July 22, 1952

F. MASSA

2,604,182

LOUDSPEAKER WITH A TAPERED HORN COUPLED TO THE SPEAKER DIAPHRAGM

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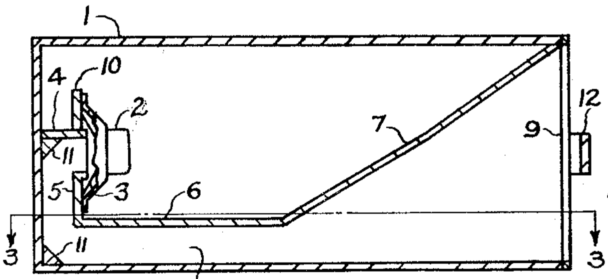

Fig. 2

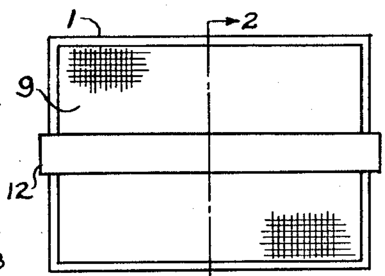

Fig. 1

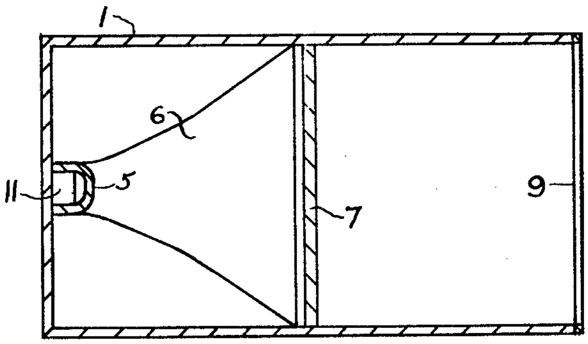

Fig. 3

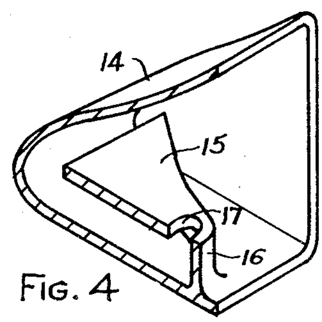

Fig. 4

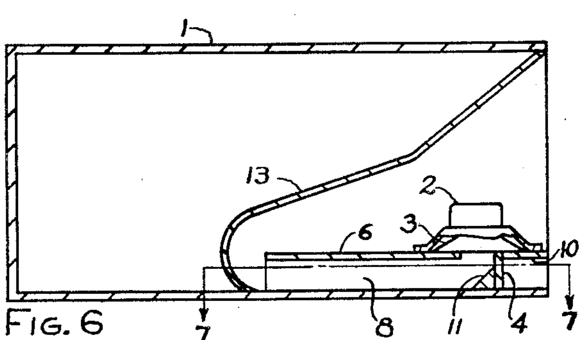

Fig. 6

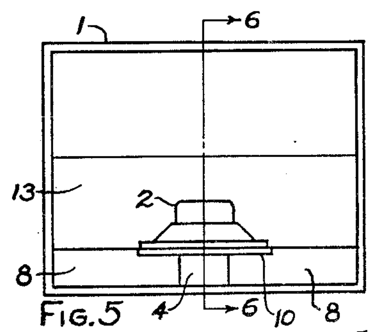

Fig. 5

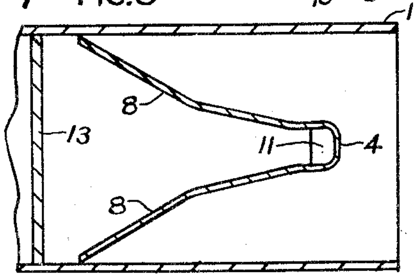

Fig. 7

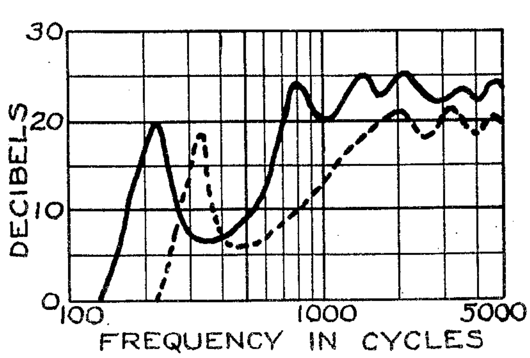

Fig. 8

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LOUD-SPEAKER WITH A TAPERED HORN COUPLED TO THE SPEAKER DIAPHRAGM

Frank Massa, Cleveland Heights, Ohio

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9 Claims. (Cl. 181—31)

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My invention is concerned with loud speakers and, more particularly, with loud speakers of very small size such as are generally employed in the so-called "personal" types of battery-operated portable radio receivers. Due to the space limitations in these small size radio sets, the dimensions of the loud speaker must necessarily be very small. Loud speakers employing diaphragms having a vibrating surface corresponding to the area of a 2″ diameter disc, more or less, are typical of the loud speakers generally employed for this application. Because of the small size of the vibrating diaphragm, the acoustic efficiency and the corresponding power output from these loud speakers is very low and since the small portable radios which employ this type of loud speaker are operated with batteries, a considerable drain on the battery power is necessitated if a reasonable acoustic power output is to be established. Another disadvantage of the tiny loud speaker is that the resonant frequency of the vibrating diaphragm is generally in the neighborhood of 300 cycles or higher and, as a result, there is a complete absence of any low-frequency reproduction from the loud speaker, resulting in the well-known "tinny" quality of reproduction that is typical of this type radio set.

The general object of my invention is to improve both the efficiency of reproduction of small-size loud speakers and also to increase their low-frequency response.

Another object of this invention is to provide a low-cost loud speaker design which permits the economical use of my new loud speaker system in a small-size portable radio set.

Still another object of this invention is to provide a design such that the space requirement for my improved loud speaker will be kept at a minimum.

A further object of my invention is to reduce the resonant frequency of the vibrating system of the loud speaker by means external to the diaphragm structure, thereby resulting in increased low-frequency range of reproduction without sacrifice in the high-frequency performance.

One method for increasing the low-frequency response of a loud speaker would be to reduce the natural resonance frequency of the vibrating diaphragm by the addition of a weight to the moving structure, but if this means were employed, there would be a lowering of the mid and high-frequency sensitivity of the loud speaker because of the added weight that would have to be set into vibration by the driving mechanism,

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thus resulting in still further reduced efficiency of the loud speaker over most of its operating frequency range.

In one specific embodiment of my invention, I provide an increased mass on the vibrating surface of the diaphragm only at the lower frequencies, so that the resonance frequency of the diaphragm is materially lowered and at the same time the effective mass of the diaphragm at the higher frequencies remains substantially unchanged. I achieve this objective by providing an air chamber into which the vibrating diaphragm operates which acts effectively as a true exponential horn at the higher frequencies, but which acts as an acoustic mass reactance at the lower frequencies.

In one form of my invention, a conventional midget-size loud speaker is coupled to a suitably-shaped air chamber which acts as a mass reactance at the low frequencies and serves to lower the resonant frequency of the loud speaker diaphragm and also acts as an exponential horn at the higher frequencies to increase the output efficiency at the higher frequencies.

In another form of my invention, the air chamber is designed so that a portion of the structure coincides with some of the walls of the radio cabinet, thereby requiring minimum space for the loud speaker structure.

In still another illustrative embodiment of my invention, the small throat opening of the tapered air chamber which is employed is placed within the region of the large end of the chamber and the loud speaker mechanism is actually placed inside the large opening of the air chamber and coupled to the small throat, thereby effecting a considerable saving in space requirement.

In still another form of my invention, I show an economical design of the air chamber structure which can be fabricated by molding two symmetrical halves and then cementing them together.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention, itself, however, both as to its organization and method of operation, as well as advantages thereof, will best be understood from the following description of several embodiments thereof, when read in connection with the accompanying drawings, in which:

Fig. 1 is an end view of a portable radio incorporating one form of my invention.

Fig. 2 is a section taken along the line 2—2 of Fig. 1.

Fig. 3 is a section taken along the line 3—3 of Fig. 2.

Fig. 4 is a perspective view of a half portion of a folded horn which, in combination with a mating half of the same shape, results in a low-cost construction of a type of horn disclosed in this invention.

Fig. 5 is an end view of a portable type radio incorporating another form of my invention.

Fig. 6 is a section taken along the line 6—6 of Fig. 5.

Fig. 7 is a section taken along the line 7—7 of Fig. 6.

Fig. 8 is a graph showing the measured improvement in the performance characteristics of one type of loud speaker built in accordance with one of the teachings of my invention.

Referring more particularly to the figures in which the same reference character represents the same part throughout:

Figs. 1, 2, and 3 show three views of one embodiment of my invention. The reference character 1 represents the outer case of a portable type radio receiver. Instead of employing a conventional arrangement for the loud speaker in which the sound is radiated directly from the diaphragm through a grill placed on one wall of the radio cabinet, I provide a tapered air chamber which is designed to act as an exponential horn at the higher frequencies, resulting in improved efficiency for the loud speaker 2 at these higher frequencies. The air column is also designed so that at the low frequencies, it acts as a sufficiently large mass reactance load on the loud speaker diaphragm 3 to cause a substantial reduction in the resonance frequency of the vibrating diaphragm. In order to achieve this dual function for the air chamber, I found it necessary to make the developed length of the air column less than one-quarter wavelength of the lowered frequency of resonance of the diaphragm and air column combined, and I also found it desirable to give the air column an approximate exponential taper so that it behaves effectively as an "infinite" exponential horn at the higher frequencies. This results in the elimination of the mass reactance air load on the diaphragm at these higher frequencies and also results in an increase in the acoustic efficiency of the loud speaker at these higher frequencies because of the increased acoustic radiation resistance which is imposed on the vibrating diaphragm by the exponential horn attachment.

In the form of my invention shown in Figs. 1, 2, and 3, the tapered air chamber is formed by several adjacent walls of the radio cabinet and the fabricated portions 4, 5, 6, 7, and 8. The strip 7 shown in section in Fig. 2 and in partial section in Fig. 3, is joined to a pair of opposite outer walls of the radio housing 1 to form the relatively large funnel-like mouth opening of the air column which discharges the sound, in this particular instance, through the sound transparent grill 9 which covers one end of the radio cabinet, as indicated. The flat portion 6 flares in a plane at right angles to the direction of flare of the portion 7, as is indicated in the plan view of Fig. 3. The portion 6 of the horn structure, in combination with a pair of side walls, one of which, 8, is shown in Fig. 2, forms a second portion of the tapered air chamber of the loud speaker system. The final portions 5 and 4 complete the tapered air chamber which is continuously expanding from its small throat opening shown adjacent to the diaphragm 3 to its large mouth opening shown adjacent to the sound transparent grill 9. An additional flat portion 10 shown in section in Fig. 2 provides a flat platform around the small throat opening of the air column to permit the loud speaker 2 to be mounted upon it without air leakage between the diaphragm 3 and the throat opening of the air chamber. Angular blocks 11 are placed in the corners of the right-angle bends, as indicated in Fig. 2, in order to minimize the discontinuity in the rate of increase of the cross-sectional area of the air chamber at the particular 90° bends. The reference character 12 illustrates a carrying handle for the radio set which may be mounted, as illustrated. Although the design shown in Fig. 2 employs some of the walls of the radio cabinet as part of the air column structure, it would obviously be possible to fabricate the air chamber as a separate complete unit, if desired, and then mount it in the same relative position, as indicated in Fig. 2. Such a construction, however, would add thickness to the radio cabinet and it would also increase the cost of production. The space which remains within the cabinet 1 outside of the horn structure may be used for housing the radio set proper and batteries in any manner desired. The radio chassis and batteries are not shown in these figures since no claim is made to any particular arrangement of these parts.

For the ordinary loud speaker generally employed in small-size portable radio sets, the resonant frequency of the small diaphragm is generally in the vicinity of or greater than 300 cycles. As a result of this high resonant frequency, which results inherently from the small diaphragm size, the sound reproduction is lacking in low-frequency response, with the result that the quality of reproduction is very thin. Also, because of the small radiating area of the diaphragm, which in many cases is less than that of a piston having a 2" diameter, the efficiency of reproduction is extremely low, which means that in addition to the lack of low-frequency tone reproduction, the volume of sound reproduction is also weak, especially for those sets which are designed for economical use of batteries. By employing a tapered air column designed according to the teachings of this invention such that the developed length of the air column is less than one-quarter wavelength at the lowest frequency of reproduction, I am able to effectively load the loud speaker diaphragm 3 with a relatively large mass of air such that the resonant frequency of the diaphragm is very substantially reduced. In one embodiment of my invention, for example, in which the air chamber as shown in Fig. 2 was adjusted so that its developed length was approximately 8", the area at the small end of the chamber was one-half sq. in., and the area at the large end of the tapered column was 8 sq. in., I was able to reduce the resonant frequency of the diaphragm, whose effective vibrating diameter was in the neighborhood of 1½ inches, by about 100 cycles, thereby adding a little more than one-half octave additional low-frequency range to the loud speaker reproduction. By designing the air column to have an approximately exponentially increasing cross-section, the air chamber becomes an efficient exponential horn for the loud speaker at the higher frequencies and thereby serves to materially increase the efficiency of reproduction. These combined advantages of the specially-designed air chamber are clearly evident from the experimental response curves shown in Fig. 8. The dotted curve in Fig. 8 shows the measured response characteristic of the loud speaker when mounted conventionally opposite a grill opening on one wall of a small radio cabinet. The solid curve in Fig. 8 shows the measured response characteristics of the same loud speaker arranged as illustrated in Fig. 2 and coupled to the specific air chamber above described. The great improvement in low-frequency reproduction as well as the indicated increase in the efficiency at the higher frequencies actually produced a most spectacular improvement in the quality of reproduction from the small portable radio. The reproduction was very considerably louder and much more pleasing in tone balance because of the greatly added low-frequency range.

The important principle which achieves the added low-frequency response without sacrifice in high-frequency performance is that in my design of the air chamber, I add mass to the loud speaker diaphragm only at the low frequencies, thereby reducing the diaphragm resonance. At the higher frequencies, the air chamber becomes effectively a long exponential horn and the load on the diaphragm becomes essentially a resistance and the mass reactance disappears. In this way, the mass load is eliminated at the higher frequencies and the acoustic efficiency is materially increased.

Figs. 5, 6, and 7 illustrate another embodiment of my invention. Fig. 5 is a view similar to Fig. 1 except that the grill cloth **9** and the carrying handle **12** have been removed. Fig. 6 illustrates the essential difference between this second embodiment of my invention over the previous embodiment shown in Figs. 1, 2, and 3. The portion **13** in Fig. 6 runs from wall to wall in the radio cabinet **1** the same as was the case with portion **7** in Fig. 2. The portion **6** in Fig. 6 is the same as the portion **6** shown in Figs. 2 and 3. The side pieces **8** shown in Figs. 5, 6, and 7 combine with the portion **6** to form a tapered horn section in the same manner as part **6** and **8** were employed in the construction shown in Figs. 2 and 3. Parts **4** and **10** serve to complete the sealing of the small end of the air column so that the loud speaker **2** may have its diaphragm **3** coupled to the air chamber exactly in the same manner as was described for the corresponding parts in Figs. 2 and 3. The essential difference between the structure in Figs. 5, 6, and 7 as compared with the structure in Figs. 1, 2, and 3 is that the tapered air chamber in Fig. 6 is made re-entrant and, in this way, provides a different space factor for accommodating the radio set components than results from the construction of Fig. 2. Although the construction illustrated in Figs. 5, 6, and 7 utilizes some of the walls of the radio cabinet for part of its structure, it is likewise possible to fabricate the re-entrant horn as a separate unit and then install it within the radio cabinet. One method for economically fabricating the re-entrant horn is illustrated in the perspective view of Fig. 4. In this design, the bell-shaped portion **14** surrounds a second portion **15** which has side walls **16** and an opening **17** such that when a symmetrical mating half, having the same shape as Fig. 4, is joined to the cross-sectioned face, a complete re-entrant horn similar to that illustrated in Figs. 5, 6, and 7 will be produced. The type of design shown in Fig. 4 can be very economically produced in molded plastic or molded paper pulp. The horn shown in Fig. 2 could likewise be molded as a separate complete unit, if so desired, and then assembled within the carrying case **1**.

Although I have chosen certain specific embodiments of my invention for illustrating the basic features of my invention, it will be obvious to those skilled in the art that numerous departures may be made in the specific details for executing the required functions and I, therefore, desire that my invention shall not be limited except insofar as is made necessary by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In combination in a sound reproducing system, a loud speaker including a vibratile diaphragm whose resonant frequency lies in the approximate range 200 cycles per second to 400 cycles per second, means for substantially reducing the resonant frequency of said diaphragm said means comprising a tapered horn coupled to said diaphragm, the cross-sectional area of said tapered horn increasing along the horn axis such that the area of the open end of said horn is greater than the area of the horn in the vicinity of the diaphragm, the length of said tapered horn being greater than the diameter of the diaphragm and less than 1/4 wavelength at the reduced resonant frequency of the diaphragm.

2. The invention set forth in claim 1 further characterized in that the effective vibrating area of the diaphragm is less than four square inches.

3. The invention set forth in claim 1, further characterized in that said horn has a cross-sectional area which increases along its length approximately in accordance with an exponential law whereby said horn behaves essentially as a long exponential horn at the higher frequencies of sound reproduction, thereby serving to increase the acoustic efficiency of said vibratile diaphragm in said higher frequency region.

4. In combination in a small size radio set of the portable type, a loud speaker having a fundamental resonant frequency within the approximate range 200 cycles per second to 400 cycles per second, means for substantially reducing the resonant frequency of said diaphragm said means comprising a tapered horn coupled to said diaphragm, the cross-sectional area of said tapered horn increasing along the horn axis such that the area of the open end of said horn is greater than the area of the horn in the vicinity of the diaphragm, the length of said tapered horn being greater than the diameter of the diaphragm and less than 1/4 wavelength at the reduced resonant frequency of the diaphragm.

5. The invention set forth in claim 4, further characterized in that said horn is constructed with some of the walls of the radio set serving also as walls for said air column.

6. The invention set forth in claim 4 further characterized in that said horn has a cross-sectional area which increases along its length approximately in accordance with an exponential law whereby said horn behaves essentially as a long exponential horn at the higher frequencies of sound reproduction thereby serving to increase the acoustic efficiency of said loud speaker.

7. The invention set forth in claim 4 further characterized in that said horn has a cross-sectional area which increases along its length approximately in accordance with an exponential law whereby said horn behaves essentially as a long exponential horn at the higher frequencies of sound reproduction thereby serving to increase the acoustic efficiency of said loud speaker, and further characterized in that the large opening

of said horn terminates at one end of the radio set through which end the sound is radiated.

8. The invention set forth in claim 4 further characterized in that said horn has a cross-sectional area which increases along its length approximately in accordance with an exponential law whereby said horn behaves essentially as a long exponential horn at the higher frequencies of sound reproduction thereby serving to increase the acoustic efficiency of said loud speaker, and further characterized in that said horn is folded back on itself such that the larger portion of the horn surrounds the smaller end portion.

9. The invention set forth in claim 4 further characterized in that said horn has a cross-sectional areaa which increases along its length approximately in accordance with an exponential law whereby said horn behaves essentially as a long exponential horn at the higher frequencies of sound reproduction thereby serving to increase

the acoustic efficiency of said loud speaker, and further characterized in that said horn is folded back on itself such that the larger portion of the horn surrounds the smaller end portion, and said loud speaker is mounted inside the larger portion of said horn structure.

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