June 10, 1969 M. J. MOWRY 3,449,519

SPEAKER SYSTEM FOR SOUND-WAVE AMPLIFICATION

Filed Jan. 24, 1968 Sheet 1 of 2

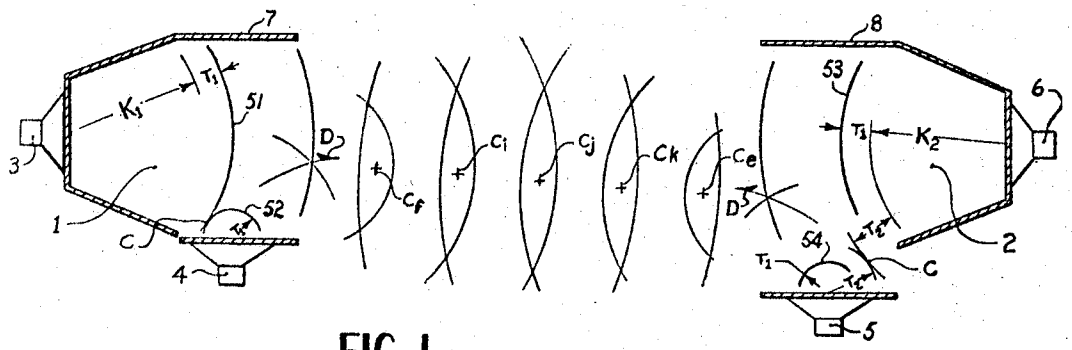


FIG. 1

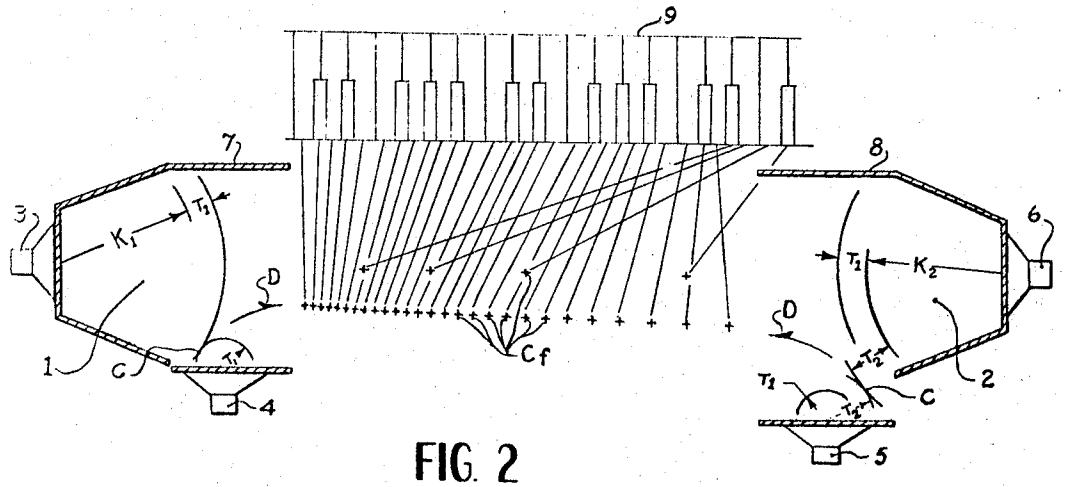


FIG. 2

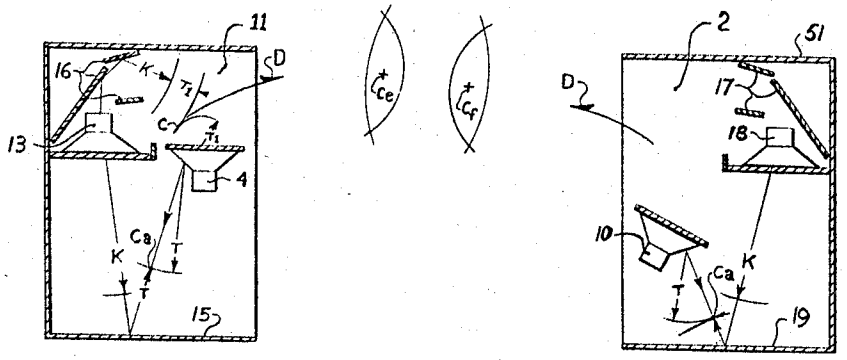
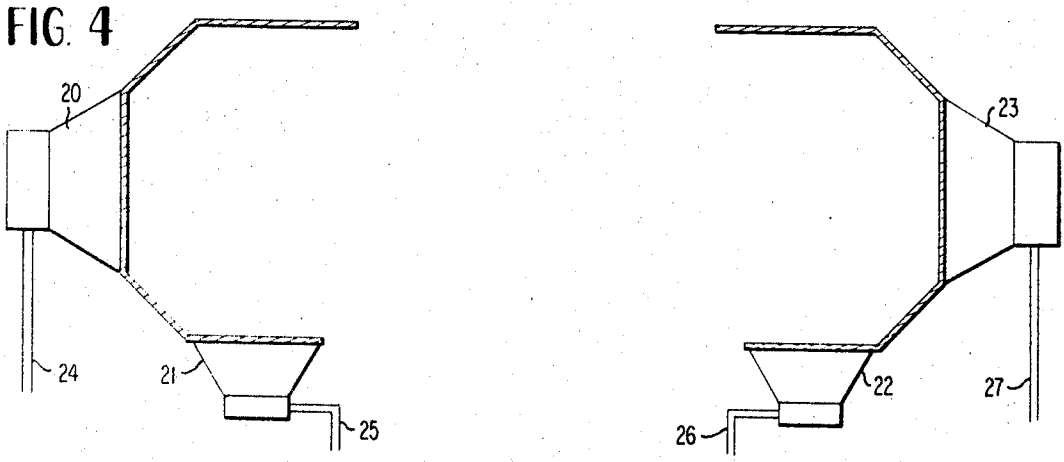


FIG. 3

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FIG. 4



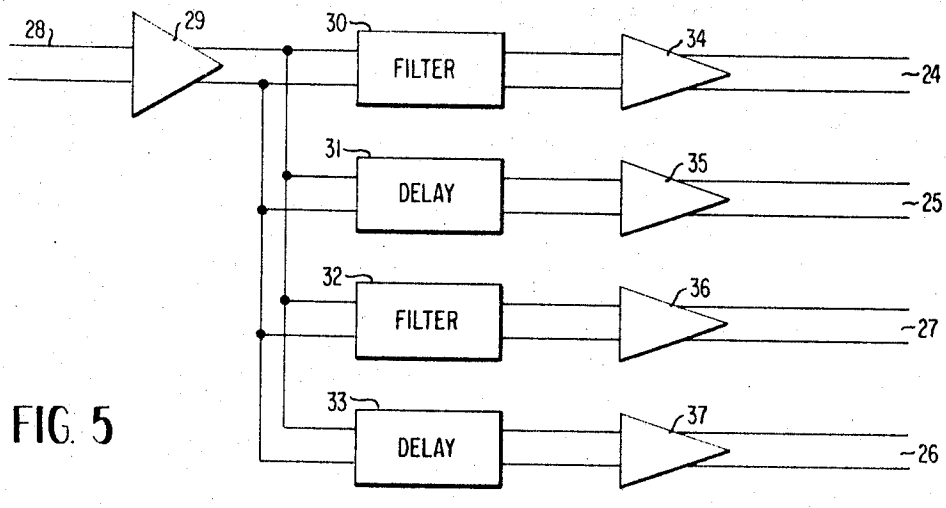


FIG. 5

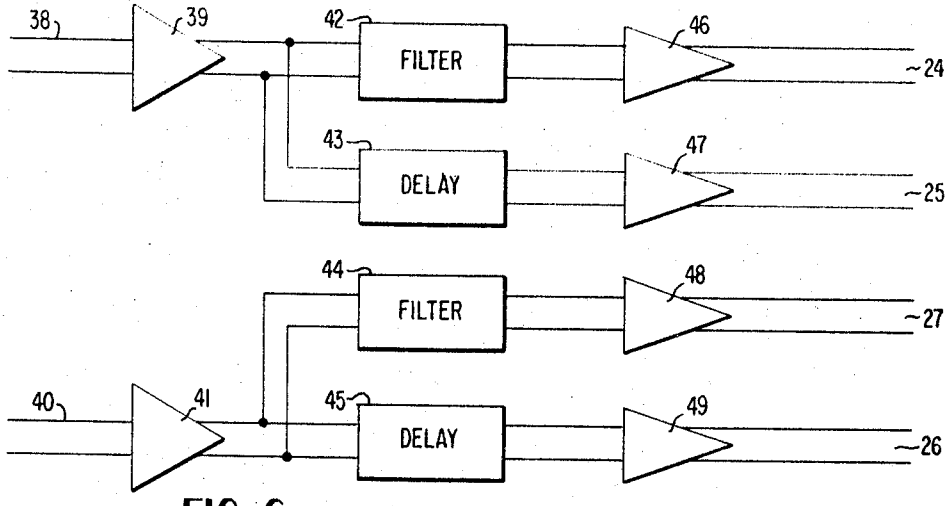


FIG. 6

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SPEAKER SYSTEM FOR SOUND-WAVE AMPLIFICATION

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Continuation-in-part of application Ser. No. 480,679, Aug. 18, 1965. This application Jan. 24, 1968, Ser. No. 700,196

Int. Cl. H04r 1/26

U.S. Cl. 179—1 8 Claims

ABSTRACT OF THE DISCLOSURE

A system for receiving one or more electrical input signals and developing sound waves from the signals, such that the various frequency components of the output sound wave appear to originate at various points in the free air in the vicinity of the system. Two pairs of speakers are placed at a distance from each other such that the output sound from each speaker pair is directed toward the other speaker pair, causing wave interference between the two speaker pairs. The speakers of each pair are also placed to cause interference between the sound waves from the two speakers in the pair. This interference is the apparent cause of the frequency separation.

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of my co-pending application Ser. No. 480,679, filed Aug 18, 1965, now abandoned, entitled "Atmospheric Amplification Process."

BACKGROUND OF THE INVENTION

This invention relates to an acoustical and electrical device for use in the reproduction of sound from electrical signals, producing apparent separation of sounds of different frequencies in an area of free air.

SUMMARY

I have designed and built a speaker system as described in more detail in the figures and specification. The system has the unusual characteristic of separating the frequencies of the output sound wave so that various frequencies appear to originate from different points in free air space. In its most basic embodiment, my system is not, in itself, a stereo system wherein two or more different signal channels are provided to control corresponding speakers. In this basic embodiment, my system operates with only one input signal provided to at least four speakers. This one input signal can be subject to various delays and frequency shaping prior to being applied to these speakers. The apparent point of origin of a sound wave from the speaker system depends upon the frequency of the sound wave.

In another embodiment of my invention, useable with a stereo system, the signal from one stereo channel is used to control two of the speakers and the signal from the other stereo channel is used to control the other two channels. These signals may also be subject to frequency shaping and delay before being applied to their corresponding speakers.

The theory used to explain the system in the following pages is an attempt to explain the observed effect. However, I do not know for sure that the theory is correct. My invention is in the speaker arrangement to create the separation of the apparent points of origin of the sound in free air space. The theory is added only as a possible explanation of the observed effect. Although this invention is explained in connection with the theory of operation, only that part of the explanation which

sets forth or implies physical structure is to be taken as a necessarily correct explanation of my invention.

I believe that the reason the system creates the unusual frequency separation set forth in the following paragraphs can be explained in accordance with the basic theories of wave interference.

Huygen's theorem states that "each element of a wavefront may be regarded as the center of a secondary disturbance which gives rise to spherical wavelets; the position of the wavefront at any later time is the envelope of all such wavelets." Fresnel's postulate states that secondary wavelets mutually interfere.

After interference and phase addition or subtraction), it is reasonable to suppose that the new position of the wavefront is determined by the positions of phase addition. The secondray wavelets at the positions of phase subtraction will have nulled. I suspect that my invention works because of a new wave front originating at the points of phase addition.

Because of the different frequencies involved, interference does not take place at only one point. Each frequency will have a different wavelength and thus, a different point of maximum interference. These different points serve as apparent points of origin for different frequency sounds.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is an illustration of a simple speaker arrangement according to this invention.

FIGURE 2 is an illustration of the speaker arrangement of FIGURE 1, illustrating, for an arbitrary spacing of components, the location within the atmosphere where the various notes of a piano are apparently reproduced.

FIGURE 3 illustrates the preferred embodiment of the invention. In this figure the speakers are shown arranged to compensate for the overloading which can occur because of the sonic interference between speakers.

FIGURE 4 illustrates the connections possible to the basic system of FIGURE 1.

FIGURE 5 illustrates an electrical system useable in connection with FIGURE 4 for monaural sound reproduction.

FIGURE 6 illustrates an electrical system useable in connection with FIGURE 4 for stereo sound reproduction.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGURE 1 illustrates a speaker having two channel activators, each having two speakers and associated enclosure material. The left channel activator **1** contains a primary speaker **3** producing an output sound wave indicated by wave front **51**. The left channel activator also contains a secondary speaker **4** producing a sound wave indicated by wave front **52**. These two speakers are situated to cause interference between wave fronts **51** and **52** in an area enclosed by deflector **7** of channel activator **1**. At the moment when the illustrated wave fronts exist, wave front **52** has travelled outward from speaker **4** for a time interval T_1. The wave front **51** has travelled outward from speaker **3** for a time interval T_1+K_1. Thus it can be seen that the electrical signal controlling speaker **4** must be delayed if wave fronts **51** and **52** are to represent the same instant of the same electrical signal.

K_1 represents the distance traveled by sound wave **51** from the primary speaker **3** before a like sound wave **52**, with the same characteristics but with a constant delayed difference in time separation, is produced in a secondary speaker **4**. Distance K can be equal to the effective length of an air filled sound delay chamber con-

taining a speaker, air, and a microphone, used to delay the signal controlling speaker **4**.

T_1 represents the distance traveled by the sound waves, after the original delay period, before the sound waves arrive at an initial point of contact.

C represents the initial point of contact of the two sound waves. This point is not equidistant from the speakers; hence, the radii of the sound waves are not equal, and, the arc length of the sound waves will not be equal to any progression of the intersection after their initial contact at point C.

Note that wave fronts **51** and **52** meet at an angle. The vectoral resultant of this angular meeting of waves forces the resulting combined sound wave out of the left channel activator in a direction toward the right channel activator. During at least some part of the contact between wave fronts **51** and **52**, interference between the waves will cause intensification of the sound energy at ondary speaker **4**. Distance K_1 can be equal to the effecpoints of phase addition. The observed effect of intensification of sound energy coming from such points seems to be best explained by the creation of new sound sources at the points of intensification. It seems to be from these new sound sources that the sound is forced in the direction of the other channel activator.

The amount of intensification, or intensification ratio, appears to be directly related to the ratio between the lengths of the radii of the two sound waves; however, the intensification ratio is also affected by the efficiency of the angle of contact. The efficiency of the angle of contact should vary as the strength of either sound wave varies; it should vary also if the ratio between the lengths of the radii of the two sound waves is varied.

The area of contact, now intensified in strength, acts as a new sound source with dissipation in all directions. Effectively, atmospheric intensification seems to provide a non-mechanical atmospheric speaker with spherical emission. It has fidelity capabilities that are unlimited by the individual fidelity characteristics of the component primary and secondary speakers.

By varying the speaker locations and arranging deflectors **6** to divert the sound waves from the primary speaker **3** into a desirable direction, special effects may be obtained from the atmospheric intensification process.

A single channel activator is an atmospheric intensification unit that is highly efficient at intensifying sound waves with short wavelengths, but it becomes increasingly inefficient as the wavelength of the applied sound wave lengthens beyond a predetermined length. The secondary speaker **4** is placed just beyond the delay time K_1 so that only the short wavelengths can develop condensations and rarefactions during the progression of the contact of the two sound waves. Effective contact is limited to the space which is to the front of and between the two speakers; tangents of the two sound waves, at corresponding condensation or rarefaction periods, should form an acute angle between the waves. Maximum wavelength for an effective contact with spherical omission quality cannot exceed the length of the contact progression which occurs where the angle between the tangents is acute. Beyond this point the emission should be directional, or the vectorial resultant of the forces (sound waves) at that part of the progressing contact where the sound waves intensify.

Because the system will also be used for sound waves that have wavelengths too long to develop condensation and rarefaction periods within the limited contact time, in which the two forces remain more directional than spherical, or semispherical, two channel activators are used.

Regardless of the amount of intensification along the line where tangents to the colliding sound waves form an acute angle, the speaker arrangements in the channel activator will have a directional dissipation as shown by

the half-arrows D. This directional dissipation may be compared to the sound produced by a trumpet—the sound is expelled directionally but concentrated forces within the sound wave attempt to dissipate spherically, and there are no deflective surfaces present.

In summary, the waves illustrated in the channel activator speaker arrangements will develop a spherical directional, spherically emissive output sound wave beamed along the line of contact as illustrated by the directional half-arrows D; however, the relationship of wavelength and component equipment spacing causes a variation in the quantity and quality of any intensification or modification which may develop. It is this variation, which is utilized to produce the inverse effectiveness of the channel activator upon sounds with different apparent wavelengths.

The right hand channel activator **2** contains speakers **5** and **6** for producing wave fronts **54** and **53** respectively in an area enclosed by deflector **8**. The operation of channel activator **2** is analogous to the operation of the channel activator **1**.

To produce a new sound source, from a monaural signal, in free air between two channel activators, the channel activators should modify the sound waves from the respective channel activators in somewhat different manners. Differing amounts of spherical emission qualities should be effected upon the sound waves from the respective channel activators. Generally, for those sounds which are to be produced between the channel activators, the change in the amounts of spherical/directional emission qualities imparted respectively by left and right channel activators should be inverse to the change in the wavelength of the sound waves.

A difference in the manner in which the individual channel activators affect the respective sound wave components may be controlled by making a physical difference in variables such as: the length of time delay between a primary signal and its respective secondary signal; spacing of baffles; spacing between the primary speaker and its respective secondary speaker; variation in electrical characteristics of signals from the primary amplifiers (such as tone adjustment); size of primary speaker cones and/or size of enclosures. Any combination of these differences can be used to add to the total mis-matching of the channel activator units.

So that the final sound will be produced with full tone and harmonic responsiveness, differing tone-inflections should be applied upon the sound waves from the respective primary speakers. A natural tone response can be obtained even when one channel activator is adjusted for extreme treble and the other adjusted for extreme bass.

For illustration, an effective method of accomplishing a difference in the amounts of modification performed by two channel activators in order to produce a spherical type sound emission with multiple concentrated sources of this emission spaced throughout an elongated mass of free air between the two channel activators is to have a different spacing between the primary and secondary speakers in the two channel activators. A difference in the tone characteristics of the signals from the primary amplifiers may also be applied.

Components in the channel activators are spaced to provide a large ratio, more than 2/1 at the point of initial contact, between the radii of the sound waves which are produced by primary and secondary speaker cones. The distance between the speakers in channel activator **1** is only slightly greater than the distance which a sound wave travels from the primary speaker before a delayed signal causes the secondary speaker to produce a corresponding secondary sound wave. This arrangement allows sound waves with a wavelength of approximately 3 inches or less to develop a strong point of initial contact in the space in front of the secondary speaker **4**. Longer sound waves are allowed to escape without developing in

initial contact which is as highly effective; however, the sound wave from secondary speaker 4 will continue to impose spherical/directional emission characteristics upon the sound wave from the primary speaker, but the quality of spherical characteristics decreases as the wavelength increases.

Components in channel activator 2 are spaced to allow the shorter wavelengths to escape without an effective contact as strong as the more efficient contact which is developed in channel activator 1. The ratio between the radii of the sound waves from the primary and secondary speakers is reduced because of the increased distance between primary speaker 6 and secondary speaker 5. The ratio of intensification appears to be directly related to the ratio of the radii between the primary and secondary sound waves; the intensification ratio for short wavelengths in channel activator 2 is not as high as in channel activator 1.

Since the longer wavelengths escape a highly effective point of initial contact in channel activator 1 the strongest point of contact for the longer wavelengths will occur either between the primary and secondary speakers of channel activator 2 or within the elongated mass of free air between the two channel activators. Since a half-note change in musical pitch produces a much larger change in wavelength at lower frequencies where the wavelength is longer, only a relatively few musical notes produce a strong point of initial contact in the area between the primary and secondary speakers in channel activator 2.

The location of remaining effective contact points for the development of atmospheric intensification will occur within the mass of free air between the two channel activators. Directional sound waves from channel activators 1 and 2 proceed into the area between the two channel activators. A strong point of effective contact is then developed at a point between the two channel activator units. The location at which the strongest point of effective contact occurs is influenced by variables such as frequency, harmonic content, amount of modification performed by the respective channel activators, spacing between the channel activators, phase relationship of the speakers, and differences in responsiveness within the amplifiers.

The sound waves which escape from channel activator 1 are intercepted, at one or more points (*Ce*, *Cf*, *Ci*, *Cj*, *Ck*) within the mass of free air, by sound waves from channel activator 2. The points of interception nearest to either channel activator (*Ce* and *Cf*) should have the greatest ratio between the radii of the sound waves from the two channel activators, but since channel activator 1 has a higher intensification ratio for the shorter of the spherical/directional wavelength than channel activator 2 the point of contact *Cf* nearest to channel activator 1 has the highest concentration of energy to dissipate. As the wavelength becomes longer the effectiveness of spherical/direction qualities imposed upon the respective sound waves from the channel activators decreases for channel activator 1 and increases for channel activator 2.

As the wavelengths become longer or shorter the above variables change in value and the strongest point of effective contact *Cf* for various wavelengths can occur at a point anywhere within the mass of free air between the two channel activator units. Charging of the spacing between the two channel activator units (the length of the mass of free air) also changes the locations at which the various wavelength arrive at their strongest point of effective contact.

Spherically dissipated sound waves which result from a sound wave interception and intensification process between channel activator 1 and channel activator 2 also will be intercepted by additional sound waves, but any energy dissipation from this contact will not reach the amplitude attained at the initial interception of the strong directional sound waves. Most of the energy from the new sound source will have been dissipated in a spherical direction rather than in a concentrated directional wave.

Up to this point, the sound waves which have been discussed would have a sine wave as a representative form of voltage or current, but most musical tones do not have a voltage wave form comparable to that of a sine wave.

For example, a musical tone from a violin, with prominent 3rd, 4th, and 5th harmonics, has many condensation and rarefaction changes within one wavelength. Whereas the illustration in FIGURE 1 may appear to be limited to effectiveness within a narrow range of wavelengths, the harmonic content of musical sound waves multiplies the range of effectiveness.

Also, the overtone, or harmonic content, of sound waves of the same musical note but from different musical instruments causes the effective point of contact *Cf* for the given musical note to be at different locations for the different instruments.

Generally, as illustrated in FIGURE 2, with a given spacing of components and the channel activators, the reproduced sounds from at least a segment of the range of a given musical instrument, such as a piano, will be located with the shorter wavelengths developing a final sound source near to channel activator 1. The longer wavelengths will be near to channel activator 2. The remaining intermediate notes of the segment of the range will be located, in proportion to the change in wavelength between the various notes, within elongated mass of air between the channel activators.

When the wavelengths become too long to develop an atmospheric intensification interception within a limited predetermined spacing of the channel activator components, the progression pattern, for the location at which a half-note tone change produces the next point of sound production, is terminated. Any further change in tone (wavelength) beyond the predetermined pattern will begin a new sound production pattern with the intensification process occurring at an interception of wavelengths which are one or more wavelengths different in time of origin at their respective primary speakers.

The entire family of musical sound waves can be reproduced, with atmospheric intensification, in the space between the primary speakers of channel activators 1 and 2. Under theoretical circumstances no two tone variations would have exactly the same point of origin of the final development of atmospheric intensification. However, an overlapping of areas in which distinctively different groups of musical tones develop can be allowed without harm to the reproduced sounds. This allows the distance between the channel activators to be changed arbitrarily.

The monaural speaker arrangement of FIGURE 1 which has been described will produce a desirable sound product, but better results may be achieved if the reverse sides of the four speakers have their outputs cancelled (absorbed) to prevent dumping non-spherical type sound waves and mechanical distortion into the atmosphere. The cancellation of these four outputs would be costly, and the efficiency of the four speakers would be reduced.

By altering the speaker placement as shown in FIGURE 3, and by using deflectors **16** and **17** and semi-open enclosures **50** and **51** to obtain the desired direction of travel for the elementary sound waves from the conventional cone primary speakers **13** and **18**, the outputs from both sides of all four speakers can be used to produce atmospheric intensification. Primary sound waves in the added areas are reflected by the walls **15** and **19** of the respective enclosures. The output from the reverse sides of the respective secondary speakers **14** and **10** intercept the reflected primary sound waves to attain an added point of effective contact *Ca*. The sound waves are traveling in opposite directions when they meet; atmospheric intensification as previously illustrated in FIGURE 1, will develop without any regard for wavelength.

Since the outputs from both sides of all the speakers encounter physical activity which resists equalization of

the pressure differences which exist at the opposite sides of each speaker cone, conventional long-pathed baffle isolation of these pressure differences is not required.

The inclusion of the newly described areas of development of atmospheric intensification, with reflected primary sound waves, now gives each channel activator the ability to respond to all audio frequencies. The channel activators are capable of fully reproducing atmospherically, stereo signals with wide separation; however, stereo signals that contain a common sound source but with different time dimensions are reproduced in the elongated mass of air between the primary speakers of the two channel activators. The location of the apparent atmospheric sound source is determined primarily by the time dimensioning within the stereo signals.

The added areas of development of atmospheric intensification reduce the effectiveness of the system to reproduce a given tone from a monaural signal with maximum amplitude at a specific concentrated area; a given tone now can have three prominent areas of atmospheric intensification.

To retain the stereo capabilities and yet regain the concentrated origin of an atmospheric intensification product from a monaural signal, the tone control of the primary amplifier which feeds into channel activator **1** should be adjusted for bass response, and, the tone control for the primary amplifier which feeds into channel activator **2** should be adjusted for treble. These adjustments reduce the effectiveness of the added areas of development on monaural signals. The original area of atmospheric intensification, between the two channel activators, will have a higher intensification ratio and regain its dominant characteristics.

FIGURE 4 shows connections to the speaker system of FIGURE 1. This is illustrative only and such connections could also be made to the system of FIGURE 3.

FIGURE 5 illustrates an electrical system useable with the speaker system of FIGURE 4 for monaural sound reproduction. An electrical signal bearing sound information enters pre-amplifier **29** over line **28**. Filters **30** and **32**, which may be treble emphasis and bass emphasis filters, feed the signal from pre-amplifier **29** to power amplifiers **34** and **36** which respectively feed primary speakers **20** and **23** via lines **24** and **27**. Delay means **31** and **33**, which may include acoustical delay lines, feed the pre-amplifier output to power amplifiers **35** and **37** which respectively feed secondary speakers **21** and **22** via lines **25** and **26**.

FIGURE 6 illustrates an electrical system useable with the speaker system of FIGURE 4 for stereophonic sound reproduction. An electrical signal bearing the sound information from one channel of a stereo system enters pre-amplifier **39** via line **38**. Filter **42** feeds power amplifier **46** which drives primary speaker **20** via line **24**. Delay means **43** feeds power amplifier **47** which drives secondary speaker **21** via line **25**. An electrical signal from the other channel of the stereo system enters pre-amplifier **41** via line **40** and controls, in like manner, speakers **23** and **22**.

As noted earlier, the use of filters for difference in tone characteristics provides an improved response but is not absolutely necessary for system operation. Filters **30**, **32**, **42** and **44** could be reduced to a unity transfer function and the system would still work.

Many more examples of the application of the present invention will suggest themselves to those skilled in the art. Alternative methods of accomplishing the invention may suggest themselves to those skilled in the art. Accordingly, the scope of the present application is only limited to the extent of the claims which follow.

I claim:

1. A speaker system for the reproduction of sound from electrical signals comprising:

(a) a first primary speaker for receiving a first electrical signal and for generating a first sound wave corresponding to said first electrical signal, said first primary speaker having a front face in a first plane,

(b) a first secondary speaker for receiving a time-delayed version of said first electrical signal and for generating a second sound wave corresponding to said time-delayed version of said first electrical signal, said first secondary speaker having a front face in a second plane effectively perpendicular to said first plane, said first sound wave and said second sound wave acting together to produce a resulting third sound wave,

(c) first means for directing said first primary speaker and said first secondary speaker in such a manner as to cause said third sound wave to be directed in a first direction along an atmospheric path,

(d) a second primary speaker for receiving a second electrical signal and for generating a fourth sound wave corresponding to said second electrical signal, said second primary speaker having a front face in a third plane,

(e) a second secondary speaker for receiving a time-delayed version of said second electrical signal and for generating a fifth sound wave corresponding to said time-delayed version of said second electrical signal, said second secondary speaker having a front face in a fourth plane effectively perpendicular to said third plane, said fourth sound wave and said fifth sound wave acting together to produce a resulting sixth sound wave, and

(f) second means for directing said second primary speaker and said second secondary speaker in such a manner as to cause said sixth sound wave to be directed in a direction opposite to said first direction along said atmospheric path,

whereby a listener situated away from said atmospheric path can hear tones which appear to originate from said path at points determined by the frequencies of said electrical signals and therefore by the frequencies of said tones.

2. A speaker system for reproduction of monaural sound according to claim **1** wherein said first electrical signal and said second electrical signal are identical to each other.

3. A speaker system for reproduction of stereophonic sound according to claim **1** wherein said first electrical signal is derived from one channel of a stereophonic system and said second electrical signal is derived from a second channel of said stereophonic system.

4. A system according to claim **1** further comprising:

(a) a bass emphasis filter in the input signal path of one of said primary speaker means, and

(b) a treble emphasis filter in the input path of the other of said primary speaker means.

5. A speaker system for the reproduction of sound from electrical signals comprising:

(a) a first primary speaker having a front end and a back end for receiving a first electrical signal, for generating a first front-end sound wave from its front end, and for generating a first back-end sound wave from its back end,

(b) a first secondary speaker having a front end and a back end situated to one side of said first primary speaker for receiving a delayed version of said first electrical signal, for generating a second front-end sound wave from its front end, and for generating a second back-end sound wave from its back end,

(c) first reflector means for reflecting said first front-end sound wave to the back end of said first secondary speaker,

(d) first deflector means for deflecting said first back-end sound wave across a region in front of the front end of said first secondary speaker to produce a resulting first output sound wave directed in a first direction along an atmospheric path,

(e) a second primary speaker having a front end and a back end for receiving a second electrical signal, for generating a third front-end sound wave from its front end and for generating a third back-end sound wave from its back end,

(f) a second secondary speaker having a front end and a back end situated to one side of said second primary speaker for receiving a delayed version of said first electrical signal, for generating a fourth front-end sound wave from its front end and for generating a second back-end sound wave from its back end,

(g) second reflector means for reflecting said third front-end sound wave to the back end of said second secondary speaker, and

(h) second deflector means for deflecting said third back-end sound wave across a region in front of the front end of said second secondary speaker to produce a resulting second output sound wave directed in a direction opposite to said first direction along said atmospheric path,

whereby a listener situated away from said atmospheric path can hear tones which appear to originate from said path at points determined by the frequencies of said electrical signals and therefore by the frequencies of said tones.

6. A speaker system for reproduction of monaural sound according to claim **5** wherein said first electrical signal and said second electrical signal are identical to each other.

7. A speaker system for production of stereophonic sound according to claim **5** wherein said first electrical signal is derived from one channel of a stereophonic system and said second electrical signal is derived from a second channel of said stereophonic system.

8. A system according to claim **5** further comprising:

(a) a bass emphasis filter in the input signal path of one of said primary speaker means, and

(b) a treble emphasis filter in the input path of the other of said primary speaker means.

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U.S. Cl. X.R.

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