Title: A LOUDSPEAKER, A STACKED SOUND SOURCE AND A METHOD FOR LOADING A SPEAKER ELEMENT

Abstract: A horn speaker, in particular for reproducing bass sound in public address systems, in which the horn (23) is mounted directly to the driver element (21) without any intervening compression chamber. The back side of the driver element (21) is covered by a resistance chamber (24) with acoustical impedance equal to the acoustical impedance in the horn (25).
A LOUDSPEAKER, A STACKED SOUND SOURCE AND A METHOD FOR LOADING A SPEAKER ELEMENT

Field of the invention

The present invention relates to horn loaded loudspeakers, and in particular loudspeakers for public address systems.

Technical background

Horn speakers consist of a speaker element or driver with a horn funnel placed in front of the element. The horn serves to couple acoustic energy emitted by the element into the surrounding air, by transforming the acoustic impedance of the element to the impedance of the space. The advantages of the horn speaker compared with other speaker designs, such as bass reflex, band pass and closed systems, are a high sensitivity and a good transient response due to the good coupling properties. In addition the well controlled spreading of the sound may be exploited to avoid echo and feedback in public address systems. However, a horn speaker is a complicated construction, and it is well known that many horns designs have an inferior sound quality, with a characteristic horn sound.

Fig. 1 shows the principle followed by most horn speaker designs, with a compression chamber in front of an element leading into a horn funnel with an exponential expansion. The back of the element is closed by a small closed chamber. Even though the exponential expansion function is the most popular, other expansion functions has been tried, including parabolic, conical and hyperbolic functions. The coupling and sensitivity becomes greater with increasing curvature, but the colouring of the sound is also increasing.

One of the disadvantages with the horn design shown in the figure is that the driver cone will meet different
resistances when moving outward and inward. In the inward direction the resistance is defined by the closed chamber behind the driver element, while the resistance in the other direction is defined by the horn loading. The main problem is that the pressure in the closed chamber will increase with increasing cone excursion. The uneven resistance will colour the sound. The compression chamber in front of the driver has as its object to compensate for this uneven resistance. However, it will only work effectively over a limited range of sound pressures, and the resultant colouring of the sound is responsible for the distinct horn sound (compression and honking) disliked by many audio enthusiasts. The part of the horn sound described as honking is also a result of the horn being too short.

It has been proposed to replace the closed chamber with another horn at the back that is identical to the normal front mounted horn. It is evident that such a solution will be unrealistic in most cases due to the large volume needed. And most horn speakers are very voluminous already. Other has tried to circumvent the problem by eliminating the closed chamber altogether (Bassmaxx) and let the driver work with an open back. Then, the back resistance will become much smaller than the forward resistance through the horn, with colouring as a result. However, this solution is an improvement over speakers with closed chambers, as the resistance will be increase more linear with increasing sound level.

As mentioned above, bass horn speakers are generally very voluminous. The lowest frequency a horn may reproduce is given by the distance from the throat to the mouth of the horn. The minimum length amounts to one fourth of the wavelength in air. At 20 Hz and room temperature this equals 4.3 m. And maximum efficiency is achieved when the length equals a half wavelength or more. Similar relationships concerning directivity exist for the size of
the mouth opening. Even though the horn is folded into a more compact design, a bass horn tends to become very large, if it is to reproduce low frequencies. A large loudspeaker is unfeasible for transport. It is also difficult to achieve a sufficiently stiff construction, due to large wall panels. The speaker enclosure should ideally be acoustically dead, but with large wall panels resonances may often occur.

In the mid/treble range horn speakers have very narrow direction diagrams, which may be a problem in public address settings. One solution is to stack several speakers, the sub-speakers pointing in different directions. However, such an arrangement easily leads to interference between the sub-speakers, with the direction diagram breaking up into several lobes (grating lobes). This is due to the large distance between individual sub-speakers and the curved form of wavefront of the sound leaving each sub-speaker. The sub-speakers can not be stacked as tightly as desired due to the large size of the closed chamber at the rear of each sub-speaker.

Summary of the invention

It is an object of the present invention to provide a horn loaded speaker with an improved sound quality over prior art systems, in particular a larger sound pressure and a better linearity at low frequencies.

Another object is to provide a speaker that is small in size and may be stacked into an efficient sound source.

Still another object is to provide a speaker with a stiff enclosure that is light in weight, the size considered, and easy to transport single-handed.
The objects above are achieved in a loudspeaker, a stacked sound source and a method for loading a speaker element as defined in the appended claims.

**Brief description of the drawings**

The invention will now be described in detail in reference to the appended drawings, in which

Fig. 1 is illustrating the principle used by conventional horn loaded speakers,

Fig. 2 is a sectional view through an embodiment of the inventive horn speaker,

Fig. 3 is a perspective view of the inventive speaker with an end wall removed

Fig. 4 shows a treble sound source consisting of a number of stacked horn speakers.

**Detailed description of the invention**

Fig. 1 illustrates the basic design of most current horn speaker designs. A driver element 1 is mounted facing a compression chamber 2. The compression chamber 2 is opening into a horn 3 that conducts the sound into the surrounding space. The horn is expanding with an exponential function, which is the most common design nowadays. In bass speakers, the horn will be folded into a more compact unit in order to conserve space. A small closed chamber 4 is mounted at the back side of the driver element 1.

As mentioned in the introduction, this speaker construction has a number of disadvantages which are remedied in the present inventive construction depicted in Fig. 2. In this construction, the driver element 21 is mounted facing a horn 23. No compression chamber is present. The horn shown
in this illustration follows a composite expansion function starting with a normal exponential expansion leading into a more steep expansion rate towards the end of the horn, i.e. the mouth. This fast expansion results in a high efficiency for the speaker, which is important in a public address system, while the slow start near the driver element 21 prevents the distortion to rise into undue high levels.

Behind the driver 21 there is a small "leaky" resistance chamber 24 with walls made of a material with defined acoustical impedance, e.g. a cell foam or dense fibrous material. The specific acoustic impedance is a ratio of acoustic pressure to specific flow, or flow per unit area, or flow velocity. The acoustical impedance of the chamber 24 should mate the acoustical impedance in the horn 23. The acoustical impedance values of the chamber 24 and the horn 23 may be calculated given the acoustical properties of the material in the walls and the physical layout of the horn 23. However, presently it is preferred to measure the conformity between driver and horn by exciting the driver with a signal from an audio generator and observing the cone excursion. When the acoustical impedances of the chamber and horn are of similar values, the driver cone will meet equal resistance in both directions and move symmetrically around the resting position. The cone excursion may be observed with laser interferometry, or any other suitably method.

The resistance chamber may be matched to the horn at a specific frequency. The resistance chamber can be designed to have a very flat distribution of impedance versus frequency, and this impedance curve will of course not match exactly the impedance curve of a horn. However, experience has shown that the horn and driver combination may be designed with a very flat frequency curve within a quite wide bandwidth, easily covering the active or usable bandwidth of the loudspeaker driver. Alternatively, the matching may be measured at a number of frequencies, and
the impedance of the resistance chamber varied until a mean error is achieved. Outside the active bandwidth, any impedance mismatch will be of no consequence.

The driver is delivering the sound directly into the horn, without any interfering pressure chamber. This is made possible by the symmetric loading of the driver and ensures low distortion even at high sound pressure levels.

Physically, the loudspeaker enclosure is made with walls and partitions 26 of wooden panels, chipboard or plywood. The walls/partitions 26 are fastened to end walls (not shown). The shape defined by the wooden panels is modified by adding flexible plates 27, 28, 29, or pre formed plates which have been through a rolling mill. The plates are made from a metal, such as aluminium, a plastic or fibre reinforced plastic. The plates may form bends in the enclosure, such as the parts 27, 29, and are fastened to the wooden parts with any suitable fastener, such as screws, nails or glue. The voids between the wooden parts and the plates are filled with foam 36, such as hardening expansion foam of polyethylene (PE) or polyurethane (PU). This particular construction of wood, flexible or pre formed plates and foam are light in weight, mechanically strong and acoustically dead.

The enclosure is in addition reinforced with aluminium tubes 30, 31, 32 between the end walls. The tube 32 is placed at the mouth of the horn, in which there is a large span with no wall or partition plate, and where vibrations may easily occur. The tubes 30, 31 serve as handles during transport and give a measure of protection for the driver 21. The chamber 24 is also covered by a protective perforated plate 34, of a metal such as aluminium, or plastic. The plate will introduce an additional measure of acoustic impedance that must be taken into account when fitting the chamber 24 to the horn. Lastly, the enclosure
may be equipped with castors 35 making it possibly to move the speaker single-handed.

Fig. 3 has been added to give an impression of the finished enclosure. One end wall has been removed to show the interior of the enclosure.

Fig. 4 shows a part of an omni-directional treble sound source comprising a multitude of stacked sub-speakers. At treble frequencies speakers are designed with straight horns, as the small dimensions of the funnel make this feasible. Thus, the design in Fig. 4 includes a number of sub-speakers, each with a straight conical horn 43a-c. Conical horns have been chosen over other designs as this design gives less distortion, although at the cost of a lower efficiency. Behind each driver element 41a-c there is mounted a small resistance chamber 44a-c. As explained above, this resistance chamber 44a-c, as well as the avoidance of a compression chamber in front of the driver 41a-c, means an improvement in sound quality at high sound pressure levels. The small size of the resistance chamber means that the sub-speakers may be stacked tightly; thus preventing the formation of grating lobes. Another effect of this design is that the front of the sound waves at the mouth of the horn is very flat. Then, the sound waves from adjacent sub-speakers will superimpose with nearly no interference. Altogether, this means a very clean sound pattern from this source.
Claims

1. A loudspeaker, said loudspeaker including a driver element (21) mounted in an enclosure, said enclosure forming a horn (23) mounted directly in front of said driver element (21), characterized in a resistance chamber (24) covering the driver element (21) on its back side, said resistance chamber (24) having an acoustic impedance equal to the acoustic impedance in said horn (23) at a given frequency.

2. A loudspeaker as claimed in claim 1, characterized in that the resistance chamber (24) is made from a foam or dense fibre material with known acoustical impedance.

3. A loudspeaker as claimed in claim 1, characterized in a protective housing (35) of perforated metal or plastic covering said resistance chamber (24).

4. A loudspeaker as claimed in claim 1, characterized in that the horn (23) has an exponential expansion near the driver element (21) with a larger expansion rate towards the opening of the horn (23).

5. A loudspeaker as claimed in claim 1, characterized in that horn (23) has a conical expansion.

6. A loudspeaker as claimed in claim 1, characterized in that the enclosure including wooden walls and partition plates (26) with thin covering plates (27, 28, 29) of plastic or metal covering curved parts in the interior of the enclosure, foam (36) filling voids between the wooden walls or partition plates (26) and the covering plates (27, 28, 29).
7. A loudspeaker as claimed in claim 6, characterized in that the foam (26) being a hardening expansion foam of polyethylene or polyurethane.

8. A sound source, characterized in that said sound source includes a number of loudspeakers as claimed in any of the claims 1-7 stacked tightly together.

9. A method for loading a speaker element, the method including mounting a horn directly in front of said speaker element, the horn having an acoustic impedance for sound waves propagating in said horn, characterized in placing a resistance chamber at a rear side of the speaker element, the resistance chamber having an acoustic impedance equal to the acoustic impedance of the horn.

10. A method as claimed in claim 9, characterized in measuring the displacement of a diaphragm in said driver element when being excited by an audio source, and adjusting the acoustical impedance of said resistance chamber until the diaphragm obtains a symmetrical displacement around a resting position.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. H04R1/30

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where possible, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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| X | Further documents are listed in the continuation of Box C. | X | See patent family annex. |

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**Date of the actual completion of the international search**

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**Date of mailing of the international search report**

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