

Nov. 5, 1935.

J. P. MAXFIELD

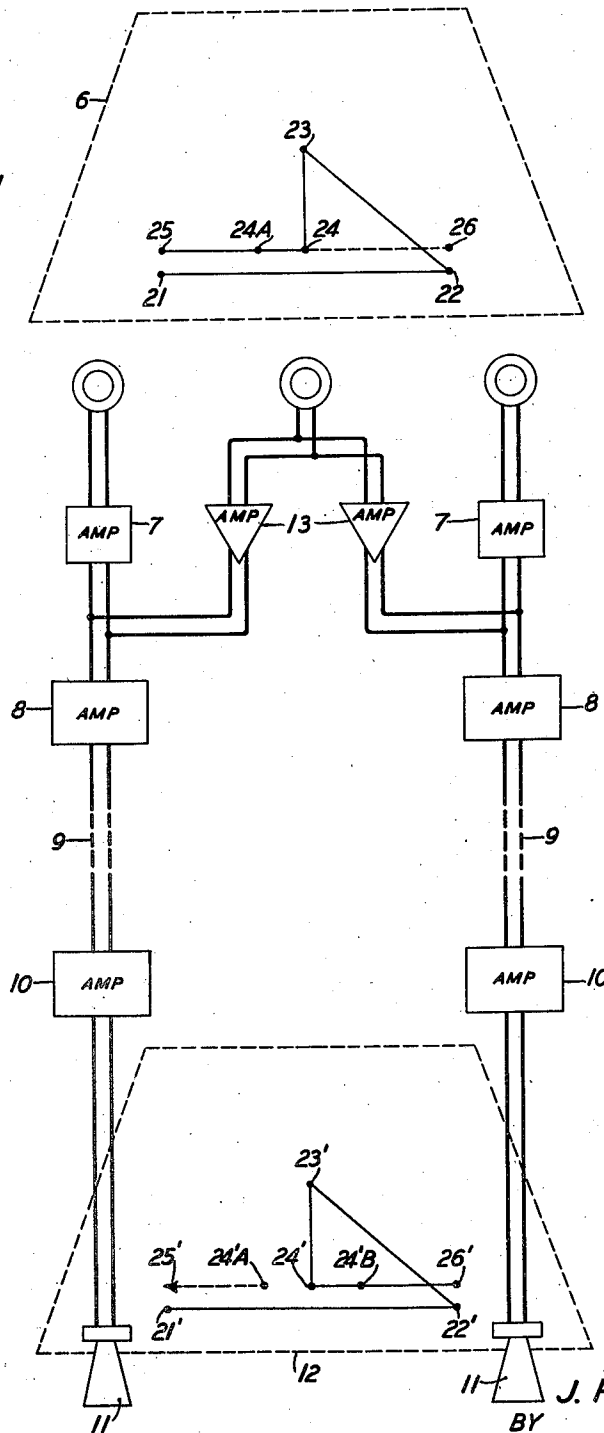
2,019,615

SOUND TRANSMISSION SYSTEM

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2 Sheets-Sheet 1

FIG. 1



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FIG. 2

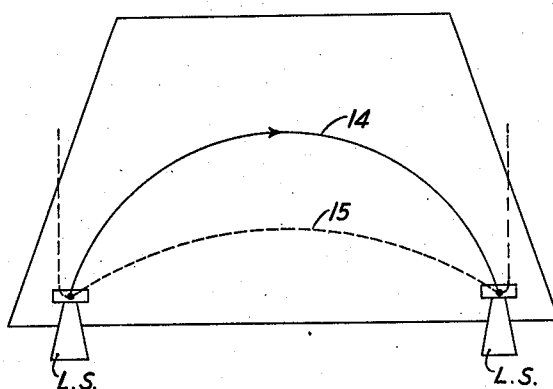
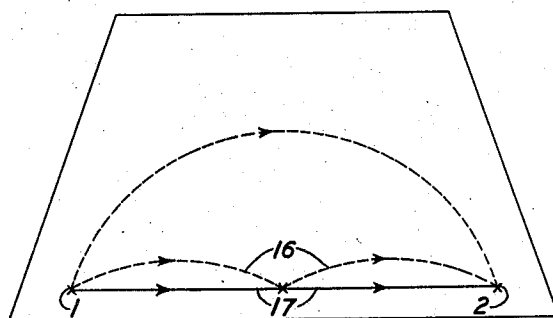


FIG. 3



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SOUND TRANSMISSION SYSTEM

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7 Claims. (Cl. 179—1)

This invention relates to sound transmission systems and more particularly to those capable of reproducing sounds in their proper auditory positions.

Heretofore many attempts have been made to create in the mind of the listener the illusion of a special distribution of reproduced sound instead of the "point source" effect obtained from a single loudspeaker. This illusion is very necessary for a realistic reproduction particularly in reproducing orchestral music or speech, music or other sound emanating from a moving source such, for example, as a speaker or singer walking about on a stage.

Of the several distinct types of such systems only two are of particular interest with respect to the present invention. The first of these is the so-called "binaural" type wherein the orientation of the source of sound is obtained by producing the same (or a slightly exaggerated) phase difference in the waves reaching the two ears of the listener as when the original sounds are heard at the pick-up point. Such a system includes two pick-up microphones spaced apart about the width of the human head, a pair of head receivers and separate transmission circuits between the microphones and the receivers. This is a true binaural system as described in more detail in such patents as 1,508,432 to Wier, September 14, 1924 and Fletcher et al. 1,624,486 of April 12, 1927.

The second type of system which should not be confused with the first is disclosed by Rosenberg in British Patent 23,620 of 1911. Rosenberg's system is described with reference to its application to a sound picture system and comprises essentially a pick-up microphone at each front corner of the recording stage, separate recording and reproducing channels and two loudspeakers on the reproducing stage in the same relative positions as the microphones. In systems of this type the sounds emitted from the receivers coalesce in the air so that sounds from both receivers are heard by both ears of the listener. Obviously, there can be no phase difference in the components reaching the ears from the two loudspeakers such as will orient the sound as in the case of a true binaural system, but with this arrangement some degree of auditory location can nevertheless be obtained. With high quality apparatus of the type described in a copending application of Harvey Fletcher, Serial No. 665,702, filed April 12, 1933, a system of the Rosenberg type gives fairly satisfactory lateral distribution, but the forward and backward orientation is rather

poor at center stage due to what is known as the "bowing" effect. With this system the reproduction of an actor walking across the front of the producing or dummy stage sounds as if the actor were traversing an arc, the central portion of which is at least half-way to the back wall of the stage.

The prior art also includes a decided improvement on Rosenberg's system, namely, the addition of a third independent channel comprising a third microphone disposed between the other two, a transmission circuit and a third loudspeaker similarly disposed between the other two loudspeakers. Systems of this type are disclosed in French Patent 381,901 to Gaumont and in Patent 1,589,139 to Foley, June 15, 1926 and, with high quality channels of the type already referred to, such systems give fairly satisfactory localization of sound in any portion of the area corresponding to the producing stage. A three-channel system, however, is inherently very expensive and for some applications such as the production of sound effects in theatres it has the even more serious disadvantage of requiring a bulky loudspeaker unit in the central portion of the reproducing stage which ought to be entirely unobstructed in order to obtain the desired visual effect.

The object of the present invention is a system for reproducing sound in true auditory location which combines the simplicity of a two channel system with an ability to localize the sound equal to that of a three-channel system.

The operation of two and three-channel systems of the Rosenberg and Foley or Gaumont types has heretofore been explained by a "relative loudness" theory which is, briefly, that the apparent source of the reproduced sound at any instant is determined by the ratio of sound intensity from the two loudspeakers. Applicant has found, however, that the apparent lateral location depends upon the ratio of the intensities of the direct sound at the two microphones and not on the ratio of the intensities of the total sound. (The total sound at each microphone of course includes the intensity of the direct sound plus the intensity of the reflected or reverberant sound. For many positions of the sound source on the dummy stage the intensity of the reverberant sound may be five to ten times that of the direct sound at one or more of the microphones). His experiments therefore show that the controlling factor is the ratio of the intensities of the direct sounds only acting on the several microphones and that the reverberant

sound has very little influence on the lateral location. The lateral displacement of an apparent source of reproduced sound (for a two-channel system) depends on the relative values of this intensity of direct sound at the two microphones while the apparent nearness to the foreground (for a two or three-channel system) depends on the largest value of the ratio of direct to reverberant sound at any of the microphones used. (This occurs, naturally, at the nearest microphone).

In accordance with the general feature of this invention, applicant has therefore been able to eliminate the center transmission channel and its expensive amplifier and bulky loudspeaker entirely and at the same time to obtain not only as accurate auditory perspective, but also the ability to locate a sound at the front of the stage in any lateral position. This is accomplished, according to the invention, by controlling the apparent foreground position when it occurs at the front center of the stage by introducing into both channels currents corresponding to a pick-up position giving a large ratio of direct to reverberant sound for these sounds. This is preferably done by connecting a single centrally located microphone to both outside channels through unilaterally conducting devices. Such a system combines the advantages inherent in the two-channel system, namely, relatively lower cost and an unobstructed reproducing stage with the more accurate localization of sound obtainable with three channels. Since it is essential that the outside transmission channels be kept effectively isolated from each other, the central microphone must be connected to each of these channels through a separate amplifier or other suitable unilaterally conducting device.

Since the apparent distance of a reproduced sound from the foreground increases as the ratio of the direct sound to the reverberant sound at the nearest microphone decreases and since the central microphone delivers to both channels currents with a high value of this ratio for sounds originating near the central microphone, such sounds as judged by the output of the two loudspeakers, will appear to come from their proper position at the front center of the stage and "bowing" is thereby eliminated without using the third transmission channel. The lateral position will not be changed, at the centre, since the currents delivered to the two loudspeakers from the central microphone being equal in value, represent the same intensity of direct sounds and therefore locate the sound at the centre of the reproducing stage.

The invention may be used for direct reproduction of sounds at a location more or less remote from the sound source or the currents representing the sounds in the two channels may be recorded for subsequent reproduction.

In the drawings, Fig. 1 is a schematic representation of applicant's sound reproducing system with the phantom third channel;

Fig. 2 shows the effect of varying the microphone and loudspeaker spacing in a two-channel system; and

Fig. 3 shows the distribution of sound obtained with the several types of systems discussed above.

In general the apparatus used in the circuit of Fig. 1 is preferably the same as the corresponding apparatus in the three-channel system disclosed in Fletcher application referred to above. Three high quality electrodynamic pick-ups 5 are located in front of the "dummy" or producing stage

6 to receive the sounds produced by the orchestra or other sound source. For good results these pick-ups must be positioned far enough from the front of the stage to receive direct sound effectively from any part of the stage. The two lateral microphones are connected to small preliminary amplifiers 7, transmitting amplifiers 8, the transmission lines 9, receiving and power amplifiers 10 and loudspeaking receivers 11 located on the "real" or reproducing stage 12 in similar relative lateral positions as the pick-ups 5. The central pick-up is associated with the input circuits of two separate preliminary amplifiers 13 which may be similar to amplifiers 7. The output circuits of the amplifiers 13 are connected respectively to the input circuits of the transmitting amplifiers 8 so that the output of the central pick-up is divided equally between the lines 9 without conductively associating either lateral pick-up with the other transmission line. It will be understood that other schemes may be used for this purpose. For example, any other suitable unilaterally conducting devices may be substituted for the amplifiers 13 but these amplifiers are of small capacity, inexpensive and hence well adapted to the purpose.

In cases where the stages are relatively close together so that the lines 9 are short, amplifiers 8 may not be required but where the stages are located in widely separated cities multi-stage amplifiers and other auxiliary transmitting and receiving apparatus may be used to insure that the signal currents maintain their proper amplitudes. The loudspeakers 11 should be capable of responding to a wide range of frequencies and they are, at present, preferably of the multiple-unit type disclosed in the above Fletcher application.

The deficiencies of a two-channel system particularly with respect to locating sounds originating at the front center of the stage has already been mentioned. This is shown graphically by the curve 14 of Fig. 2 which represents the apparent path on the real stage of an actual source moving across the front of the dummy stage. The reason for this bowing effect in the apparent path of reproduced sound will be more clearly understood by noting how the ratio of the direct to the average reverberant sound varies for each microphone as the real source moves across the stage. This ratio which for convenience may be termed the "closeness factor" and denoted by "C" with subscripts to indicate the microphone involved, C_L being for the left-hand microphone, and C_R for the right-hand microphone.

The average reverberant sound is substantially the same for all positions in the room but the direct sound acting on a microphone is inversely proportional to the square of the distance to the sound source. Hence as the source moves from one microphone to the centre, the value of C for the nearer microphone will vary between wide limits from its maximum to its minimum values. Disregarding for the present the apparent motion of the sound in a lateral direction, the bowing effect is explained as follows: When the sound source is close to the left-hand microphone, i. e., where the direct sound is a maximum for this microphone and a minimum for the other, C_L is at its maximum value. As the sound source moves toward the right across the front of the stage, the direct sound decreases for the left-hand microphone so that C_L progressively decreases and the sound appears to move toward

the back of the stage. This backward movement continues until the real source reaches the center of the dummy stage where $C_L = C_R$. From here on C_R becomes the controlling ratio and the reproduced sound again moves forward as the real source proceeds to a position in front of the right hand microphone. Therefore when the real source is at front center stage, the closeness factors will be the same for both microphones but much less than when the source is directly in front of either microphone and since the apparent fore and aft position is determined by the largest value of C for any of the microphones used, the sound will appear to come from a point at center stage but a considerable distance back from the front. For intermediate positions the fore and aft error is reduced due to the increase in the closeness factor for the nearer microphone so that the path traced is of the general shape indicated by curve 14 of Fig. 2. The fore and aft error at center stage can, of course, be materially decreased by moving both microphones toward the center of the stage in which case the apparent path of the reproduced sound is represented by the dotted curve 15. With this arrangement, however, there is a corresponding loss of "spread" that is to say, a sound source moving from one of the relatively closely spaced pick-ups to the other, is reproduced as traversing the whole distance between the widely spaced loud-speakers and sounds produced at the right or left of both pick-ups are concentrated behind the corresponding loudspeaker as shown by the straight end portions of the curve 15. This scheme, therefore, avoids bowing at center stage only by sacrificing distribution or spread for sounds in other portions of the stage.

The addition of the center channel disclosed in the Fletcher application and in the Foley patent provides a microphone with a large close-up factor for sounds at front center stage which controls the fore and aft location of these sounds and reproduces them in substantially their proper position as shown by curve 16. But as already pointed out even this arrangement leaves much to be desired because of both its high cost and the necessity of obstructing the central portion of the reproducing stage with a third loudspeaker.

By unilaterally connecting this third microphone to both outside channels and eliminating the center transmission line and its receiver, this close-up sound is reproduced from both loudspeakers and since this microphone has the largest close-up factor for sounds at front center stage, the output of this microphone is controlling in fixing the sounds reproduced from center stage in their proper fore and aft positions. Not only is the fore and aft localization correct within the limits of observation but the lateral movement of sound across the stage is also correct.

Many systems proposed heretofore which apparently gave rather good localization both laterally and fore and aft relied on the psychological effect of an apparent source of sound such as a pantomimer or a moving picture associated with the reproducing stage to fix the various sounds in their proper positions. The presence of such an apparent source will compensate to a considerable extent for deficiencies in the reproducing system so that the sound will appear to follow the pantomimer in many cases where with an empty reproducing stage, the sound would not be localized in any particular place.

The fact that applicant's good localization is not dependent on this psychological effect has

been shown by having a singer traverse path 21, 22, 23, 24, 25 on the dummy stage (Fig. 1) and a pantomimer simultaneously move along path 21', 22', 23', 24', 26' on the real stage 12, the observers being entirely unaware of the configuration of the path being taken by the singer. Under these conditions observers unanimously agreed that the voice followed the pantomimer up to point 24' and for some small distance beyond in the direction of point 26' due to the psychological effect. The localization of the sound was so definite, however, that when the pantomimer reached some such point as 24'B the voice had definitely located itself at 24'A in accordance with the singer's actual position 24A and it continued to point 25' while the pantomimer moved silently to point 26.

It will be understood that while the invention has been described with reference to a single moving sound source for purposes of illustration, the ability to localize sounds in any part of the stage is equally important when a number of sound sources are involved, for example, the reproduction of orchestral music is much more realistic when rendered by applicant's system rather than by one in which the localization is poor due to bowing and inaccurate lateral orientation.

Various modifications of applicant's system will occur to those skilled in the art. For example, while a single microphone connected to both channels in the manner described is preferred, substantially the same results can be obtained, at least theoretically, by using two separate microphones located close together at the central pick-up position, one microphone being connected to each channel. With this arrangement, however, care must be taken to use matched microphones, to locate them so that they are substantially in the same sound field and to keep their outputs equal within close limits.

In some cases, as for example when the voice of a solo artist is to be reproduced at the front center of the reproducing stage, the central microphone (or group of microphones) may be located at some distance from its preferred position near the front center of the dummy stage and shielded in such a manner that it is actuated largely by direct sound. With the phantom third channel system of the present invention it will be obvious that the relative loudness of the reproduction of the artist with respect to the orchestral background is readily controllable in the same manner as when an independent third channel is used for this purpose.

It will be observed, however, that all such systems control the localization of sounds at front center stage in essentially the same way, namely, by introducing into both channels currents from pick-up devices adapted to be actuated largely by direct sounds for sources in this portion of the stage.

What is claimed is:

1. In a transmission system, the combination with a pair of independent transmission channels each comprising sound pick-up means, a transmission line and a receiving device of a phantom third channel for transmitting sounds from a source intermediate the pick-up means comprising means for transmitting over the lines to both receiving devices currents corresponding to a pick-up position having a higher closeness factor than either of said pick-up means for sounds from said source.

2. In a transmission system, the combination

- with a pair of independent transmission channels each comprising sound pick-up means, a transmission line and a receiving device, of a phantom third channel for transmitting sounds
5 from a source intermediate the pick-up means comprising means for introducing into both of the channels and receiving devices currents corresponding to sound waves existing near said source.
- 10 3. In a transmitting system, the combination with a pair of independent transmitting channels each comprising a pick-up microphone, a transmission line and a receiving device, of other microphonic means disposed between said pick-
15 up microphones and connected across each of the channels.
4. In a transmitting system, the combination with a pair of independent transmitting channels each comprising a pick-up microphone, a
20 transmission line and a receiving device of a third microphone and a separate unilaterally conducting device connecting said microphone across each of the channels.
- 25 5. In a system for reproducing sounds in their proper relative locations, the combination with a lateral microphone on either side of a source of sound, two remote receivers laterally disposed with respect to the desired virtual source of the

reproduced sound, and transmission lines connecting the receivers with the lateral microphones, of a central microphone disposed between the lateral microphones and means including a pair of unilaterally conducting devices
5 connecting the central microphone across each of the transmission lines.

6. A system for reproducing sounds in their proper relative locations, comprising in combination a sound producing area, a corresponding
10 sound reproducing area remote therefrom, two lateral microphones in front of the producing area, two receivers correspondingly located with respect to the reproducing area, transmission
15 lines between the microphones and the receivers, and a third microphone disposed intermediate the lateral microphones and means for unilaterally connecting the third microphone with both
transmission lines.

7. In a transmitting system the combination
20 with two spaced pick-up microphones, a transmitting line for each microphone, and other pick-up means, of an amplifier for each line having its output circuit connected across the line
25 and its input circuit connected to the other pick-up means.

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