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(54) **Loudspeakers.**

(57) A transmission line loudspeaker (20) comprises at least one driver (21), an acoustic filter in the form of a cavity (12a), and a transmission line (19). The driver (21) is positioned adjacent to the entry to the transmission line (19) so that the driver effects a parallel driving of both the filter (12a) and the transmission line (19) simultaneously. The driver can alternatively be positioned within the transmission line, again provided that it is close to the entry. The low frequency response of the loudspeaker is thereby improved.

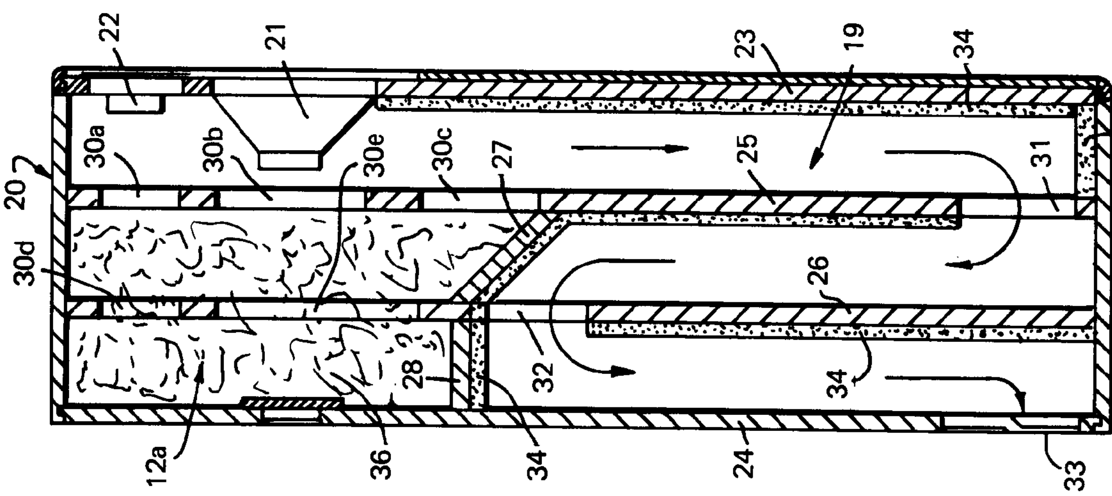

FIG. 5

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This invention relates to loudspeakers and loudspeaker systems and is particularly concerned with transmission line loudspeakers and loudspeaker systems.

Transmission line loudspeaker systems have traditionally consisted of a woofer or a combination of drivers mounted at the end of a long tube. The simplest form of tube is a pipe of uniform diameter. At the frequency where the wavelength of sound is approximately four times the length of the tube, a resonance occurs (the "quarter-wave" resonance) such that the sound which is radiated from the open end of the tube reinforces that coming directly from the loudspeaker drive unit itself. Higher up the frequency scale the tube will have more resonances, at roughly odd integer multiples of the quarter-wave resonance frequency, i.e. 3/4, 5/4, etc. However, these modes are undesirable, because it is only the first mode which provides reinforcement. The higher frequency modes either reinforce or cancel the direct output from the loudspeaker drive unit.

Loudspeaker designers usually take two steps to reduce these higher frequency modes. The first step is to introduce damping/absorption into the system. The second is to change the shape of the pipe, notably its longitudinal profile. So far as damping/absorption is concerned, absorbent material such as foam has a frequency-dependent attenuation characteristic, so that higher frequency modes are damped but not completely eliminated. Placing more absorbent material in the pipe does not help, because the first mode can then be damped out so much that the main advantage of using a transmission line is diminished. So far as changing the shape of the pipe is concerned, one proposal is to introduce a taper, so that the diameter of the pipe decreases in the direction from the loudspeaker drive unit towards the open end of the pipe. However, a tapered pipe has almost the same acoustic characteristics at low frequencies as a pipe of uniform diameter, with the result that the resonant modes are only attenuated to a small extent by this technique.

An alternative to the use of damping/absorption materials within the transmission line is the provision of an acoustic filter or filters within the transmission line. The inclusion of such acoustic filters makes it possible significantly to reduce the quantity of mid-frequency and high-frequency sounds radiated from the end of the transmission line. These acoustic filters take the form either of an expanded or a restricted zone of the pipe, or a series of expanded or restricted zones. The expansion zone, i.e. acoustic compliance, or restriction zone, i.e. acoustic inertance, in the pipe behaves like a reactive low pass filter, similar to a parallel capacitor (or series inductor) found in electrical engineering. The efficacy of such an acoustic filter is dependent on the relative sizes of the loudspeaker diaphragm, expansion or restriction zone or zones, and cross-sectional area of the pipe. It is important to draw a distinction between this type of device and some transmission lines which are known which use a tapered pipe behind the driver. The acoustic low pass filter works because a compliance (for an expansion zone) or inertance (for a restriction zone) is introduced into the pipe. The theory for these devices is very different from that of a tapered pipe which behaves rather like an acoustic horn, but in reverse.

Fig. 1 of the accompanying drawings shows a known transmission line loudspeaker system which comprises the combination of a loudspeaker, a cavity and a pipe arranged "in series". Here the cavity is formed at the end of the pipe and the loudspeaker is situated immediately opposite the entry to the pipe on the wall of the cavity most remote from the pipe. In this arrangement the cavity performs the role of an expansion-type low pass filter by being situated between the loudspeaker and a pipe which has approximately the same cross-sectional area as the loudspeaker, although pipes having areas substantially different from that of the loudspeaker could be used.

The transmission line loudspeaker system of the present invention, although it uses a low-pass filter, differs from the system shown in Fig. 1. For a cavity to have a significant effect on the frequency response it will necessarily be relatively large. Therefore, the acoustic pressure distribution within the cavity will not be uniform across all frequencies. The relative positions of the driver, the cavity and the pipe, and the shape of the cavity, will all have an effect on the response of the system.

It is an object of the present invention to design a transmission line loudspeaker system having at least one driver, acoustic filter and transmission line, in which the response of the system is optimised or is at least an improvement upon the known systems.

It is a further object of the present invention to provide a transmission line loudspeaker system which will produce the desired frequency response of sound radiated from the open end of the transmission line.

It is yet a further object of the present invention to provide a transmission line loudspeaker system in which the system performance is superior to commonly available transmission line systems using constant diameter or tapered transmission line elements.

In accordance with the present invention there is provided a transmission line loudspeaker comprising at least one driver, an acoustic filter and a transmission line, in which the driver, or one of the drivers if more than one, is positioned at or adjacent to the entry to the transmission line such that the driver effects a parallel driving of both the filter and the transmission line simultaneously.

Preferably, the acoustic filter comprises a cavity.

The positioning of the driver, or one of the drivers if more than one, close to the entry to the transmission line means that the pressures at the driver and at the entry to the pipe are approximately equal over a wide range of frequencies.

The pressures at the driver and at the entry to the transmission line are approximately equal for a wide range of frequencies, even when modes inside the cavity mean that there is a non-uniform pressure distribution. In this way the configuration behaves more like an idealised acoustic low pass filter.

In a preferred embodiment the driver at or adjacent to the entry to the transmission line is positioned on a side wall of the acoustic filter which is a continuation of a wall of the transmission line.

Preferably the distance between the entry to the transmission line and the driver at or adjacent to said entry is less than approximately one quarter of the wavelength at the highest frequency at which the transmission line makes a contribution to the output.

The frequency is preferably of the order of 500 Hz.

In a preferred embodiment of the invention the at least one driver, the filter and the transmission line are housed within a cabinet, in which a first portion of the cabinet constitutes a cavity acting as a low pass filter and a second portion of the cabinet constitutes the transmission line defined as a sinuous track from the front to the rear of the cabinet.

In a preferred embodiment, the driver or drivers are mounted at the upper front of the cabinet and the open end of the transmission line is at the lower rear of the cabinet.

In order that the invention may be more fully understood, one presently preferred embodiment of loudspeaker in accordance with the invention will now be described by way of example and with reference to the accompanying drawings, in which:

Fig. 2 is a schematic illustration of the novel configuration of driver, acoustic filter and transmission line for a loudspeaker system in accordance with the invention;

Fig. 3 is an alternative schematic illustration of the configuration shown in Fig. 2;

Fig. 4 shows a development of the configuration shown in Fig. 3;

Fig. 5 is a vertical sectional view through a loudspeaker constructed in accordance with the invention;

Fig. 6 is a front view of the loudspeaker of Fig. 5; and,

Fig. 7 is a rear view of the loudspeaker of Fig. 5.

Fig. 2 illustrates the concept behind the present invention. The transmission line of the system is constituted by a pipe 10 of constant cross-section. At the end of the pipe 10 remote from its open end is formed a cavity 12 defined by appropriately shaped walls. This cavity acts as an acoustic filter. In the illustrated arrangement the cavity 12 is offset relative to the central longitudinal axis of the transmission line, with one wall 14 of the cavity being an extension of one wall of the pipe 10. A driver 16 is mounted in the wall 14 adjacent to the entry from the cavity 12 into the pipe 10. The driver 16 could alternatively be positioned just within the pipe, or actually at the junction between cavity and pipe.

Fig. 3 shows the system of Fig. 2 in an alternative way. Fig. 3 makes it clearer that, in contrast to the "series" arrangement of acoustic filter and pipe in Fig. 1, the present invention uses a parallel arrangement where the driver 16 drives both the acoustic filter 12 and the transmission line 10 at the same time. It does this by being positioned at or close to the entry to the transmission line.

It is an object of the invention to improve the bass, i.e. low frequency, characteristics of a loudspeaker, and particularly the response below approximately 500 Hz. This is the order of frequency at which the transmission line makes an effective contribution.

It is this frequency also which is a determining factor in deciding the maximum distance that one can place the driver away from the filter/pipe junction and still achieve an advantage from the parallel driving. The distance from the centre of the driver to the junction should not be more than a quarter wavelength ($\lambda/4$) at the maximum frequency appropriate for the transmission line concerned. Thus, if the frequency is 500 Hz, using the formula $c=f\lambda$, where c is the velocity of sound, the quarter wavelength dimension is 16.5 cm (6.5 inch), assuming c=330 metres/second. If the frequency is taken to be 300 Hz, then $\lambda/4 = 27.5$ cm (10.8 inch), etc.

The transmission line loudspeaker system shown in Fig. 2 can be modified by incorporating additional acoustic filters at strategic points along the pipe 10, for example in the form of expansion zones or restriction zones. Fig. 4 shows schematically the addition of an acoustic filter 17 in series with the transmission line 10. The combination of filter 17 and pipe 10 could be repeated, in series with the first filter and pipe 17, 10. Also, absorbent filling material can be incorporated within the pipe 10 and/or within the cavity 12 to have a dissipative effect.

The loudspeaker shown in Figs. 5 to 7 comprises a multi-component housing, indicated generally at 20. The cabinet includes a front wall 23 and a rear wall 24. A driver 21 is mounted in the front wall of the housing, at the upper part of the housing. The driver 21 is here within the cavity (acoustic filter) i.e. spaced from the entry to the transmission line, but is sufficiently close to perform the parallel driving function. A treble unit with a sealed rear enclosure is indicated at 22. Spaced between the front wall 23 and the rear wall 24 of the housing are a pair of partition walls 25 and 26 which are parallel to the front and rear walls of the housing and which divide the interior of the housing into three approximately equal size parts. Between the partition walls 25 and 26 and approximately halfway up the partition walls is provided an obliquely extending dividing wall 27. The inclination of the dividing wall 27 helps to avoid an abrupt change in the acoustic properties. A similar dividing wall 28 is provided between the partition wall 26 and the rear wall 24 of the housing, although with the dividing wall 28 extending horizontally. Both the internal partition walls and the cabinet outer walls are preferably made of a suitable rigid material such as medium density fibreboard or aluminium honeycomb sandwich to give the structure rigidity.

Above the level of the dividing walls 27 and 28 the partition walls 25 and 26 are provided with large-size holes 30a, 30b, 30c, 30d and 30e. Thus, the volume above the dividing walls 27 and 28 constitutes a cavity 12a, equivalent to the cavity 12 of Fig. 2. The cavity is immediately behind the driver 21.

Below the level of the dividing walls 27 and 28 the partition wall 25 is provided with an aperture 31 adjacent to the bottom of the partition wall. The other partition wall 26 is provided with an aperture 32 immediately below the dividing walls 27 and 28. The apertures are all substantially rectangular. The apertures thus define horizontal struts which provide bracing and a rigid structure. The cross-sectional area of the apertures 31 and 32 is equal to the cross-sectional area of the transmission line pipe 19. The rear wall 24 of the housing is provided with a vent 33, here shown as a double vent, towards the bottom of the rear wall. The vent 33 shown here has the same area as the pipe 19, although vents of larger or smaller area could be used. With this configuration of apertures and vents 31, 32, 33 there is created within the loudspeaker cabinet a transmission line 19 which extends vertically downwards from the driver 21 to the bottom of the cabinet, upwards from the bottom of the cabinet to the dividing wall 27, and downwards from there to the vent 33, thus mapping out a sinuous track from the driver to the vent. This is indicated by the broken arrows in Fig. 3.

In one embodiment of loudspeaker built as shown in Fig. 5, the volume of the cavity 12a is approximately 18 litres and the length of the pipe 19 from entry to vent is approximately 1.7 metres (5.5 feet).

Sound-absorbent filling material which has a dissipative effect is incorporated within the cabinet to enhance the frequency response. Preferably, the transmission line section of the system is lined with a fibrous or cellular foam material 34, for example with a thickness of 15 mm. At the bottom of the cabinet the lining 35 is preferably of double thickness. The material of the walls within the cabinet also has a dissipative effect to a greater or lesser extent. Alternatively, instead of lining the pipe 19 it can be filled with a foam or fibreglass material. The cavity 12a at the top of the cabinet is also substantially filled with the same or similar material 36.

Claims

1. A transmission line loudspeaker comprising at least one driver (21), an acoustic filter (12;12a) and a transmission line (10;19), characterised in that the driver (21), or one of the drivers if more than one, is positioned at or adjacent to the entry to the transmission line such that the driver effects a parallel driving of both the filter (12;12a) and the transmission line (10;19) simultaneously.

2. A transmission line loudspeaker as claimed in claim 1, characterised in that the acoustic filter comprises a cavity (12;12a).

3. A transmission line loudspeaker as claimed in claim 1 or 2, characterised in that the driver (21) at or adjacent to the entry to the transmission line is positioned on a side wall (14) of the acoustic filter (12) which is a continuation of a wall of the transmission line (10).

4. A transmission line loudspeaker as claimed in any preceding claim, characterised in that the distance between the entry to the transmission line (19) and the driver (21) at or adjacent to said entry is less than approximately one quarter of the wavelength at the highest frequency at which the transmission line makes a contribution to the output.

5. A transmission line loudspeaker as claimed in claim 4, characterised in that said frequency is of the order of 500 Hz.

6. A transmission line loudspeaker as claimed in any preceding claim, characterised in that the at least one driver, the filter and the transmission line are housed within a cabinet (20), in which a first portion of the cabinet constitutes a cavity (12a) acting as a low pass filter and a second portion of the cabinet constitutes the transmission line (19) defined as a sinuous track from the front (23) to the rear (24) of the cabinet.

7. A transmission line loudspeaker as claimed in claim 6, characterised in that the driver or drivers is/are mounted at the upper front of the cabinet (20) and the open end (33) of the transmission line (19) is at the lower rear of the cabinet.

8. A transmission line loudspeaker as claimed in claim 6 or 7, characterised in that the transmission line (19) consists of three zones divided by parallel walls (25,26) having apertures (31,32) therethrough for communication between the zones, in which the cross-sectional area of the aperture (31,32) between the respective zones is

substantially equal to the cross-sectional area of each zone.

9. A transmission line loudspeaker as claimed in any preceding claim, characterised in that the acoustic filter comprises a cavity (12a) substantially filled with a sound-absorbent material (36), and the transmission line (19) is substantially filled with or is lined with a sound-absorbent material (34,35).

10. A transmission line loudspeaker as claimed in any preceding claim, characterised in that a further acoustic filter (17) is provided in series with and in advance of the transmission line (10).

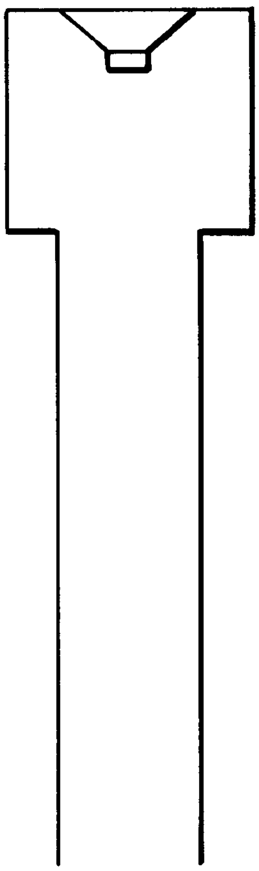

FIG. 1
PRIOR ART

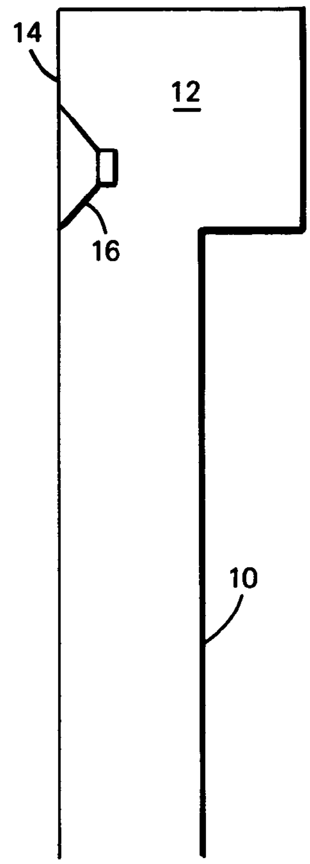

FIG. 2

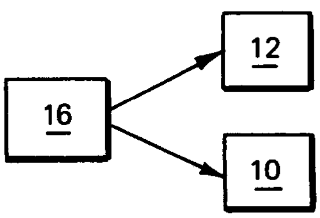

FIG. 3

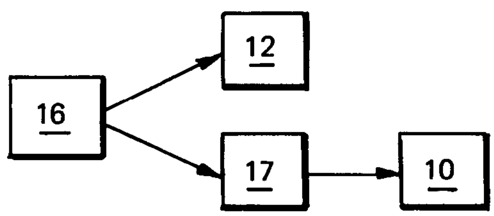

FIG. 4

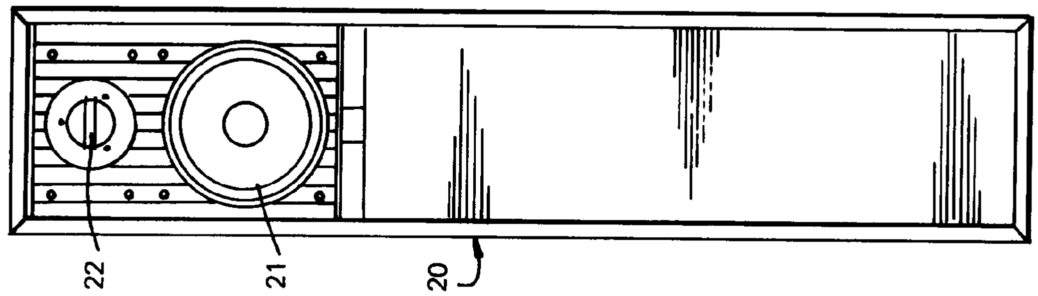

FIG. 6

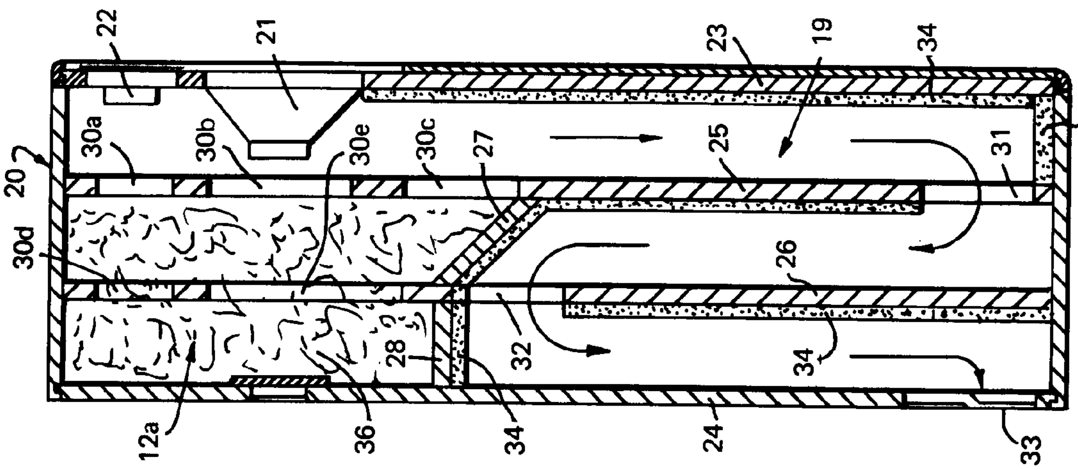

FIG. 5

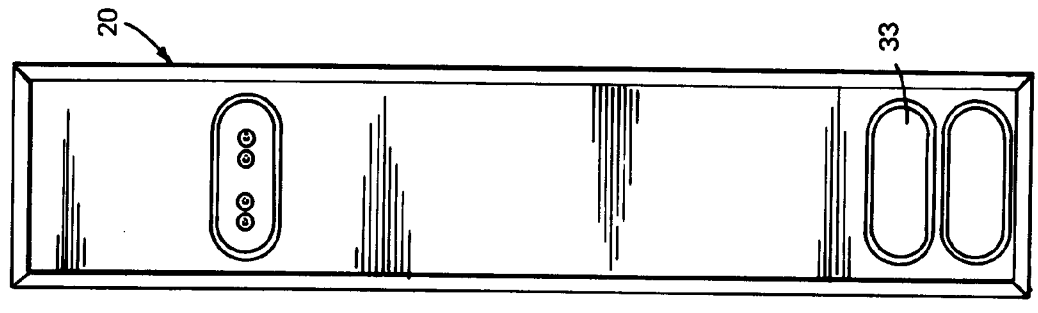

FIG. 7