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$$H_1 = \frac{1}{Bl\,Z_{at}}(S_d Z_{at} + Z_m) \qquad \text{Formula (I)}$$

$$H_2 = -\frac{Z_m}{Bl\,Z_{at}}\left(1 - \frac{Z_{at}}{S_d Z_{ar}}\right) \qquad \text{Formula (II)}$$

(57) Abstract: A versatile electroacoustic absorber-diffuser configured for a use in a space comprises an electrodynamic loudspeaker comprising at lea st a loudspeaker diaphragm with one active face exposed to a sound pressure field; and a voice coil for electromechanical conversion attached to the loudspeaker diaphragm, with exogenous electrical terminals; further an enclosure arranged to separate a front radiation and rear radiation of the electrodynamic loudspeaker whereby the electrodynamic loudspeaker is mounted on the enclosure; means for monitoring the total sound pressure acting on the active face of the loudspeaker diaphragm, and producing a monitoring signal; and an electrical circuit connected to the exogenous electrical terminals, and comprising: i. a first electronic filtering device configured to generate a first output signal by filtering the monitoring signal by a first transfer function, which is Formula (I) where Bl is a force factor of an electro-mechamcal coupling of the electrodynamic loudspeaker, S_a is an effective area of the loudspeaker diaphragm, Z_m is a mechanical impedance of the electrodynamic loudspeaker, and Z_{a_t} is a frequency dependent specific target acoustic impedance; ii. a second electronic filtering device configured t o generate a second output signal by filtering a sound source signal re presenting the sound to be produced by a second transfer function, which is Folmula (II) where Z „ is a radiation impedance dependent on a geometry of the enclosure and the space in which the loudspeaker diaphragm radiates, and its position therein; iii. a transconductance amplifier configured for driving a current flowing through the voice coil, wherein an input voltage of the transconductance amplifier is a sum of the fir st output signal and the second output signal.

WO 2016/083970 A1

VERSATILE ELECTROACOUSTIC DIFFUSER-ABSORBER

Technical field

The invention relates to acoustic absorbers.

State of the art

Problem

All premises used for sound measurement, recording, processing and diffusion, such as recording or post production studios, concert halls, sound laboratories, etc. need to be acoustically treated to obtain the adequate reverberation and echo that is required by for their use. It is relatively easy to install passive damping systems made of porous material to adequately absorb frequencies above approximately 500 Hz. These passive absorbers are not suitable for lower frequencies as the necessary thicknesses increases with the wavelength. As an example a minimum thickness of 1 m is necessary to suitably absorb frequencies of 100 Hz with porous materials. In a standard sized room, the natural standing resonance frequencies are in general low and therefore represent a serious problem to be controlled.

Several attempts to solve this problem have been made but they all have several limitations.

Passive materials

Passive soundproofing materials are generally a robust solution in order to reduce the natural room reverberation. Passive techniques such as Helmholtz resonators or membrane-type absorbers are tuned to totally absorb the acoustic energy at specified low-mid frequencies. But they are often bulky and not suited for broadband sound absorption.

Another technique is the use of shunt loudspeakers. The absorption capability of the loudspeaker membrane can be improved by connecting simple passive shunt resistors at the terminals of the loudspeaker. With such technique, the loudspeaker can present a total absorption around its resonance but only on a short frequency range.

When several frequencies need to be treated, the amount of absorbing materials or devices increases while the volume of the room decreases.

Parametric equalization

The principle is to include equalization in the reproduction chain as a standard room adjustment procedure for thr ee to five o f the most problematic room modes. Through the use of Shelving filters cent red at the modes frequencies, the parametric equalizers limit th e amplitudes of standing waves at these frequencies. The drawback is that such filters may deteriorate the per ceived quality because of audible artefacts and the response may be enhanced at a very specific location, but deteriorated in other positions in the room.

Multiple-point equalization

This technique takes into account the effects of both source and listening positions with the use of primary and secondary sound sources. The method is to apply to secondary sources an inverse filter from a measurement taken at primary listening positions in the room to compensate the resonance s amplitude. It is only effective within a rela tively small area from the measurement positions. For counteracting this effect of spatial dependence, the sensor must be very close to th e listening position, typically within one or two centimetres of the listener ears.

This correction technique is efficient to address a few modes only , and is sensitive to the positio ns of the primary and secondary sound sources. Furthermore the number of control sources in creases with the number o f modes.

E-bass traps—Bag End Loudspeakers patent US 7, 190, 796

The publication describes a device comprising a speaker in a closed cabinet, with a microphone and an electronic controller receiving the electrica l signal from the microphone a nd re-injecting it to the speaker, after modification through an electrical transfer function taking into account a dynamic model of the speaker, and a power amplifier. This system is designed to supplement an existing sound diffusing system, reducing one or two desired modal resonances of a room that af feet sound reproduction in the low frequency range, acting as a trap bass (bass trap) that can be adjusted electron ically fe'-trap). Properly se t, it allows improved audio system electroacoustic diffusion in listening rooms (recording studios, small audiences).

The advantage is that the footprint is smaller than with passive bass traps. The main limitations are the limited bandwidth and the need to adjust to a specific frequency that is dependent on the room specificities. It mu st therefore be set up using precise sound measurements and adjusted each time the room arrangement changes.

Active acoustic impedance control system for noise reduction—international publication WO 99/59377

The international publication describes an active acoustic impedance system comprising a loudspeaker in a closed cabinet connected to a feedback control loop based on a combination of pressure measured through an impedance bridge, and the velocity of the loud speaker's membrane acquired through an accelerometer or impedance bridge.

Although this system covers a large bandwidth, it rapidly becomes unstable as the gain of the retroaction is increased. Furthermore it is not possible to adjust the central frequency of the system, where absorption is maximized.

Loudspeaker circuit with means for monitoring the pressure at the speaker diaphragm, means for monitoring the velocity of the speaker diaphragm and a feedback circuit—international publication WO 99/03536

The publication describes a loudspeaker circuit, the performance of which can be adapted to the acoustical charecteristics of the space in which it is placed. The loudspeaker behavior is monitored using means for measuring the pressure in the vicinity of its diaphragm, and means for measuring the velocity of the speaker. A desired impedance value, ratio between the monitored pressure and velocity, is aimed at using the feedback control circuit.

Such loudspeaker circuit is said to be able to generate sound, according to an input signal, and at the same time absorb sound coming from external sound sources, by controlling the acoustic input impedance of the speaker.

This invention thus addresses the problem of room resonances in the low frequency domain, by absorbing sound disturbances, such as reflections from hard surfaces. However, it suffers from several limitations. First it requires an accelerometer or any other mean to measure the velocity of the speaker. Second, in the publication, the desired acoustic impedance is a constant coefficient, while the actual optimal acoustic impedance for such a device is usually frequency dependent. Third, the simple feedback control proposed in this publication is not effective unless very high gains are used, which can also cause stability problems.

Electroacoustic absorber—international publication WO 2014/053994

An active impedance control system comprises a loudspeaker in a closed cabinet, which is connected to a specific electric impedance synthetized and made up of a combination of filters implemented in a digital processor with a setup of analog components, associated to a transconductance amplifier.

The limitation of this system is that it is intrinsically unstable depending on the type of electric impedance that is connected to the loudspeaker.

Problems solved by the invention

The present invention addresses the shortcomings of the existing solutions for absorbing sound at low frequencies, and damping low-frequency room modal resonances. The use of a means for measuring the pressure ensures a greater stability of the system, whose band width can therefore be greatly enlarged. The use of a transconductance amplifier ensures that the loudspeaker coil is current driven, instead of being voltage-driven as in most existing solutions. It overcomes the need for a precise modeling of the electrical part of the loudspeaker. Means to measure the velocity of the speaker is not needed, which makes the system simpler and more robust.

Additionally, the invention can be used as both an absorber and a sound source at the same time, for better sound reproduction in closed spaces. Sound from external disturbance, including reflections on hard surfaces, will be absorbed while the desired sound signal will be generated.

Summary of the invention

In a first aspect, the invention provides a versatile electroacoustic absorber-diffuser configured for a use in a space. The electroacoustic absorber-diffuser comprises

a. an electrodynamic loudspeaker comprising at least:
   i. a loudspeaker diaphragm with one active face exposed to a sound pressure field;
   ii. a voice coil for electromechanical conversion attached to the loudspeaker diaphragm, with exogenous electrical terminals;
b. an enclosure arranged to separate a front radiation and rear radiation of the electrodynamic loudspeaker, whereby the electrodynamic loudspeaker is mounted on the enclosure;
c. means for monitoring the total sound pressure acting on the active face of the loudspeaker diaphragm, and producing a monitoring signal;
d. an electrical circuit connected to the exogenous electrical terminals, and comprising:
   i. a first electronic filtering device configured to generate a first output signal by filtering the monitoring signal by a first transfer function, which is:

$$H_1 = \frac{1}{Bl\, Z_{at}}(S_d Z_{at} + Z_m)$$

where Bl is a force factor of an electro-mechanical coupling of the electrodynamic loudspeaker, S_d is an effective area of the loudspeaker diaphragm, Z_m is a mechanical impedance of the electrodynamic loudspeaker, and Z_{at} is a frequency dependent specific target acoustic impedance;

ii. a second electronic filtering device configured to generate a second output signal by filtering a sound source signal representing the sound to be produced by a second transfer function, which is:

$$H_2 = -\frac{Z_m}{Bl\, Z_{at}}(1 - \frac{Z_{at}}{S_d Z_{ar}})$$

where Z_{ar} is a radiation impedance dependent on a geometry of the enclosure and the space in which the loudspeaker diaphragm radiates, and its position therein;

iii. a transconductance amplifier configured for driving a current flowing through the voice coil, wherein an input voltage of the transconductance amplifier is a sum of the first output signal and the second output signal.

In a preferred embodiment the means for monitoring comprises a microphone placed at a distance of the loudspeaker diaphragm that is less than half of a wavelength of a sound wave propagating in the air with a frequency equal to the maximum frequency to be absorbed by the versatile electroacoustic diffuser-absorber.

In a further preferred embodiment, the means for monitoring the total sound pressure acting on the active face of the loudspeaker diaphragm comprise at least two microphones placed at a distance of the loudspeaker diaphragm that is less than half of a wavelength of a sound wave propagating in the air with a frequency equal to the maximum frequency to be absorbed by the versatile electroacoustic diffuser-absorber, and configured to produce respective monitoring signals. The electroacoustic diffuser-absorber further comprises averaging means configured to input the respective monitoring signals, compute an average, and derive a signal related to the total sound pressure acting on the active face of the loudspeaker diaphragm.

In a further preferred embodiment, the versatile electroacoustic diffuser-absorber comprises at least a further electrodynamic loudspeaker with same values as for the electrodynamic loudspeaker for the force factor, the effective area of the loudspeaker diaphragm, and the mechanical impedance, the further electrodynamic loudspeaker being mounted on a separate enclosure of same volume as for the enclosure, and used in place of the electrodynamic loudspeaker mounted on the enclosure, whereby the at least one further electrodynamic loudspeaker is connected in series with the electrodynamic loudspeaker and driven by the same current delivered by the transconductance amplifier.

In a further embodiment, the versatile electroacoustic diffuser-absorber comprises at least a further electrodynamic loudspeaker with same values as for the electrodynamic loudspeaker for the mechanical impedance, the effective area of the loudspeaker diaphragm and the force factor, the further electrodynamic loudspeaker being mounted on a separate enclosure of same volume as for the enclosure, and used in place of the electrodynamic loudspeaker mounted on the enclosure, whereby the at least one further electrodynamic loudspeaker is driven by a current delivered by a further transconductance amplifier with the same input voltage as for the transconductance amplifier.

In a second aspect the invention provides a use of the versatile electroacoustic diffuser-absorber as an absorber only, comprising a step of setting the second output signal to zero independent of the filtered input signal.

In a third aspect, the invention provides an electroacoustic drffuser configured for a use in a space, the electroacoustic drffuser comprising

a. an electrodynamic loudspeaker comprising at least:

   i. a loudspeaker diaphragm with one active face exposed to a sound pressure field;

   ii. a voice coil for electromechanical conversion attached to the loudspeaker diaphragm, with exogenous electrical terminals;

b. an enclosure arranged to separate a front radiation and rear radiation of the electrodynamic loudspeaker, whereby the electrodynamic loudspeaker is mounted on the enclosure;

c. an electrical circuit connected to the exogenous electrical terminals, and comprising:

   i. an electronic filtering device configured to generate an output signal by filtering a sound source signal representing the sound to be produced by a transfer function, which is:

$$H_2 = \frac{S_d}{Bl}\left(1 + \frac{Z_m}{{S_d}^2 Z_{ar}}\right)$$

where Bl is a force factor of an electro-mechanical coupling of the loudspeaker, S_d is an effective area of the loudspeaker diaphragm, Z_m is a mechanical impedance of the electrodynamic loudspeaker, and Z_{ar} is a radiation impedance dependent on a geometry of the enclosure and the space in which the loudspeaker diaphragm radiates, and its position therein;

ii. a transconductance amplifier configured for driving a current flowing through the voice coil, wherein an input voltage of the transconductance amplifier is the output signal of the electronic filtering device.

Brief description of the drawings

The invention will be better understood from the following detailed description of preferred embodiments with reference to the appended figures given as non-limiting examples.

Figure 1 is an example realisation of the invention comprising an electrodynamic loudspeaker mounted on an enclosure, two electronic filtering devices, one transconductance amplifier and one microphone for monitoring the total pressure acting on the active face of the loudspeaker diaphragm.

Figure 2 is a further example realisation of the invention comprising two electrodynamic loudspeakers connected in series but mounted on separated enclosures, two electronic filtering devices, a transconductance amplifier and a microphone for monitoring the total pressure acting on the active face of the loudspeaker diaphragm.

Figure 3 is a further example realisation of the invention comprising several electrodynamic loudspeakers mounted on separated enclosures, each with their own transconductance amplifier, two electronic filtering devices and a microphone for monitoring the total pressure acting on the active face of the loudspeaker diaphragm.

Figure 4 is a further example realisation of the invention comprising an electrodynamic loudspeaker mounted on an enclosure, two electronic filtering devices, a transconductance amplifier and several microphones for monitoring the total pressure acting on the active face of the loudspeaker diaphragm.

Figure 5 is a further example realisation of the invention comprising an electrodynamic loudspeaker mounted on an enclosure, an electronic filtering device, a transconductance amplifier and a microphone for monitoring the total pressure acting on the active face of the loudspeaker diaphragm.

Figure 6 is a further example realisation of the invention comprising an electrodynamic loudspeaker mounted on an enclosure, an electronic filtering device, and a transconductance amplifier.

Detailed description of preferred embodiment of the invention

The present invention provides a versatile device with capabilities of equalizing the acoustic energy in rooms in the low-frequency range, and optionally for use as a sound source simultaneously. In the preferred embodiment, referring to figure 1, the invention comprises

- an electrodynamic loudspeaker 1 comprising at least:
  - o a diaphragm with one active face exposed to a sound pressure field
  - o a voice coil for electromechanical conversion attached to said diaphragm, with exogenous electrical terminals;
- an enclosure or an acoustic baffle 2 to separate a front radiation and a rear radiation of the electrodynamic loudspeaker; advantageously and not represented in figures;
- means for monitoring 3 the total sound pressure acting on the active face of the loudspeaker diaphragm and delivering a monitoring signal 9 related to the total sound pressure acting on the active face of the loudspeaker diaphragm; and
- an electrical circuit connected to exogenous electrical terminals, and comprising:
  i. a first electronic filtering device 4 generating a first output signal by filtering the monitoring signal 9 related to the total sound pressure acting on the active face of the loudspeaker diaphragm by a first transfer function:

$$H_1 = \frac{1}{Bl\, Z_{at}}(S_d Z_{at} + Z_m)$$

where Bl is the force factor of the electro-mechanical coupling of the loudspeaker, S_d is the effective area of the loudspeaker diaphragm, Z_m is the mechanical impedance of the loudspeaker, and Z_{at} is a frequency dependent specific target acoustic impedance;

ii. a second electronic filtering device generating a second output signal by filtering a so und source signal 8 representing the sound to be produced by a second transfer function:

$$H_2 = -\frac{Z_m}{Bl\,Z_{at}}\left(1 - \frac{Z_{at}}{S_d Z_{ar}}\right)$$

where Z_{ar} is the radiation impedance dependent on the geometry of the enclosure and room or other space in which the loudspeaker diaphragm radiates, and its position therein;

iii. a transconductance amplifier 6 configured for driving a current 11 flowing through t he voice coil of the electrodynamic loudspeaker, wherein the inp ut voltage 10 of the transconductance amplifier 6 is the sum of the first output signal generated by the first electronic filte ring device 4 and seco nd output signal generated by the second electronic filtering device 5.

By definition, the specific acou stic impedance Z of the electrodynamic loudspeaker 1 is a ratio of the total sound pressu e pt acting on the active face of the loudspeaker dia phragm and the loudspeaker diap hragm velocity v, whatever the load or feedback at the electrical terminals of the transducer, and is expressed as:

$$Z = \frac{p_t}{v}$$

From Newton's law of motion, for small disp lacements and below th e first modal frequency of the diaphra gm, the mechanical dynamics of the loudspeaker diaphragm can b e modeled with the following linear differential equation:

$$-S_d p_t = Z_m v - Bli$$

where S_d is the effective area of the loudspeaker diaphragm, Z_m is the mechanical impedance (i.e. mass, resistance, compliance) of the loudspeaker 1 mounted on the enclosure 2, Bl is the force fa ctor of the electro-mechanical coupling and i the current 11 circulating through the voice coil.

The first electronic filtering device 4 and the second electronic filtering device 5 are configured to provide a fre quency-dependent specific target acoustic impedance Z_{at} in ord er to absorb an acoust ic energy from a sound field according to the following expression:

$$p_t - Ap_i = Z_{at} v$$

where pi is the sound source signal 8, representing the sound to be produced, and A a transfer function described below.

In the absence of exog enous pressure, the total sound pressure p t acting on the active face of the loudspeaker diaphragm is exactly equal to that produced by the loudspeaker, and is expected to be equa l to the input signal pi. In this case the total sound pressure ptcan be expressed as:

$$p_t = p_i = S_d Z_{ar} v$$

where Zar is the radiation impedance of the loudspeaker diaphragm mounted in the enclosure 2. The radiation impedance Zar depends on the geometry of the enclosure 2, and more importantly on the geometry of the room or other space in which the loudspeaker diaphragm radiates, and its position therein.

The transfer function A is then defined as:

$$A = 1 - \frac{Z_{at}}{S_d Z_{ar}}$$

The functional relationship between the sound source signal 8, the monitoring signal 9 related to the total pressure p_t acting on the active face of the diaphragm, and the current 11 depends on the internal model of the electrodynamic loudspeaker (i-e. mechanical impedance Z_m, force factor Bl of the electro-mechanical coupling and effective area Sd of the diaphrag m) and the specific acoustic target impedance Zat, and is expressed as:

$$i = H_1 p_t + H_2 p_i$$

where the t ransfer function H_1 implemented in the first electronic filt ering device 4 is:

$$H_1 = \frac{1}{Bl\, Z_{at}} (S_d Z_{at} + Z_m)$$

and the transfer function H_2 implemented in the second electronic filtering device 5 is:

$$H_2 = -\frac{Z_m}{Bl\, Z_{at}} (1 - \frac{Z_{at}}{S_d Z_{ar}})$$

As described in figure 1, the invention in its preferred embodiment comprises the electrodynamic loudspeaker 1 comprising at least th e voice coil and diaphragm subjected to an exogenous sound pressure field. The loudspeaker 1 is mounted on the enclosure or acoustic baffle 2 to prevent the sound waves emitted — or received — from its rear side to interfere or cancel the sound waves emitted — or received — from its f rent side. Advantageously a microphone 3 is used for monitoring the total sound pressure acting on the active face of the loudspeaker diaphragm, and placed at a distance of the loudspeaker diaphragm that is less than half of a wavelength of a sound wave propagating in the air with a frequency equal to the maximum frequency to be absorbed by the versatile electroacoustic diffuser-absorber, as illustrated in fig. 3. An output of the microphone 3, i.e., a monitoring signal 9 related to the total sound pressure, is a v oltage proportional to t he total so und pressure. The monitoring signal 9 is filtered through a first electronic filtering device 4. A sound source signal 8, related to the sound to be generated by the versatile device, is filtered by a second electr onic filtering device 5, and then su mmed to the output signal of the first electronic filtering device 4. The resulting sum of the output signals of t he first e lectronic filtering devices 4 and the second electronic filtering device 5, i.e., a voltage signal 10, is then converted into a current 11 with the help of a transconductance amplifier 6, for driving the voice coil of the loudspeaker 1.

As shown in figure 2, the invention in another embodiment is similar as described above, but the means for monitoring the total sound pressure acting on the active face of the loudspeaker diaphragm of the electro dynamic loudspeaker 1 are two or more microphones 3Aand 3B placed at a distance of the loudspeaker diaphragm that is less than half of a wavelength of a sound wave propagating in the air with a frequency equal to the maximum frequency to be absorbed by the versatile electroacoustic dif fuser-absorber, the respective monitoring signals 9A and 9B of which are advanta geously combined (means of signals for instance) to derive a signal to the total sound pressure acting on the active face of the loudspeaker diaphragm.

As described in figure 3, the invention in an other embodiment comprises two or more electrodynamic loudspeakers 1A and 1B with identical internal model (i.e. Zm, Bl and Sd), each mounted on separate enclosures 2A and 2B, in place of the elect rodynamic loudspeaker mounted on the enclo sure or aco ustic baffle. In this configuration, the electrodynamic loudspeakers 2A and 2B are connected in series an d driven by the same current 11 delivered by the transconductance amplifier 6.

As described in figure 4, the invention in anot her embodiment is similar as described above, each electrodynamic loudspeaker 1A/1B being driven by a dedicated current 1 1A/11 B delivered by its own transcond uctance amplifier 6A/6B, whose input voltage signal 10 is the same.

In such configurations, the versatile electroacoustic diffuser-absorber may be used simultaneously for sound diffusion and room modal equalization.

From the corrfiguratio ns described above, the versa tile electroacoustic drffuser-absorber may also be used as absorber only as described in figure 5, by ignoring the second e lectronic filtering device 5, which in this configuration has no sound source signal 8.

As described in figure 6, the versa tile electroacoustic diffuser-absorber may also be used as diffuser only. In this configuration, the first electronic filtering device 4 is ignored, and the means for monitoring 3 the tot al sound pressure acting on the active face of the loudspeaker diaphragm are discarded. In this case, the total sound pressure p t acting on the active face of the loudspeaker diaphragm is exactly e qual to that produced by the loud speaker 1, and is expected to be equal to the input signal pi. The invention then comprises the electrodynamic loudspeaker 1 comprising at least the voice coil and diaphragm subjected to an exogeno us sound pressure field. The loudspeaker 1 is mounted on the enclosure or acoustic baffle 2 to prevent the sound waves emitted — or received — from its rear side to interfere or cancel the sound waves emitted — or received — from its front side. A sound source signal 8, related to the sound to be generated by the versatile device, is f iltered by an electronic filtering device 5, whose the transfer function is:

$$H_2 = \frac{S_d}{Bl}\left(1 + \frac{Z_m}{{S_d}^2 Z_{ar}}\right)$$

The output signal 10 of the electronic filtering device 5, is then converted into a current 11 with the he lp of a transconductan ce amplifier 6, for drivi ng the voice coil of the loudspeaker 1.

Claims

1. A versatile electroacoustic absorber-diffuser configured for a use in a space, the electroacoustic absorber-diffuser comprising:

   a. an electrodynamic loudspeaker (1) comprising at least:

      i. a loudspeaker diaphragm with one active face exposed to a sound pressure field;

      ii. a voice coil for electromechanical conversion attached to the loudspeaker diaphragm, with exogenous electrical terminals;

   b. an enclosure (2) arranged to separate a front radiation and rear radiation of the electro dynamic loudspeaker (1), whereby the electrodynamic loudspeaker (1) is mounted on the en closure (2);

   c. means for monitoring (3) the total sound pressure acting on the active face of the loudspeaker diaphragm, and producing a monitoring signal;

   d. an electrical circuit connected to the exogenous electrical terminals, and comprising:

      i. a first electronic filtering device (4) configured to generate a first output signal by filtering the monitoring signal by a first transfer function, which is:

$$H_1 = \frac{1}{Bl\, Z_{at}} (S_d Z_{at} + Z_m)$$

      where Bl is a force factor of an electro-mechanical coupling of the electrodynamic loudspeaker, S_d is an effective area of the loudspeaker diaphragm, Z_m is a mechanical impedance oft he electrodynamic loudspeaker (1), and Z_{at} is a frequency dependent specific target acoustic impedance;

      ii. a second electronic filtering device (5) configured to generate a second output signal by filtering a sound source signal (8) representing the sound to be produced by a second transfer function, which is:

$$H_2 = -\frac{Z_m}{Bl\, Z_{at}} (1 - \frac{Z_{at}}{S_d Z_{ar}})$$

      where Z_{ar} is a radiation impedance dependent on a geometry of the enclosure (2) and the space in which the loudspeaker diaphragm radiates, and its position therein;

iii. a transconductance amplifier (6) configured for driving a current (11) flowing through the voice coil, wherein an input voltage (10) of the transconductance amplifier (6) is a sum of the first output signal and second output signal.

2. The versatile electroacoustic diffuser-absorber from claim 1, wherein the means for monitoring (3) comprises a microphone placed at a distance of the loudspeaker diaphragm that is less than half of a wavelength of a sound wave propagating in the air with a frequency equal to the maximum frequency to be absorbed by the versatile electroacoustic diffuser-absorber.

3. The versatile electroacoustic diffuser-absorber from any one of claims 1 to 2, wherein

the means for monitoring (3) the total sound pressure acting on the active face of the loudspeaker diaphragm comprise at least two microphones (3A & 3B) placed at a distance of the loudspeaker diaphragm that is less than half of a wavelength of a sound wave propagating in the air with a frequency equal to the maximum frequency to be absorbed by the versatile electroacoustic diffuser-absorber, and configured to produce respective monitoring signals (9A, 9B),

the electroacoustic diffuser-absorber further comprising

averaging means configured to input the respective monitoring signals, compute an average, and derive a signal related to the total sound pressure acting on the active face of the loudspeaker diaphragm.

4. The versatile electroacoustic diffuser-absorber of any one of claims 1 to 3, comprising at least a further electrodynamic loudspeaker (1B) with same values as for the electrodynamic loudspeaker (1) for the force factor, the effective area of the loudspeaker diaphragm, and the mechanical impedance, the further electrodynamic loudspeaker being mounted on a separate enclosure (2B) of same volume as for the

enclosure (2A), and used in place of the electrodynamic loudspeaker mounted on the enclosure, whereby the at least one further electrodynamic loudspeaker (1B) is connected in series with the electrodynamic loudspeaker (1A) and driven by the same current (11) delivered by the transconductance amplifier (6).

5. The versatile electroacoustic diffuser-absorber of any one of claims 1 to 3, comprising at least a further electrodynamic loudspeaker (1B) with same values as for the electrodynamic loudspeaker (1) for the force factor, the effective area of the loudspeaker diaphragm, and the mechanical impedance, the further electrodynamic loudspeaker (1B) being mounted on a separate enclosure (2B), and used in place of the electrodynamic loudspeaker mounted on the enclosure, whereby the at least one further electrodynamic loudspeaker (1B) is driven by a current (11b) delivered by a further transconductance amplifier (6B) with the same input voltage (10) as for the transconductance amplifier (6A).

6. Use of the versatile electroacoustic diffuser-absorber of any one of claims 1 to 5, as an absorber only, comprising a step of setting the second output signal to zero independent of the filtered input signal.

7. An electroacoustic diffuser configured for a use in a space, the electroacoustic diffuser comprising:

   a. an electrodynamic loudspeaker (1) comprising at least:

      i. a loudspeaker diaphragm with one active face exposed to a sound pressure field;

      ii. a voice coil for electromechanical conversion attached to the loudspeaker diaphragm, with exogenous electrical terminals;

   b. an enclosure (2) arranged to separate a front radiation and rear radiation of the electrodynamic loudspeaker (1), whereby the electrodynamic loudspeaker (1) is mounted on the enclosure (2);

   c. an electrical circuit connected to the exogenous electrical terminals, and comprising:

      i. an electronic filtering device (5) configured to generate an output signal by filtering a sound source signal (8) representing the sound to be produced by a transfer function, which is:

$$H_2 = \frac{S_d}{Bl}(1 + \frac{Z_m}{S_d{}^2 Z_{ar}})$$

where Bl i s a force factor of an electro-mechanica l coupling of the loudspeaker, S_d is an effective area of the loudspeaker diaphragm, Z_m is a me chanical impedance of the electrodynamic loudspeaker (1), and Z_{a^-} is a radiation impedance dependent on a geometry of the enclosure (2) and the space in which the lou dspeaker diaphragm radiates, and its position therein;

ii. a transconductance amplifier (6) configured for driving a current (11) flowing through the voice coil, w herein an input voltage (10) of the transcond uctance amplifier (6) is the output signal of the electronic filtering device (5).

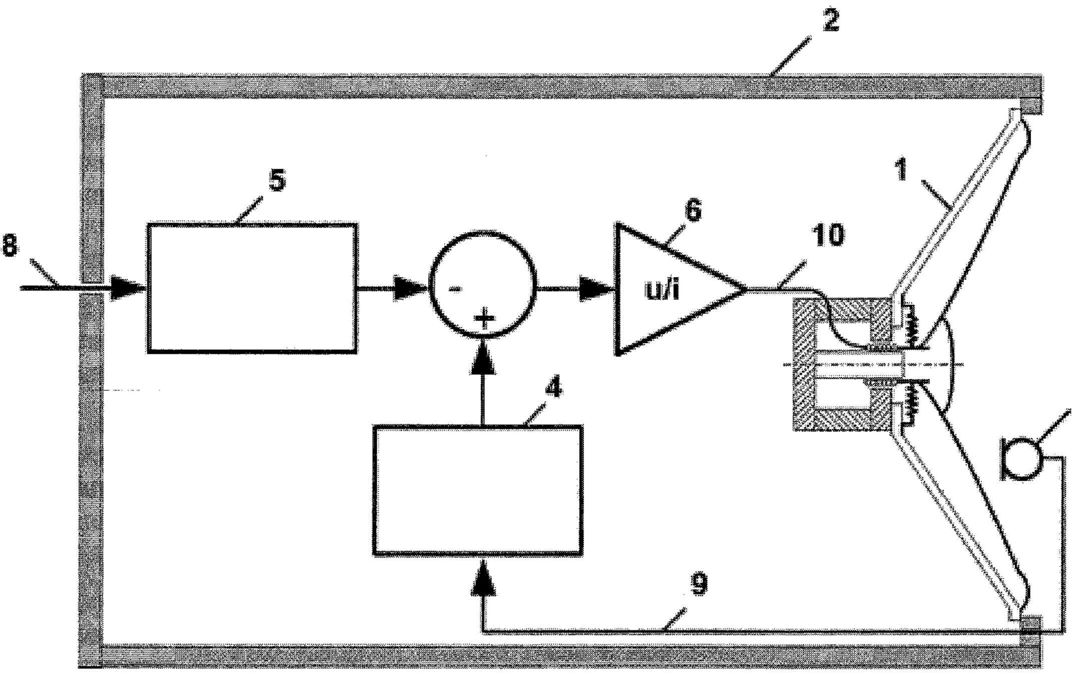

Fig. 1

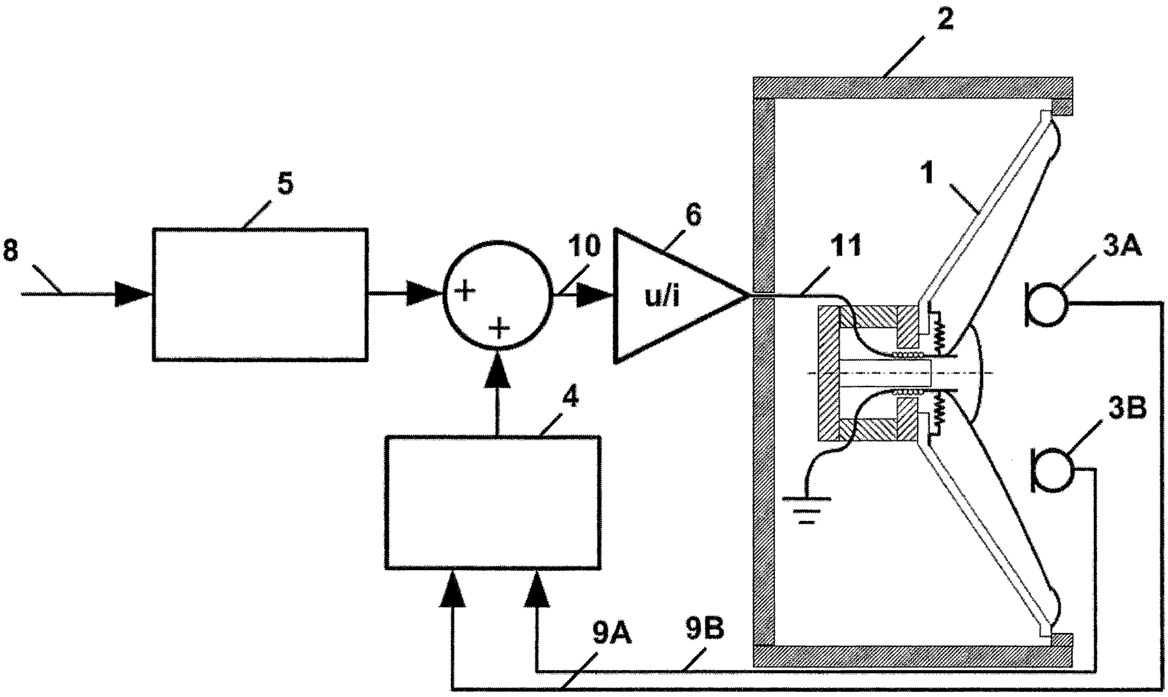

Fig. 2

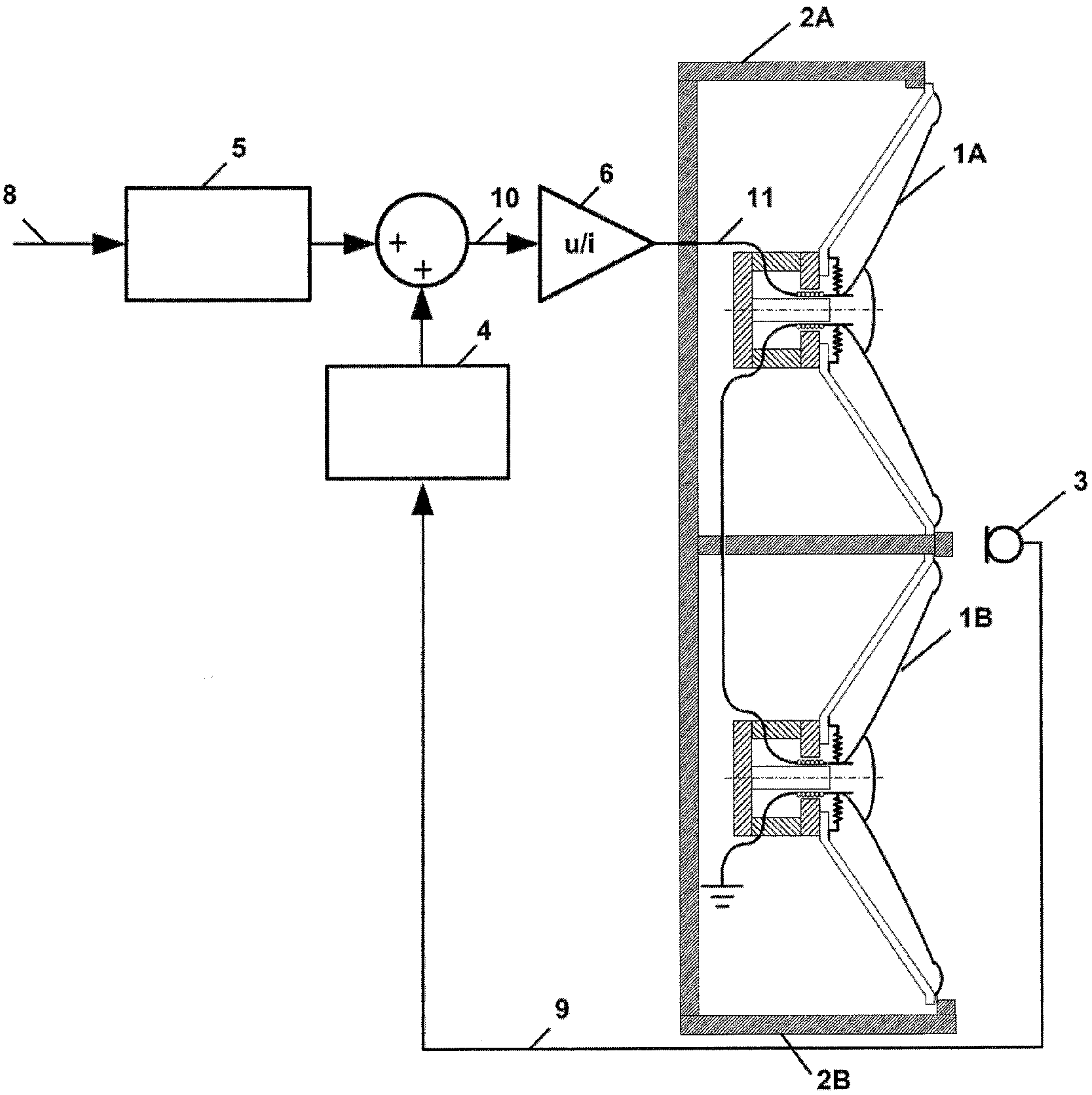

Fig. 3

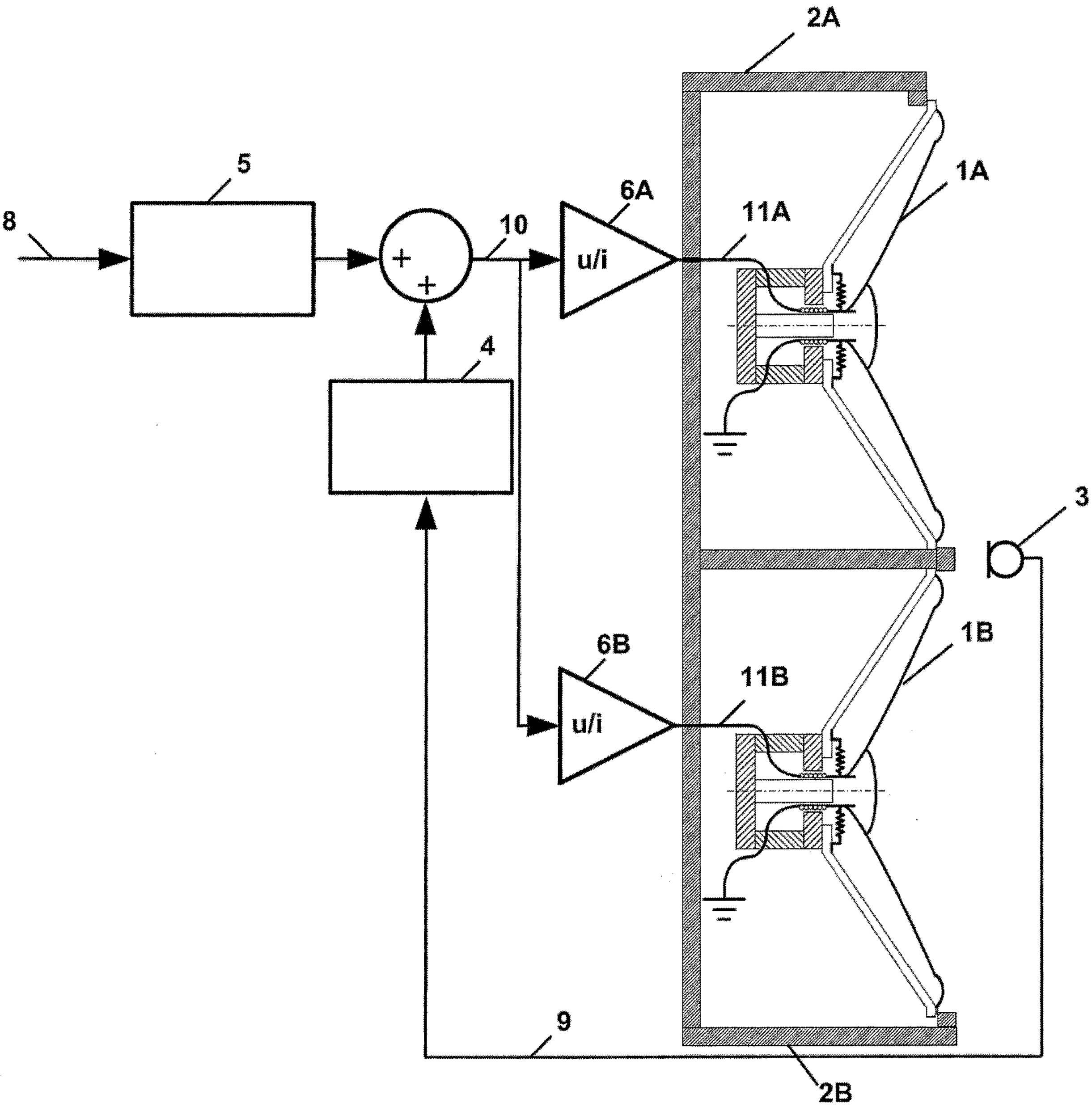

Fig. 4

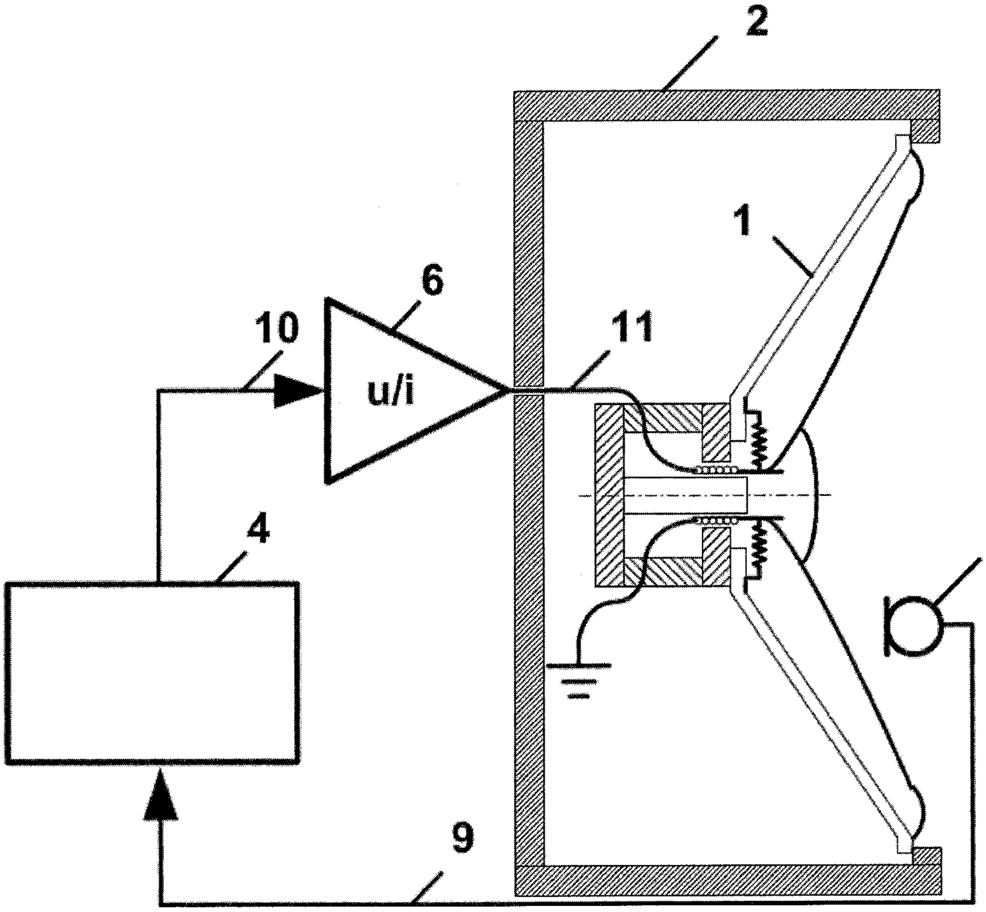

Fig. 5

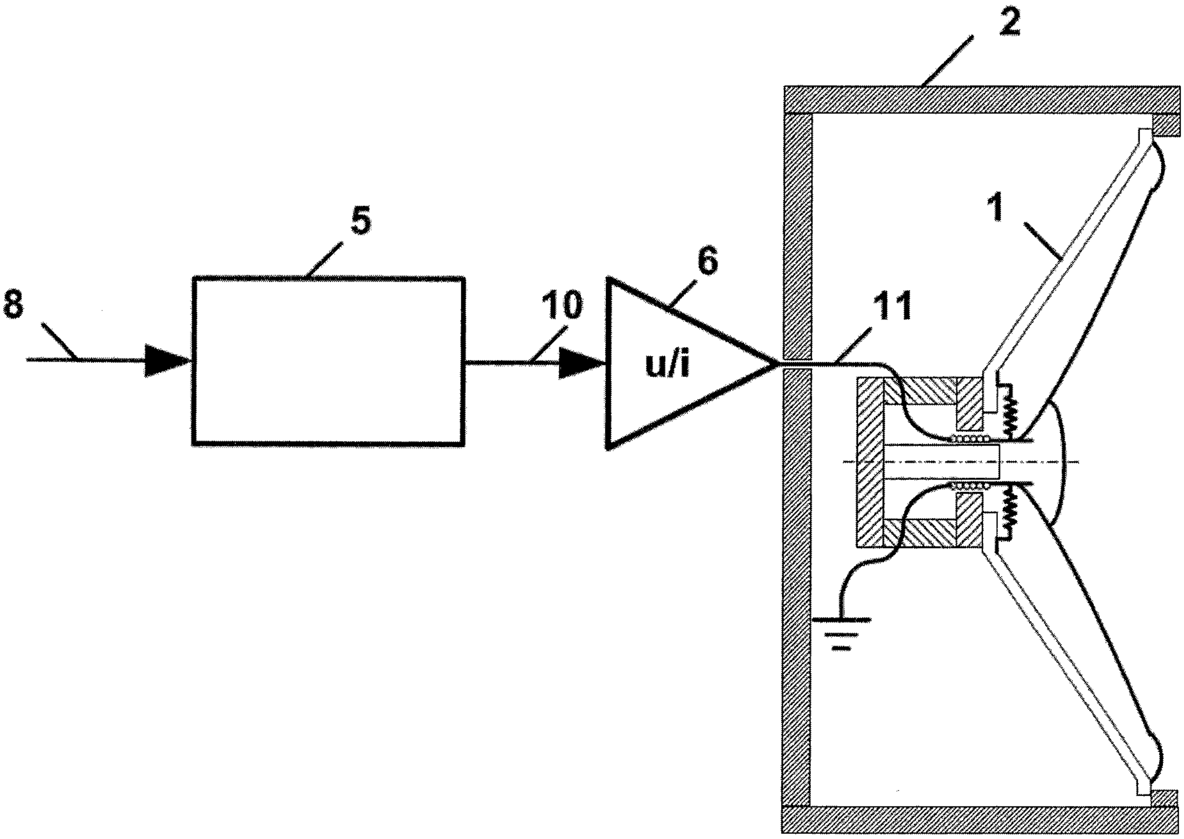

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/059028

A. CLASSIFICATION OF SUBJECT MATTER
INV. H94R3/0O
ADD. H04R3/Q8

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 data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 84/00274 AI (B & W LOUDSPEAKERS [GB]) 19 January 1984 (1984-01-19) page 9, line 27 - page 10, line 20; figure 3	1-6
Y	WO 2014/053994 AI (EC0LE P0LYTECH [CH]) 10 April 2014 (2014-04-10) cited in the application claim 1	1-7
Y	EP 0 772 374 A2 (BANG & 0LUFSEN AS [DK]) 7 May 1997 (1997-05-07) column 2, line 26 - line 57; figures 2, 3	7

☐ Further documents are listed in the continuation of Box C.

m See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 March 2016	14/03/2016

Name and mailing address of the ISA/	Authorized officer
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2

INTERNATIONAL SEARCH REPORT

Information on patent Tamlly members

International application No
PCT/IB2015/059028

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