April 19, 1932. W. B. JONES 1,855,146

METHOD AND APPARATUS FOR AUDITION

Filed Dec. 14, 1928

Fig. 1.

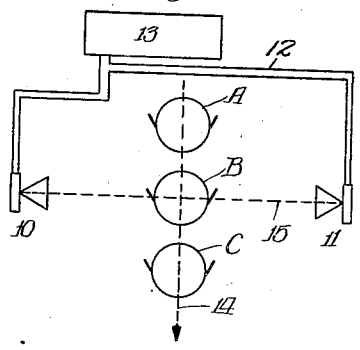


Fig. 2.

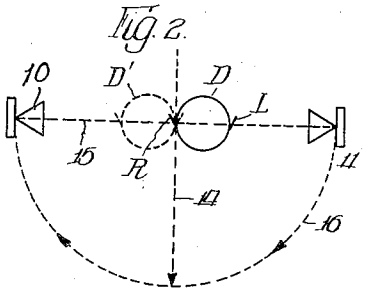


Fig. 3.

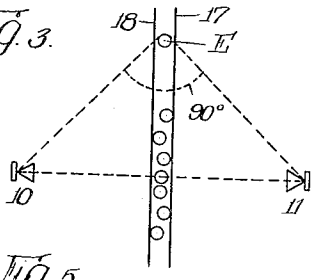


Fig. 4.

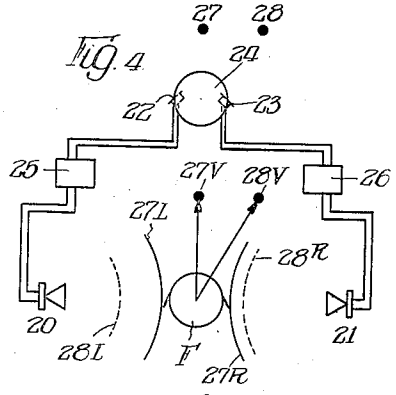


Fig. 5.

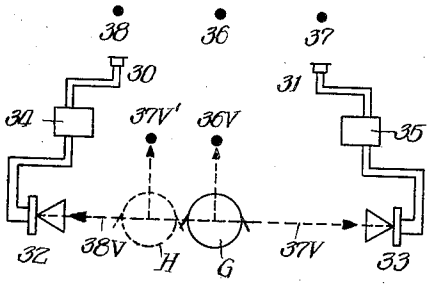


Fig. 6.

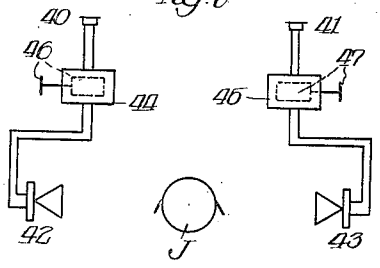


Fig. 7.

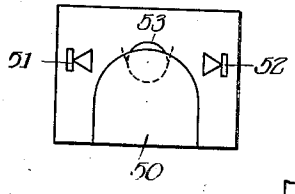


Fig. 9.

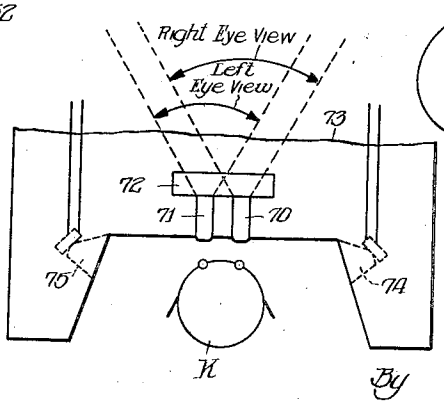
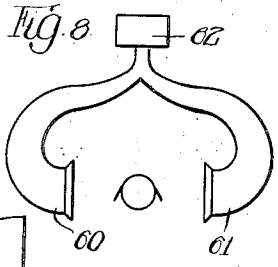


Fig. 8.



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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR AUDITION

Application filed December 14, 1928. Serial No. 326,023.

The present invention relates primarily to the transmission, reproduction and reception of sound to secure new and improved effects in audition and involves both method and apparatus.

This application and invention is generic to the inventions described in my copending applications Ser. No. 183,414, filed April 13, 1927, Ser. No. 210,629, filed Aug. 5, 1927, Ser. No. 311,488, filed Oct. 10, 1928, Ser. No. 331,783, filed Jan. 11, 1929, and Serial No. 496,434, filed November 18, 1930. It is also a continuation in part of the above mentioned applications Ser. No. 183,414 and Ser. No. 210,629.

The invention involves the principles of binaural reception. For the purposes of this application this may be defined as the reception of sound by both ears by means of which directional effects can be obtained when there is a definite phase relation between waves received at the two ears. In binaural reception a particular sound heard in one ear is substantially the same in character as the sound heard by the other ear, and hereinafter these are referred to as dual sounds. The dual sounds may be in the same phase relation, or they may be out of phase. The dual sounds may be two components of two compound waves, the remaining components of which may or may not be dual sounds. The sounds may be out of phase within the binaural limit, or they may be out of phase to a greater extent. The invention in its preferred embodiment contemplates that the dual sounds received by the ears be produced by two wave fronts travelling toward each ear in such a way that one source is heard in each ear prior to the other ear hearing the same source. This will be more readily understood from the description hereinafter found.

The primary object of the invention is the production of a new and different sensation in the reception of sound, or more particularly, the production of a virtual origin for one set of dual sounds, and for a plurality of virtual origins in spaced relation for a plurality of sets of dual sounds.

Another object of the invention is improvement in the character of sound ordinarily perceived from aural reception of a single wave front.

Still another object of the invention is the production of audition which is more natural in character.

A further object is the presentation of sound such as may be produced by a single means such as an acoustic tube, a phonograph or an electrical system, so as to separate the apparent sources of sound into spaced virtual relations according to the frequencies of particular sounds, much as a prism separates a beam of light into a band according to wave length.

A more specific object of the invention is the causation of a more natural reception of sound by utilizing head reception or bone reception, and conduction as well as eardrum reception.

Various other objects and advantages of the invention will become apparent from the following description of the invention as exemplified by various embodiments as shown in the accompanying drawings in which:

Fig. 1 represents an auditory station comprising two electrical sound producers connected in series for simultaneous operation, spaced apart and arranged in substantial opposition, with an auditor stationed between them.

Fig. 2 represents similarly arranged sound producers with an auditor in different relation to them, and is diagrammatic in character.

Fig. 3 represents two widely spaced and opposed sound producers with a large number of auditors stationed between them in a particularly advantageous zone.

Fig. 4 represents similarly arranged sound producers which are connected to a dummy head having microphones for ears, so that binaural effects are reproduced.

Fig. 5 represents an arrangement similar to Fig. 4 in which microphones are extra-binaurally located.

Fig. 6 represents an arrangement similar to Fig. 5 in which delay means is contained

in each circuit for varying the phase of sound picked up by the microphones.

Fig. 7 illustrates an auditory station in the form of a chair equipped with spaced and opposed sound producers or presenting means.

Fig. 8 illustrates two horn type sound presenting means connected to a common sound box.

Fig. 9 illustrates apparatus adapted for presenting pictures in stereoscopic relation accompanied by directional sound in conformity with the picture presentation.

In order best to explain the invention I will describe what is a simple and practical form as shown in Fig. 1. But first I wish to discuss a feature of the prior art in order to show the advantage of the invention. The use of head phones connected in series produces the well known effect of sound located within the head and apparently in the central plane between the two ears. Such reception is not normal and is not experienced except by presenting the same sounds at the same time to the two ears, or in other words, presenting to the ears dual sounds which are in phase. When a listener faces a source of sound the ear drums are similarly treated to the same sounds at the same time, but in this instance the sound can be detected as outside the head and located directly forward of the auditor. So far as the ear-drum reception is concerned the effects are the same when facing the sound as when using ear phones. However, there is in fact a great difference in the character of sound and the location in which it is detected, and I have attributed the difference in effect to the fact that when an auditor is facing the sound, his whole head is exposed to the sound and thus immersed in a sound wave in such a way that a goodly portion of it is picked up by the head, conducted by the bones of the head, and transmitted so that it is combined with the vibrations received at the ears, producing a combination effect that characterizes normal hearing of external sounds. Natural reception of sound therefore comprises ear drum reception and head reception, and the receiving unit is the human head with two ears, as distinguished from two ears alone as receiving units.

In Fig. 1 I show two sound producers such as loud speakers 10 and 11, positioned in such a way as to provide a region in which the sound waves travel towards each other. I prefer to place them in direct opposition as illustrated. The spacing may be varied over a large range. Three feet or ten feet is suitable and less or more is readily permissible. The two speakers are connected in series in a circuit 12 which may be energized from any sound carrying electrical system, such as may be found in phonographs or radio apparatus. I have indicated a radio set 13.

The line of the dotted arrow 14 indicates the points where opposing sound waves from the two speakers 10 and 11 collide or meet. A, B and C represent human heads centered along the line 14, as indicated by the diagrammatic ears. It will be noted that B is on the line 15 drawn between the two speakers 10 and 11, and that A faces the line, and that C is in front of the line.

The ears of A, B and C must receive dual sounds at the same time. A's head receives dual sounds, first in front and then at the rear. C's head receives dual sounds first at the rear and then at the front. B receives a major portion of the sound at the front of his head because a major portion of the normal head lies in front of the ears. I have found that A and B will observe the sound as coming from a point directly ahead, while C will detect a source of sound to his rear. But as a matter of fact there are two sources, neither of which can be detected. The observed false sources are illusive and are called virtual origins.

In Fig. 2 the head D is shown in a position nearer speaker 11. Each head is figured roughly as about six inches from ear to ear, and therefore the sound paths to ears R and L on D are different in length by six inches. D′ indicates the head moved to the other side of line 14. D hears sounds as coming from speaker 11 and does not recognize the presence of speaker 10. D′ hears sound as coming from speaker 10 and does not recognize the presence of speaker 11. Motion from D to D′ causes the apparent source of sound to swing in the arc designated 16 from one speaker to the other.

Motion to the listener's right beyond D′ or to the listener's left beyond D does not produce any noticeable change. Within the region from D′ to D virtual origins in space are produced and the direction of such origins may be varied by moving the head within the limited range. Both speakers are necessary to produce this effect, and cutting off any one of them causes the sound reception to revert to the usual reception obtained when listening to one speaker. Outside the region D to D′ no virtual origins are produced, and the nearest speaker is the only one recognized as a source of sound. Cutting off the farther speaker produces a marked change in the quality of sound that appears to be coming from the nearer speaker. This is in accordance with the observation set forth in my copending application Ser. No. 183,414; that when a sound is heard in one ear, and the same sound is then impressed on the other ear later than the binaural time limit (corresponding to about a six inch travel) the sound first heard is amplified and increased in quality, and its detected location is not varied.

From the foregoing it may be understood that there is a narrow zone between the two loud speakers wherein a distinctly different

character of sound reception can be had, and that outside of said zone there is had a sound reception of improved quality. In Fig. 3 the long narrow zone is represented diagrammatically. Lines 17 and 18 define the range for speakers 10 and 11 herein shown widely spaced. It is to be understood by comparison of Figs. 1 and 3 that the length of the narrow zone increases with the spacing of the speakers, and that a longer zone will accommodate more auditors. In Fig. 3 E represents a listener at the vertex of a substantially 90° angle. The boundary effects between the lines 17 and 18 are somewhat distorted as the angle closes from a 180° angle, because it then becomes impossible for a listener, such as E, to hear any speaker directly to his right or left.

In the arrangement above described a compound sound wave may be considered as the one sound under discussion. In Fig. 4 I show binaural transmission, so that each speaker 20 and 21 may reproduce one sound source as dual sounds in phase, and another sound source as dual sounds which are out of phase. Two pick-up devices such as microphones 22 and 23 are located at points corresponding to human ears, as for example by making them act as ears on a dummy head 24 in angular relation to each other. Connecting sound paths such as the circuits and apparatus 25 and 26 are provided so that equal length paths are provided from each microphone to the corresponding loud speaker, 22 being connected to 20 and 23 to 21. A source of sound is indicated at 27 directly ahead of the dummy 24, so that it produces in-phase dual sounds 27R and 27L from the two loud speakers. A laterally angular source is indicated at 28 which will produce out-of-phase dual sounds 28R and 28L from the two loud speakers. The sounds above designated as 27R and 27L and as 28R and 28L are shown in the drawings as component waves of the compound sound emitted by each loud speaker. When the head F is located centrally in listening position between the loud speakers 20 and 21, the two sets of dual sounds produce the virtual origins 27V and 28V respectively, as indicated.

In the foregoing examples the whole head acts as the human receiving unit in a medium carrying intense sound waves. This is to be distinguished from ear-phone reception with the ear drums acting as separate units of reception in local and separated regions of weak sound waves, thus excluding the important contribution made by bone reception.

In Fig. 5 I show a system more particularly described in my copending application Ser. No. 210.629, in which the sound pick-up devices are located apart from each other by a distance greater than the binaural limit, or in other words, are extra-binaurally located. The apparatus comprises microphones 30 and 31, loud speakers 32 and 33 with similar connecting paths such as the electrical apparatus 34 and 35. A source of sound 36 is shown equidistant from the two microphones so that the dual sounds from the source 36 are in phase in the two microphone systems. A head G located centrally of the speakers will observe a virtual source 36V directly ahead of him. But two other sources 37 and 38 are also shown, each being located so that the differential distances to the two microphones are extra-binaural. The dual sounds of 37 and 38 are therefore out of phase more than the binaural time or distance, and the origin of 37 and 38 will appear to G as located in the speaker whose microphone first picks up the sound from the source 37 or 38, as indicated by the arrows 37V and 38V. A head H is shown as located nearer speaker 32 at such a point that the changed distances to the speakers equalizes the air sound paths (37 to 31) + (33 to H) and (37 to 30) + (32 to H), making the dual sounds of 37 which are received by H in phase at the time of reception. Thus, 37V′ will be a virtual origin directly in front of H, the former virtual origin 36V being moved in the direction of speaker 32, the shortest air-line path to the listener.

The foregoing description shows that the line of collision of dual sound waves may be different for different sets of components of the two compound waves issued by the speakers.

Fig. 6 illustrates apparatus substantially like that shown in Fig. 5. Microphones 40 and 41 are extra-binaurally located. Speakers 42 and 43 are positioned and spaced apart in the manner characterizing this invention. The connecting portions 44 and 45 each contain adjustable delay devices, indicated at 46 and 47. These may be any well known means suitable to the type of sound channel employed. In the present instance the well known electrical delay circuits may be introduced. Using such means it is not necessary for the listener to move from one position to another in order to secure a shifting or selection of the virtual origins which are to be placed in front of him.

Fig. 7 illustrates a chair 50 into which may be built or with reference to which may be fixed a pair of loud type sound producers. These are indicated at 51 and 52, as electrical loud speakers. The chair may have positioning means, such as a rounded portion 53 into which a human head may fit and rest to position the head properly for reception in middle position.

Fig. 8 represents a modified form of device which is equivalent to the series connected speakers of Fig. 1. Two acoustic horns 60 and 61 are joined in common to a single sound box 62 which may be found on a phonograph, or any other sound box, which may be mechanically or electrically energized.

Fig. 9 represents another application of this invention, the details of which will be found in my copending application Ser. No. 496,434, filed November 18, 1930. Briefly, the apparatus represents the combined effects of sight and sound. Stereoscopic pictures, such as motion pictures, may be viewed as right and left eye views, providing means for excluding from each eye the presentation made for the other eye. Sound may be recorded so that on presentation it will be coordinated with the picture, as to time, location, and direction. In the drawings I represents two optical systems 70 and 71. The part indicated 72 represents a shutter device which operates in synchronism with the picture presentation to exclude the views not required for the effect. The optical systems may be housed in a cabinet 73 in which are mounted two loud type sound producers 74 and 75, spaced so as to give the benefits of ear drum and bone reception. K indicates a head observing the combined and coordinated effects. The optical system may be considered as a means for centering the head at the proper position between the two sound producers.

In spite of the fact that the invention as above described may appear to be most useful in the field of binaural transmission as shown in Figs. 4, 5 and 6, and less useful in a system like Fig. 1, I have found that there is a greater advantage to be obtained than has hereinabove appeared. It may appear that the improved quality of reception obtained by connecting two loud speakers in series is insufficient to warrant any general practice of it, since it would only move the apparent source of sound to a new location in space. Nothing so far described indicates that such an arrangement can be made to effect a separation of the origins that are combined in a single wave. But I have found that such a separation can be effected by a proper selection of the type of loud speakers employed or by any equivalent means.

I have found that when I use two sound producers arranged in opposed relation as described, employing one of the type which is commonly termed more resonant to high frequencies than the other sound producer, there is a separation of the virtual origins, with the virtual origins of the higher pitched tones displaced in the direction of such a resonant producer. For example, I have used a horn type of speaker, such as may be found on a phonograph employing an electrical attachment, at the right, which speaker is commonly termed resonant to high frequencies, connected in series with a cone speaker which is commonly termed more resonant to lower frequencies, located on the left. Such a combination effects a separation of origins according to frequencies, much as a prism separates a beam of light into a band according to frequencies of light vibrations. A piano reproduced by such a combination can be heard over a considerable range comparable with the span of the sounding board, the high notes coming from the right and the lower notes coming from the left. Musical tones or those having prolonged vibrations, are more affected by this displacement feature than is the spoken voice containing complex waves which have no repeating prolonged vibrations. I am therefore enabled to distinguish a singer at a more or less fixed point and the accompanying musical tones at spaced points to the right and left of the singer.

The arrangements of Figs. 5 and 6 are more particularly described and claimed in my copending application Serial No. 210,629, filed August 4, 1927. The arrangement of Fig. 9 is more particularly described and claimed in my copending application Serial No. 496,434, filed November 18, 1930. The arrangement for distortion referred to in the paragraph last above is more particularly described and explained in my application Serial No. 331,783, filed January 11, 1929.

In the above description the sounds in the two systems have been termed dual sounds for convenience in description. In the dual sounds all the sounds involved may have their respective components binaurally phased or only some of them may be binaurally phased. In the reception of the sounds or in picking up the sounds the binaurally related sounds are companionate right ear and left ear versions, the word companionate being used to indicate that one is a companion to the other for the purpose of binaural hearing. In the accompanying claims the reference to one ear version and a companionate version for the other ear signifies that the sounds are so phased that the two versions produced in the ears upon reception a binaural sensing of direction.

In the appended claims I aim to cover all such uses of the invention as are described and such others as will be obvious from an understanding of the principles herein explained and disclosed. Accordingly, the appended claims are to be construed broadly in conformity with the scope of the invention as it improves over the practice and understanding of those skilled in the art.

I claim:

1. Two loud type sources of sound directed towards each other and sufficiently separated by a distance which permits inserting more than one human head at a listening position between them, in combination with means adapted to provide one with a left ear version and the other with a companionate right ear version of the same sounds.

2. Two loud type sources of sound spaced horizontally from each other at a consider-

able angle with a given position to be occupied by an auditor and directed toward said position, in combination with means adapted to provide one with a right ear version and the other with a companionate left ear version of the same sounds, said angle limiting the range within which binaural origins may be sensed by an auditor in said position.

3. Two loud type sources of sound directed generally towards each other and separated by a distance from each other greater than the width of a human head, whereby sound from each may be audible in each ear of a listener positioned between them, and means to center the head of a listener between them, in combination with means adapted to provide one source with a left ear version and the other source with a companionate right ear version of the same sounds.

4. Two loud type sources of sound directed generally towards each other and separated from each other by a distance greater than the width of a human head, whereby sound from each may be audible in each ear of a listener positioned between them, means to center the head of a listener between them, and means to actuate said sources of sounds with different versions of the same sound which are companionate ear versions.

5. Two loud type sources of sound directed substantially towards each other and sufficiently separated by a distance which permits inserting more than one human head at a listening position between them, in combination with means adapted to provide each source with companionate ear versions of the same sounds such that each contains components of the same sound, which components may be heard by an auditor in binaurally phased relation at some point between said sources.

6. The method of improving audition which comprises subjecting the whole human head to two different sound waves carrying common components of at least a single source of sound in such a manner that binaurally phased audition of the common components indicates a virtual origin spaced from the head at an angle determined by the phase difference in the two components at the time of reception binaurally.

7. The method of improving audition which comprises subjecting the whole human head to two different sound waves carrying different versions of the same sounds phased in true binaural relation in such a manner that the two versions approach the head from generally opposite directions from two sources for producing binaurally phased audition in the first hearing of each version.

8. The method of improving audition which comprises subjecting the whole human head to two different sound waves carrying different versions of the same sounds phased in true binaural relation in such a manner that the two versions converge toward the head for binaurally phased audition in the first hearing of each version, and that the said two waves which effect directional sense through the ears impinge on the head proper and determine an outside locus for said sound.

9. Two loud type sources of sound directed generally towards each other and separated a distance from each other greater than the width of a human head, whereby sound from each may be audible in each ear of the listener positioned between them, means to provide said two sources of sound with different versions of the same sounds intercepted at different loci corresponding to the positions of human ears, and means to fix the head of a listener in a given position between said two sources for presenting to the auditor the binaural effect of said different versions.

10. The method of securing virtual sound origins which comprises intercepting a right ear effect and a left ear effect of sound waves from a plurality of origins, whereby producing different compound waves comprising substantially similar components in different phase relation, and transferring each effect independently to both ears of a listener in such a way that the earlier effect at one ear reaches the other ear after the later effect has reached the other ear, whereby the similar components in different phase relation indicate characteristics angular virtual sources of sound, corresponding to the real origins.

11. The method of securing virtual sound origins which comprises picking up a right ear version and a companionate left ear version, transferring each of said versions to a sound emitting area, and transmitting each version from said area by air path independently to both ears of a listener in such a way that the first and earliest effect at one ear fails to reach the other ear before the second and later effect reaches the other ear.

12. The method of transmitting sound binaurally to human beings for determination of an outside locus of a virtual origin for said sound which comprises transmitting to one ear one of two binaurally related versions of sound, and transmitting to the other ear and to the head the remaining version of the sound in phase for binaural hearing, said last mentioned transmission being effected by directing a sound wave of said version toward the head whereby to immerse the head in said wave with concurrent presentation to the ear.

13. The method of transmitting sound binaurally to human beings for determination of an outside locus of a virtual origin for said sound which comprises transmitting in binaural relation to the two ears two binaurally related versions of the same sound, the transmission of at least one of them being effected by directing a sound wave of said

version toward the head whereby to immerse the head in said wave.

14. The method of transmitting sound binaurally to human beings for determination of an outside locus of a virtual origin for said sound which comprises transmitting to the two ears in binaural relation two versions of sound capable of producing a sense of direction upon reception by the ears, and immersing the head in a sound wave arriving at the head substantially simultaneously with arrival of the sound at the ears.

15. The method of transmitting sound binaurally to human beings for determination of an outside locus of a virtual origin for said sound which comprises transmitting to the two ears in binaural relation two differently phased versions of sound, and simultaneously immersing the head in sound waves corresponding to said two versions.

16. The method of transmitting sound binaurally to human beings for determination of an outside locus of a virtual origin for said sound which comprises transmitting to the two ears in binaural relation two differently phased versions of sound, and simultaneously immersing the head in a sound wave carrying said sound.

In testimony whereof I have hereunto affixed by signature.

W. BARTLETT JONES.