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(54) **Title:** LOW FREQUENCY ACTIVE ACOUSTIC ABSORBER BY ACOUSTIC VELOCITY CONTROL THROUGH POROUS RESISTIVE LAYERS

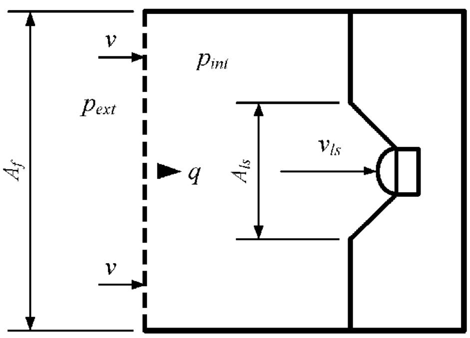

Fig. 1

$$\frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_i} \quad (I)$$

(57) **Abstract:** Low frequency active acoustic absorber by acoustic velocity control through porous resistive layers. The invention provides an electroacoustic device for wide band low frequency absorption. The device comprises at least one electroacoustic transducer, mounted on an acoustic baffle, separating a closed rear volume and a front volume, the front volume being closed by an acoustic fabric of determined acoustic air-flow resistance; a power amplification electronic with feedback control, configured to obtain a transducer membrane velocity proportional to an input voltage, coming from a microphone located in front of the acoustic fabric on a side opposite from the front volume, connected to a microphone preamplifier; and a feedforward control, with adjustable gain and band-pass filter, taking a first pressure signal coming from the microphone preamplifier and driving the power amplifier input, the feedforward control gain being equal to Formula (I) where A_f is the fabric area, A_{ls} the projected transducer membrane area, *R* the fabric air-flow resistance and Gi, the preamplifier gain, minimizing the acoustic pressure in the front volume, thus having a specific impedance, defined as pressure/velocity ratio, in front of the acoustic fabric equal to the determined air-flow resistance of the acoustic fabric.

WO 2016/083971 A1

Low frequency active acoustic absorber by acoustic velocity control through porous resistive layers

Technical field

The invention relates to acoustic absorbers.

Background

Technical domain of the invention

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 for their use.

It is relatively easy to install passive dampening systems made of fiber material to adequately absorb frequencies above 500 Hz approximately. However, these passive absorbers are not suitable for lower frequencies as the necessary thickness of material increases with the wavelength. As an example, a minimum thickness of 1 m of material is necessary to suitably absorb frequencies of 100 Hz.

In a standard sized room, the natural standing resonance frequencies are in general relatively low and therefore represent a serious problem to be controlled.

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

State of the art

Electronic equalization of a room

In order to reduce the resonance in a room, an equalizing system compensates the signal transmitted to the loudspeaker by reducing the frequencies that resonate in a particular room with particular equipment, furniture and people inside it.

A main problem with this system is that it alters the primary sound emitted by the loudspeaker thus reducing the fidelity of the source—this is not acceptable to some users. A second problem is that the equalizing is not adaptive and the setup process must be done each time the room specifics change, e.g. if an extra person enters the room.

Passive bass-trap

There are several different ways of designing a passive bass-trap. In general the passive bass-trap comprises a resonating membrane in front of a damping material or air volume with a size tuned to the frequency that needs to be absorbed—typically 20-100 Hz.

The system needs to have large dimensions and is dedicated to a single frequency when typically several frequencies need to be treated and these several frequencies vary according to the specificities of the room. The large amount of absorbing equipment needed also increases the cost as well as significantly reduces the volume of the room.

E-bass trap (Bag End Loudspeakers patent US 7,190,796)

This system comprises a microphone that controls a loudspeaker to absorb specific low frequencies. An advantage of this system is that the footprint is smaller than with a passive bass-trap. A main limitation to this system is that it needs to be adjusted to a specific frequency and therefore is also dependent on the room specificities. It must therefore be set up using precise sound measurements and adjusted each time the room specificities change, e.g., if a person enters the room.

Active acoustic impedance control system for noise reduction (international publication WO 99/59377 to X. Meynial)

An active acoustic impedance system comprises a loudspeaker in a closed cabinet connected to a feedback control loop based on a combination of pressure measured with a microphone and the velocity of the loudspeaker's membrane, acquired through an impedance bridge—motional feedback principle patented by Philips.

Although this system covers a large bandwidth, it rapidly becomes instable as the gain of the counter reaction is increased. Furthermore it is difficult to adjust the central frequency that the loudspeaker will absorb.

Electroacoustic absorber (international publication WO 2014/053994 A 1 to H. Lissek, R. Boulandet and E. Rivet)

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

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

Problems solved by the invention

It is an aim of the invention to provide an adaptive device that adjusts to absorb the predominant resonant frequencies of a closed area.

It is further an aim of the invention to provide a device that presents a large active absorption area, significantly larger than the area of the transducers used.

Summary of the invention

The invention provides an electroacoustic device for wide band low frequency absorption. The device comprises at least one electroacoustic transducer, mounted on an acoustic baffle, separating a closed rear volume and a front volume, the front volume being closed by an acoustic fabric of determined acoustic air-flow resistance; a power amplification electronic with membrane velocity feedback control, configured to obtain a transducer membrane velocity proportional to an input voltage, coming from a microphone located in front of the acoustic fabric on a side opposite from the front volume, connected to a microphone preamplifier; and a feedforward control, with adjustable gain and band-pass filter, taking a first pressure signal coming from the microphone preamplifier and driving the power amplifier input, the feedforward control gain being equal to

$$\frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_1}$$

where A_f is the fabric area, A_b the projected transducer membrane area, R the fabric air-flow resistance and G_y the preamplifier gain, minimizing the acoustic pressure in the front volume, thus having a specific impedance, defined as pressure/velocity ratio, in front of the acoustic fabric equal to the determined acoustic air-flow resistance of the acoustic fabric.

In a preferred embodiment the membrane velocity feedback control is based on an impedance bridge.

In a further preferred embodiment the electroacoustic device further comprises an additional microphone located behind the acoustic fabric in the front volume, with an additional microphone preamplifier; and a feedback control loop, with adjustable gain and band-pass filter, taking a second pressure signal coming from the additional microphone preamplifier, the signals coming from the feedforward control and the membrane velocity feedback control being added to drive the power amplifier input, the feedforward control gain being equal to

$$\frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_1}$$

and the feedback control gain being equal to a significantly larger value than the feedforward control gain, minimizing the acoustic pressure in the front volume, thus having the specific impedance in front of the acoustic fabric equal to the specific air-flow resistance of the fabric.

In a further preferred embodiment, the membrane velocity feedback control is realized using an integrator circuit, configured to integrate over time a signal coming from an accelerometer located on the transducer membrane.

In a further preferred embodiment, the membrane velocity feedback control is realized using a differentiator circuit, configured to differentiate over time a signal coming from an additional microphone preamplifier, with an additional microphone located in the closed rear volume and connected to the additional microphone preamplifier.

In a further preferred embodiment, the electroacoustic transducer is equipped with two coils, one of which is connected to the output of the power amplification electronic and the other of which produces an induced voltage representative of a velocity measurement, the induced voltage being proportional to the transducer membrane velocity and output as membrane velocity feedback control to the power amplification electronic.

In a further preferred embodiment, the electroacoustic device further comprises at least one additional acoustic fabric layer in front of the acoustic fabric, whereby the first microphone is located between the two acoustic fabric layers.

In a further preferred embodiment, the electroacoustic device further comprises at least one additional microphone in front of a second acoustic fabric, on a side opposite to the first microphone, with its microphone preamplifier and feedforward control with adjustable gain and band-pass filter, the signal coming from the two feedforward controls being linearly combined to drive the power amplifier input, the first feedforward control gain being equal to

$$\rho_1 \cdot \frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_1}$$

and the second feedforward control gain being equal to

$$\rho_2 \cdot \frac{A_f}{(R+R') \cdot A_{ls}} \cdot \frac{1}{G_2}$$

where G_2 is the second preamplifier gain and p_x and p_2 are weighting coefficients linked by $\rho_1 + \rho_2 = 1$, minimizing the acoustic pressure in the front volume, thus having the specific impedance in front of the acoustic fabric equal to the sum of specific air-flow resistances of the fabrics.

Brief description of the drawings

The invention will be better understood in view of the description of preferred embodiments of the invention and in light of the drawings, wherein:

Fig. 1 shows the general principle of acoustic pressure cancellation behind a resistive acoustic fabric;

Fig. 2 is a schematic of a preferred embodiment of the invention;

Fig. 3 shows the voltage to acoustic velocity converter used in the power amplifier;

Fig. 4 shows a modification of the embodiment of Fig. 2 with the use of an additional microphone;

Fig. 5 shows the embodiment of Fig. 2, wherein an accelerometer is used to measure the loudspeaker membrane velocity;

Fig. 6 shows the embodiment of Fig. 2, using a microphone inside the closed rear volume to measure the loudspeaker membrane velocity;

Fig. 7 shows the general principle of using a dual coil loudspeaker to get the membrane velocity from the induced voltage in the second coil;

Fig. 8 shows a modification of the embodiment of Fig. 2 with the use of an additional fabric layer;

Fig. 9 is a further modification of the embodiment in Fig. 8, comprising two microphones.

Legend

(1) Transducer (loudspeaker)
(2) Acoustic baffle
(3) Closed rear volume
(4) Front volume
(5) Acoustic resistive fabric

(6) Power amplifier with velocity feedback control
(7) Velocity measurement
(8) Microphone
(9) Microphone preamplifier
(10) Feedforward control (electronic filter)
(11) Feedback microphone
(12) Additional microphone preamplifier
(13) Additional feedback control (electronic filter)
(14) Accelerometer
(15) Integrator circuit
(16) Rear volume microphone
(17) Microphone preamplifier
(18) Differentiator circuit
(19) Additional acoustic resistive fabric
(20) Additional microphone
(21) Additional microphone preamplifier
(22) Additional feedforward control (electronic filter)

General description of the invention

The present invention generally concerns an active low-frequency acoustic absorber system which has a relatively small footprint compared to systems from prior art, is auto-adaptive and avoids any altering of the sound source.

The invention allows controlling modal acoustic resonances in closed areas by using one or more absorbers and avoiding any initial setup. The invention further allows doing away with any adjustment in case the room specifics are changed, such as moving people or furniture. The bandwidth of action is also much larger than in any other system from prior art.

The realization of a low frequency passive absorption system with low acoustic impedance involves physical dimensions around a quarter of the wavelength. Compared to a passive system of prior art, the inventive device is much smaller in volume and footprint, and is a mobile asset. The footprint and lateral area of the absorber box are small compared to the area of the walls of the room.

Absorption principle

Given a medium of impedance Z_c and a wall of impedance $\underline{Z}_w$ and considering plane waves in normal incidence, the reflection factor $\underline{r}$ and the absorption factor a are given by:

$$\underline{r} = \frac{\underline{Z}_w - Z_c}{\underline{Z}_w + Z_c} \quad \text{and} \quad \alpha = 1 - |\underline{r}|^2$$

Absorption is maximal when a = 1; i.e. when $\underline{Z}_w = Z_C$. However if the absorber does not entirely cover the wall surface, the target impedance has to be smaller than Z_c, as demonstrated in [1]. Passive absorbers cannot present a surface impedance lower than Z_c, hence an active system is required.

The invention is built starting from a layer of porous acoustic fabric of given flow resistance. As the layer is thin, the flow resistance is essentially resistive, i.e. with negligible reactive part.

At low frequencies, viscous forces in a porous material predominate over inertia! ones and the acoustic velocity across a resistive layer can be approximated using Darcy's law [2]. This means that the acoustic velocity v is proportional to the pressure difference between both sides of the resistive layer and inversely proportional to its flow resistance R, as given by:

$$v = \frac{p_{ext} - p_{int}}{R}$$

Hence, when acoustic pressure on the rear side of the layer is cancelled ($p_{int} = 0$), the surface impedance Z is given by the flow resistance R, according to:

$$Z = \frac{p_{ext}}{v} = R$$

In order to cancel the internal pressure, the invention uses a predictive setpoint (feedforward control). Considering the schematic given in Fig. 1, the in-going volume flow rate q has to match:

$$q = v \cdot A_f = \frac{p_{ext}}{R} \cdot A_f$$

where A_f is the fabric area. This volume flow rate q is realized with a velocity transducer. At low frequencies, the physical dimensions of the device are significantly smaller than the wavelength. Assuming volume flow rate continuity, the transducer velocity setpoint v_b is given by:

$$v_{ls} = \frac{q}{A_{ls}} = \frac{1}{R} \cdot \frac{A_f}{A_{ls}} \cdot p_{ext}$$

where A_{ls} is the projected transducer membrane area.

The absorption area is significantly increased by this method, as A_f can be easily ten times bigger than A_b.

In order to increase the precision of the internal pressure cancellation, one can add a feedback control loop using the internal pressure p_{int}. As the internal pressure setpoint is zero, the pressure p_{int} is equivalent to an error signal that can be used directly: a positive internal pressure has to produce a positive transducer velocity, according to Fig. 1. With this additional control loop, the velocity setpoint becomes:

$$v_{ls} = \frac{1}{R} \cdot \frac{A_f}{A_{ls}} \cdot p_{ext} + K \cdot p_{int}$$

where the feedback gain K is chosen significantly larger than the feedforward gain $A_f \cdot A_{ls}^{-1} \cdot R^{-1}$.

A different embodiment of the invention can include a second layer of acoustic fabric of resistance R' in front of the first one, on a side opposite to the transducer. Naming p_{mid} the pressure between the two layers, the acoustic velocity across the resistive layers is given by:

$$v = \frac{p_{ext} - p_{mid}}{R'} = \frac{p_{mid} - p_{int}}{R}$$

Hence, when acoustic pressure on the rear side of the inner layer is cancelled $(p_{int} = 0)$, the surface impedance Z is given by the sum of the flow resistances R and R' according to:

$$Z = \frac{p_{ext}}{v} = R + R'$$

Using only the pressure between the layers p_{mid}, the velocity setpoint is given by:

$$v_{ls} = \frac{A_f}{A_{ls}} \cdot \frac{p_{mid}}{R}$$

Using only the external pressure p^, the velocity setpoint is given by:

$$v_{ls} = \frac{A_f}{A_{ls}} \cdot \frac{p_{ext}}{R + R'}$$

The velocity setpoint can be expressed as the linear combination of the last two equations:

$$v_{ls} = \frac{A_f}{A_{ls}} \cdot \left(\rho_1 \frac{p_{mid}}{R} + \rho_2 \frac{p_{ext}}{R + R'} \right)$$

where the weighting coefficients p_i and p_2 are linked by $\rho_1 + \rho_2 = 1$.

Description of preferred embodiments of the invention

Fig. 2 shows a schematic of a preferred embodiment of the invention, starting with a resistive acoustic fabric (5). These fabrics are manufactured with precise and well-known characteristics and with flow resistance lower than Z_c. in a preferred embodiment of the invention, the acoustic fabric is a synthetic weaved mesh with an air-flow resistance of 100 Pa-s/m—an optimal value to efficiently absorb modal resonances in the range 10-200 Hz for a room of 40-60 m^3. As the layer is thin (about 50 μιη), the air-flow resistance is essentially resistive, i.e. with negligible reactive part at low frequencies.

The acoustic fabric (5) forms the front side of a closed volume (4), of which the back side is a baffle (2) including one or more velocity transducers (1). The transducers are then mounted on a closed rear volume (3).

The acoustic pressure in front of the fabric (5) is acquired by a microphone (8). The pressure signal is then converted to an appropriate voltage level by a preamplifier (9). A feedforward control (10) takes the preamplifier output signal and drives a power amplifier input (6), including a transfer function H_1 given by:

$$H_1 = \frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_1}$$

where A_f is the fabric area (5), A_h the projected transducer membrane area (1), R the fabric air-flow resistance and G_l the preamplifier (9) gain. The feedforward control (10) also includes a band-pass filter to control the bandwidth of the system and guarantee its stability.

To end with, the power amplifier (6) uses a measurement (7) of the transducer (1) membrane velocity in a feedback loop in order that the membrane velocity matches the input signal of the amplifier.

In a preferred embodiment of the invention, the velocity transducer—consisting of the transducer (1), the power amplifier (6) and the velocity measurement (7)—is based on an impedance bridge shown in Fig. 3, where the input voltage V_m is the power amplifier input.

The voltage V_{is} is given by:

$$V_{ls} = Z_{ls} \cdot I + Bl \cdot v_{ls}$$

where $Z_{ls} = R_e + j\omega \cdot L_e$ is the electric impedance of the loudspeaker, I the current through the loudspeaker coil, Bl the force factor and v_b the membrane velocity. Resistor R_0 is chosen small in order to save power. Resistors $R_{\{}$ and R_2 are proportional to R_0 and R_e respectively. Inductor L_0 is given by:

$$L_0 = \frac{R_0}{R_e} L_e$$

Hence the induced voltage in the loudspeaker coil $Bl \cdot v_b$ is proportional to the input voltage V_m. This leads to a membrane velocity given by:

$$v_{ls} = \frac{1}{Bl} \cdot \frac{R_e}{R_0} \cdot V_m$$

This bridge can also be realized without the inductor L_0. In this case, complex impedances $Z_\}$ and Z_2 shall be used in place of resistors R_1 and R_2 respectively. This is also true when a more accurate loudspeaker model is used for Z_b, e.g. to account for eddy currents, according to [3]. In practical applications, the accuracy of this model will determine the bandwidth of the system.

In other embodiments of the invention, the velocity measurement (7) can be realized with an accelerometer (Fig. 5), a microphone in the closed rear volume (Fig. 6) or a dual coil loudspeaker (Fig. 7).

In a particular embodiment shown in Fig. 5, the membrane (1) acceleration is acquired by means of an accelerometer (14) located on the loudspeaker (1) membrane. This acceleration signal is then integrated over time in an integrator circuit (15) to get the proper velocity signal to drive the power amplifier (6) feedback input.

In a particular embodiment shown in Fig. 6, the membrane (1) displacement is acquired by means of an additional microphone (16) located inside the closed rear volume (3) with the help of an additional preamplifier (17). The microphone gets the pressure inside the closed volume, which is proportional to the membrane displacement. A derivative circuit (18) takes the derivative over time of this displacement signal, which is used to drive the power amplifier (6) feedback input.

In a particular embodiment shown in Fig. 7, the loudspeaker (1) is equipped with two coils, one of which is connected to the output of the amplifier (6) and the other of which produces an induced voltage that is used as a velocity measurement (7). This velocity voltage is proportional to the membrane velocity and is used to drive the power amplifier (6) feedback input.

In order to increase the precision of the internal pressure cancellation, a particular embodiment of the invention shown in Fig. 4 includes an additional microphone (11) located behind the acoustic fabric (5), on a side opposite to the first microphone (8), an additional preamplifier (12) and a feedback control (13). As the internal pressure setpoint is zero, the second microphone delivers an error signal, which is used in a feedback loop. The feedback control (13), including a transfer function $H_2 = K$, where A' is a large value in comparison to the feedforward gain, and a band-pass filter, takes the second preamplifier (12) output signal and drives the power amplifier input (6) in addition to the feedforward control (10).

In a different embodiment shown in Fig. 8, the invention of the preferred embodiment further comprises an additional acoustic fabric (19) of air-flow resistance R' in front of the first one, on a side opposite to the transducer (1). The acoustic pressure between the two fabrics (5) and (19) is acquired by the first microphone (8). The feedforward control (10) takes the microphone pressure signal and drives the power amplifier input (6), including the transfer function H_1 and the band-pass filter.

In addition to this additional acoustic fabric, the invention of a last embodiment shown in Fig. 9 further comprises an additional microphone (20) in front of the additional acoustic fabric (19), on a side opposite to the transducer (1), an additional microphone preamplifier (21) and an additional feedforward control (22), including a band-pass filter, which takes the second preamplifier (21) output signal and drives the power amplifier input (6) in addition to the first feedforward control (10).

The transfer function H_1 of the first feedforward control (10) is replaced by H_3, given by:

$$H_3 = \rho_1 \cdot \frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_1}$$

The second feedforward control (21) includes the transfer function H_4, given by:

$$H_4 = \rho_2 \cdot \frac{A_f}{(R+R') \cdot A_{ls}} \cdot \frac{1}{G_2}$$

where G_2 is the second preamplifier (21) gain. The weighting coefficients p_1 and p_2 are linked by $\rho_1 + \rho_2 = 1$.

Industrial applications

The invention may advantageously be used to build an adaptive acoustic absorber, compact and mobile, destined to be used in single or several units in rooms typically the size of cabin studios up to large recording studios.

The inventive technology may also advantageously be put to use to achieve small dimension anechoic chambers as well as laboratory measurement of acoustic impedance on surfaces.

In summary the invention provides a target acoustic impedance lower than the characteristic impedance of the medium (air); works on a broad bandwidth; and provides a large active absorption area, significantly larger than the area of the transducers used.

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Claims

1. An electroacoustic device for wide band low frequency absorption, the device comprising:

   at least one electroacoustic transducer (1), mounted on an acoustic baffle (2), separating a closed rear volume (3) and a front volume (4), the front volume being closed by an acoustic fabric (5) of determined acoustic air-flow resistance;

   a power amplification electronic (6) with membrane velocity feedback control (7), configured to obtain a transducer membrane velocity proportional to an input voltage, coming from

   a microphone (8) located in front of the acoustic fabric (5) on a side opposite from the front volume (4), connected to a microphone preamplifier (9);

   a feedforward control (10), with adjustable gain and band-pass filter, taking a first pressure signal coming from the microphone preamplifier (9) and driving the power amplifier input (6), the feedforward control gain being equal to

$$\frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_1}$$

   where A_f is the fabric area (5), A_h the projected transducer membrane area (1), R the fabric air-flow resistance and G_i the preamplifier (9) gain, minimizing the acoustic pressure in the front volume (4), thus having a specific impedance, defined as pressure/velocity ratio, in front of the acoustic fabric equal to the determined air-flow resistance of the acoustic fabric.

2. The electroacoustic device of claim 1, wherein the membrane velocity feedback control (7) is based on an impedance bridge.

3. The electroacoustic device of claim 1, further comprising:

   an additional microphone (11) located behind the acoustic fabric (5) in the front volume (4), with an additional microphone preamplifier (12);

   a feedback control loop (13), with adjustable gain and band-pass filter, taking a second pressure signal coming from the additional microphone preamplifier (12), the signals coming from the feedforward control (10) and the feedback control (13) being added to drive the power amplifier input (6), the feedforward control gain being equal to

$$\frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_1}$$

and the feedback control gain being equal to a significantly larger value than the feedforward control gain, minimizing the acoustic pressure in the front volume (4), thus having the specific impedance in front of the acoustic fabric equal to the specific air¬flow resistance of the fabric.

4. The electroacoustic device of claim 1, wherein the membrane velocity feedback control (7) is realized using

an integrator circuit (15), configured to integrate over time a signal coming from

an accelerometer (14) located on the transducer membrane (1).

5. The electroacoustic device of claim 1, wherein the membrane velocity feedback control (7) is realized using

a differentiator circuit (18), configured to differentiate over time a signal coming from

an additional microphone preamplifier (17), with an additional microphone (16) located in the closed rear volume (3) and connected to the additional microphone preamplifier.

6. The electroacoustic device of claim 1, wherein the electroacoustic transducer (1) is equipped with two coils, one of which is connected to the output of the power amplification electronic (6) and the other of which produces an induced voltage representative of a velocity measurement, the induced voltage being proportional to the transducer (1) membrane velocity and output as membrane velocity feedback control (7) to the power amplification electronic (6).

7. The electroacoustic device of claim 1, further comprising at least one additional acoustic fabric layer (19) in front of the acoustic fabric (5), whereby the first microphone (8) is located between the two acoustic fabric layers (5 and 19).

8. The electroacoustic device of claim 7, further comprising at least one additional microphone (20) in front of a second acoustic fabric (19), on

a side opposite to the first microphone (8), with its microphone preamplifier (21) and feedforward control with adjustable gain and band-pass filter (22), the signal coming from the two feedforward controls being linearly combined to drive the power amplifier input (6), the first feedforward control gain being equal to

$$\rho_1 \cdot \frac{A_f}{R \cdot A_{ls}} \cdot \frac{1}{G_1}$$

and the second feedforward control gain being equal to

$$\rho_2 \cdot \frac{A_f}{(R + R') \cdot A_{ls}} \cdot \frac{1}{G_2}$$

where G_2 is the second preamplifier (21) gain and p, and p_2 are weighting coefficients linked by $p_x \div p_2 = \backslash$, minimizing the acoustic pressure in the front volume (4), thus having the specific impedance in front of the acoustic fabric equal to the sum of specific air-flow resistances of the fabrics.

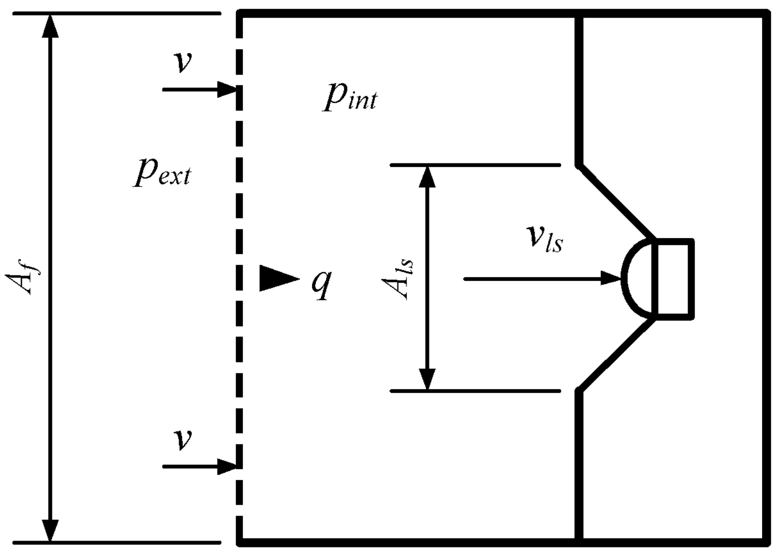

Fig. 1

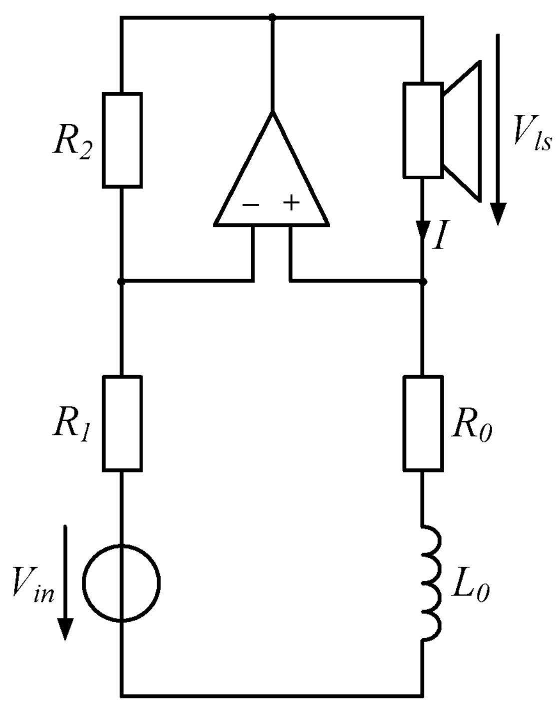

Fig. 3

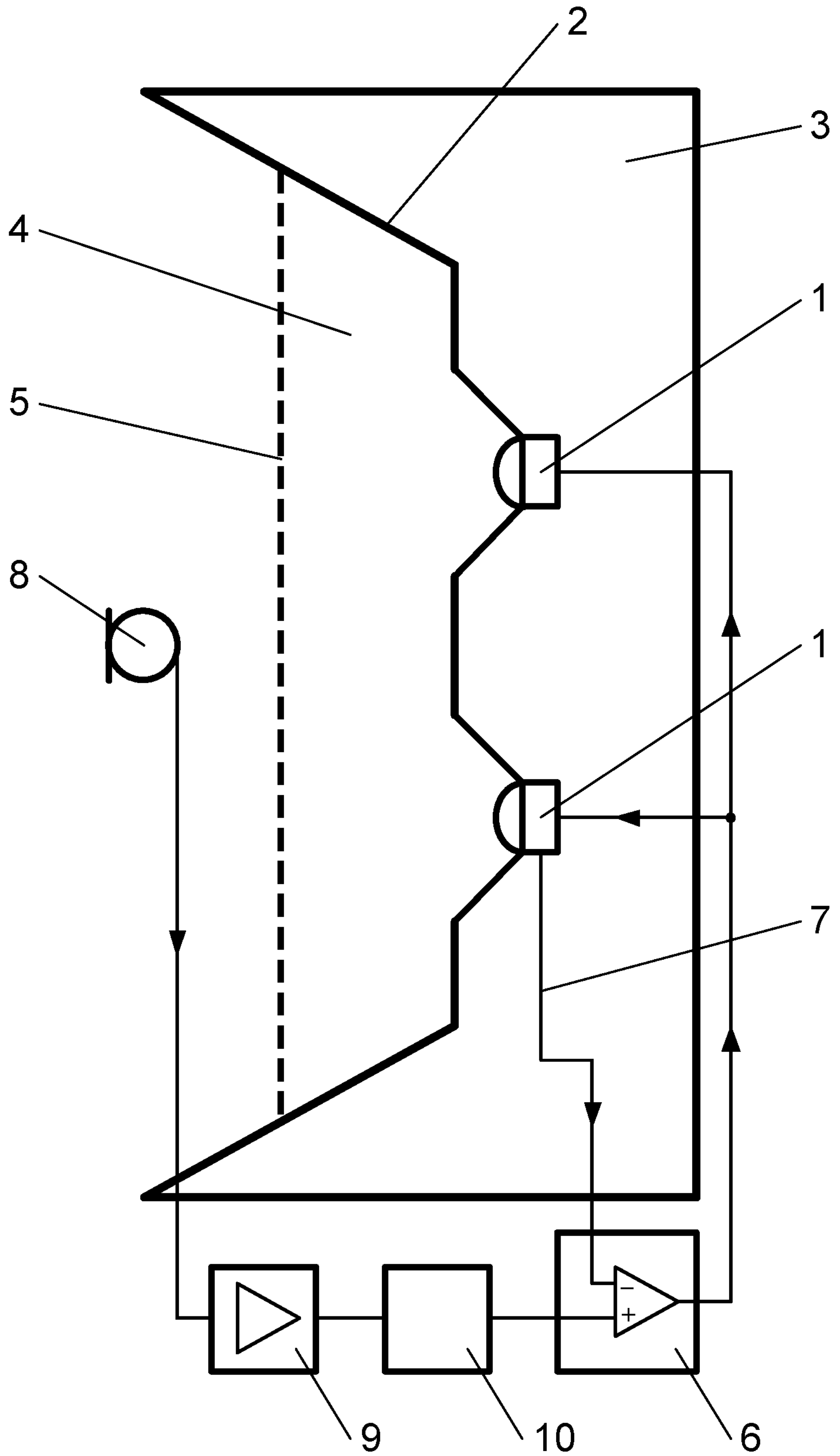

Fig. 2

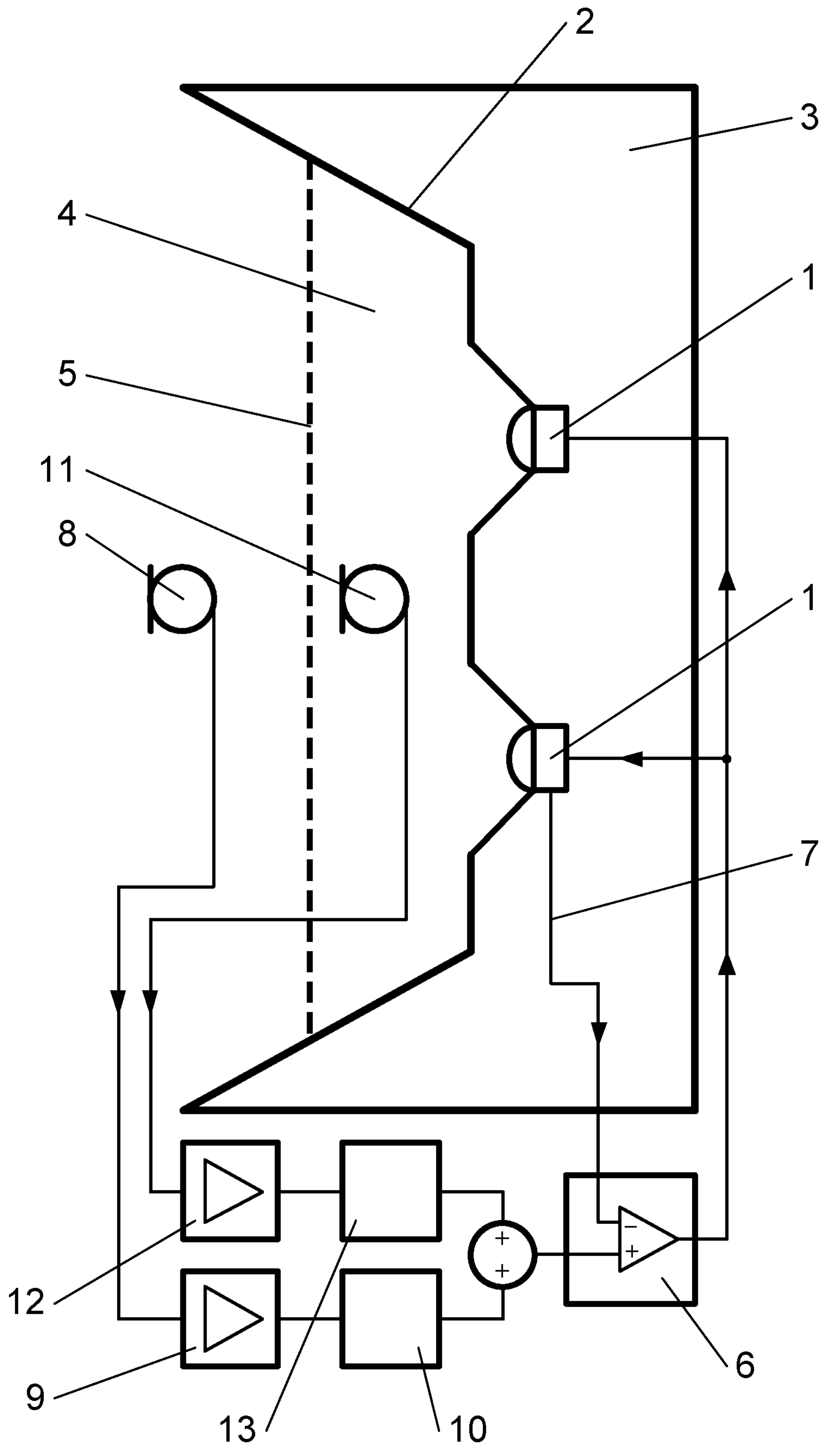

Fig. 4

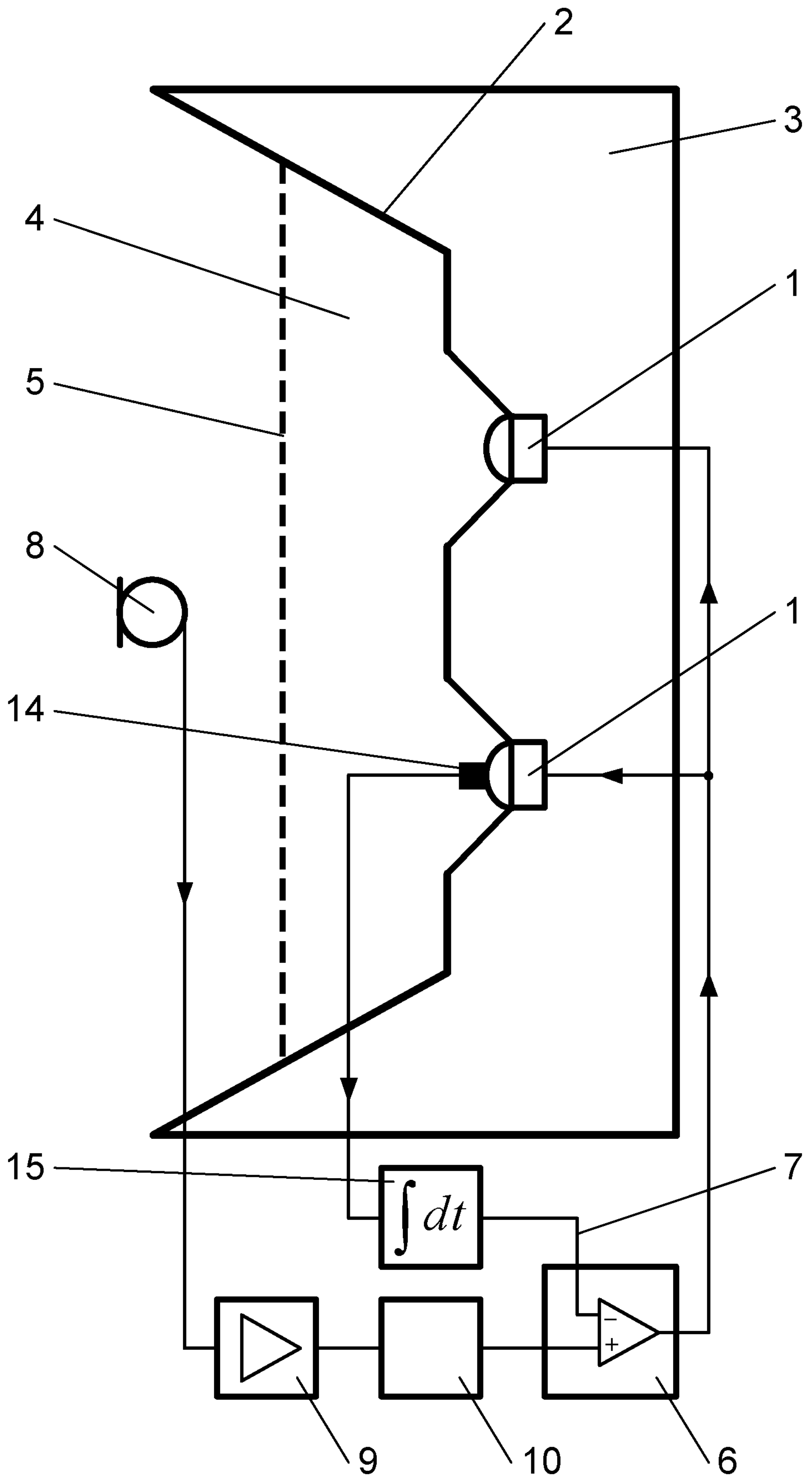

Fig. 5

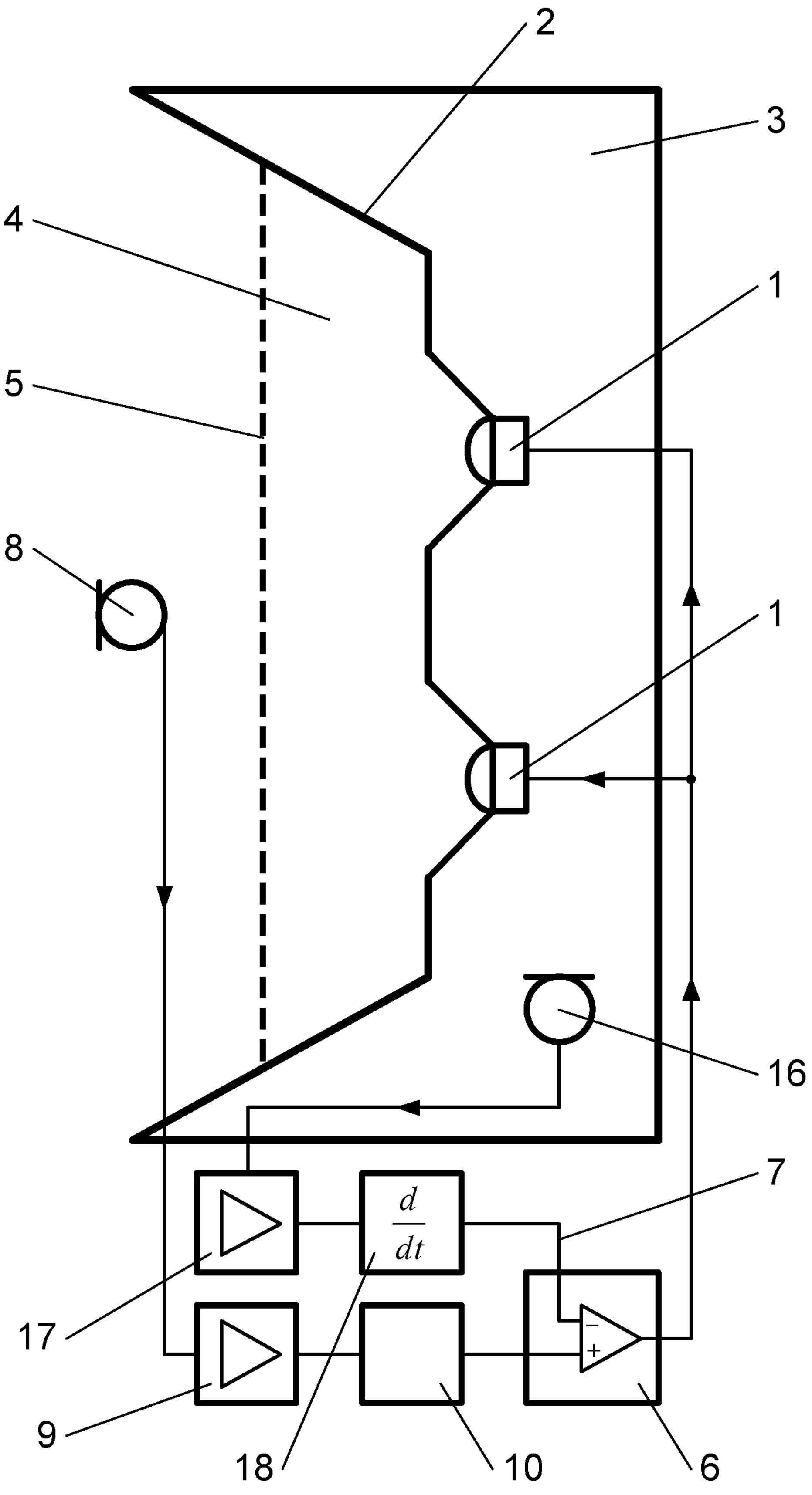

Fig. 6

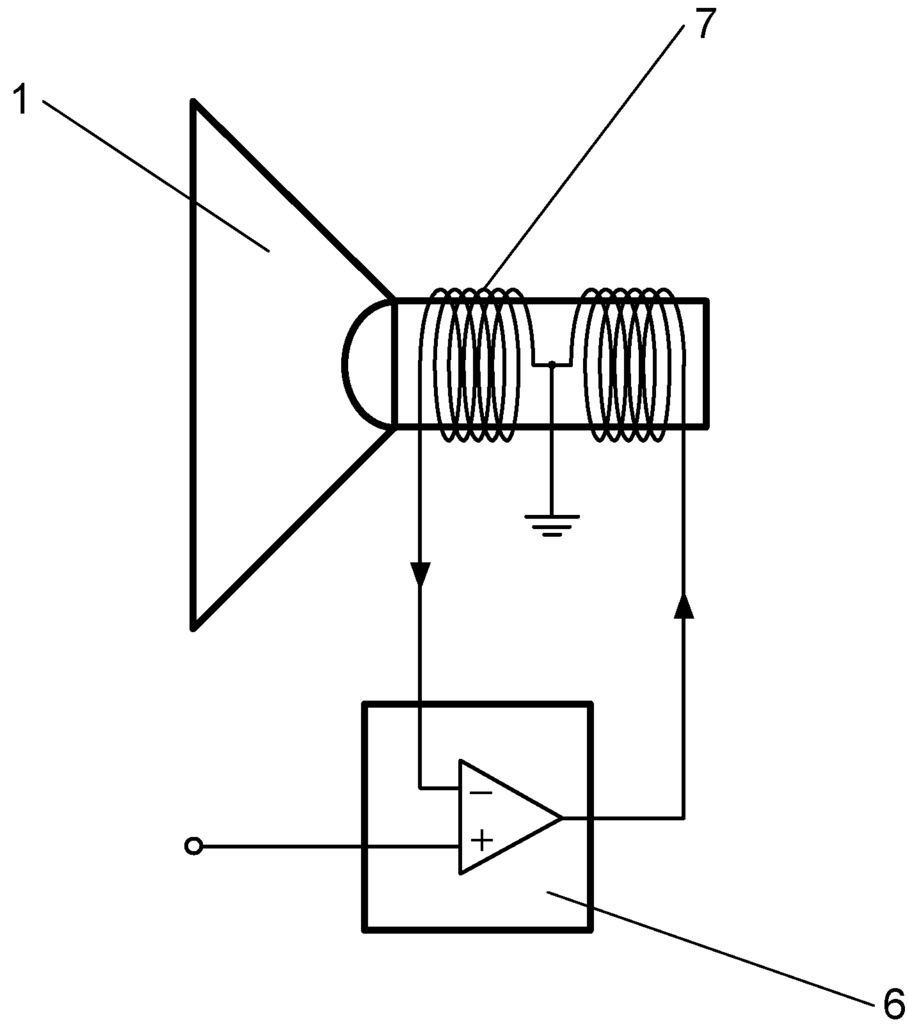

Fig. 7

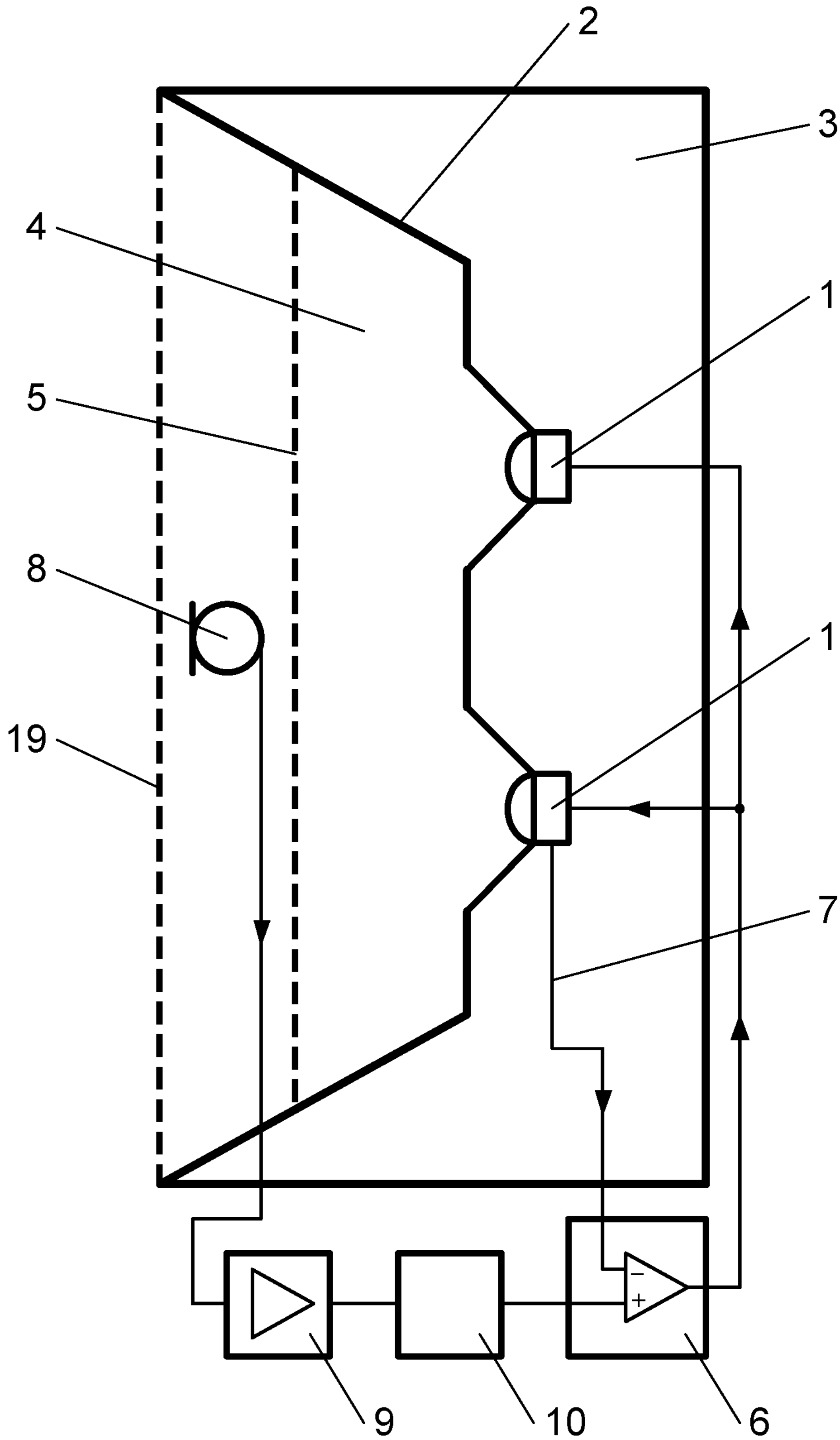

Fig. 8

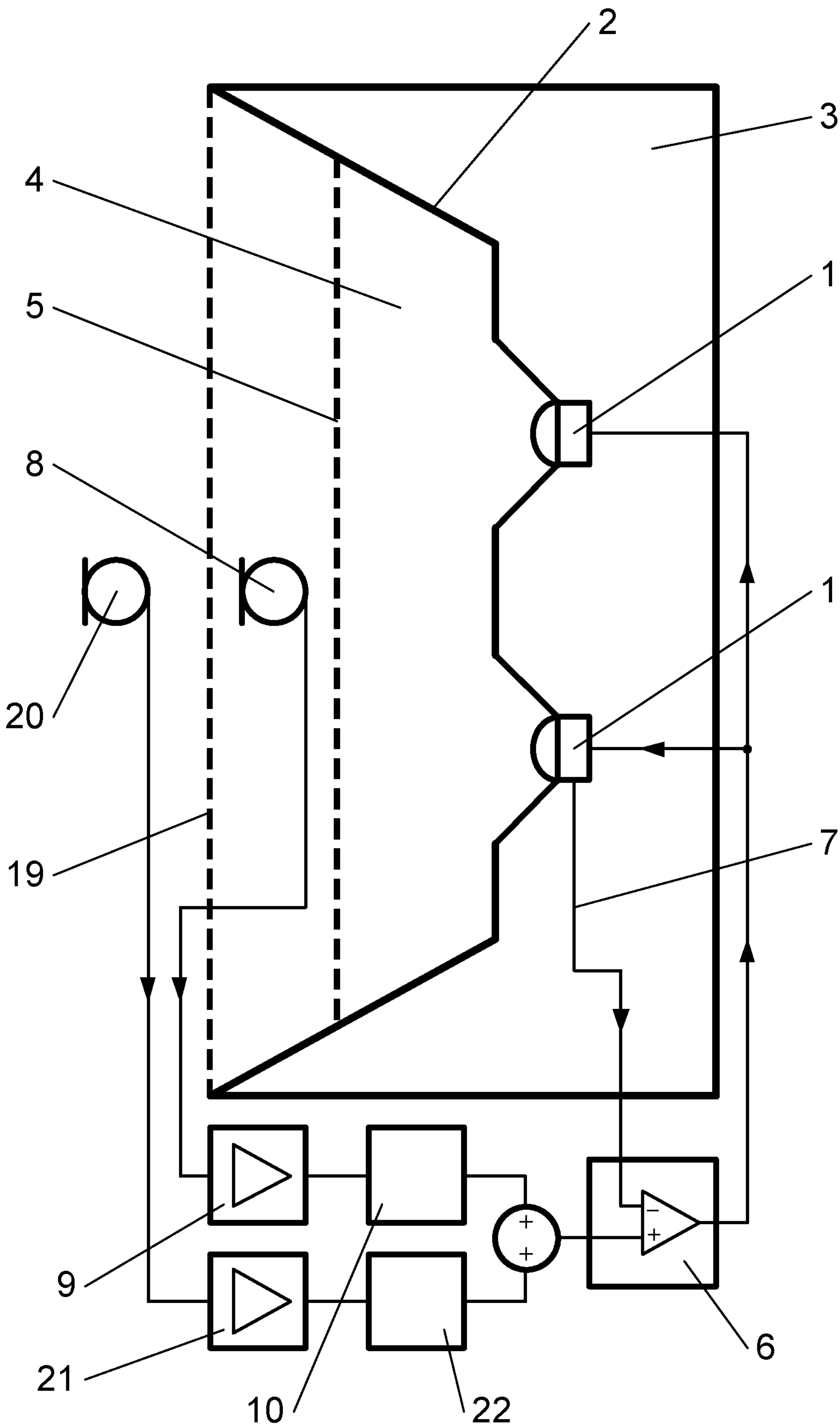

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/059029

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04R3/00
ADD. H04R29/00

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 G10K

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, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 7 970 148 B1 (REMINGTON PAUL JAMES [US] ET AL) 28 June 2011 (2011-06-28) figure 2 column 3, lines 21-59 column 4, lines 12-35 column 5, lines 16-52 -----	1-8
A	GB 2 265 520 A (HOBELSBERGER MAXIMILIAN HANS [CH]) 29 September 1993 (1993-09-29) figure 1 page 3, lines 16-27 -----	1-8
A	US 6 778 673 B1 (HOBELSBERGER MAXIMILIAN HANS [CH]) 17 August 2004 (2004-08-17) figure 2 column 7, line 15 - column 8, line 14 ----- -/--	1-8

[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	Date of mailing of the international search report
23 February 2016	16/03/2016

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/059029

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

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International application No
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