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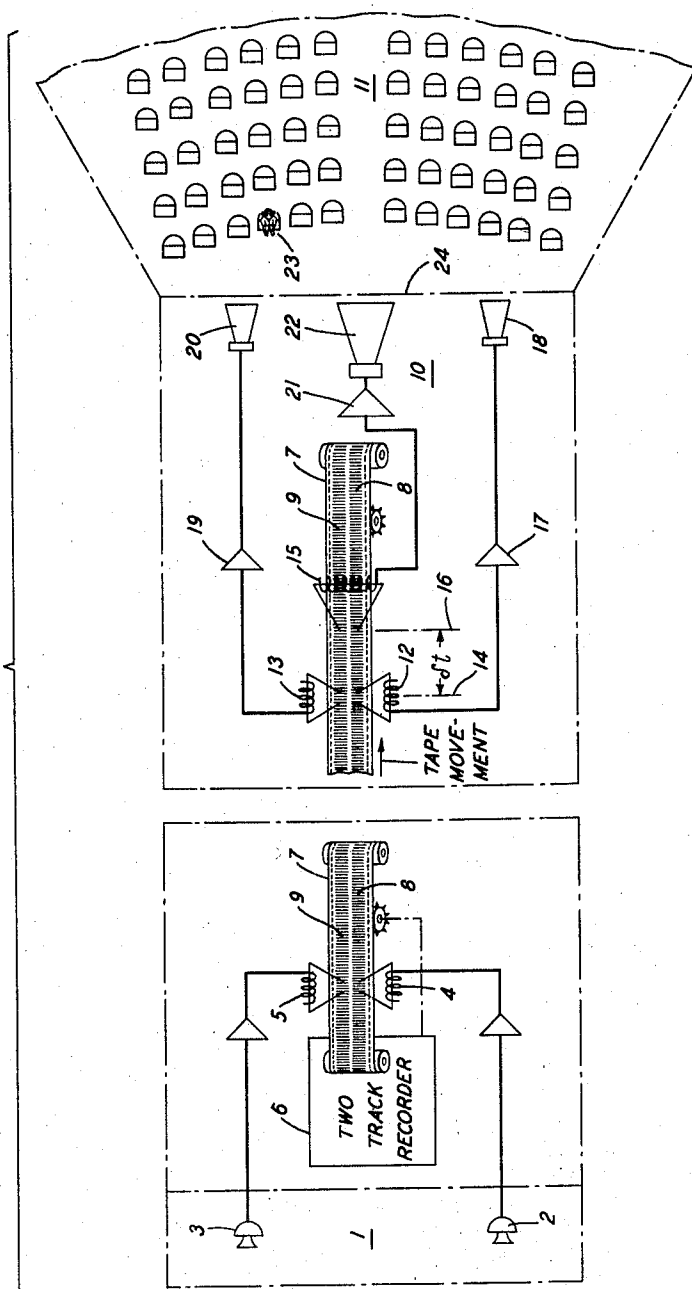
2,819,348

STEREOPHONIC REPRODUCTION OF SOUND

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2 Sheets-Sheet 1

FIG. 1



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2 Sheets-Sheet 2

FIG. 2

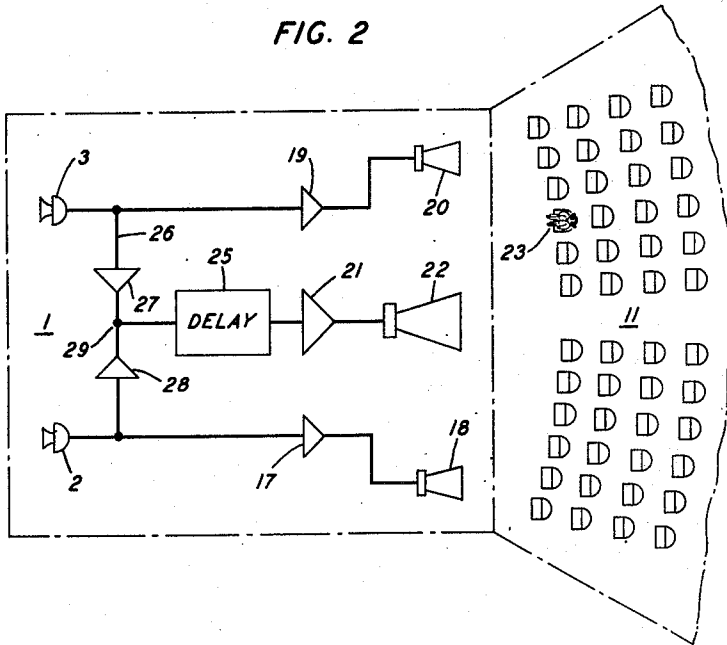
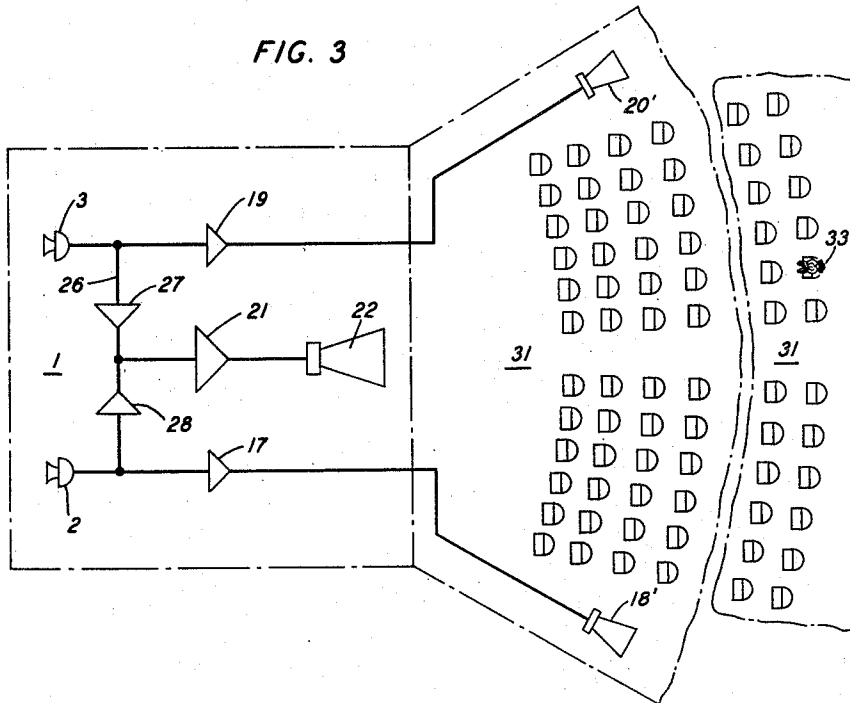


FIG. 3



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1

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STEREOPHONIC REPRODUCTION OF SOUND

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5 Claims. (Cl. 179—100.1)

This invention relates to the stereophonic reproduction of sound and has for its principal object to provide an audience in a concert hall, conference room or other auditorium with a realistic sense of the direction from which reproduced sounds are heard.

It is well known that strong directional effects may be achieved by binaural techniques in which each hearer is provided with two earphones, one of which is clamped to each of his ears, two microphones located near the real sound source, and preferably disposed on either side of a dummy human head, and two individual channels, fully isolated from each other, linking the left-hand microphone to all of the left-hand earphones and the right-hand microphone to all of the right-hand earphones. With this arrangement the impression received by each hearer is as though his head were in the location of the dummy head. The directional sensation which characterizes such a system is well known to be dependent principally on the relative times of arrival of each sound at the two ears. Marked differences in the apparent direction of origin of sounds depend on time of arrival differences of a few microseconds, corresponding to the travel time of sound in air through distances of a few inches. This matter is fully discussed for example in Jones Patent 1,855,149.

Because of the awkwardness of providing earphones to each member of an audience and electrical transmission of signal currents thereto by wires, and because of the inconvenience to auditors of wearing such earphones, alternative systems have been proposed which have come to be known as stereophonic systems. In a stereophonic system two or more microphones, which may be widely spaced apart, are individually connected by way of transmission channels which are normally isolated, each from the others, to sound reproducers or loudspeakers. In such a system complete separation is not maintained for the reason that, in principle, the sound waves from each loudspeaker may reach both ears of each hearer. To minimize the degradation in directionality which follows from such loss of isolation, it has come to be the practice to employ many more than two individual channels, e. g. 4, 5, 6 or so. Since, in general, to maintain the quality of the reproduction the channels must all be of equally excellent frequency response and equally high power handling capacity, an installation of this kind is necessarily costly.

It is generally accepted that the sense of direction provided by a system of this character depends principally on the relative intensities of the sounds originating at different points as they are received by an auditor. Systems of this type are described in a group of papers published in Electrical Engineering for January 1934.

The present invention is predicated on the discovery that even in a stereophonic system, as distinguished from a binaural system, the directional impression is to a large extent dependent on the relative times of arrival of sounds originating at two different points. More specifically, it

2

has been discovered that the first sound to reach a hearer governs his impression as to the location at which this sound originates, even though it be somewhat faint and somewhat degraded; while his impressions of its loudness, quality, etc., may be governed largely by the loudness and quality of a similar sound arriving later from a different point. Accordingly, the invention provides two low capacity, mutually isolated side channels, each comprising a source, amplifiers as needed, and a reproducer; and a third high capacity channel comprising amplifiers, a reproducer, and an element which introduces the required delay. While this third channel may include a third source, it is preferred in the interests of economy of apparatus and to reduce annoyances to actors, etc. to supply the third channel with a mixture of the voice currents of the side channels. It has been determined that with such an arrangement the quality and power handling capacity of the two side channels may be far lower than those of the central channel, and that auditors judge of the quality of the system as a whole as being dependent on that of the third channel while receiving directional impressions based on the advance reception of sounds from the low capacity side channels.

The invention lends itself readily to reproduction, as in a motion picture theater, from a record of sound signals on photographic film, magnetic tape or the like, made elsewhere. In this situation the required delay between the side channel reproduction and the central channel reproduction may conveniently be secured merely by a displacement of the central channel reproducer heads in the direction of movement of the record.

The invention will be fully apprehended from the following detailed description of preferred illustrative embodiments thereof, taken in connection with the appended drawings in which:

Fig. 1 is a block schematic diagram showing a system embodying the invention;

Fig. 2 is a block schematic diagram showing a modification of the system of Fig. 1; and

Fig. 3 is a block schematic diagram showing an alternative to the system of Fig. 2.

Referring now to the drawings, Fig. 1 shows a studio stage 1 on which a drama may be enacted. The scene and the movements of the actors may be registered with a motion picture camera, not shown, for later reproduction in an auditorium which may be at a remote point. The sounds of the drama, including the speech of the actors, are picked up by two microphones 2, 3 which may be located at or near to the extremities of the stage 1 in a fashion to introduce the least interference with the action of the drama and the least annoyance to the actors. The left-hand microphone 2 is connected by way of a buffer to a first recording head 4 and the right-hand microphone 3 is connected by way of another buffer to a second recording head 5 whose characteristics are preferably identical with those of the first recording head. A two-track recorder 6 of a type well known per se causes the advance of a suitable elongated element 7 such as magnetic tape or photographic film past these recording heads. Each sound originating on the studio stage 1 reaches both microphones 2, 3. Unless it originates at a point which is equidistant from both microphones, the intensity at one microphone exceeds that at the other. Furthermore, in general, any sound originating off center of the stage reaches the nearer microphone at an earlier instant than it reaches the farther microphone. As a consequence of both of these effects the sound tracks 8, 9 recorded on the film or tape 7 differ one from the other in detail, while, being records of the same original sound, they are of course generally similar.

After such processing as the characteristics of the record member may require, it may be transported to a

distant point where its variations of intensity constitute virtual sound sources. There the tape may be advanced by any well known mechanism, not shown, mounted on a reproduction stage 10 or in the control booth of a moving picture theater, the auditorium of which is indicated at 11. The tape 7 as a whole moves past three reproducer heads, of which the first two 12, 13 are disposed in one transverse plane 14 of the tape while the third 15 is disposed in another transverse plane 16. The first reproducer head 12 generates currents proportional to the recorded intensity on one sound track 8 of the tape, which is in turn proportional to the left-hand microphone currents. These are transmitted by way of an amplifier 17 to a sound reproducer or loudspeaker 18 which may be mounted at the left side of the theater stage 10. Similarly the second sound reproducer head 13 generates currents determined only by the right-hand sound track 9 and therefore proportional to the intensity and waveform of the sound which reached the right-hand microphone 3 at the studio stage 1. These sound currents are transmitted by way of an amplifier 19 to a reproducer 20 which may be mounted at the right-hand in the center of the stage 10.

The third reproducer head 15 is arranged to generate currents proportional to the sum or average of the sound track intensities of both sound tracks 8, 9. It may comprise an aperture, optical or magnetic in dependence on the character of the record, which embraces both sound tracks. Its current output is supplied by way of an amplifier 21 to a third reproducer 22 which may be mounted in the center of stage 10.

The location of the third reproducer head 15 in a transverse plane 16 which is separated in the fashion shown from the plane 14 of the first two reproducer heads 12, 13 introduces a delay, indicated as δt , equal to the distance of separation between these two transverse planes divided by the velocity of movement of the tape 7. In accordance with a specific aspect of the present invention this delay is of the order of 10-50 milliseconds; i. e., it is equal to the time required for a sound wave to travel through a distance of 10 to 50 feet in air.

Furthermore, in accordance with the invention, while for high quality reproduction in a large theater all of the electrical and acoustical characteristics of the center channel, including the pickup head 15, the amplifier 21, the reproducer 22 and any additional networks which it may contain, should be of a quality and should have a capacity for handling power at least equal to those of conventional single channel systems, the same is by no means true of the two lateral channels. On the contrary, it has been experimentally determined that, provided the central channel be of suitably high quality and power handling capacity, an auditor 23 seated in the auditorium 11 receives an impression of sound reproduction of high quality and wide volume range originating, however, not at the centrally located reproducer 22 but at a point behind the screen or curtain 24 corresponding with the point of origin of the sound on the studio stage 1. This impression is believed to be due to the fact that, for each sound originating in the central reproducer 22, a premonitory sound, which may be both of lower level and of lower quality, reaches the auditor 23 from the laterally located reproducers. Such premonitory sounds appear to govern the auditor's sense of direction while the major sound which follows, delayed by 10 to 50 milliseconds, governs his impressions of quality and of volume level. The cost of a low quality, low capacity installation is of course much less than that of a high quality, high capacity, installation; indeed it is so much less that the cost of the three channels shown, of which only one is a high quality, high capacity channel, is substantially less than the cost of a conventional stereophonic installation having only

two reproducer channels both of which are of equally high quality and high capacity.

The delay which the invention contemplates between the reproduction in the lateral channels and the reproduction in the central channel may be introduced by any desired technique. In the event that a recording step is interposed between generation of the sounds and their reproduction as in Fig. 1, this delay may conveniently be introduced by a longitudinal offset between the lateral reproducer heads 12, 13 and the central reproducer head 15. When such intermediate recording step is not included, the required delay may be introduced, as shown in Fig. 2, by the connection, in series in the central channel, of a delay device 25 which may be a terminated wave transmission line, electromagnetic, acoustic or mechanical. It may also comprise an endless tape which may be mounted, for example, on the periphery of a drum which rotates continuously, each of its elements passing by a recording head, a reproducer and an eraser in turn, the separation between the recorder and the reproducer being adjusted in well known fashion to introduce the desired delays. In this case, moreover, the supply to the central reproducer 22 of currents which are the sum or average of the currents of the two microphones 2, 3, is advantageously achieved by the addition of a bridging path 26, including buffers 27, 28, which translate currents unidirectionally to a mixing point 29 to which the central reproducer 22 is connected.

For an auditor 33 seated in the back rows of an elongated auditorium 31 a similar result may be achieved merely with an acoustic delay, consequent upon the location of the lateral reproducers 18', 20' from 10 to 50 feet closer to such auditor than the central reproducer 22. Such an arrangement is shown in Fig. 3, which is open to the obvious disadvantage that incorrect impressions may be received by an auditor seated in one of the front rows of the auditorium.

The invention is not limited to the employment of three reproducer channels. For example, four microphones may be placed in a row across the studio stage, each being connected through an individual channel to a reproducer, these reproducers again being disposed in a row to obtain the benefits of the invention. A fifth reproducer may be mounted centrally on the reproducer stage and supplied with signal currents derived from all four microphones; i. e., with the average of their voice currents. Provided this average signal be delayed in the fashion described above and by the appropriate amount prior to its reproduction in a high capacity, high quality channel, auditors throughout the theater receive impressions of high grade sound reproduction having a pronounced directional feature.

Still other variations of the illustrative arrangements shown will suggest themselves to those skilled in the art. What is claimed is:

1. A stereophonic system which comprises a plurality of voice current sources spaced apart, a like plurality of sound reproducers, similarly spaced apart, a voice current channel of relatively low capacity supplying each of said reproducers with the signals of one only of said sources, an additional reproducer of relatively high capacity centrally located with respect to said plurality of reproducers, means for supplying said additional reproducer with all the frequency components of the average of the signals of all of said sources, and means for delaying all the frequency components of the sound reproduced by said additional reproducer as compared with the sounds reproduced by said plurality of reproducers by 10-50 milliseconds.

2. Apparatus as defined in claim 1 wherein said delaying means comprises an electrical delay device connected in tandem with said additional reproducer.

3. A stereophonic system which comprises a plurality of microphones spaced apart in relation to a sound source, means for making a record of the current of each of

5

said microphones, a like plurality of sound reproducers, similarly spaced apart, means for deriving a current from each of said records, a voice current channel of relatively low capacity individually connecting each of said reproducers to one of said current deriving means, an additional reproducer of relatively high capacity centrally located with respect to said plurality of reproducers, means for supplying said additional reproducer with all the frequency components of the currents of all of said current deriving means, and means for delaying all the frequency components of the sound reproduced by said additional reproducer as compared with the sounds reproduced by said plurality of reproducers by 10-50 milliseconds.

4. Apparatus as defined in claim 3 wherein said delaying means comprises an electrical delay device connected in tandem with said additional reproducer.

5. A stereophonic system which comprises a plurality of microphones, spaced apart in relation to a sound source, a recording element connected to each of said microphones, said recording elements being disposed in a plane, an elongated sensitive element, means for advancing said sensitive element past said recording elements in a direction transverse to said plane, thereby to form on said sensitive element individual record tracks

6

of the several microphone currents, a like plurality of sound reproducers, each of relatively low capacity, disposed similarly to said microphones, a reproducing element connected to each of said sound reproducers, each arranged to generate a current from one of said record tracks, said reproducing elements being disposed in a plane, means for advancing said record-bearing element in a direction transverse to the plane of said reproducing elements, an additional high capacity sound reproducer disposed centrally of said first named sound reproducers, an additional reproducing element connected to said additional sound reproducer and arranged to generate a current from all of said record tracks, said additional reproducing element being displaced from said transverse plane in the direction of advance of said record-bearing element.

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