

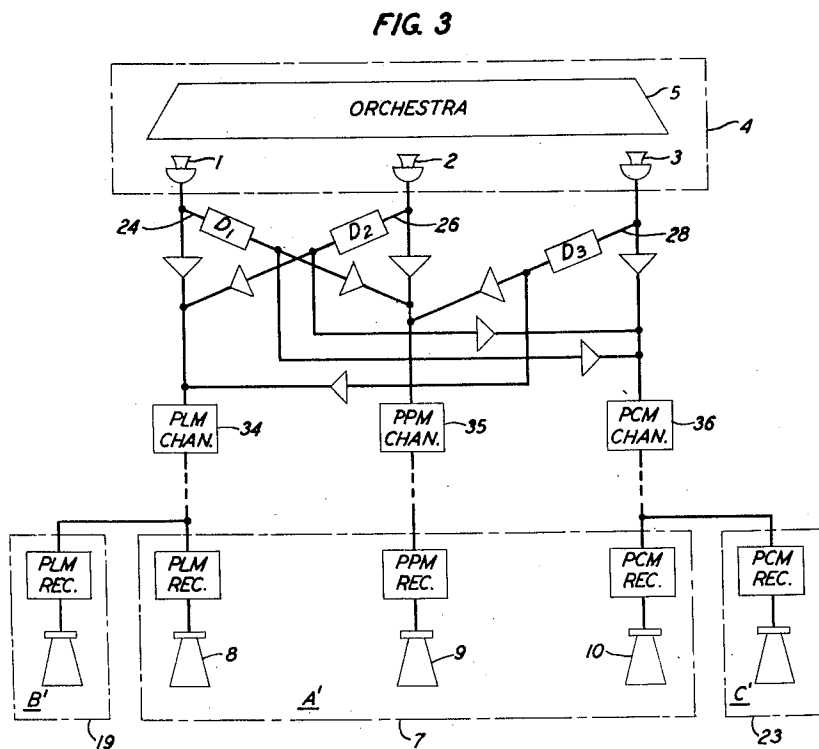
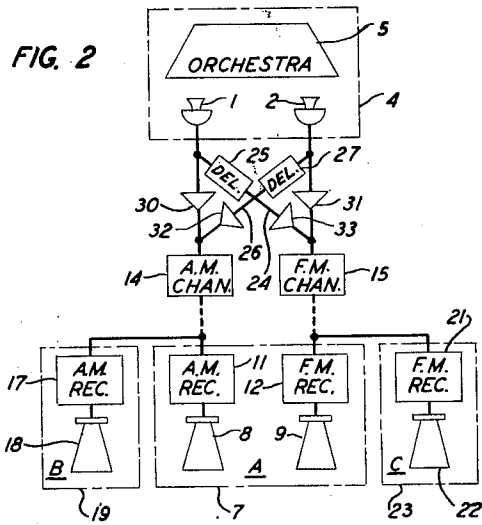
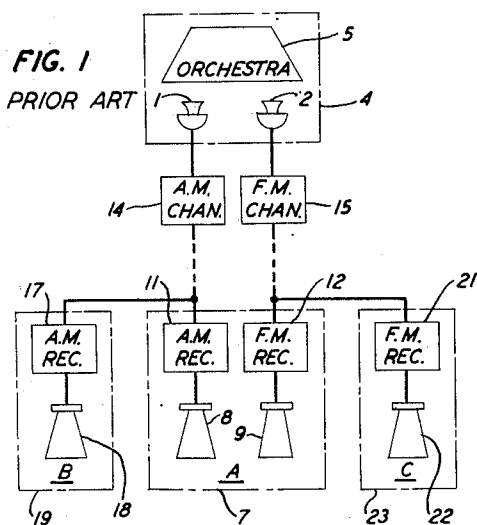
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MONAURAL-BINAURAL TRANSMISSION OF SOUND

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MONAURAL-BINAURAL TRANSMISSION OF SOUND

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This invention relates to the high quality transmission of sound signals, e. g., musical programs. Its principal object is to provide for the interchangeability, at the choice of the listener, as between multichannel stereophonic reproduction and single channel transmission.

As the art of transmitting and reproducing sound signals advances, an increasing amount of attention is paid to refinements. One such refinement, which is presently becoming of increasing importance, is to increase the listener's impression of realism or "presence" by employment of binaural or stereophonic techniques. In its simplest form a system of this character comprises at least two wholly independent channels leading from a studio housing an extended sound source, e. g., an orchestra engaged in the performance of a musical composition. Each channel is complete with a microphone at the studio, a sound reproducer in the listener's room, and an intervening transmission medium. Various well known techniques may be employed to maintain complete independence of each channel from the others. For example, if the program is broadcast by radio transmission the broadcast carrier frequencies may be different. A presently popular approach is to employ the same carrier frequency for both of two channels, utilizing the output of one microphone to modulate the amplitude of its carrier wave and utilizing the output of the other microphone to modulate the frequency of its carrier wave.

With such systems the microphones are ordinarily placed on a line parallel with the front of the stage and are spaced apart along this line, one being placed toward the right-hand end of the stage and the other toward the left-hand end.

When two such channels are individually connected to earphones in such a fashion that the listener's right ear hears only the output of one microphone and his left ear hears only the output of the other, very pronounced, even startling, impressions of the spatial distribution of the sound source are the result. To avoid the inconvenience of wearing earphones and to permit all the occupants of a room to hear the program it is customary to employ loudspeakers instead of individual earphones. When such loudspeakers are appropriately disposed a realistic impression of the spatial disposition of the orchestra or other sound source is the result.

It happens, however, that it is not always convenient or even possible for a listener to utilize both of such channels. When, for instance, in the example given he is provided only with an amplitude modulation radio receiver and a single speaker the music or other sounds which he receives are unbalanced to an annoying extent. This is because of the asymmetrical disposition of the single microphone to which his receiver is in effect connected. Thus the quality of the musical program which he receives is distinctly poorer than it would be with a single microphone symmetrically located in the studio.

The same situation arises in still more extreme form when three or more channels are employed, in which

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case one microphone is located close to one end of the studio stage, another microphone is located close to the other end of the studio stage, while the third is located at the center of the stage and too close to the central part of the sound source for balanced reproduction. In this situation a listener who is in effect connected to only one of the end microphones receives an impression of a highly unbalanced performance.

The present invention provides a cure for this situation, permitting the single channel listener to take full advantage of all the studio microphones which are in operation. It does so by the addition of a cross-coupling path from the output point of each microphone to the input points of the transmission channels connected to all the other microphones. Each such cross-coupling path includes a delay device which is proportioned to delay signal transmission through such cross-coupling path by about 5–30 milliseconds relatively to the transmission over the direct paths. The cross-coupling paths are preferably provided with unidirectional devices such as buffer amplifiers to ensure that transmission shall take place only in the desired direction. With this arrangement the single channel listener receives sound signals originating in all the microphones, the signals originating in the microphone to which he is directly connected being undelayed and the others delayed by 5–30 milliseconds. The impression formed in his mind by a delay of this magnitude is merely one of reverberation; i. e., his impression is that the sound signals are originating in a "live" studio as distinct from a "dead" one. On the other hand, a listener who is provided with the two or more channels and takes full advantage of the disposition of the microphones at the studio for the sake of the realism thus produced receives the output of each microphone as in the ordinary stereophonic system. He also receives in each of his reproducers a delayed reproduction of the output of each other microphone. Such delayed reproduction, however, does not noticeably reduce the sense of directionality achieved by way of the undelayed reproduction. The invention thus takes advantage of the "Haas" effect, now a well established phenomenon which is described by its discoverer in *Acoustica*, vol. 1, No. 2, pages 49–58, 1951, wherein it is shown that a hearer's impression of the direction from which he receives a sound is determined principally by which one of two sounds of like character first reaches him.

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 conventional binaural sound transmission system reduced to its simplest terms;

Fig. 2 is a block schematic diagram showing a binaural-monaural sound transmission system in accordance with the invention; and

Fig. 3 is a block schematic diagram showing an extension of the system of Fig. 2 to a number of channels greater than two for stereophonic-monaural transmission.

Referring now to the drawings Fig. 1, shows a left-hand microphone 1 and a right-hand microphone 2 spaced apart on the stage of a studio on which is an extended sound source 5 such as an orchestra engaged in the performance of a musical composition. In the residence 7 of a first listener A which may be located at a distance, are two sound reproducers 8, 9 spaced apart for stereophonic reproduction, each supplied with voice frequency signals from a receiver 11, 12. The receiver 11 of the left-hand reproducer 8 is coupled to the left-hand microphone 1 by way of a first transmission channel 14 and the receiver of the right-hand reproducer 9 is coupled to the right-hand

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microphone 2 by way of a second transmission channel 15. These channels, which may be of any desired variety, are completely decoupled from each other, as for example by employment of amplitude modulation radio transmission in the left-hand channel and frequency modulation transmission in the right-hand channel. The respective receivers 11, 12, are of course designed accordingly. With this arrangement the listener A receives high quality sound reproduction which includes a realistic impression of the spatial distribution of the orchestra 5 or other sound source in the studio 4.

An additional amplitude modulation receiver 17 and a sound reproducer 18 are coupled to the left-hand channel 14. They are indicated as being located in the residence 19 of a second listener B who is provided with no other receiving or reproducing facilities. A frequency modulation receiver 21 and a reproducer 22 are coupled to the right-hand channel 15 and are shown as being located in the residence 23 of a third listener C who again is provided with no other receiving or reproducing facilities.

Evidently the listener B, with his amplitude modulation receiver and reproducer, receives the output only of the left-hand microphone 1, while the listener C with his frequency modulation receiver and reproducer receives the output only of the right-hand microphone 2. Because of the asymmetrical location of each of these microphones with respect to the orchestra 5 or other extended sound source, the reproduced music appears to the listener B to be highly unbalanced in one way and to the listener C to be highly unbalanced in another way.

Fig. 2 shows a system in accordance with the invention wherein the studio 4, the sound source, e. g., the orchestra 5 the microphones 1, 2, the transmission channels 14, 15 the sound reproducers 8, 9, 18, 22 and the interconnections between these components are as before. Fig. 2 differs from the conventional system of Fig. 1, however, by the addition of a first cross-coupling path 24 interconnecting the output of the left-hand microphone 1 with the input point of the right-hand transmission channel 15 and containing a first delay device 25, and similarly by the addition of a second cross-coupling path 26 interconnecting the output point of the right-hand microphone 2 with the input point of the left-hand transmission channel 14 and containing a second delay device 27. Buffers 30-33 are interposed to prevent circulation of signal currents.

In the operation of the system of Fig. 2, consider first the two sound reproducers 8, 9 that are located together in A's residence and disposed in appropriate fashion for binaural reproduction. A sound originating close to one microphone, for example the left-hand microphone 1, e. g., the sound of an orchestra instrument played by a performer who is seated close to this microphone, reaches the hearer by two paths. The first path is the direct one, via the channel 14 to the left-hand reproducer 8, while the second path comprises delayed transmission via the channel 15 to the right-hand reproducer 9. In accordance with the Haas effect the listener A recognizes the sound as reaching his ears from the left-hand reproducer 8 and not from the right-hand one 9. Inasmuch as the same considerations hold for partial sounds originating in other portions of the studio, the listener A, who is provided with both channels, both receivers and both reproducers, receives the impression that the orchestra 5 is spread out spatially before him.

Consider, to the contrary, the two reproducers that are located in the two wholly separated residences of which the left-hand one 19 is equipped with an amplitude modulation receiver 17 and the right-hand one 23 with a frequency modulation receiver 21. The two listeners B and C are obviously restricted to single channel reception. However, each one receives sounds originating at both microphones 1, 2 and consequently the apparent point of origin of such sounds is at a location intermediate between the two microphones so that no impression

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of orchestral imbalance is received. Under such conditions he receives the sounds originating at one microphone directly and those originating at the other microphone after a short time delay which, however, is noticeable only as a slight increase in the apparent reverberative quality of the studio.

Fig. 3 shows the extension of the invention to three or more channels. For the sake of illustration the transmission media, which must remain mutually independent as before are indicated as comprising pulse transmission facilities, e. g., a pulse length modulation channel 34, a pulse position modulation channel 35 and a pulse code modulation channel 36. As in the case of Fig. 2 a cross-coupling path 24, 26, 28 interconnects the microphone of each channel with the transmission facilities of each of the other channels, and includes a delay device D₁, D₂, D₃ which as before is preferably proportioned to introduce a delay of the order of 5-30 milliseconds. With such a system a listener A', provided with receiving facilities for all three channels and a reproducer 8, 9, 10 coupled to each one receives a pronounced stereophonic impression, while a listener B', or C' provided with receiving facilities for only one of the channels and with a single reproducer receives his music from his single reproducer to which are supplied the output currents of all three microphones 1, 2, 3 one being slightly advanced in time with respect to the others. As before, such time displacement is noticeable only as an apparent increase in the studio reverberation.

The above described arrangements are illustrative of the application and operation of the principles of the invention. Other arrangements may be devised by those skilled in the art without departing from its spirit or modifying its scope. Thus, for example, while the invention has been described as applied to the concurrent transmission of a "live" program, it is evident that the microphone outputs may be stored for an indefinite period in record form, e. g., on magnetic tape, the resulting space record being then picked up at a later time by conventional means at a studio for transmission to listeners by way of the apparatus of the invention.

What is claimed is:

1. Apparatus for generating and transmitting stereosignals representative of sounds originating in an extended sound source which comprises a plurality of microphones disposed in spaced relation to each other and to said source in a fashion selectively to receive sound energy from various parts of said source, a like plurality of mutually independent transmission channels, a direct path for supplying output energy of each of said microphones to one of said channels, and a cross-coupling path extending from each of said microphones to the channel of each other microphone, said cross-coupling path including means for delaying the transmission of signals there-through.

2. In combination with apparatus as defined in claim 1, a receiver for the signals of one of said channels, a reproduction chamber, a sound reproducer disposed within said chamber, and connections for supplying said reproducer with output signals of said receiver.

3. In combination with apparatus as defined in claim 1, a plurality of mutually independent receivers, means for supplying each of said receivers with the signals of one of said channels, a reproduction chamber, a plurality of sound reproducers disposed in spaced relation within said chamber for stereoreproduction of sound, and connections for supplying each of said reproducers with output signals of one of said receivers.

4. In combination with apparatus as defined in claim 3, an additional reproducer, acoustically isolated from all other reproducers, and means for supplying said additional reproducer with signals received from only one of said channels.

5. In combination with apparatus as defined in claim 1, a plurality of acoustically isolated reproduction chambers,

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a sound reproducer disposed within each of said chambers, a plurality of independent receivers, means for supplying each of said receivers with the signals of one of said channels, and connections for supplying each of said reproducers with the output signals of one of said receivers.

6. Apparatus for generating and transmitting stereo-signals representative of sounds originating in an extended sound source which comprises a pair of microphones disposed in spaced relation to each other and to said source in a fashion selectively to receive sound energy from various parts of said source, an amplitude modulation transmission channel and a frequency modulation channel, a direct path for supplying output energy of each of said microphones directly to one of said channels, and a cross-coupling path extending from each of said micro-

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phones to the channel of the other microphone, said cross-coupling path including means for delaying the transmission of signals therethrough.

7. In combination with apparatus as defined in claim 6, an amplitude modulation receiver and a frequency modulation receiver, means for supplying each of said receivers with the signals of one of said channels, a reproduction chamber, a pair of sound reproducers disposed in spaced relation within said chamber for stereoreproduction of sound, and connections for supplying each of said reproducers with output signals of one of said receivers.

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