a signal-input terminal to a succeeding signal-output terminal, a different one of said networks coupling a signal-input terminal to a preceding signal-output terminal, each said network including a time-delay network which attenuates signals passing therethrough and an amplifier in series with said time-delay network, the time delay of each of said networks being determined by the time required for sound to travel between adjacent ones of said input transducers in said desired sound-reproduction layout, the gain of each amplifier being established to compensate for all of the attenuation except that due to the attenuation of sound traveling in air for the time of one of said time-delay networks, and means to selectively switch signals from said signal source to one of said plurality of input terminals in accordance with the desired direction from which the reproduced sound signal is to emanate.

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