

June 23, 1964

R. C. AVEDON
LOUDSPEAKER SYSTEM

3,138,667

Filed March 29, 1962

3 Sheets-Sheet 1

Fig. 1

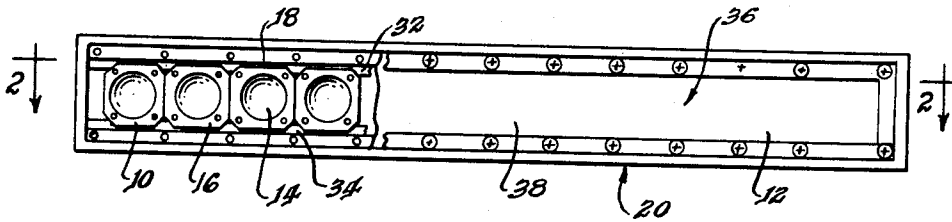


Fig. 2

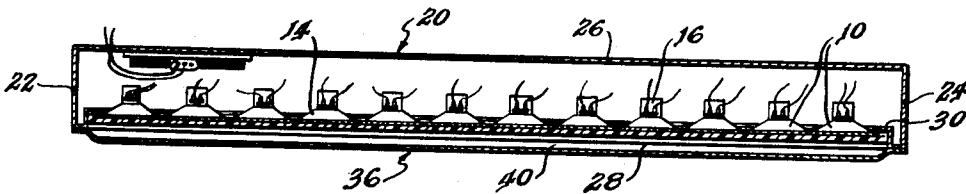
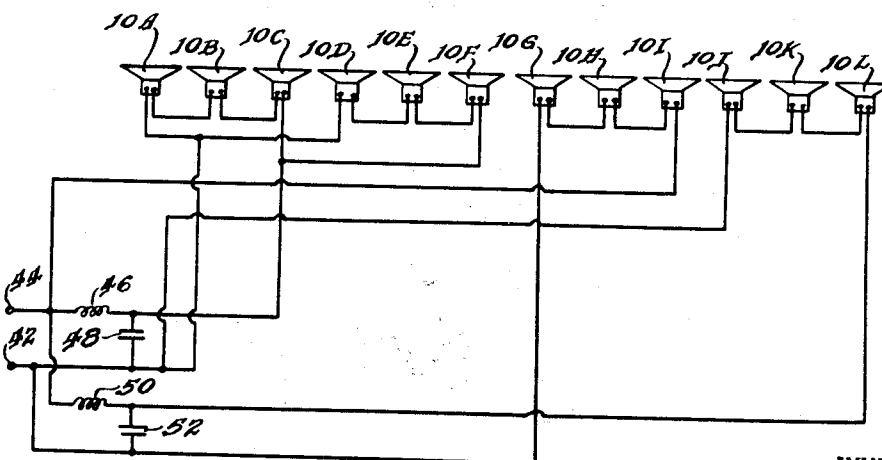


Fig. 3



INVENTOR.
Robert C. Avedon
BY
*Stone, Niernan,
Burmeister & Zimmer
Attorneys*

June 23, 1964

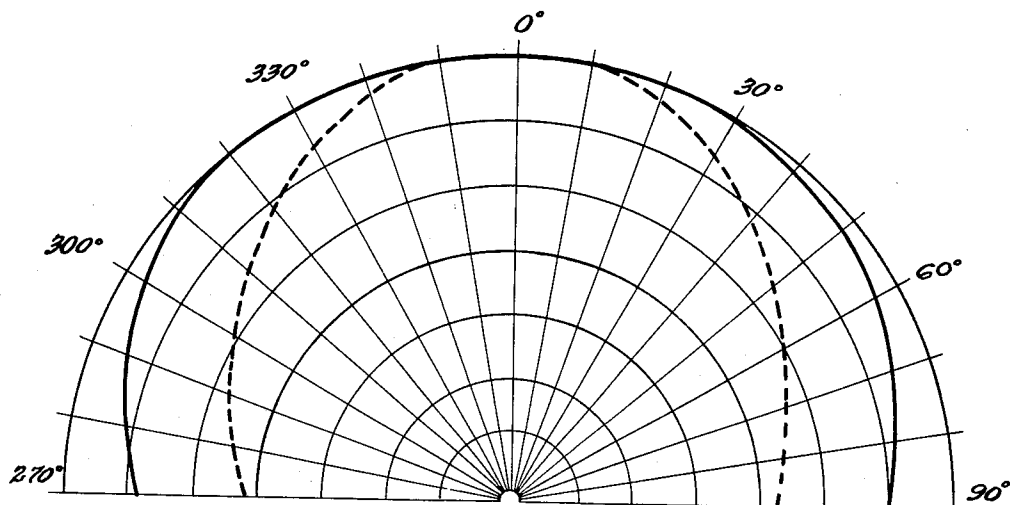
R. C. AVEDON
LOUDSPEAKER SYSTEM

3,138,667

Filed March 29, 1962

3 Sheets-Sheet 2

Fig - 4



INVENTOR.
Robert C. Avedon
BY
Stone, Nierman
Burmeister & Zumner
Attorneys

June 23, 1964

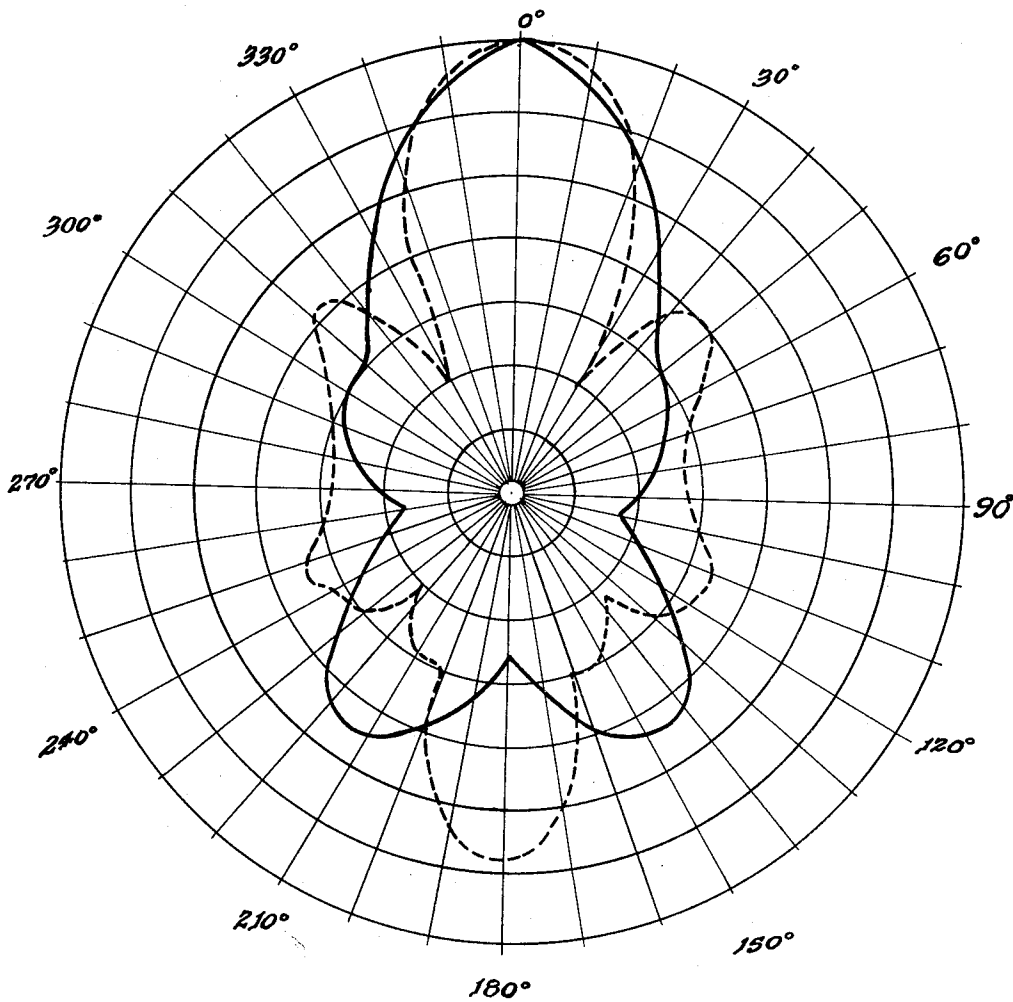
R. C. AVEDON
LOUDSPEAKER SYSTEM

3,138,667

Filed March 29, 1962

3 Sheets-Sheet 3

Fig - 5



INVENTOR.
Robert C. Avedon

BY

*Stone, Nierman,
Burmeister & Zummer
Attorneys*

1

3,138,667

LOUDSPEAKER SYSTEM

Robert C. Avedon, Rio Piedras, Puerto Rico, assignor to Electro-Voice, Incorporated, Buchanan, Mich., a corporation of Indiana

Filed Mar. 29, 1962, Ser. No. 190,515

10 Claims. (Cl. 179—1)

The present invention relates generally to loudspeaker systems, and is particularly directed to loudspeaker systems for public address uses.

The prime purpose of a public address system is, of course, to provide the audience with the illusion that no such system exists, that is, that all the sound they hear is reaching the audience directly from its original source. It is often difficult and costly to provide this illusion, particularly when the auditorium does not possess optimum acoustic characteristics and when microphones used with the sound system are located within the auditoriums, such as on a stage or the like. Acoustic feed back between the loudspeakers and the microphones places stringent requirements on the loudspeaker systems, particularly when the performers are working at relatively great distances from the microphones. The present invention is directed to providing a loudspeaker system which has particular usefulness in such surroundings.

A loudspeaker system constructed according to the teachings of the present invention employs a plurality of separate loudspeakers mounted on an axis at very short intervals to simulate a straight line source of audio power. Loudspeakers in the form of straight line audio sources are not broadly new and are disclosed by Harry F. Olson in "Acoustical Engineering" by D. van Nostrand Company, Inc., Princeton, New Jersey, 1957, at page 36. As clearly shown in this book, the directional characteristics as measured along a plane intersecting the line source, become increasingly sharp as the length of the line increases, that is, as the line source increases in length from a fraction of a wave length to a plurality of wavelengths, the major lobe which is directed normal to the axis of the line source becomes narrower. Of great importance for public address uses is the fact that the radiation off the ends of the line of such a line acoustic source is very small and is made up solely of side lobes. This fact makes it possible to mount the line source loudspeaker system above the microphone in the auditorium with the axis of the loudspeaker system vertically disposed, and, in this manner, position the microphone at a null point in the radiation pattern of the loudspeaker system.

Unfortunately, the beam radiated by a straight line source becomes narrower as the frequency increases for a given length source. Further, as the length of the source becomes a plurality of wavelengths long, additional lobes are generated, thus reducing the effective radiation of the straight line source, and further, generating lobes which are apt to increase the likelihood of feedback between the loudspeaker and the microphone. For these reasons, straight line loudspeaker sources have been limited in their application, since the range of audio frequencies which must be handled in a public address system is relatively large.

It is therefore an object of the present invention to provide a line source loudspeaker system with a radiation distribution in the plane of the line source which is more nearly uniform throughout the useful audio frequency range.

It is a further object of the present invention to provide a line source loudspeaker system with a radiation distribution in the plane of the line source which is not excessively sharp at the higher frequencies.

Further, it is an object of the present invention to provide a line source loudspeaker system for the useful range

2

of audio frequencies which has a polar distribution minimizing spurious lobes, particularly at the higher frequencies and particularly off the ends of the line.

These and further objects of the present invention will be more fully appreciated from a further consideration of this specification, particularly when viewed in the light of the drawings, in which:

FIGURE 1 is a front elevational view of a loudspeaker system constructed according to the teachings of the present invention, partly broken away and in sections;

FIGURE 2 is a sectional view of the loudspeaker system illustrated in FIGURE 1 taken along the line 2—2 of FIGURE 1;

FIGURE 3 is a schematic electrical circuit diagram of the loudspeaker system illustrated in FIGURES 1 and 2;

FIGURE 4 is a graph illustrating the horizontal distribution of sound energy from the loudspeaker system in FIGURES 1 through 3, the loudspeakers being mounted in a vertical line; and

FIGURE 5 is a graph illustrating the vertical energy distribution of the loudspeaker system of FIGURES 1 through 3, the loudspeakers being mounted on a vertical axis as in FIGURE 4.

The embodiment of the invention illustrated in FIGURES 1 through 3 employs a plurality of loudspeakers 10 which are mounted in a straight line which has been designated 12 and confronting a common plane. The loudspeakers 10 are of conventional construction and employ diaphragms 14 which are actuated by magnetic transducers 16. The diaphragms 14 are in the shape of a cone, and the axis of the cone intersects normally the line 12. Each of the speakers 10 is mounted as close as feasible to the adjacent speakers in order to provide the nearest simulation to a line source of audio energy. Each of the speakers 10 is provided with a flange 16 which surrounds the cone 14 thereof, and the flanges 16 have rectangular edges 18. The edges 18 of each speaker abut the edges 18 of the adjacent speakers.

While the present invention may be practiced without any baffle means, destructive interference as a result of out of phase sound waves originating from one surface of a cone impinging on the other surface of the cone deleteriously affect frequency response of the loudspeaker system. For this reason, the loudspeaker system illustrated in the figures employs a baffle means in the form of a closed elongated rectangular box 20 which is provided with a top 22, bottom 24, back 26 and face 28. The face 28 has a recessed flange 30 with parallel sides 32 and 34. The face 28 of the box 20 is open between the sides 32 and 34, and the loudspeakers 10 are mounted within this opening, the flanges 16 of the loudspeakers being mounted on the sides 32 and 34 of the recess 30. The loudspeakers 10 completely fill the entire opening, and are sealed in position by a face plate 36 which is also mounted on the recessed flange 30. The face plate 36 has a central protrusion 38 which accommodates a porous strip 40 of open cellular foam material. Also, the face plate 36 is perforated in the region of its protrusion, so that the acoustically permeable strip 40 protects the loudspeakers from the ambient atmosphere.

All of the loudspeakers 10 are excited in phase, in order to provide a straight line source of audio energy. FIGURE 3 illustrates the electrical connections of the speakers 10. It is to be noted that twelve speakers are employed in the disclosed embodiment, and these speakers have been designated 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10h, 10i, 10j, 10k, and 10l. It is to be noted that one terminal of speaker 10a is connected to an input terminal 42 and that speaker 10a, speaker 10b and speaker 10c are connected in series. The other terminal of speaker 10c is connected to an input terminal 44 through a choke 46, and a capacitor 48 is connected between this terminal of

speaker 10c and input terminal 42. Also, loudspeakers 10d, 10e and 10f are connected in series and also connected in parallel with the speakers 10a, 10b, and 10c. The loudspeakers 10g, 10h and 10i, are also connected in series and are directly connected across the terminals 42 and 44. The speakers 10j, 10k and 10-1, are connected in series, and one terminal of the speaker 10j is connected to the terminal 42, while the one terminal of the speaker 10-1 is connected to the input terminal 44 through a choke 50. A capacitor 52 is connected between the terminal 42 and that terminal of the speaker 10-1.

From the electrical connections illustrated in FIGURE 3, it is clear that the speakers 10g, 10h and 10i are effective radiators throughout the entire frequency range of the loudspeaker system. The loudspeakers 10j, 10k and 10-1, however, are in effect connected in series with a low pass filter comprising the choke 50 and capacitor 52, and this filter is selected to have a cut-off frequency of approximately 2,000 cycles, that is, the signal transmitted through the filter is down by three decibels at 2,000 cycles and approximately 15 decibels at 4,000 cycles. In like manner, the speakers 10a, 10b, 10c, 10d, 10e and 10f are connected in series with a low pass filter comprising the choke 46 and capacitor 48, and this filter is designated to have a cut-off frequency of approximately 500 cycles, that is, the low pass filter attenuates electrical signals of a frequency of 500 cycles by approximately three decibels and frequencies of 1,000 cycles per second by approximately fifteen decibels.

Each of the loudspeakers 10 has a circular cone with a four inch diameter, and the entire length of the loudspeaker measured along the line 12 is approximately 48 inches. Since all of the loudspeakers 10 operate at frequencies below 500 cycles per second, the loudspeaker system comprises a straight line source of audio radiation with a length of 48 inches in this portion of its frequency range. For frequencies between approximately 230 cycles and 920 cycles per second, the length of the line 12 would be between a wavelength and four wavelengths, but since the line length is shortened to 24 inches at 920 cycles, the effective length of the line is from a wavelength to two wavelengths in this frequency range. Below the frequency of 230 cycles per second, the length of the line 12 is less than a wavelength, and, since the loudspeaker of the present construction is designed to reproduce 100 cycles per second, the 48-inch length of the line 12 is only approximately .4 of a wavelength at this frequency. The inventor has found that a desirable radiation distribution in a plane traversing the line 12 is obtained if the line 12 is between approximately one and four wavelengths in length. If the line 12 is less than a wavelength in length, the energy distribution in the plane of the line approaches a semi-circle, however, the radiation off the ends of the line 12 becomes substantially reduced for all lengths in excess of a half wavelength and substantially no radiation lobes are produced off the ends of the line 12 for all lengths ranging from 1 through 4 wavelengths. For wavelengths in excess of four wavelengths, the radiation distribution in the plane of the line narrows, and some spurious lobes appear off the ends of the line 12.

With the filter illustrated in FIGURE 3, loudspeakers 10g, 10h, 10i, 10j, 10k and 10-1 are effective radiators for frequencies above approximately 1,000 cycles per second, and for frequencies greater than approximately 4,000 cycles per second, only loudspeakers 10g, 10h and 10i are effective radiators. In other words, for frequencies in excess of 1,000 cycles per second, the effective length of the line 12 is approximately 24 inches, and for frequencies in excess of 4,000 cycles per second, the effective length of the line is approximately 12 inches. Hence, the loudspeaker illustrated has an effective length for the line 12 of between 2 wavelengths and 4 wavelengths from 1,000 cycles to 4,000 cycles per second, and an effective

length of between 4 wavelengths and 10 wavelengths from 4,000 cycles per second to 10,000 cycles per second.

It would of course be desirable that the length of the line 12 should be at least a wavelength for the lowest frequency to be radiated from the loudspeaker system, but since this requires a length of approximately ten feet for a system designed to radiate down to 100 cycles per second, the physical requirements of the environment in which the loudspeaker system is to be employed often limit the low frequency polar distribution. Also, preferably, the length of the line 12 operating at the highest frequencies should be limited to four wavelengths at those frequencies. In order to preserve the line frequency source, however, it may be not possible in some applications to switch out or attenuate the response of enough speakers to provide this length of line. In order to effectively shorten the length of the line 12 at higher frequencies, the diameter of the loudspeaker cone required also must become smaller in order to preserve the line source effect. It may not, in all applications be possible to provide adequate power for the loudspeaker system with the small speakers required for this short length of line. In the loudspeaker construction illustrated, the length of the line source of acoustical radiation is between one and four wavelengths for frequencies between approximately 230 cycles per second and 4,000 cycles per second, and the most desirable frequency distribution of the loudspeaker system is produced in this range.

FIGURE 4 illustrates the horizontal polar pattern of the loudspeaker system shown in FIGURES 1 through 3, the pattern for signals of 5,000 cycles per second being shown in dash lines and those for 500 cycles per second being shown in solid lines. It is apparent from this figure that the horizontal polar distribution, that is, the polar distribution normal to the line 12, is extremely broad for all frequencies even though this distribution narrows at the higher frequencies. FIGURE 5 illustrates in dashed lines the frequency response of a loudspeaker constructed in the manner of the loudspeaker system set forth in FIGURES 1 and 2 but without the filter networks comprising chokes 46 and 50 and capacitors 48 and 52 and indicates the large radiation off the ends of the loudspeakers, line 12. The solid line illustrates this loudspeaker system employing the low pass filters and illustrates also the fact that the radiation off the ends of the line is substantially reduced.

The loudspeakers 10 are shown connected in series parallel combinations in order to provide the desired impedance at the input terminals 42 and 44. Each of the loudspeakers is selected to have an impedance of 8 ohms, so that the impedance of the entire system at the low end of the frequency response range is also 8 ohms.

From the foregoing disclosure, those skilled in the art will readily devise many loudspeaker system within the spirit of the present invention. For example, the particular baffle structure employed in this embodiment of the invention and the particular type of loudspeakers employed may be replaced with other constructions. The present invention is obviously useful with all types of line source or columnar speaker systems, whether the loudspeakers radiate only in one direction or are omnidirectional. It is therefore intended that the scope of the present invention be not limited by the foregoing disclosure, but rather only by the appended claims.

The invention claimed is:

1. A loudspeaker system for reproducing a continuous range of frequencies comprising means supporting a plurality of loudspeakers adjacent to each other to form a line source of acoustical radiation, the length of the line source of acoustical radiation exceeding four wavelengths at the highest frequency to be reproduced, the line having two adjacent segments formed by said plurality of loudspeakers, the first segment being formed by a first group of loudspeakers and the second segment being formed by a second group of loudspeakers adjacent to

5

the first group, and means operatively associated with the first group of loudspeakers for limiting the response of this group of speakers to sounds having wavelengths longer than a value in the range between one-fourth the length and the length of the segment of the line formed by the second group of loudspeakers.

2. A loudspeaker comprising the elements of claim 1 wherein the loudspeakers are provided with sound directing means, and the loudspeakers are mounted on a baffle with the sound directing means oriented in a single plane traversing the line formed by the plurality of loudspeakers.

3. A loudspeaker system comprising the elements of claim 1 wherein each loudspeaker comprises a cone shaped diaphragm coupled to an electromechanical transducer, and wherein the means supporting the loudspeakers comprises a baffle for acoustically shielding one side of the cone from the other.

4. A loudspeaker system for reproducing a continuous range of frequencies comprising means supporting a plurality of electroacoustical loudspeakers in a straight line adjacent to each other to form a line source of acoustical radiation, the length of the line source of acoustical radiation exceeding four wavelengths at the highest frequency to be reproduced, the line having two adjacent segments formed by said plurality of speakers, the first segment being formed by a first group of loudspeakers at one end of the line and the second segment being formed by a second group of loudspeakers adjacent to the first group, and a low pass filter electrically coupled to the first group of loudspeakers for limiting the acoustical response of the first group of speakers to wavelengths above a value in the range between one-fourth the length of the segment formed by the second group of loudspeakers and the length of the segment formed by the second group of speakers.

5. A loudspeaker system comprising the elements of claim 4 wherein the supporting means for the loudspeakers comprises an elongated sealed enclosure having a flat face with an elongated slot therein extending along a straight line, and each electroacoustical loudspeaker comprises a cone shaped diaphragm coupled to an electromechanical transducer, said cones being mounted on the face of the enclosure confronting the slot.

6. A loudspeaker system for reproducing a continuous range of frequencies comprising means supporting a plurality of electroacoustical loudspeakers adjacent to each other in a line to form a line source of acoustical radiation, the length of the line source of acoustical radiation exceeding four wavelengths at the highest frequency to be reproduced, the line having three adjacent segments, the first segment being at one end of the line and formed by a first group of loudspeakers, the second segment being adjacent to the first segment and formed by a second group of loudspeakers, and the third segment being adjacent to the second segment on the side thereof opposite the first segment and formed by a third

6

group of loudspeakers, a first low pass filter coupled electrically to the first group of loudspeakers for limiting the acoustical response of the first group of loudspeakers to wavelengths above a value between one-fourth and one times the combined length of the second and third segments, and a second low pass filter coupled electrically to the third group of loudspeakers for limiting the acoustical response of the third group of loudspeakers to wavelengths above a value between one-fourth and one times the length of the second segment.

7. A loudspeaker system comprising the elements of claim 6 wherein the supporting means for the loudspeakers comprises an elongated sealed enclosure having a flat face with an elongated slot therein extending along a straight line, and each electroacoustical loudspeaker comprises a cone shaped diaphragm coupled to an electromechanical transducer, said cones being mounted on the face of the enclosure confronting the slot.

8. A loudspeaker system comprising an elongated rectangular closed box having a front wall with an elongated flat opening therein, twelve loudspeakers disposed within the box, each loudspeaker having a cone diaphragm with an approximately four inch diameter, the diaphragms of the speakers being sealed in the opening of the box in a straight line along the axis of elongation of the opening, a pair of input terminals, a first low pass filter connected between a first group of six of said loudspeakers disposed at one end of the box and the input terminals, means directly connecting a second group of three loudspeakers immediately adjacent to the first group of loudspeakers to the input terminals, and a second low pass filter electrically connected between a third group of loudspeakers immediately adjacent to the second group of loudspeakers on the opposite side thereof from the first group, the pass band of the second filter extending to a frequency approximately four times that of the upper frequency limit of the first pass band.

9. A loudspeaker system comprising the elements of claim 8 wherein the first and second low pass band filters comprise a choke in series with the respective group of speakers and a capacitor in parallel with the respective group of speakers.

10. A loudspeaker comprising the elements of claim 8 wherein the first low pass filter has substantial attenuation for frequencies of approximately 500 cycles per second and above, and the second low pass filter has substantial attenuation for frequencies of approximately 2,000 cycles per second and above.

References Cited in the file of this patent

UNITED STATES PATENTS

2,632,055 Parker ----- Mar. 17, 1953

OTHER REFERENCES

Mahler-Hi-Fi Performance from Small Speakers; Audio; December 1959; pp. 22, 23, 92, 93.