

LOUDSPEAKER ARRANGEMENT

The invention relates to a loudspeaker arrangement comprising a first loudspeaker unit for reproducing a low-frequency audio signal and a second separate loudspeaker unit provided with a loudspeaker for reproducing a high-frequency audio signal, the two loudspeaker units either being constructed to have no rigid mechanical connection between them or being provided with connecting means whereby they can be rigidly mechanically connected to one another but which will permit detachment of the units from one another, and connecting means being provided whereby the loudspeaker units can be electrically connected to one another and which comprise interengageable parts that can be disengaged from one another to disconnect the units from one another.

A loudspeaker arrangement of this modular construction is disclosed in German Gebrauchsmuster DE-GM 78.34.296. The known loudspeaker arrangement comprises modules which can be coupled to each other so as to be electrically and mechanically disconnectible, by connecting means in the form of connectors.

It is an object of the invention to provide a modular loudspeaker arrangement which offers more possibilities than the known loudspeaker arrangement and which is very suitable for use as a loudspeaker system in a motor car.

According to the present invention there is provided a loudspeaker arrangement comprising a first loudspeaker unit for reproducing a low-frequency audio signal and a second separate loudspeaker unit provided with a loudspeaker for reproducing a high-frequency audio signal the two loudspeaker units either being constructed to have no rigid mechanical connection between them or being provided with connecting means whereby they can be rigidly mechanically connected to one another but which will permit detachment of the units from one another, and connecting means being provided whereby the loudspeaker units can be electrically connected to one another and which comprise interengageable parts that can be disengaged from one another to disconnect the units from one another, wherein the first loudspeaker unit comprises at

least two flat diaphragms.

Preferably, the flat diaphragms extend at least substantially in one plane, have a rectangular shape and adjoin each other along one side. The flat diaphragms of the first loudspeaker unit may each form part of a flat-diaphragm loudspeaker. The first
5 loudspeaker unit then comprises two flat-diaphragm loudspeakers. However, alternatively, one flat diaphragm may form part of a flat-diaphragm loudspeaker and the other flat diaphragm may form part of a passive radiator. The provision of two or more flat
10 diaphragms in the module of the first loudspeaker unit means that this module can function in different ways in the loudspeaker arrangement and the two flat diaphragms in said module can cooperate in different ways with one or more second loudspeaker units. Moreover, the use of two flat diaphragms in accordance with
15 the invention may have a positive effect on the dimensions of the first loudspeaker unit. The use of flat diaphragms (flat-diaphragm loudspeakers), instead of the more frequently used cone loudspeakers, enables the thickness of the first loudspeaker unit to be reduced. In flat-diaphragm loudspeakers the end of the
20 voice-coil former is generally secured directly, or via an auxiliary cone, to the flat diaphragm. In either case the distance between said end of the voice-coil former and the "front-face" of the flat diaphragm is smaller than the distance between the end of the voice-coil former and the plane defined by the rim of the cone
25 in the case of a cone loudspeaker, which means that the flat-diaphragm loudspeaker can generally be thinner than a cone loudspeaker of the same acoustic output power. This reduced thickness is of advantage if the loudspeaker arrangement is used in a car and is mounted on the shelf behind the back seat of the car.
30 The loudspeaker arrangement then occupies a smaller volume. When two square flat-diaphragm loudspeakers are used the width dimension is also smaller than in a situation in which one cone loudspeaker is employed. This may be explained as follows. If the acoustic output power of the two flat-diaphragm loudspeakers and the
35 acoustic output power of the cone loudspeaker must be equal to each

other with the same average excursion of the diaphragms of the flat-diaphragm loudspeaker and the cone loudspeaker the surface areas of the two flat diaphragms must be equal to the surface area of the diaphragm of the cone loudspeaker. When square flat diaphragms are used a calculation will show that one side of the flat diaphragm is smaller than the external diameter of the (cone) diaphragm. This smaller dimension is also of advantage because the loudspeaker arrangement in accordance with the invention can now be dimensioned so that it can be accommodated on the usually narrow shelf behind the back seat of a car and still be capable of delivering an adequate acoustic output power.

In one embodiment of the loudspeaker arrangement in accordance with the invention the flat diaphragms each form part of a flat-diaphragm loudspeaker, and a first and a second input terminal are provided for receiving a first and a second electric audio signal respectively, for example, the left-hand and the right-hand signal of a stereophonic signal, and for applying the first and the second electric signal to the first and the second flat diaphragm loudspeaker respectively.

Preferably, the first loudspeaker unit is provided with these first and second input terminals. In this way one flat-diaphragm loudspeaker will supply one (left-hand) signal and the other flat-diaphragm loudspeaker the other (right-hand) signal.

The loudspeaker arrangement may further comprise a third separate loudspeaker unit provided with a loudspeaker for reproducing a high-frequency audio signal, the first and the third loudspeaker units either being constructed to have no rigid mechanical connection between them or being provided with connecting means whereby they can be rigidly mechanically connected to one another but which will permit detachment of the units from one another, and connecting means being provided whereby the first and third loudspeaker units can be electrically connected to one another and which comprise interengageable parts that can be disengaged from one another to disconnect the units from one another, and the first and the second input terminal being coupled

to the second and the third loudspeaker unit respectively, for applying the first and the second electric signal to the second and the third loudspeaker unit respectively. The second and the third loudspeaker unit may be connected to the first loudspeaker unit both electrically and mechanically. Then they are each connected to one of two opposite sides of the first loudspeaker unit and radiate the one (left-hand) and the other (right-hand) signal respectively. Alternatively, the second and the third loudspeaker unit may be arranged at a specific distance from and diametrically opposite the first loudspeaker unit. However, this requires the provision of an electrical connection by means of leads.

In another embodiment of the loudspeaker arrangement in accordance with the invention the flat diaphragms each form part of a flat-diaphragm loudspeaker and the loudspeaker arrangement is provided with an input terminal for receiving an electric audio signal and for applying this signal to the first and the second flat-diaphragm loudspeaker and to the second loudspeaker unit. Preferably, the first loudspeaker unit is provided with these first and second input terminals. The two flat-diaphragm loudspeakers now deliver the same acoustic output signal (namely, the low-frequency portion thereof) and the second loudspeaker unit, which may be located remotely from the first loudspeaker unit or which is connected to it in such a way as to be mechanically detachable therefrom, delivers the same acoustic output signal (namely, the high-frequency portion thereof). This signal may be, for example, the left-hand signal of a stereo signal. In that case there will be provided a second loudspeaker arrangement which reproduces the right-hand signal. Alternatively, the signal may be a monophonic signal.

In yet another embodiment of the loudspeaker arrangement in accordance with the invention one flat diaphragm forms part of a flat-diaphragm loudspeaker and the other flat diaphragm forms part of a passive radiator, and the loudspeaker arrangement is accommodated in an opening or openings in an otherwise at least substantially air-tight enclosure and is provided with an input terminal for receiving an electric audio signal and for applying this electric signal to the flat-diaphragm loudspeaker and to the

second loudspeaker unit. This embodiment is very suitable for normal home-entertainment use, in which case the enclosure would be a loudspeaker box. The second loudspeaker unit, or each of the second and third loudspeaker units, may also comprise a second
5 loudspeaker for reproducing a mid-range audio-frequency signal.

It is to be noted that Japanese Kokai No. 55-46623 describes a loudspeaker arrangement with four flat-diaphragm loudspeakers, of which three reproduce a low-frequency audio signal and one reproduces both a medium-range frequency and a high-frequency audio
10 signal. However, this known loudspeaker arrangement is not of a modular construction.

In one embodiment of the loudspeaker arrangement in accordance with the invention the loudspeaker or loudspeakers of the second loudspeaker unit, or of each of the second and third loudspeaker
15 units, is or are pivotable about at least one axis. This enables the (more directional and more concentrated) radiation from the second and the third loudspeaker unit respectively to be directed towards the listener in an optimum manner.

Embodiments of the invention will now be described in more detail, by way of example, with reference to the accompanying
20 drawings, in which:

Figures 1, 2 and 3 are diagrammatic plan views of three embodiments of the invention,

Figure 4 is a perspective view of a second loudspeaker unit with loudspeakers which are pivotally mounted, and
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Figure 5 is a perspective view of a fourth embodiment of the invention.

The loudspeaker arrangement shown in Figure 1 comprises a first loudspeaker unit 1, which is a module with two flat-diaphragm
30 loudspeakers 4 and 5. The two flat diaphragms of these loudspeakers are disposed at least substantially in one plane, have a rectangular, preferably square, periphery and adjoin each other along one side. The flat-diaphragm loudspeakers 4 and 5 are intended for the reproduction of a substantially low-frequency
35 audio signal. Such loudspeakers are also referred to as "woofers". The first loudspeaker unit 1 is provided with a first and second input terminal 6-6' and 7-7' respectively, for receiving

a first and a second electric audio signal respectively. The signal may be, for example, a stereophonic signal. The left-hand signal is then applied to the first input terminal 6-6' and the right-hand signal to the second input terminal 7-7'. The

5 loudspeaker arrangement comprises two further modules, namely, a second loudspeaker unit 2 provided with a loudspeaker 8 (a "tweeter"), which may be a dome loudspeaker, for reproducing the high-frequency audio signal, and a loudspeaker 9 (a "squawker"), which may also be a dome loudspeaker, for the reproduction of a

10 mid-range audio frequency signal, and a third loudspeaker unit 3 also comprising a tweeter 8 and a squawker 9. It is not necessary to divide the entire audible frequency range into three parts; it is alternatively possible to divide the frequency range into two parts. Then, the second and the third loudspeaker units will each

15 comprise only one loudspeaker 8. The loudspeaker arrangement comprises connecting means 10 for coupling the first loudspeaker unit 1 electrically and mechanically to the second loudspeaker unit 2. The mechanical connection is a rigid connection, that is to say, it is not flexible. The expression "rigid connection" is to

20 be understood to include a pivotal connection. The connecting means 10 are such as to permit the loudspeaker units 1 and 2 to be electrically disconnected and also mechanically disconnected, i.e. detached, from one another. The connecting means 10 comprise interengageable parts which can be disengaged from one another to

25 effect the electrical disconnection and mechanical detachment of the units 1 and 2 from one another. The connecting means 10 may, for example, take the form of a pin and hole or a plug and socket. It is obvious that other types of connecting means may be used. In the embodiment shown in Figure 1 the connecting means 10 provide

30 both the mechanical and the electrical coupling between the loudspeaker units 1 and 2. Alternatively, the connecting means 10 may provide only a disconnectible electrical coupling between the two loudspeaker modules 1 and 2. In that case there must be additional connecting means (not shown) for providing a

35 disconnectible rigid mechanical coupling between the two modules. The loudspeaker arrangement also comprises connecting means 11 for

coupling the first loudspeaker unit 1 electrically and mechanically to a third loudspeaker unit 3, these connecting means also having a construction such as to permit the units 1 and 3 to be electrically and mechanically disconnected from one another. The connecting means 11 also may be constructed as a pin and hole or a plug and socket. What has been stated for the connecting means 10 also applies to the connecting means 11. Via the first input terminal 6-6' the first (left-hand) signal can be applied to the first flat-diaphragm loudspeaker 4 and (via the connecting means 10) to the second loudspeaker unit 2. Via the second input terminal 7-7' the second (right-hand) signal can be applied to the second flat-diaphragm loudspeaker 5 and (via the connecting means 11) to the third loudspeaker unit 3. Instead of the loudspeaker unit 1, the loudspeaker units 2 and 3 may be provided with input terminals (namely, one terminal for each unit). Then, via the input terminal of loudspeaker unit 2 one (left-hand) signal must be applied to the second loudspeaker unit 2 and (via the connecting means 10) to the flat-diaphragm loudspeaker 4, and via the input terminal of the loudspeaker unit 3 the other (right-hand) signal must then be applied to the third loudspeaker unit 3 and (via the connecting means 11) to the flat-diaphragm loudspeaker 5.

This results in a compact loudspeaker arrangement which comprises three modules and is capable of reproducing a stereophonic signal. The left-hand signal is then reproduced by the loudspeaker unit 2 (namely the mid-range and high-frequency parts) and the loudspeaker 4 (for the low-frequency part), and the right-hand channel is reproduced by the loudspeaker unit 3 (for the mid-range and high-frequency parts) and the loudspeaker 5 (for the low-frequency part). Such a loudspeaker arrangement is particularly suitable for use in cars because of its dimensions. The loudspeaker arrangement can be mounted on the shelf behind the back seat. The surfaces of the two flat-diaphragms 4 and 5 are then disposed in a horizontal plane. For the bass reproduction this presents no problems, because the flat-diaphragm loudspeakers 4 and 5 have substantially spherical directivity patterns. The

squawker 9 and the tweeter 8, however, have directivity patterns which are highly concentrated in a vertical direction (i.e. in a direction perpendicular to the plane of drawing in Figure 1). For directing the acoustic sound radiation towards the listener(s) in an optimum manner, the sound must be radiated in a direction closer to the horizontal. This may be achieved by constructing the second and third loudspeaker units 2 and 3 in the manner shown in Figure 4. Figure 4 shows an example of the loudspeaker unit 2. The loudspeakers 8 and 9 are accommodated in an enclosure 40 which is pivotable about a horizontal axis 41 in a casing 42. The casing 42 carries the connecting means 10 by means of which the loudspeaker unit 2 can be electrically and mechanically coupled to the loudspeaker unit 1 in such a way as to allow the two units to be electrically and mechanically disconnected from one another. The enclosure 40 with the loudspeakers 8 and 9 can be pivoted, as indicated by the arrow 43, to any position between a horizontal position, in which it lies wholly inside the casing 42, and a fully upright position. When the enclosure 40 is in a substantially vertical position the sound is radiated in the horizontal direction.

Figure 2 is a plan view of an embodiment which is similar to that shown in Figure 1 except that the second and third loudspeaker units 2 and 3 are located remotely from each other. This provides a better stereophonic reproduction. In this embodiment there is no need for the provision of means for establishing rigid mechanical connections between the loudspeaker unit 1 and the loudspeaker units 2 and 3. Consequently, the connecting means 10 and 11 provide only disconnectible electrical couplings between the loudspeaker unit 1 and the loudspeaker units 2 and 3, and they comprise two leads with plugs and sockets for establishing the necessary electrical connections between the loudspeaker units. In this embodiment also the loudspeaker units 2 and 3 may be of the construction shown in Figure 4.

The loudspeaker arrangement 21 in Figure 3 comprises two modules, namely a module 22, which is the first loudspeaker unit,

and a module 2, which is the second loudspeaker unit. The loudspeaker unit 22 is provided with two flat-diaphragm loudspeakers 4 and 5 and with an input terminal 6-6' for receiving an electric signal and for applying this signal to the two flat-diaphragm loudspeakers 4 and 5. Again connecting means 10 are provided for electrically and mechanically coupling the loudspeaker units 2 and 22 to each other in such a way that they can be electrically and mechanically disconnected from one another. The connecting means are again constructed as a pin and hole or a plug and socket. The signal applied to the terminals 6-6' is also applied to the second loudspeaker unit 2 via the connecting means 10.

The loudspeaker arrangement 21 is capable of reproducing a signal (for example a monophonic signal or the signal from one channel of a stereophonic signal). The loudspeakers 4 and 5 then reproduce the low-frequency part and the loudspeakers 8 and 9 the high-frequency part and the mid-range part, respectively.

If one (left-hand) channel of a stereophonic signal is reproduced by means of the arrangement 21, a second loudspeaker arrangement, for example, the arrangement 23 in Figure 3, is required for the reproduction of the other (right-hand) channel of the stereophonic signal. As regards the positioning of the loudspeakers in each loudspeaker arrangement, the arrangement 23 is preferably a mirror-image of the arrangement 21.

It is to be noted that the embodiments shown in Figures 1, 2 and 3 are very suitable for use as loudspeaker arrangements in cars because of their dimensions. In particular, the narrow dimension b of the loudspeaker arrangement 2 in Figure 3 may be such that the arrangement can readily be accommodated on the shelf behind the back seat of a car. The use of flat-diaphragm loudspeakers has the advantage that the height of the loudspeaker arrangement (i.e. the dimension in a direction perpendicular to the plane of drawing) can be reduced. As a result of this, the arrangement will occupy a small(er) volume and is therefore very suitable for mounting on the rear shelf in a car.

The embodiments of Figures 2 and 3 have a further advantage in that the high-frequency (and if present the mid-frequency) signals can be radiated along the sides of the head-rests, if present, on the rear seats of the car, so that the sound can reach the front part of the passenger compartment.

Figure 5 shows an embodiment of the invention for home-entertainment use. The loudspeaker arrangement is accommodated in an opening or openings in an otherwise at least substantially air-tight enclosure, for example, a loudspeaker box 48. If a loudspeaker box of small dimensions is required, the amount of air contained in the box volume presents a certain spring force to the diaphragms. Frequently a passive radiator is employed in order to reduce this force. Passive radiators have been known for a long time (see United States Patent Specification No. 1,988,250) and in principle comprise solely a diaphragm which can vibrate under the influence of air-pressure variations in the loudspeaker box. The effective stiffness constant of the air enclosed in the box is thereby reduced so that the spring force is also reduced. This results inter alia in a higher acoustic output power, especially for the low frequencies. For this purpose the embodiment shown in Figure 5 comprises a first loudspeaker unit 45 with a flat-diaphragm loudspeaker 46 and a passive radiator 47. The loudspeaker arrangement further comprises a second loudspeaker unit 2 with a loudspeaker 8 and a loudspeaker 9. The loudspeaker unit 2 is similar to the unit 2 in Figures 1, 2, 3 and 4. The flat-diaphragm loudspeaker 46 serves for reproducing a substantially low-frequency audio signal. Screw-and-nut connecting means 49 provide both a disconnectible electrical coupling and a disconnectible rigid mechanical coupling between the loudspeaker units 2 and 45. The loudspeaker arrangement is provided with an input terminal 50-50' for receiving an electric signal and applying the electric signal to the flat-diaphragm loudspeaker 46 and to the second loudspeaker unit 2.



CLAIMS:

1. A loudspeaker arrangement comprising a first loudspeaker unit for reproducing a low-frequency audio signal and a second separate loudspeaker unit provided with a loudspeaker for reproducing a high-frequency audio signal, the two loudspeaker units either being constructed to have no rigid mechanical connection between them or being provided with connecting means whereby they can be rigidly mechanically connected to one another but which will permit detachment of the units from one another, and connecting means being provided whereby the loudspeaker units can be electrically connected to one another and which comprise interengageable parts that can be disengaged from one another to disconnect the units from one another, wherein the first loudspeaker unit comprises at least two flat diaphragms.

2. A loudspeaker arrangement as claimed in Claim 1, wherein the flat diaphragms extend at least substantially in one plane, have a rectangular shape and adjoin each other along one side.

3. A loudspeaker arrangement as claimed in Claim 1 or 2, wherein the flat diaphragms each form part of a flat-diaphragm loudspeaker, and wherein a first and second input terminal are provided for receiving a first and a second electric audio signal respectively, and for applying the first and the second electric signal to the first and the second flat-diaphragm loudspeaker respectively.

4. A loudspeaker arrangement as claimed in Claim 3, wherein the loudspeaker arrangement further comprises a third separate loudspeaker unit provided with a loudspeaker for reproducing a high-frequency audio signal, the first and third loudspeaker units either being constructed to have no rigid mechanical connection between them or being provided with connecting means whereby they can be rigidly mechanically connected to one another but which will permit detachment of the units from one another, and connecting means being provided whereby the first and third loudspeaker units can be electrically connected to one another and which comprise interengageable parts that can be disengaged from one another to disconnect the units from one another, and the first and the second input terminal being coupled to the second and the third



loudspeaker unit respectively, for applying the first and the second electric signal to the second and the third loudspeaker unit respectively.

5 5. A loudspeaker arrangement as claimed in Claim 1 or 2, wherein the flat diaphragms each form part of a flat-diaphragm loudspeaker and the loudspeaker arrangement is provided with an input terminal for receiving an electric audio signal and for applying this signal to the first and the second flat-diaphragm loudspeaker and to the second loudspeaker unit.

10 6. A loudspeaker arrangement as claimed in Claim 1 or 2, wherein one flat diaphragm forms part of a flat-diaphragm loudspeaker and the other flat diaphragm forms part of a passive radiator, and wherein the loudspeaker arrangement is accommodated in an opening or openings in an otherwise substantially air-tight enclosure and is provided with an input terminal for receiving an
15 electric audio signal and for applying this electric signal to the flat-diaphragm loudspeaker and to the second loudspeaker unit.

7. A loudspeaker arrangement as claimed in any of the preceding claims, wherein the second loudspeaker unit comprises a
20 second loudspeaker for reproducing a mid-range audio-frequency signal.

8. A loudspeaker arrangement as claimed in Claim 4, wherein the third loudspeaker unit comprises a second loudspeaker for reproducing a mid-range audio-frequency signal.

25 9. A loudspeaker arrangement as claimed in any of the preceding claims, wherein the loudspeaker or loudspeakers of the second loudspeaker unit is or are pivotable about at least one axis.

30 10. A loudspeaker arrangement as claimed in Claim 8 or Claims 8 and 9, wherein the loudspeaker or loudspeakers of the third loudspeaker unit is or are pivotable about at least one axis.

~~11.22~~ 11. A loudspeaker arrangement substantially as herein described with reference to Figure 1, 2, 3, 4 or 5 of the accompanying drawings.

35 ~~12.23~~ 12. A loudspeaker unit comprising at least two flat diaphragms, for use as the first loudspeaker unit in a loudspeaker arrangement as claimed in any of Claims 1 to ~~22-11~~.