

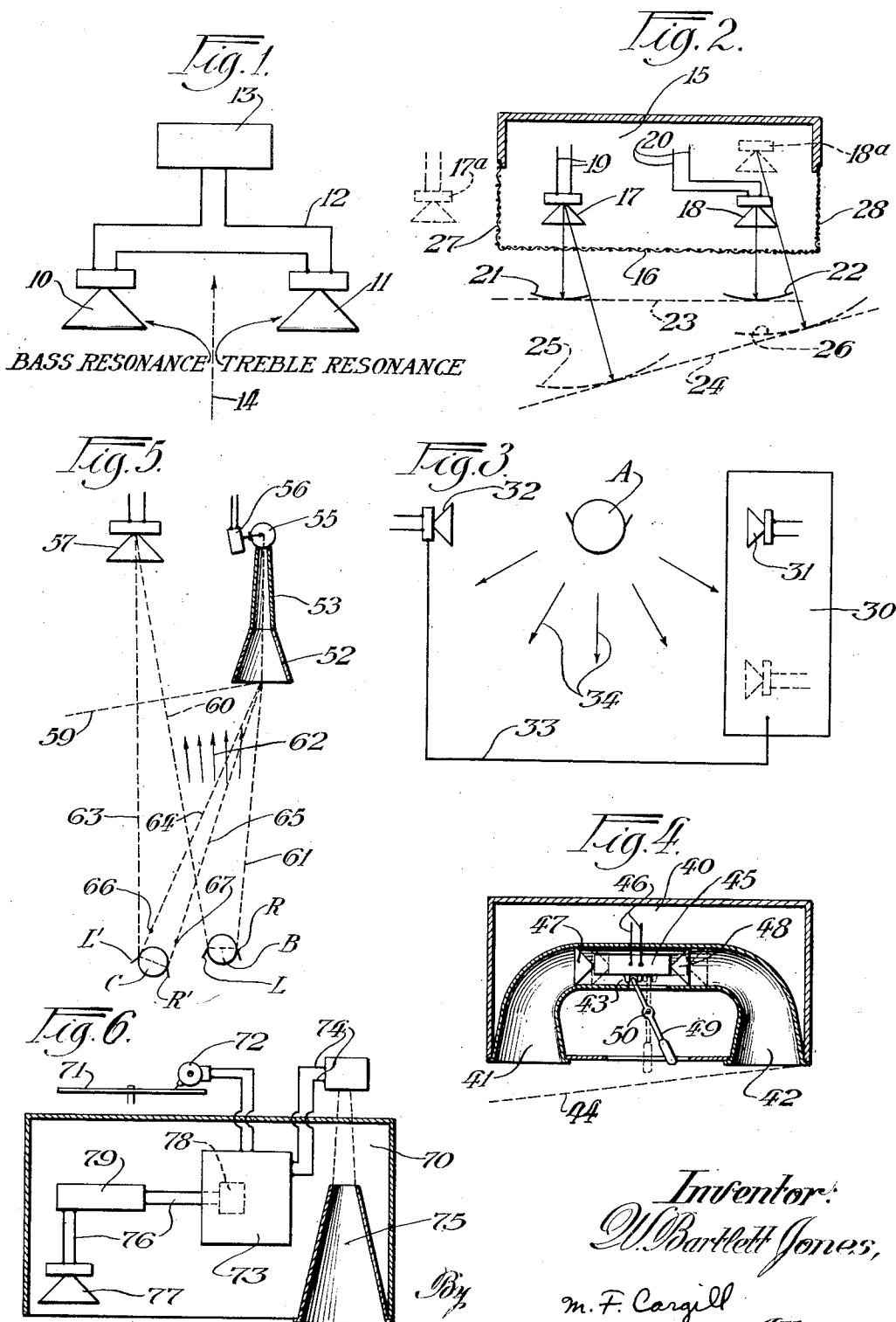
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DISTORTION IN SOUND TRANSMISSION

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## UNITED STATES PATENT OFFICE

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## DISTORTION IN SOUND TRANSMISSION

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The present invention relates to audition and especially to improved audition caused by presenting two related sound waves to a human being.

5 The invention has many aspects and is related to other of my inventions, being in one respect specific to the invention generally claimed in my copending application Ser. No. 326,023, filed Dec. 14, 1928, which is related  
10 to my copending application Ser. No. 183,414, filed April 13, 1927. The present invention is also generic in respect to phasing in response to different frequencies in dual sound systems and certain disclosures in Ser.  
15 No. 326,023 are specific embodiments of the present invention.

In order best to explain the invention I wish first to explain certain facts relating to the reception of sound by the human mechanism. Sound which reaches an individual  
20 from a single source directly ahead of the auditor travels in a single wave which strikes each ear at the same time. If the source is angular to the auditor this wave strikes the  
25 head at an angle and reaches one ear earlier than it reaches the other ear. The mind, through the hearing organs or senses, is accustomed to interpret a time lag in reception by the two ears as an angular direction. This  
30 is how human beings sense direction of sound.

Advantage has been taken of this knowledge to present two separate waves to the ears, so phases that angular directions may be sensed. Telephone receivers for the ears  
35 have been employed for this purpose in binaural systems. It is a known fact that sound heard through ear-phones or other ear-pieces is lacking in some feature which defect makes the sound unnatural. For ex-  
40 ample, two series-connected ear-phones produce sound that is sensed as originating in the center of the head. This is not natural, yet so far as the ears are concerned, the reception is the same as when a wave strikes  
45 the ears from an external source. Natural hearing requires that the sound be sensed as arising at a point in space outside the head.

I have discovered that when two separate waves are presented to the ears in a binaural  
50 system, the same sounds should also be pre-

sented to the head in order to secure the effect of sound originating in space outside the head. This may be concluded from the facts that sounds originating in space normally reach the head as well as the ears, and that  
55 head reception or bone conduction of sound by the head bones or other media is combined with the ear-drum reception to produce normal sound reception. I have found that the ear-drum reception alone is sufficient to de-  
60 termine direction, and that the head reception aids in determining the outside location of the sound origin in the direction determined by the ears.

When there are two sources and hence two  
65 waves containing the same sounds, I term these dual waves, or companion sound waves.

It is well known that delayed portions of sound, such as reflections from walls and the like, may be added to the primary wave to  
70 improve the quality of the sound. I have found that the two ears play an important part in this effect. When sound is heard in one ear alone and then is impressed on the other ear at a later time, two distinct effects  
75 may be produced according to the time of lag. If the second wave is not sufficiently delayed, that is, if it is within the binaural limit of about six inches lag, an angular direction is perceived. At or beyond the bi-  
80 naural limit the sound is sensed directly to the side of the head at which it is first heard. If the second sound arrives too late to determine an angular origin there is no ap-  
85 preciation that sound is being heard in the second ear, but the sound which is perceived in the first ear is increased in tone value and quality and in respects which make it more pleasing.

In the inventions of my earlier applica-  
90 tions I have taken advantage of these facts by producing two waves of the same sound from spaced sources, so arranged that a human head may be exposed to them, and that  
95 the ears may be exposed to them to detect the phase difference for determining angular directions.

Binaural effects may be obtained by picking up sounds at two locations corresponding to the relative positions of human ears,  
100

and transferring said sounds to the ears and head of an auditor. To obtain true reproductions of original directional relations the sounds should approach the ears of the auditor from opposite directions. When the angle of approach is made acute or otherwise less than  $180^\circ$ , the angle employed establishes the limits over which directions may be determined, and the true relations are distorted.

Should the two sources be spaced but a few feet apart and generally centered in the same direction, the effect may be heard only over the intervening space. To obtain the full effect with such an arrangement it is to be understood that the auditor should be so stationed that each ear receives the in-phase transmitted sounds at the same time, and this generally means that the auditor is substantially equidistant from the two sound reproducers that are employed. For perfect effects the foregoing presupposes the use of two sound channels of duplicating characteristics and of similar reproducers, or otherwise, that the two systems be such that there is no effective disturbance in phase relation during transmission and presentation.

The present invention depends upon the introduction of a change in phase in the sounds in the two systems, and particularly upon the introduction of phase changes for different frequencies. It has application to a variety of systems, including binaural systems, and a system in which a single sound channel is divided to form two sound channels for dual presentation. As an example of such a divided sound channel I refer to two series-connected electrical sound reproducers which are located to present their sounds over two paths to the auditor. Such a system may embody the present invention to present sounds at different frequencies at different phase relations, so that the direction that is sensed varies with the frequency of the sound.

Hereinafter, I have used the term "responsiveness" broadly to include all the phase changing characteristics of the systems.

One object of the invention is to provide a response characteristic in one system which is not duplicated in the other, so that a phase displacement, or a difference in phase displacement may be produced at a specific range of frequencies.

A more specific object is to employ two reproducing systems which have different natural frequency characteristics.

Still another object is to produce a sound reproducing unit having a horizontally elongated area from which the auditor senses that sound issues at different places according to the frequency and according to the relation of the auditor to it.

More generally stated it is an object of the invention to spread sound sources over a band

in a manner comparable to the way a prism breaks up a light beam into a spectrum.

Various other objects and advantages of the invention will become apparent from the following description of the several embodiments which are illustrated in the accompanying drawings to exemplify the invention.

Fig. 1 represents two series-connected loud speakers one of which is more quickly responsive to frequencies to which the other is not so quickly responsive, showing a treble-resonant one on the right and a bass-responsive one on the left.

Fig. 2 represents a cabinet housing two reproducers arranged as in Fig. 1 with provision for adjustment of the relation.

Fig. 3 represents two sound producers arranged in opposed relation for securing the maximum effect of the present invention.

Fig. 4 represents a cabinet having a special type of dual reproducer and means for adjusting the same with reference to the sound-emitting openings of the cabinet.

Fig. 5 represents a horn type of speaker and another type of sound reproducer embodying the invention.

Fig. 6 represents a modification of Fig. 5 and operation of the system for reproducing phonograph records.

In Fig. 1 there are two sources of sound which are actuated simultaneously by the same impulses to emit the same sounds. For this purpose I may employ two electrically operated loud speakers 10 and 11 connected in series in circuit 12 which may be operated by any electrical apparatus such as a radio, phonograph or other means generally designated 13. I prefer that speaker 10 be more quickly responsive to bass notes and that it be placed on the left, and that speaker 11 be more quickly responsive to higher tones as in the treble range, and that it be placed on the right. A wide or close spacing may be employed, three feet being given as an example. It is only required that the two be of different responsive characteristics, either one, but not both, being immediately responsive if desired, when connected as shown, and further, that they be separated in the same direction as the ears of the auditor, or normally horizontally separated.

An auditor centered on line 14 so that each ear is equidistant from the two speakers 10 and 11 will hear sound in the direction of line 14 if the emitted sounds are of the same character and are in phase. But when one source causes displacement of the phase of the emitted sound, relative to the same sound from the other source, the auditor will note a change of direction in sound of a certain frequency or range of frequencies only. When one of the dual waves issues earlier than the companion wave the observed direction will be displaced toward the source causing the early emission. I have found

that reproducing sources may be selected so that high frequencies come earlier from the right and lower frequencies come earlier from the left. Thus when a piano is heard the sounds may be made to appear from over the whole range between the two speakers, with no appreciation of the fact that there are two separate reproducers.

In Fig. 2 I have represented a cabinet 15 in which two reproducers may be housed. A screen 16 is preferably provided over the whole front of the cabinet. As near to the ends of the cabinet space behind the screen as is practicable, I employ two reproducers 17 and 18 of different response characteristics, having preferably more rapid bass response at the left and more rapid treble response at the right. These are illustrated as having separate circuits 19 and 20. The two circuits may be connected in series for simultaneous actuation as in Fig. 1, or they may be connected into a dual system, such as a binaural system, in which the actuating forces of certain components of the sound may be originally in or out of phase. Without a difference in response characteristics in the two reproducers the origin may be fixed by the position of the auditor, who may locate himself with reference to them so that he will hear the two sounds binaurally as described in my copending application Serial No. 326,023, but when the sound is displaced by different responses the origin will shift accordingly. A singer or a violin may be sensed as swaying as the musical scale is traversed.

The two reproducers 17 and 18 are preferably located so that certain waves, say those around middle C, are emitted by them at the same time to travel forward abreast each other, as indicated diagrammatically by the arcs 21 and 22 on the line 23. In such a case the region in which the greatest benefit of the arrangement may be obtained is directly forward of the line 23. But it may be desirable to place the cabinet in a corner and to have the beneficial region at an angle to the cabinet. To accomplish this the reproducers may be adjustably mounted relative to each other and to the cabinet front. I have indicated reproducer 18 moved rearwardly to a position 18<sup>a</sup> so that the line 24 of simultaneously issuing wave fronts, such as 25 and 26 is angular to the cabinet. In order to prevent possible distortions by reflection from the inner walls of the cabinet screening 27 and 28 may be provided along said sides to any extent desired. One or both may be mounted for extension laterally from the cabinet as shown at 17<sup>a</sup> to increase the spacing.

In Fig. 3 there is a cabinet 30 which may be like that of Fig. 2 with two reproducing systems, such as reproducers 31 and 32, having different response characteristics as de-

scribed. I provide at least one of the reproducers with an extension cord 33 so that it may be removed from the cabinet and placed in opposed relation to the other. By this arrangement an auditor A may obtain the maximum spreading of the sound as indicated by the arrows 34. This arrangement is more particularly described in my copending application Ser. No. 326,023. It will be understood that in reference to this use of the apparatus the spreading range is increased, but the zone in which the auditor A is permitted to locate himself is limited. In the preferred arrangement as described for Figs. 1 and 2 less spreading is obtainable but there is a greater degree of freedom for the auditor in locating himself.

In Fig. 4 I represent a modified form in which a cabinet 40 may have two tone-outlets 41 and 42 having elbows connected at the rear by a passageway 43 in which is mounted a special reproducing unit. The unit is represented as one which is movable in the passageway for the adjustment feature described. It is shown slightly at the left of central position to form the angular region defined by line 44. The unit itself has a common electro-mechanical device 45 operated by a circuit 46, and two differently responsive vibrating members 47 and 48 at opposite ends of the device, each actuated by the unit 45. A lever 49 pivoted at 50 is indicated for sliding the parts for adjustment.

In order to illustrate the wide variety of types of reproducers which may be selected I show the arrangement of Fig. 5. A horn 52 such as may be found in a cabinet phonograph with attendant extension parts 53 (shown herein in rectified form) is provided with an electrical operating attachment. I have indicated a phonograph diaphragm unit 55 with its needle operated by any well known attachment for that purpose designated 56. I have employed such a horn as a rapid high-frequency responsive reproducer. I have also employed different types of diaphragm unit 55 to vary the response characteristics. Measurement of the sound path in the horn may be made acoustically or mechanically, and for example, may be found to be about thirty inches. In the vicinity of the horn, either above or at the side, or below it, but in every case for normal hearing horizontally spaced from the horn, I may place a different type of loud speaker, such as a rapid bass-responsive cone speaker 57. I have herein shown the cone speaker 57 to be located about thirty inches behind the line 59 so that an angularly located audition region results.

B represents an auditor so spaced with reference to the two reproducers that each ear L and R is the same distance along the two direct sound paths 60 and 61. I have found that with this arrangement high frequency

sounds issue first from the right and lower frequencies issue first from the left. Some frequencies may appear directly from each reproducer and others may be located in the range between them. An orchestra appears to have an actual presence in the range covered by the two reproducers and there is a sensation of motion of the several instruments as the frequency of sound therefrom changes, giving life to the sources of sound. Improved audition results from the various out-of-phase waves received by the ears and the head, and the reflections of them which are added by the walls of the room. The bass speaker carries the body of the sound and the treble responsive speaker carries the detailed fine vibrations of the sound, and the two are coupled together to give excellent detailed reproduction.

In Fig. 5, C represents an auditor whose ears R' and L' are not equidistant from the two speakers. It is particularly to be noted that both ears are nearer to reproducer 57 than to reproducer 55. The line 63 represents the distance from L' to 57, line 64 the distance from L' to 55, and line 65 from R' to 55. The points 66 and 67 represent the points on lines 64 and 65 respectively, marking lengths equal to line 63. Certain low pitched sounds would be heard by C from source 57. At the time such a wave from 57 has reached L' the same wave from 55 is at points 66 and 67. But response in the horn type speaker brings higher frequencies to an advance position, and when the advance is sufficient to permit arrival of sound from 55 at L' or R' before arrival of the same sound wave from 57 the sound is heard as located in the horn. Other frequencies may be heard in the intermediate positions. Other auditory positions may be illustrated graphically in the same way.

Fig. 6 represents a modified form of apparatus having a horn type of speaker and a cone or other lengthless type. The cone-type and horn may be placed in the same cabinet and delay means introduced to compensate for the length in the horn. An acoustic path may be built into the cabinet or equivalent means employed, such for example as that shown in U. S. Pat. No. 1,696,315. In the arrangement shown 70 represents a phonograph cabinet. A record 71 is indicated diagrammatically, an electrical pick-up device 72 being used for the record. Electrical apparatus 73 is provided for distributing the picked up sound to the two reproducers, circuit 74 going to the horn 75, and circuit 76 going to the other speaker 77 through a suitable delay device 78 such as any well known electrical delay circuit. If desired other electrical apparatus may be placed in one of the circuits, such as circuit 76. Such apparatus is designated 79 and may be employed to introduce variations in response

characteristics in the circuit 76 as may be desired.

I have found that the selection of response characteristics has a bearing on the results obtained, and that there may be a consideration of this feature to effect the best results. For example, I have used a bass-responsive cone speaker and a treble-responsive horn in two different relations, using in each relation two different response characteristics in the horn. By substituting a high-frequency responsive diaphragm unit 55 for one which is more quickly responsive in a lower range of frequencies, different effects are produced. When the two loud speakers are pointing generally in the same direction and are moderately spaced as shown in the figures, it is possible with the higher frequency unit in the horn to hear sound from both reproducers and from the intervening space, all at the same time. Using the lower frequency unit 55 in the horn, it is possible to crowd substantially all of the tones into the intervening space with none or but few of them appearing in the separate reproducers. When the two reproducers are in opposed relation the same effects are observed. In such a case I have found a median point between them where the head may be located so that it will hear bass sounds issue from one speaker and treble tones from the other speaker, with other tones in the intervening space at various angles. When the head is moved toward one of the speakers to move the sound from the other for swinging it about the arc toward the other direction, all of the tones swing and the direction of many of them merge into the direction of the first speaker. The effect of hearing tones at the same time from opposite directions is not so pleasing as when all of the tones are located on the arc between the two speakers. By substituting the lower-frequency responsive unit 55 this may be accomplished. It is therefore desirable when using opposed reproducers that maximum phase difference lie near the binaural limit, preferably within it rather than beyond it.

Since the present invention is capable of shifting the phase relations of the same sounds in two systems according to frequency of the sounds, it may be employed to decrease or remove a phase difference as well as to create or increase a phase difference. For example, a binaural transmission system may be employed in which sounds are picked up in a true binaural relation. Such sounds are ordinarily transmitted in similar systems employing at the receiving end similar channels or apparatus which preserve the initial relation or the transmitted similar relation. Using the present invention, phasing may be introduced into the transmission system to vary the true relation according to frequency and this may be so accomplished that no true

binaural relation can be presented by ordinary apparatus at the receiving end. However when special receiving systems are employed embodying the principles of this invention, the systems may be so chosen as to compensate for the changes made in transmission, thereby bringing the sounds into or toward the true binaural relation. Use of such related transmission and receiving systems will permit a broadcasting station to transmit binaural effects which cannot be received except by apparatus specially balanced in characteristics against those characteristics which exist in the broadcasting station.

In using apparatus such as above described I have found that it is not essential for each reproducer to emit compression parts of the wave at the same time. Reversal of any one of them to change the relation in this respect has little effect upon the result. I have noted slight changes in making such a change but attribute this to the response characteristics of the devices, it being likely that the tendency to response is greater for compression than for rarification, or vice versa.

I have also found that a new mental consciousness toward the effect may be required for some individuals, and that it is readily acquired without effort or any considerable amount of exposure to the effect. The fact that the ears and the head are hearing two versions of the same sound from different directions, which may be in or out of phase, is a departure from normal conditions explaining why a new consciousness may be required.

I do not consider that the invention is limited to the use of separated loud speakers or separated sources of sound of the loud type, but contemplate broadly the introduction of frequency phasing into two systems so that sound may be presented to two ears for the effects which are produced by the phase displacement. The invention, therefore, is to be viewed broadly in keeping with the scope of the appended claims.

I claim:

1. Sound reproducing apparatus comprising in combination, two sound producers facing generally in the same direction, having different characteristics in time of response to different frequencies, and being relatively movable with respect to distance from a given plane within the direct path of the two sounds, and means for impressing upon each sound producing impulses corresponding to the same sounds.

2. Sound producing apparatus comprising in combination two horizontally separated sound producers arranged for presenting binaural effects, means to cause one of them to emit sound components over a range of frequencies, and means to cause the other to emit the same sound components, each means in combination with its producer being adapted

in combination with the other means in combination with its producer to emit the sound components in such timed relation that the sounds of components having the extremes of the frequency range emitted by the two reproducers are separated by an interval greater than the binaural time limit, and that the sounds of components of intermediate frequencies are separated by intervals within the binaural time limit.

3. Sound producing apparatus comprising in combination two horizontally separated sound producers arranged for presenting binaural effects, means to cause one of them to emit sound components over a range of frequencies, and means to cause the other to emit the same sound components, each means in combination with its producer being adapted in combination with the other means in combination with its producer to emit the sound components in such timed relation that sounds of components of some frequencies are separated by a time interval which is within the binaural time limit.

4. Sound producing apparatus comprising in combination, two sound reproducing systems, including two reproducers horizontally spaced and arranged for presenting binaural effects and means for causing each reproducer to emit the same sounds, the two systems having different characteristics in time of response to different frequencies adapting them (a) for emitting the sounds for audition by human ears in such a way that each ear hears the sound of one reproducer before the said ear hears the sound from the other reproducer, and (b) for relatively shifting the time of emission of the two same sound components according to the frequency of the sound thereof, whereby some sound according to the frequency may be heard first from one reproducer while at the same time sounds of another frequency may be heard first from the other reproducer, simultaneously with some sounds being heard at the same instant from each reproducer.

5. The method of producing sounds for audition to produce a sense of moving and spaced virtual origins with changes in frequency of the sound, which comprises impressing impulses corresponding to dual sounds upon two systems for carrying effects corresponding to sound, relatively distorting phase relations in said systems according to frequencies of said dual sounds, emitting dual sounds from said systems for binaural audition, and directing the emitted sounds to the ears of an auditor in such a way that the sound from one system may be heard by one ear in a binaural phase relation with the same sound from the other system.

6. The method of presenting sound to a human being which consists of dividing a channel carrying waves corresponding to sound into two channels, said two channels

having the properties of displacing the phase of the waves in said channels according to frequency of the sound to which components of the wave correspond, reproducing the waves in said channels as sound after such relative displacement, and presenting the reproduced sounds binaurally to a human being.

7. The method of presenting sound to a human being which consists of dividing a channel carrying waves corresponding to sound into two sound-reproducing channels, simultaneously slowing up waves of higher frequencies in one channel, simultaneously slowing up waves of lower frequencies in the other channel, and presenting said altered waves upon reproduction as sound, binaurally to a human being.

8. Two series connected loud-type electrically actuated sound reproducers having different characteristics in time of response to different frequencies, said reproducers being horizontally spaced for presenting binaural effects, being positioned to direct the sound into a common region to be occupied by an auditor, and being spaced from said region so that inphase similar sounds may be binaurally received by said auditor.

9. Two loud-type sound reproducers having different characteristics in time of response to different frequencies, said reproducers being horizontally spaced for presenting binaural effects, being positioned to direct the sound into a common region to be occupied by an auditor, and being spaced from said region so that inphase similar sounds may be binaurally received by said auditor, and means to simultaneously energize said two reproducers to produce the same sound.

In testimony whereof I have hereunto affixed my signature.

W. BARTLETT JONES.