

July 29, 1958

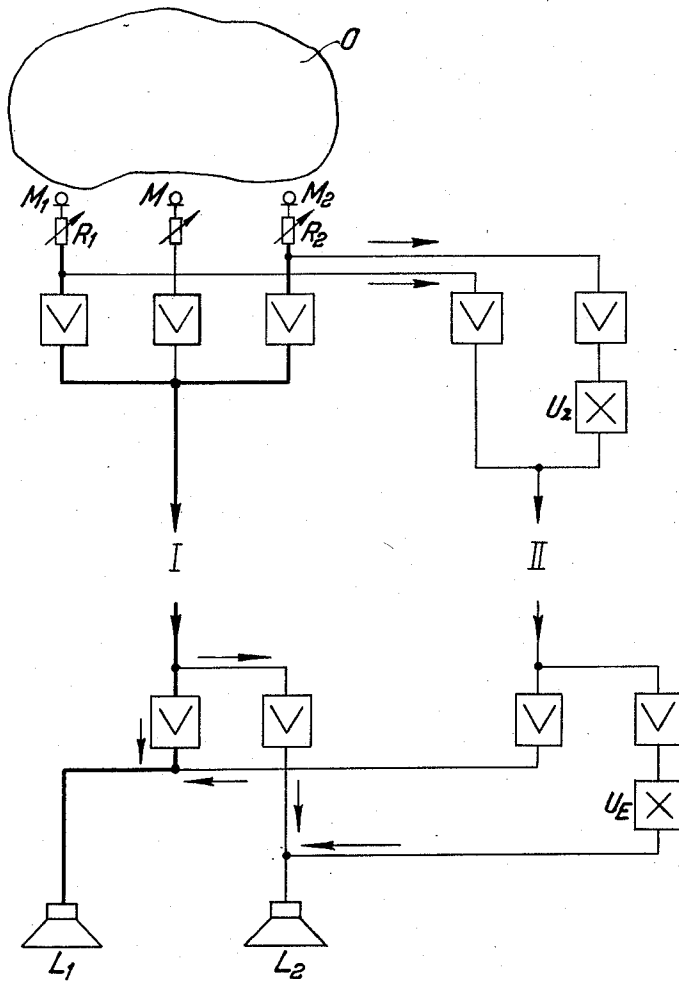
K. BERTRAM
STEREOPHONIC APPARATUS

2,845,491

Filed Dec. 17, 1956

4 Sheets-Sheet 1

Fig. 1



Inventor:

Klaus Bertram

By *Ernst D. Mauchel*
Patent Agent

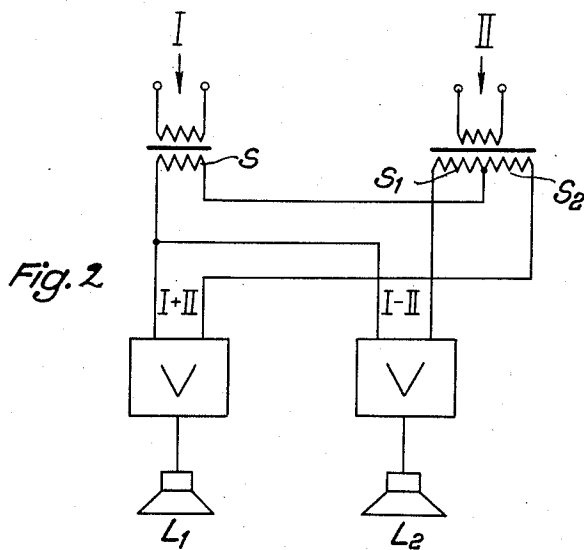
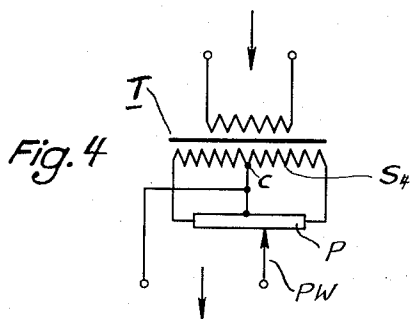
July 29, 1958

K. BERTRAM
STEREOPHONIC APPARATUS

2,845,491

Filed Dec. 17, 1956

4 Sheets-Sheet 2



Inventor:

Klaus Bertram

By *Emil D. Munkel*
Patent Agent

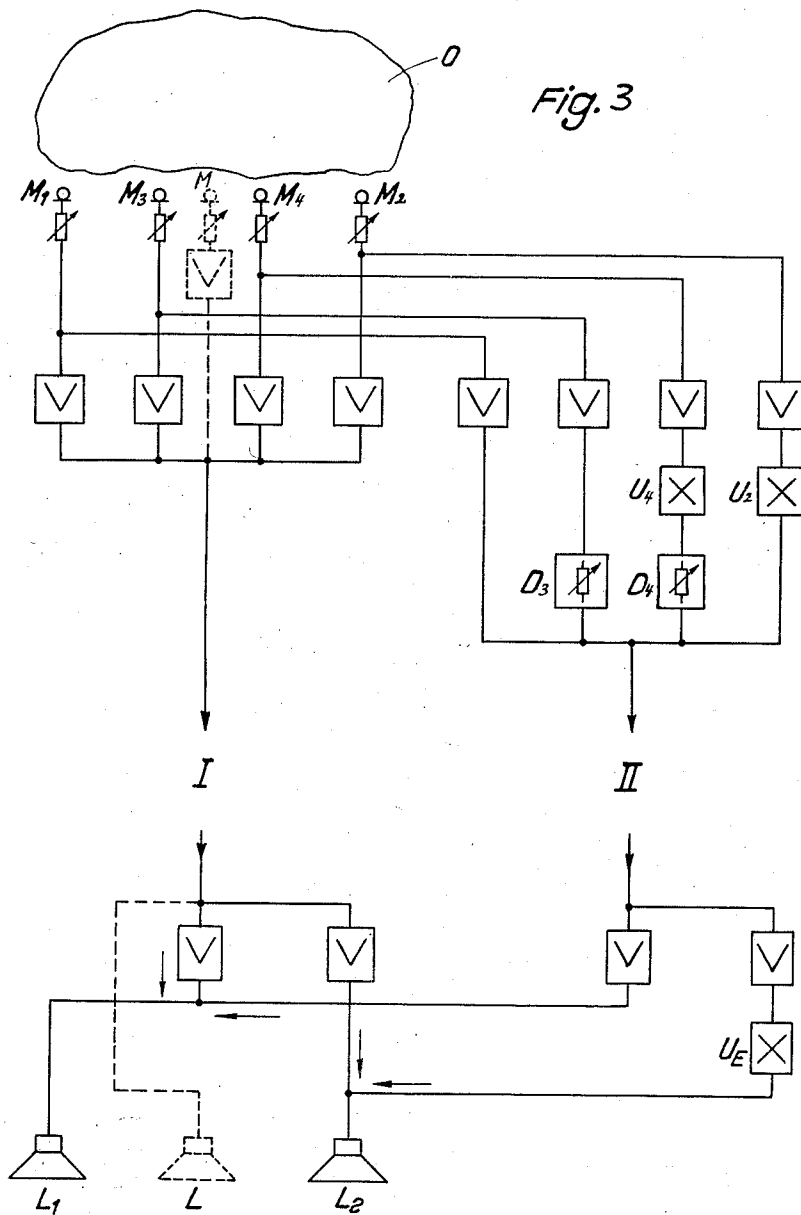
July 29, 1958

K. BERTRAM
STEREOPHONIC APPARATUS

2,845,491

Filed Dec. 17, 1956

4 Sheets-Sheet 3



Inventor:

Klaus Bertram
By *Ernst D. Frankel*
Patent Agent

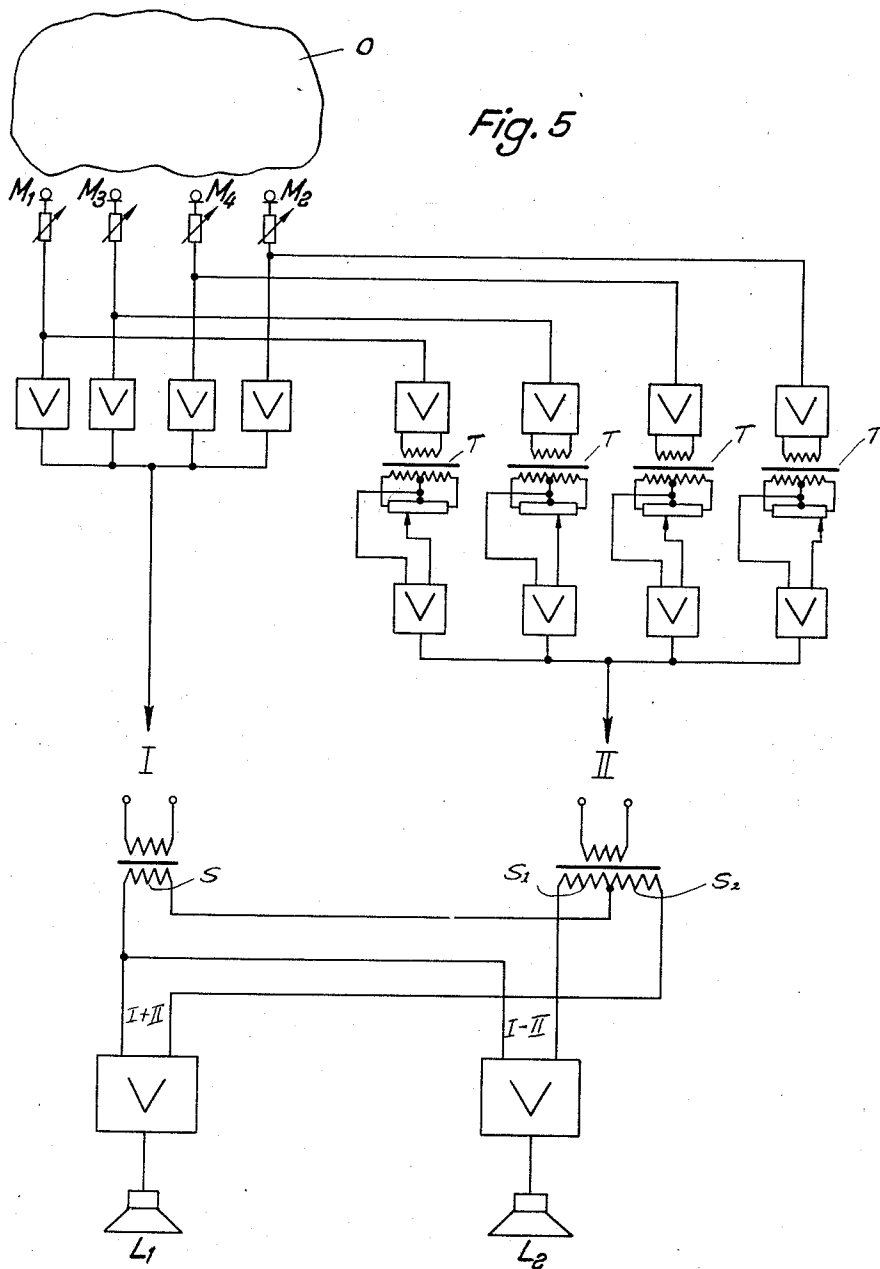
July 29, 1958

K. BERTRAM
STEREOPHONIC APPARATUS

2,845,491

Filed Dec. 17, 1956

4 Sheets-Sheet 4



Inventor:

Klaus Bertram
By *E. D. Roubel*
Patent Agent

1

2,845,491

STEREOPHONIC APPARATUS

Klaus Bertram, Hannover, Germany, assignor to
Telefunken G. m. b. H., Berlin, Germany

Application December 17, 1956, Serial No. 628,685

Claims priority, application Germany December 16, 1955

5 Claims. (Cl. 179—1)

This invention relates to stereophonic apparatus for the transmission and reproduction of audio frequencies.

It has been known to set up two microphones in front of an orchestra in order to obtain a stereophonic reproduction, to connect each of these microphones to a separate transmission channel and to assign to each of the channels a separate loudspeaker. If these two microphones are suitably spaced, for instance, the distance of the separation of the ears of a human head, such arrangement gives the impression that the orchestra is actually at the location of the two loudspeakers. Though such system is suitable for obtaining a stereophonic reproduction for listeners having two-channel receiving systems, it has the disadvantage that it is not fully compatible for use with single-channel systems for non-stereophonic reproduction, because then only one of the microphones is effective subsequently providing poor coverage of a large source of sound, such as an orchestra.

It has also been known to provide an electro-acoustical transmission system, for example, for radio broadcasting, in such a manner, that it can serve compatibly either for simple or for stereophonic reproduction by means of the same pair of microphones, transmitting via a main channel and a second channel. For this purpose, the transmitting apparatus supplies the first channel of a receiver with the sum of the voltages from the two microphones, and the second channel of the receiver with the difference of the voltages from the microphones, i. e., the voltage of the one microphone is supplied directly and the voltage of the other microphone is supplied after polarity reversal. Then, during stereophonic reproduction, one loudspeaker in the receiver is supplied with the sum of the voltages from both channels and the other loudspeaker is supplied with the voltages from both channels but after polarity reversal of the voltage from one of the channels. In this known arrangement, the two microphones are, for instance, mounted on a supporting member and spaced for stereophonic reproduction (artificial head). However, this microphone arrangement is not the best for use in single-channel reproduction, because various frequency components of the intelligence, for instance music, become lost by mutual cancellation when the two microphones are directly interconnected. Even during two-channel reproduction, this arrangement of the microphones is unsatisfactory for the transmission system, since cancellations occur in the second channel, such cancellations impairing the quality of the reproduction and of the stereophonic effect. Even if the two microphones were arranged in another way, this still would be done only with regard to the single-channel or the two-channel transmission.

It is an object of the present invention to overcome the above difficulties and to obtain a superior, or even the best possible, sound impression both in connection with single-channel and stereophonic transmission in both cases as if only one of the transmissions were in progress, so that hardly any mutual consideration is to be taken.

According to the present invention there are provided in addition to the two mentioned microphones at least one or several other microphones which are connected

2

along with the two microphones already mentioned above according to the two following characteristics, and which are arranged with said mentioned microphones especially or only with a view to good single-channel transmission:

(a) From each of said additional microphones a voltage is supplied to the second channel, particularly, via separate, controllable attenuators, these voltages being variable in intensity so that for a large voltage the reproduced sound appears to be located remotely from the line of symmetry between the two loudspeakers, and the sound appearing to approach said line of symmetry as the voltage is lowered (limiting case: equal zero).

(b) The outputs of said additional microphones are supplied directly to the first channel and, in addition, a polarity reversing device (transformer) is provided in each of the feed lines from these additional microphones to the second channel through which the sound received by these microphones, in case of stereophonic reproduction, is conducted to the loudspeaker via channel II.

Upon introduction of such a system, a radio listener having a receiving set of the conventional type for single-channel transmission could use it for single-channel reception of these stereophonic signals. The quality of reproduction will not be impaired because the above microphone arrangement can be employed at the transmitter whether or not a stereophonic reproduction means is provided at the receiver always or only sometimes, and the types of microphones can be selected without regard thereto. This is the more important, the more the use of additional microphones is relied upon to compensate for acoustical shortcomings of the studio or to obtain special musical effects. In spite of the arrangement of the microphones with a view to good single-channel transmission, the invention has the additional advantage that a sound source in front of the system of microphones may be selectively reproduced by the receiving apparatus at any point within the angle formed between the lines connecting the listener and the stereophonic loudspeakers.

Still further objects and the entire scope of applicability of the present invention will become apparent from the detailed description given hereinafter; it should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

Referring in more details to the drawings,

Figure 1 shows schematically one embodiment of the invention for the case where the reproduced sound is to lie on the axis of symmetry of the loudspeakers; (limiting case indicated under a)

Figure 2 illustrates schematically a circuit employed to connect two loudspeakers to channels I and II for stereophonic reproduction;

Figure 3 shows a novel circuit diagram suitable for use in carrying out the principles of the present invention, and

Figure 4 is a diagram of a circuit which may be used as a phase-reversal circuit in which the output amplitude may also be controlled;

Figure 5 shows schematically a circuit diagram of another embodiment according to the invention using the circuit shown in Fig. 4.

The aforementioned known system will be explained first with reference to Figure 1, wherein the microphone M and the associated connecting lines and circuit components (variable resistor and amplifier) are to be ignored. The variable resistors R_1 and R_2 are, likewise, not present in the known system. The two microphones

are placed in front of a sound source O, for instance, an orchestra. In the lines of the transmitter and the reproducer, amplifiers denoted by V are inserted. The voltages supplied by the two microphones M_1 and M_2 are fed to the channel I by interconnecting the microphones in a known manner. The voltages supplied by the two microphones M_1 and M_2 are simultaneously fed to channel II, however, after reversing the polarity of one of the microphones, for instance, the right one M_2 , in a polarity reversing device U_2 . In other words, the sum of the voltages of the two microphones is supplied to the channel I and the difference of the two voltages to the channel II. The two channels I and II are then transmitted via wire or wireless, or they may be recorded on sound carriers. Two loudspeakers L_1 and L_2 are provided at the receiver. One of these loudspeakers, namely L_1 , is fed with the sum of the voltages of the two channels I and II. The other loudspeaker L_2 will receive the difference of the voltages of the two channels, because a polarity reversing device U_E is inserted in the feed line between channel II and the loudspeaker L_2 .

According to Figure 1, single-channel transmission, during which both microphones M_1 and M_2 operate, takes place without the additional components at the right lower side of the receiver to be used in the operation of the channel II. The two loudspeakers L_1 and L_2 are operating in parallel and could be replaced by a single loudspeaker. However, the loudspeaker using the additional components at the right lower side of Figure 1 has stereophonic reproduction.

The operation of said transmission system is based on the following equations for the two channels I and II, wherein the voltage of the one microphone is denoted by A and that of the other microphone by B.

There appears in channel I $(A+B)$; and in channel II $(A-B)$.

At the reproducer, there appears at the left loudspeaker L_1 $(A+B) + (A-B) = 2A$; and at the right loudspeaker L_2 $(A+B) - (A-B) = 2B$.

Thus, the system operates as if the loudspeaker L_1 is only connected to the microphone M_1 (voltage A) and the loudspeaker L_2 only to the microphone M_2 (voltage B). The voltage of the microphone M_2 in the loudspeaker L_1 and that of the microphone M_1 in the loudspeaker L_2 are cancelled out.

Figure 2 shows a known example of a circuit for the receiver. The sum of the voltages of the channels I and II is obtained by series connection of the two secondary coils S and S_2 and the difference in voltages is obtained by connecting in opposition the secondary windings S and S_1 . The polarity reversing device U_E of Figure 1 is here illustrated by the coil S_1 provided on the transformer of the channel II.

According to the invention, the microphone M in Figure 1 is added and is connected only to the channel I. In this illustrated broadest of the invention, the voltage fed from said microphone M to the channel II equals zero. Therefore, at the reproduction apparatus, an impression is obtained as if the sound received by this microphone were in the center, i. e., on the line of symmetry, between the two loudspeakers L_1 and L_2 . It is immaterial regarding this action where the microphone M is arranged with respect to its sound source. The voltages of the microphones are interconnected in a manner known per se, whereby the phase of the microphone voltages need not be considered, since the microphones are spaced far apart and, thus, the content of intelligence coming to the microphones is so different that scarcely any mutual cancellation of the voltages takes place. Each microphone is equipped with a volume control adapted to adjust in a manner known per se in one-channel transmission systems the amplitude ratio to the most favorable value, as required for a one-channel transmission. In this way, the channel I obtains the sound spectrum necessary for balanced reproduction (correct ratio of the sound volumes

of the individual instruments). However, channel II causes a stereophonic differentiation for the listeners (perception of the stereophonic distribution of musical instruments in an orchestra).

In Figure 3, microphones M_3 and M_4 are additionally arranged with the microphones M_1 and M_2 . The microphone M as in Figure 1 may also be added, if desired. In accordance with the invention, adjustable attenuators D_3 and D_4 and polarity reversing device U_4 may be inserted in the lines between the microphones M_3 and M_4 , on the one hand, and the channel II on the other hand.

The voltages derived from the left microphone group M_1 , M_3 are applied directly to channel II, while the voltages of the right microphone group M_2 , M_4 are phase-inverted by the polarity reversing devices U_2 and U_4 . The stereophonic effect can be improved by inserting attenuating means D_3 and D_4 in the electrical connections between the two middle microphones M_3 , M_4 and channel II, whereby the attenuation may be controlled in such a manner, that the voltages passing through the attenuators are lower as compared with the voltages of the microphones M_1 and M_2 , in the proportion that the spacing of the middle microphones M_3 and M_4 from the center line of the entire microphone arrangement is smaller than the total width of the arrangement.

In accordance with a further object of the invention, shown in Figure 4, the controllable attenuation device and the polarity reversing device may be combined. In this embodiment, a potentiometer P is connected to the secondary S_4 of a transformer T. The output voltage is picked up across the wiper arm PW of the potentiometer P and the connecting line between the center tap C of the secondary S_4 and the potentiometer P. This arrangement makes it possible to reproduce a sound source in front of a microphone at any point of the angle enclosed by the lines between listener and the two loudspeakers L_1 and L_2 . Thus, a sound source which is located to the right in the orchestra O and in front of which a microphone is placed may be reproduced on the left side at the loudspeakers by moving the wiper arm PW of the respective potentiometer P beyond the tap C to the other side. The potentiometer in Figure 4 may be calibrated directly in increments of the mentioned angle.

The impression of movement over the entire angle may be produced by merely actuating the potentiometer P. If the wiper arm PW is in the center, no voltage is transmitted from the respective microphone to the channel II. This is the case mentioned above, wherein the reproduced sound appears on the line of symmetry between the loudspeaker L_1 and L_2 .

In practice, a circuit arrangement according to Figure 4 will suitably be provided in each of the amplifiers which are located in the four feed lines of the microphones to the channel II, in order to be able to freely adjust the phase as well as the amplitude. This has the advantage that all four amplifiers in these feed lines are uniformly designed.

Figure 5 shows such a circuit arrangement. The conventional double feed lines are shown partly unipolar and partly bipolar for the sake of clarity. The upper half of Figure 5 illustrates the microphones and transmitting circuits. The lower half illustrates the reproducer, and the transmission channels I and II are in-between. The microphones M_1 to M_4 are arranged and connected as in Figure 3. At the upper right, a circuit according to Figure 4 is inserted in each of the four lines connected to the microphones. The reproducer illustrated at the bottom of Figure 5 has exactly the same circuit arrangement as that shown in Figure 2.

The transmission system according to the present invention can be used in addition with another proposed transmission system. In this latter transmission system, two microphones close to one another are used, of which one constitutes a pressure, or pressure gradient, type (i.

e., with spherical or kidney shaped characteristics) and the other is a transversely directed velocity microphone with octagonal characteristics, the direction of principal incidence of which lies transverse to the sound source. The voltage of the first microphone is fed to channel I and that of the second microphone to channel II (without using the circuit arrangement according to the invention at the transmitter). At the receiver, a stereophonic result is obtained by forming the sum and the difference of the microphone voltages, for instance, by using the circuit arrangement according to Figure 2. This result may be enhanced by the system according to the invention.

Independent of the presence of a microphone M in Figure 3, a loudspeaker L may be connected to the channel I at the reproducer, said loudspeaker being arranged in the center between the two other loudspeakers. In this case, the sound emits from a larger surface and the impression that the sound originates in two different points is reduced.

The problem of optional use of simple or stereophonic reproduction occurs in electro-acoustics not only when the sound production is transmitted by wire or via a radio channel, this problem being, likewise, present when the sound is to be recorded on sound carriers for example, records, electromagnetic tapes or on sound films having two channels. It is possible in such case to reproduce the records made, according to the invention, on a normal record player by using a conventional pick-up for a one-channel reproduction, while the same records can alternatively be played on a reproduction apparatus for stereophonic reproduction. The two channels can be made on one record, for instance, by laterally recording one channel and vertically recording the other channel.

The invention may be applied to sound films as follows. The conventional cinemascope films have four electromagnetic tracks, i. e., three main tracks for the stereophonic reproduction with loudspeakers at the screen, and one special effects track for feeding loudspeakers arranged in the back of the auditorium. If films of this kind were produced according to the invention, two main tracks and one special effects track would be sufficient, since the sound received by the center microphone can be transmitted via channel I. In contrast to the conventional cinemascope films, the same films may be used in smaller movie theaters which have only one-channel reproducing apparatus. In the latter apparatus, only track I is picked up and perfect one-channel reproduction is obtained. This simpler reproducing apparatus may be built in such a way that it can later be supplemented, if desired, to provide a complete reproducing apparatus for stereophonic reproduction.

What is claimed is:

1. Stereophonic apparatus for compatible reproduction in loudspeakers by both single-channel non-stereophonic systems and also by two-channel stereophonic systems of audio signals converted into voltages by a first, a second and a third microphone system comprising a first channel; means for transmitting voltages from all the microphones to the first channel; a first and a second loudspeaker, each connected to said first channel and reproducing audio signals in accordance with the sum of the outputs of all the microphones; a second channel; means for transmitting voltages from the first microphone system to the second channel; a first polarity reversing means connected to supply a phase-inverted voltage to said second channel from said second microphone system; means for supplying a component from said second channel directly to the first loudspeaker; and a second polarity reversing means connected to supply a phase-inverted voltage to said second loudspeaker from said second channel.

2. In an apparatus as set forth in claim 1, said audio signals emanating from a broad source, and said first microphone system comprising at least two microphones

on one side of said source and said second microphone system comprising at least two other microphones on the other side of said source and symmetrically arranged with respect to said first microphones; and attenuating means for controlling the amplitudes of the outputs of at least a pair of mutually corresponding microphones in each system, the sound appearing to emanate from a source along the axis of symmetry of the two loudspeakers when the outputs of the microphones of said pair are entirely attenuated, and the emanation of the sound appearing to move off the axis of symmetry in proportion as the signal through an attenuating means is increased.

3. In an apparatus as set forth in claim 1, said means for transmitting voltages from the first microphone system to the second channel including a separate, combined phase-inverter and attenuator for each microphone in the first system, whereby both the amplitude and phase of each voltage may be selected; and said polarity reversing means connected between said second channel and said second microphone system also including an attenuator, whereby the output amplitude and phase of each microphone in the second system may be selected; the selection of the respective microphone phases fed to the second channel determining whether the emanation of sound from the loudspeakers is the same or the reverse of the original source of audio signals, the amplitude selection of the outputs of the various microphones fed to the second channel determining the width to which the stereophonic pattern extends on each side of the axis of symmetry of the loudspeakers.

4. In an apparatus as set forth in claim 3, each polarity reversing means comprising a transformer having a primary winding for receiving an input signal and having a secondary winding; and each attenuator comprising a potentiometer connected across said secondary winding and forming therewith a secondary circuit having a center tap, the potentiometer having a wiper arm and the output of the combined polarity reversing means and attenuator being taken from between said center tap in the secondary circuit and said wiper arm.

5. Stereophonic apparatus for compatible reproduction in loudspeakers by both single-channel non-stereophonic systems and also by two-channel stereophonic systems of audio signals converted into voltages by a first and a second microphone system comprising a first channel; means for transmitting voltages from all the microphones to the first channel; a first and a second loudspeaker, each connected to said first channel and reproducing audio signals in accordance with the sum of the outputs of all the microphones; a second channel; means for transmitting voltages from the first microphone system to the second channel; a first polarity reversing means connected to supply a phase-inverted voltage to said second channel from said second microphone system; means for supplying a component from said second channel directly to the first loudspeaker; and a second polarity reversing means connected to supply a phase-inverted voltage to said second loudspeaker from said second channel, said audio signals emanating from a broad source, and said first microphone system comprising at least two microphones on one side of said source and said second microphone system comprising at least two other microphones on the other side of said source and symmetrically arranged with respect to said first microphones; and attenuating means for controlling the amplitudes of the outputs of at least a pair of mutually corresponding microphones in each system, the sound appearing to emanate from a source along the axis of symmetry of the two loudspeakers when the outputs of the microphones of said pair are entirely attenuated, and the emanation of the sound appearing to move off the axis of symmetry in proportion as the signal through an attenuating means is increased.