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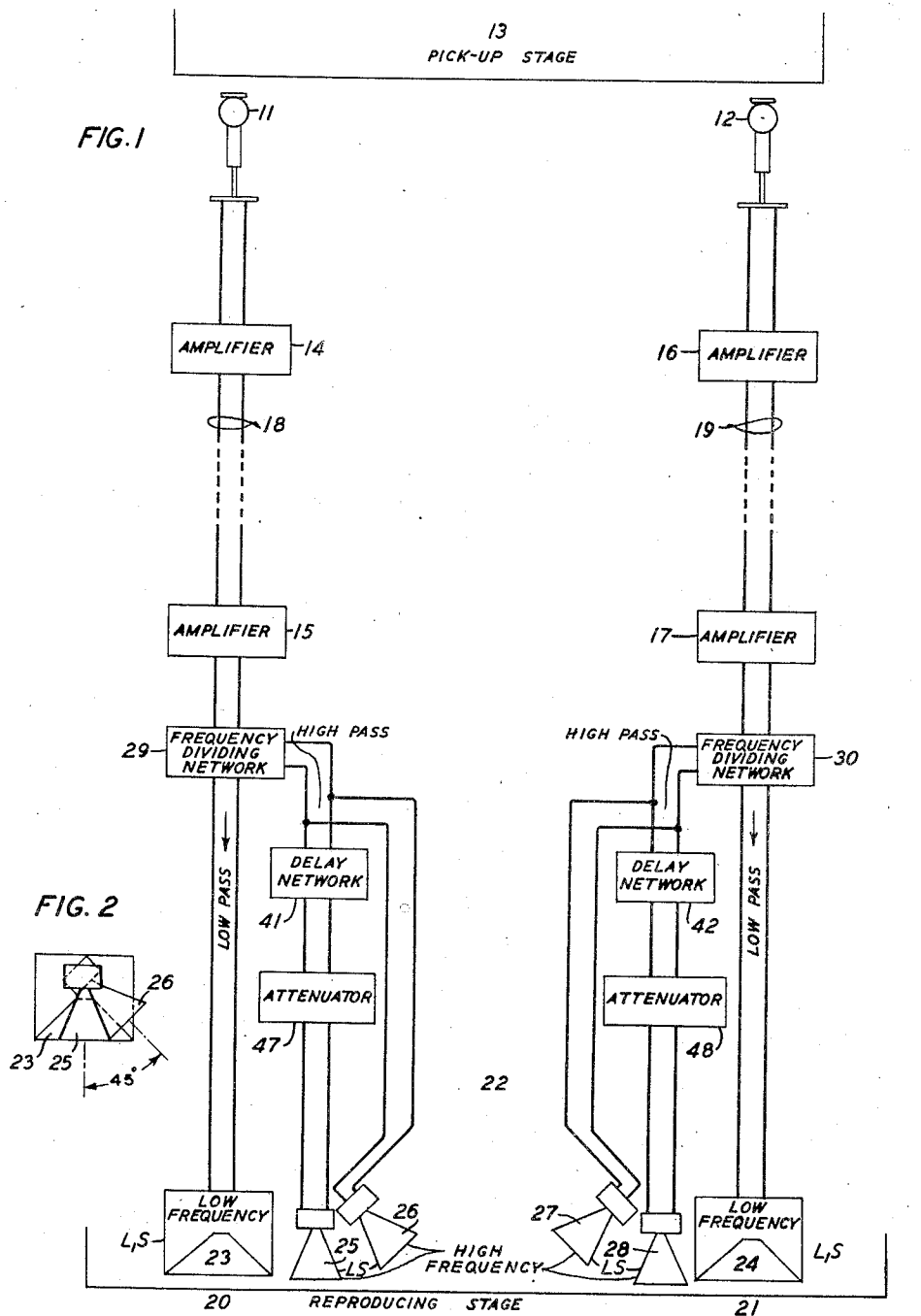
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2,137,032

SOUND REPRODUCING SYSTEM

Filed Sept. 30, 1936

2 Sheets-Sheet 1



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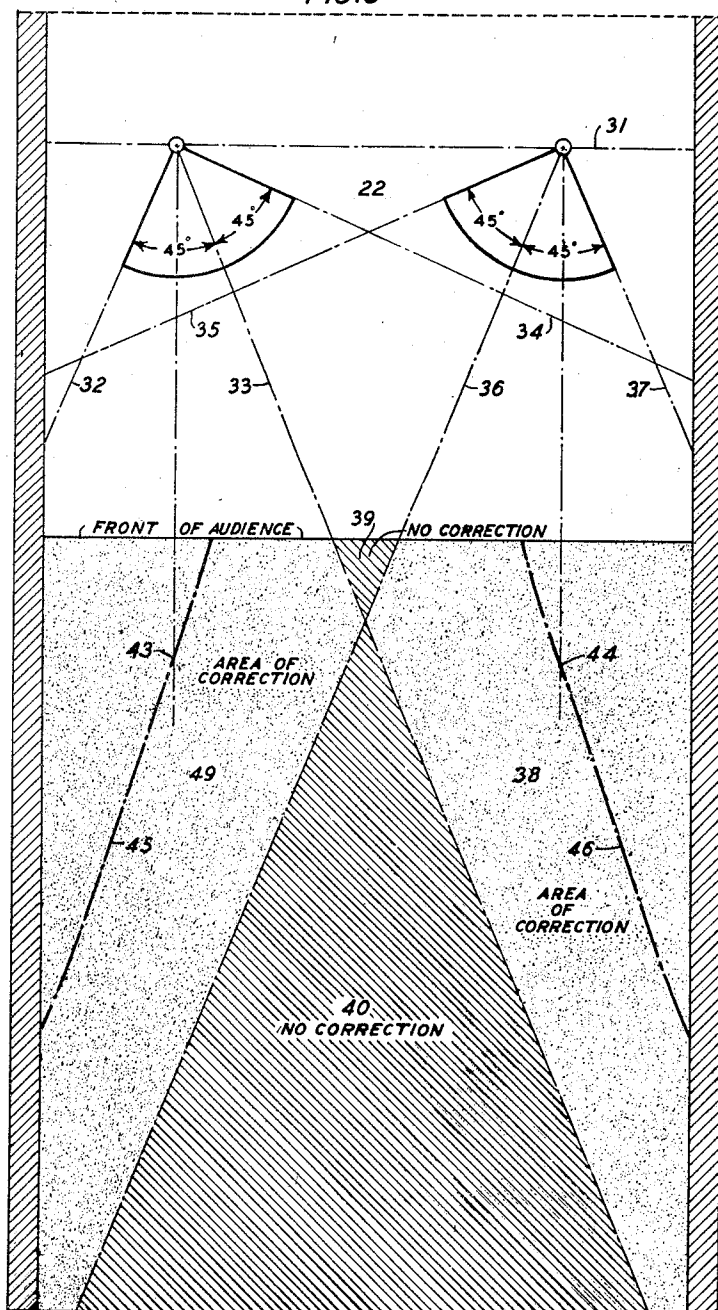
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FIG. 3



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SOUND REPRODUCING SYSTEM

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Application September 30, 1936, Serial No. 103,227

7 Claims. (Cl. 179--1)

This invention relates to the reproduction of sound with spacial distribution and the object of the invention is an improved system for producing the spacial or stereophonic effect.

It is well known in the art that when two microphones spaced in front of one stage are connected by separate lines to two loud-speakers spaced in front of another distant stage, the sounds reproduced by the loud-speakers appear to have a spacial or stereophonic distribution similar in general to that of the original sounds actuating the microphones.

It is also well known that while the localization of the virtual sound sources is quite accurate for observers in the central part of the auditorium, it is much less accurate for observers in lateral positions particularly those toward the front of the auditorium. In a copending application of W. B. Snow and J. C. Steinberg, Serial No. 79,882, filed May 15, 1936, there is disclosed a stereophonic system in which the accuracy of the localization is improved by arbitrarily accentuating the normal differences in the volume levels of the transmission channels produced by the motion of a sound source with respect to the pick-up microphones.

Observers in the central part of the auditorium are at substantially the same distance from both lateral loud-speakers whereas those in lateral positions are nearer to one of the loud-speakers than to the other so that sound waves from one loud-speaker reach a given lateral position in a shorter time than sound waves from the other loud-speaker.

It was pointed out in the application referred to above that, if with the real source stationary, an observer moves laterally from a central position, the virtual source shifts in the same direction. It will be observed that this shifting of the virtual source is toward the loud-speaker from which the direct sound reaches the observer first and applicant has found that it is due, in part at least, to the different arrival times of the direct sounds from the two (or more) loud-speakers.

In accordance with this invention this undesirable shifting is materially reduced by manipulating the "arrival time" in the direction of giving all observer positions more nearly the same arrival time from each loud-speaker for sound waves corresponding to original sound waves arriving simultaneously at both microphones. In general this requires that the sound waves projected in a path parallel to the side walls of the auditorium from each loud-speaker position be de-

layed with respect to those waves which are projected angularly across the auditorium.

It has been found that the lower frequencies have very little effect on localization and that the position of a virtual source is largely determined by the higher frequency components of the sound waves. In the preferred embodiment of the invention, therefore, one low frequency and at least two high frequency loud-speaker units are provided for each loud-speaker position. The low frequency unit and one high frequency unit at each position are placed to project sound parallel to the side walls and the other high frequency unit is placed with its axis of projection turned inward to direct sound waves angularly across the auditorium. The sound waves projected by the "parallel" units are delayed with respect to those projected by the "angular" units by electrical networks in the circuits feeding these units or by any other suitable form of delay mechanism. The amount of the delay required will vary with the requirements of each particular case and will depend on many factors such as the spacing of the units, the size and proportions of the auditorium, the section of the auditorium in which correction is most needed and various others.

It has also been found that this lateral shifting of the virtual source with changes in the observer's position laterally of the auditorium (the real source being stationary) may also be corrected for any given portion of the auditorium by arbitrary manipulation of the volume levels in the several reproducing channels. In other words, as the observer moves laterally to the right, for example, a virtual source which should be localized at center stage shifts toward the right side of the stage but, if at the same time the volume level of the channel on the left side of the stage is raised the proper amount, the localized source may be kept in its proper position. This effect may be utilized to advantage in combination with the manipulation of the arrival time as described more in detail below.

In the drawings:

Fig. 1 is a circuit diagram of one form of stereophonic reproducing system according to the invention;

Fig. 2 is a plan view of the preferred arrangement of the loud-speaker units; and

Fig. 3 is a diagram illustrating the application of the invention to a particular auditorium.

The two-channel system of Fig. 1 is of the general type described by J. C. Steinberg and W. B. Snow in *Electrical Engineering*, January

1934, and comprises essentially two microphones 11, 12 spaced in front of a pick-up stage 13 and connected by means of amplifiers 14 to 17 and transmission lines 18 and 19 to loud-speaker units 20, 21 in spaced relation on a distant reproducing stage 22.

The loud-speaker units may be of the general type disclosed in Fig. 5 of the article by E. C. Wentz and A. L. Thuras in *Electrical Engineering*, January, 1934, and comprise low frequency folded horns 23, 24 and high frequency horns 25, 26 and 27, 28. The several loud-speakers of each unit are connected to their respective channels through networks 29, 30 which apportion the band of frequencies transmitted between the high and low frequency speakers in the well-known manner. The network may divide the band at about 300 cycles in accordance with present practice but from the standpoint of proper localization according to this invention it is quite feasible and in some cases it may be desirable to divide the band at 1,000 cycles or even 2,000 cycles.

For convenience of illustration the high frequency units have been shown alongside the low frequency units but in practice it will usually be preferable to mount them above the low frequency units as shown in Fig. 2 and directed at different angles as described more in detail below.

The amount of delay introduced, the horizontal angle over which the high frequency units project the sound waves and the distribution of the units with respect to the horizontal axis of the reproducing area will vary widely with the requirements of each particular case but the general principles involved will be understood by considering the specific application illustrated in Fig. 3.

In Fig. 3 the high frequency units are located on the reproducing stage with a spacing which may be of the order of twenty feet, with the centers of curvature of the spherical waves emitted from the horns on the line 31. The horns in this case each cover a horizontal angle of 45 degrees as indicated by the dotted lines 32 to 37, the horns of the loud-speakers 25 and 28 cover the areas between the lines 32, 33 and 36, 37 respectively, and the horns of the loud-speakers 26 and 27 cover the areas between lines 33, 34 and 35, 36 respectively.

If we assume that the nearest observers are at a distance at least equal to the spacing of the loud-speakers, the area over which the sound is projected comprises the two lateral areas 49 and 38, the front central area 39 and the rear central area 40. The area 39 receives its direct sound without delay from the loud-speakers 26 and 27 and the area 40 receives its direct sound from the loud-speakers 25 and 28 which have networks 41, 42 giving equal delays so that the relative arrival times for sounds from the two channels is unchanged for these central areas in which the localization is quite satisfactory as explained above.

The lateral area 49, however, receives delayed sound from loud-speaker 25 and undelayed sound from loud-speaker 27 and since all observer positions in this area are nearer to loud-speaker 25 than to loud-speaker 28, the delay in the projector from the loud-speaker 25 will tend to equalize the arrival times throughout this area. Similarly the lateral area 38 receives undelayed sound from loud-speaker 26 and sound from loud-

speaker 28 which is delayed to make the arrival times more nearly equal throughout this area.

The velocity of sound in air is about 1,100 feet per second so that about one mil-second delay is required to equalize the arrival times for each one-foot difference in the lengths of the air paths from the observer's position to the two loud-speakers. Since correction is needed most in the front lateral positions, the delay introduced by the networks 29 and 30 should ordinarily be chosen to give best results in these positions. In the present case the arrival times are equalized for positions 43 and 44 directly in front of the loud-speakers 25 and 28 by networks giving delays of about six mil-seconds to correspond with the six-foot difference between the two air paths in each case. This delay will also equalize the arrival times for any other positions on the lines 45 and 46. The portions of areas 49 and 38 which are between the lines 45 and 46 will be slightly over-equalized while the portions outside these lines will be slightly under-equalized, so that the amount of delay introduced will always be a compromise and will depend upon the location of the area in which correction appears to be needed most in a particular case.

It will be understood that in practice the area covered by each loud-speaker is not as clearly defined as the drawings would indicate and because of this and various other factors, it will generally be found advisable to vary the amount of delay introduced, to adjust the positions of the loud-speakers and make any other changes that seem to be indicated after the usual listening tests.

The effect of manipulating the "arrival time" may be supplemented by manipulating volume levels in the system shown by operating the angularly directed loud-speakers 26 and 27 at a higher output level than the loud-speakers 25 and 28. Within the correction areas 49 and 38 the higher level of the sound projected angularly into the area in each case will supplement the effect of the arrival time manipulation in keeping the localizing more nearly correct for these lateral positions. This arrangement is particularly valuable in cases where sufficient correction cannot be obtained by varying the arrival time alone without introducing so much delay as to produce undesirable echo effects.

Since the low frequencies have little effect on localization, as explained above, the control of the volume levels may be limited to the higher frequencies and may be obtained by the use of attenuating networks 47 and 48 in the circuits supplying the loud-speakers 25 and 28, by designing these loud-speakers to operate at lower efficiency particularly in the upper portion of their range as compared with the loud-speakers 26 and 27, or by any other suitable means.

While the invention has been described with reference to a particular embodiment for purposes of illustration, it will be understood that the general principles of manipulating the arrival time or the volume levels or both for different observers' positions to improve the accuracy of localization is equally applicable to stereophonic systems of other types. It may be applied to systems having three or more channels and it may be used in conjunction with other correction schemes such, for examples, as those using means for accentuating normal level differences between the channels disclosed in the application referred to above. In some cases it may be advantageous to use three or more directive loud-speakers at

each position with each loud-speaker designed to project sound in properly timed relation over a smaller or larger angle than 45 degrees as the case requires.

- 5 It will also be understood that the necessary delays may be introduced without the use of networks by means of loud-speakers having a relatively long air path between the receiver unit and the horn mouth. Moreover, the several loud-speakers at each position may be replaced with
10 a single unit having a horn with subdividing partitions giving horn sections of different lengths to provide the necessary delays and, if desired, of different cross-sectional areas to provide the
15 volume level differences required to assist in correcting localization. The invention is therefore intended to be limited only by the scope of the following claims.

What is claimed is:

- 20 1. In a stereophonic sound reproducing system, two transmission lines carrying currents representing waves from the same sound source at different pick-up positions, and means for reproducing the sounds with spacial distribution comprising
25 loud-speakers spaced in groups before a sound reproducing area, each group being connected to one of the lines, two loud speakers, one in each group, disposed with their axes of projection substantially parallel to each other, two other
30 loud-speakers, one in each group, angularly disposed with their axes of projection intersecting each other, and means for delaying the projection of sound from the parallel loud-speakers with respect to the sound projected from the angularly
35 disposed loud-speakers.
2. A system according to the preceding claim in which sound energy is projected at a higher volume level from the angularly disposed loud-speakers than from the parallel loud-speakers to improve the accuracy of localization for lateral
40 observer positions in the reproducing area.
3. In a stereophonic reproducing system, a plurality of transmission lines carrying currents representing sound waves from the same source at
45 different pick-up positions, a plurality of groups of loud-speakers each connected to one of the

lines and disposed in spaced relation with respect to the other groups before a sound reproducing area, the loud-speakers of each group being disposed to project sound energy to different lateral portions of said area, and means for delaying the
5 projection of energy by some of the loud-speakers to produce more nearly equal arrival times at all positions within the area for sound waves projected to said positions by the several loud-speaker groups.

4. A system according to claim 3 having means for attenuating the delayed energy projected by some of the loud-speakers to increase the accuracy of localization in portions of the reproducing area.

5. In a stereophonic sound reproducing system, a plurality of transmission lines carrying currents representing sound waves from the same source at different pick-up positions, a sound reproducing
10 area, a group of loud-speakers connected to each line, said group being disposed in spaced relation before said area, a loud-speaker in each group projecting sound waves angularly across the area, and a second loud-speaker in each group projecting sound waves toward the back of the area in
15 delayed relationship to the waves projected across the area.

6. A system according to claim 5 having means for supplying energy to the angularly projecting loud-speakers at a higher level than the energy
20 supplied to the other loud-speakers.

7. In a stereophonic sound reproducing system, two transmission lines carrying currents representing waves from the same sound source at different pick-up positions, two spaced loud-speakers
25 connected to the lines and projecting sound toward a reproducing area, two other spaced loud-speakers each connected to one of the lines, with their axes of projection directed angularly across the reproducing area, and means for delaying the
30 projection of sound from the first-mentioned loud-speakers with respect to that projected by the angularly directed loud-speakers to improve the accuracy of localization for lateral observer
35 positions in the area.

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