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(54) **METHOD AND APPARATUS FOR ATTENUATING SOUND**

VERFAHREN UND ANLAGE ZUR SCHALLDÄMPFUNG

PROCEDE ET APPAREIL PERMETTANT D'ATTENUER LE SON

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Description

[0001] The invention as it is defined in the appended claims relates to a method of attenuating sound, comprising measuring at least one component of a sound field and producing attenuation sound by means of at least one actuator on the basis of the measurement result, and adjusting the measurement result by a coefficient.

[0002] The invention further relates to an apparatus for attenuating sound, comprising at least one device measuring a component of a sound field and at least one actuator producing attenuation sound on the basis of the measurement result.

[0003] It is previously known to attenuate sound by using elements known as JMC elements. The idea of the method is to measure the sound pressure and particle velocity of a sound field and on the basis of the measurements to control actuators, i.e. means for producing attenuation sound, so as to allow a sound field to be produced which is exactly similar to the original sound field but of the opposite sign. In that case, the sound field can be completely eliminated by means of the actuators. In said method a dipole actuator is driven by means of the measured sound pressure, a monopole actuator by means of the normal component of particle velocity, and a quadripole actuator by means of the tangential component of particle velocity. This method is, however, complicated and difficult to implement. Therefore, an approximation disregarding the tangential component of particle velocity has been introduced. This yields relatively good results, but the arrangement and apparatus are still complicated and difficult to implement. Furthermore, the results achieved with such an arrangement are easily spoiled e.g. by background noise. In a further arrangement that has been introduced, only the sound pressure is measured, and attenuation sound is generated by means of only one actuator, assuming that the proportion of sound pressure to particle velocity is constant. This approximation is based on plane wave approximation of the original sound field, whereby both the detector and the actuator have cardioid detection/radiation patterns. Such an approximation, however, often leads to too inaccurate results especially in confined space, and is thus not satisfactory.

[0004] An object of the present invention is to provide a method and apparatus by means of which sound attenuation can be implemented in a reasonably effective and simple way.

[0005] The method of the invention is characterized in that a measurement result is adjusted with the approximation of the impedance or admittance of a sound field, and the approximation is adjusted on the basis of the measured residual sound pressure.

[0006] The apparatus of the invention is characterized in that the apparatus comprises at least one device measuring residual sound pressure and a device producing an error signal, said apparatus being arranged to adjust the attenuation sound to be produced on the basis of the approximation of the impedance or admittance of a sound field, which has been adjusted on the basis of the measured residual sound pressure.

[0007] The basic idea of the invention is that at least one component of the sound field is measured, and at least one actuator producing a sound field of the opposite sign is controlled on the basis of the measurement, and the result is adjusted by utilizing the approximation of the impedance or admittance of the sound field, and the approximation can be estimated and adjusted by measuring the residual sound pressure. Any detector or actuator can be left out of the apparatus consisting of two detectors and two actuators and replaced with the approximation of the impedance or admittance of the sound field in question. The idea of one preferred embodiment is that the value of the impedance or admittance is adjusted substantially continuously by measuring how high the level of the residual sound pressure is.

[0008] An advantage of the invention is that with respect to sound attenuation very good and reliable results are achieved with a relatively simple method and apparatus. By adjusting the impedance or admittance function by means of feedback substantially continuously, very accurate results can be achieved with respect to sound attenuation.

[0009] The invention will be described in greater detail with reference to the accompanying drawings, in which

Figure 1 illustrates a general diagram of an apparatus according to the invention,
Figure 2 illustrates a general diagram of a second apparatus according to the invention,
Figure 3 illustrates a general diagram of a third apparatus according to the invention,
Figure 4 illustrates a general diagram of a fourth apparatus according to the invention,
Figure 5 illustrates an overall system of sound attenuation, utilizing the method and apparatus of the invention.

[0010] Figure 1 illustrates a sound attenuation element 1. The sound attenuation element 1 comprises a detector 2 for the sound pressure p. The sound attenuation element 1 further comprises a detector 3 for the particle velocity. The device is used for indicating the normal component u_x of particle velocity. The sound pressure detector 2 controls a dipole actuator 4 directly via a filter 5 on the basis of the measurement result of the sound pressure p. The dipole actuator 4 is used for producing a sound opposite to the original sound field. The intensity of the sound produced by the dipole actuator 4 is described with the strength f_s of the dipole. The normal component u_x of particle velocity measured with the particle velocity detector 3 is also utilized in controlling the dipole actuator 4. The effect of the particle velocity is taken into account by the device 6 producing a correction signal. In said device, which may be e.g. a

microprocessor, the velocity component is multiplied by the approximation of the impedance H_z of the sound field. The real value of the impedance of the sound field is not known in advance, and thus $H_z = \rho \times c$ can be considered the initial value, where ρ is the density of the medium and c is the sound velocity in the medium. The approximation of the impedance H_z is adjusted by measuring the remaining sound pressure, i.e. the residual sound pressure p_{res}, which is sent to the device 6 producing a correction signal. The algorithms needed are fully known per se to one skilled in the art, and therefore, this application will not deal with adjustment criteria in any greater detail. By controlling the dipole actuator 4 directly with the sound pressure detector 2, control can be implemented with substantially no delay, and furthermore, by utilizing the velocity signal u_x adjusted with the approximation of the impedance H_z, an accurate result can be achieved. There may be several measuring devices for the residual sound pressure p_{res}, whereby the residual sound pressure p_{res} can be measured in several places. If the environmental conditions and sound source remain constant, it is not necessary to alter the approximation of the impedance after the desired level of attenuation has been achieved. However, if the conditions are dynamic, the measuring devices 7 for residual pressure can be used continuously, whereby the approximation of the impedance H_2 can be adjusted continuously by means of the devices, and thus the attenuation sound produced by the dipole actuator 4 can also be adjusted very accurately.

[0011] Figure 2 illustrates a second sound attenuation element 1'. In Figure 2 the same numbers have the same significance as in Figure 1. In a device according to Figure 2, a monopole actuator 4' is controlled via a filter 5' on the basis of the particle velocity. The intensity of the sound produced by the monopole actuator 4' is described with the volume velocity q_s. The monopole actuator 4' is controlled by means of the sound pressure p in such a manner that the measurement result of the sound pressure p is adjusted with the approximation of the admittance $H_{1/z}$ of the sound field. The admittance of the sound field is the inverse of the impedance of the sound field. The admittance function $H_{1/z}$ of the sound field is adjusted in the same way as the impedance function H_z of the sound field.

[0012] Figure 3 illustrates a third sound attenuation element 1" according to the invention. In Figure 3 the same numbers have the same significance as in Figures 1 and 2. In the device shown in Figure 3 the dipole actuator 4 is controlled directly on the basis of the sound pressure p. The particle velocity u_x is not measured at all. Instead, the monopole actuator 4' is controlled with the measuring result of the sound pressure p, adjusted in the device producing a correction signal by means of the approximation of the admittance $H_{1/z}$ of the sound field as in the case shown in Figure 2.

[0013] Figure 4 illustrates a fourth sound attenuation element 1"' according to the invention. In Figure 4 the same numbers have the same significance as in Figures 1 to 3. The monopole actuator 4' is controlled on the basis of the value of the particle velocity u_x. The sound pressure p is not measured at all, but the dipole actuator 4 is controlled by means of the measuring result of the particle velocity u_x, adjusted in the device 6 producing a correction signal by means of the approximation of the impedance H_z as was explained in connection with Figure 1.

[0014] Figure 5 illustrates an overall system of sound attenuation. The overall system comprises several sound attenuation elements 1, 1', 1" or 1"' of the invention. All measuring results achieved with the measuring device 7 for residual sound pressure are collected in the system in order to influence the adjustment of each attenuation element. The adjustment of different elements may depend differently on different residual sound pressures.

[0015] The drawings and the related description are only intended to illustrate the idea of the invention. The details of the invention may vary within the scope of the appended claims The measuring devices 7 for residual sound pressure may be mobile and even portable, whereby the minimization of the sound pressure focuses most effectively on the persons carrying the device. The arrangement is suitable for mediums in which sound causes a longitudinal wave motion, i.e. besides air, the medium may be e.g. another gas or a liquid.

Claims

1. A method of attenuating sound, comprising measuring at least one component of a sound field, and producing attenuation sound by means of at least one actuator, and adjusting the measurement result with a coefficient, **characterized in that** the measurement result is adjusted with the approximation of the impedance or admittance of the sound field, and the approximation is adjusted on the basis of the measured residual sound pressure (p_{res}).

2. A method as claimed in claim 1, **characterized in that** the pressure (p) and particle velocity (u_x) of the sound field are measured, and a dipole actuator (4) is controlled substantially directly by means of the sound pressure (p), and the influence of the particle velocity (u_x) on the dipole actuator (4) is taken into account, adjusted with the approximation of the impedance of the sound field.

3. A method as claimed in claim 1, **characterized in that** the particle velocity (u_x) and sound pressure (p) of the sound field are measured, and a monopole actuator (4') is controlled substantially directly by means of the particle velocity (u_x), and the influence of the sound pressure (p) on the monopole actuator (4') is taken into account, adjusted with the

approximation of the admittance of the sound field.

4. A method as claimed in claim 1, **characterized in that** the sound pressure (p) of the sound field is measured, and a dipole actuator (4) is controlled substantially directly by means of the sound pressure (p), and a monopole actuator (4') is controlled by means of the sound pressure (p) adjusted with the approximation of the admittance of the sound field.

5. A method as claimed in claim 1, **characterized in that** the particle velocity (u_x) of the sound field is measured, and a monopole actuator (4') is controlled substantially directly by means of the particle velocity (u_x), and a dipole actuator (4) is controlled with the value of the particle velocity (u_x), which has been adjusted by means of the approximation of the impedance of the sound field.

6. A method as claimed in any one of the preceding claims, **characterized in that** the residual sound pressure (p_{res}) is measured substantially continuously.

7. A method as claimed in any one of the preceding claims, **characterized in that** the residual sound pressure (p_{res}) is measured in several different places.

8. An apparatus for attenuating sound, comprising at least one device measuring a component of a sound field and at least one actuator producing attenuation sound on the basis of the measurement result, **characterized in that** the apparatus comprises at least one device (7) measuring residual sound pressure and a device (6) producing a correction signal, and the device (6) is arranged to adjust the attenuation sound to be produced by means of the approximation of the impedance or admittance of the sound field, which is adjusted on the basis of the measured residual sound pressure (p_{res}).

9. An apparatus as claimed in claim 8, **characterized in that** the apparatus comprises a sound pressure detector (2), particle velocity detector (3), and dipole actuator (4) producing attenuation sound, whereby the sound pressure detector (2) is arranged to control the dipole actuator (4) substantially directly, and the particle velocity detector (3) is arranged to control the dipole actuator (4) via the device (6) producing a correction signal, and the device (6) is arranged to produce the correction signal by means of the approximation of the impedance of the sound field.

10. An apparatus as claimed in claim 8, **characterized in that** the apparatus comprises a sound pressure detector (2), particle velocity detector (3), and monopole actuator (4') arranged to produce attenuation sound, whereby the particle velocity detector (3) is arranged to control the monopole actuator (4') substantially directly, and the sound pressure detector (2) is arranged to control the monopole actuator (4') via the device (6) producing a correction signal, and the device (6) is arranged to produce the correction signal by means of the approximation of the admittance of the sound field.

11. An apparatus as claimed in claim 8, **characterized in that** the apparatus comprises a sound pressure detector (2), and a dipole actuator (4) and monopole actuator (4') producing attenuation sound, whereby the sound pressure detector (2) is arranged to control the dipole actuator (4) substantially directly and the monopole actuator (4') via the device (6) producing a correction signal, and the device (6) is arranged to produce the correction signal by means of the approximation of the admittance of the sound field.

12. An apparatus as claimed in claim 8, **characterized in that** the apparatus comprises a particle velocity detector (3), and a dipole actuator (4) and monopole actuator (4') producing attenuation sound, whereby the particle velocity detector (3) is arranged to control the monopole actuator (4') substantially directly and the dipole actuator (4) via the device (6) producing a correction signal, and the device (6) is arranged to produce the correction signal by means of the approximation of the impedance of the sound field.

13. An apparatus as claimed in any one of claims 8 to 12, **characterized in that** the apparatus comprises several devices (7) for measuring residual sound pressure (p_{res}).

14. An apparatus as claimed in any one of claims 8 to 13, **characterized in that** at least one device (7) for measuring residual sound pressure (p_{res}) is arranged to be carried by a person in the sound field.

Patentansprüche

1. Verfahren zum Dämpfen von Schall, das ein Messen mindestens einer Komponente eines Schallfeldes, und ein Erzeugen von Schalldämpfung mittels mindestens eines Aktuators, und ein Einstellen des Meßergebnisses mit einem Koeffizienten umfaßt, **dadurch gekennzeichnet, daß** das Meßergebnis mit der Näherung der Impedanz oder Admittanz des Schallfeldes eingestellt wird, und die Näherung auf der Grundlage des gemessenen Restschalldrucks (p_{res}) eingestellt wird.

2. Verfahren gemäß Anspruch 1, **dadurch gekennzeichnet, daß** der Druck (p) und die Schallschnelle (u_x) des Schallfeldes gemessen werden, und ein Dipol-Aktuator (4) im wesentlichen direkt mittels des Schalldrucks (p) gesteuert wird, und der Einfluß der Schallschnelle (u_x) auf den Dipol-Aktuator (4), die mit der Näherung der Impedanz des Schallfeldes eingestellt wurde, berücksichtigt wird.

3. Verfahren gemäß Anspruch 1, **dadurch gekennzeichnet, daß** die Schallschnelle (u_x) und der Schalldruck (p) des Schallfeldes gemessen werden, und ein Monopol-Aktuator (4') im wesentlichen direkt mittels der Schallschnelle (u_x) gesteuert wird, und der Einfluß der Schalldrucks (p) auf den Monopol-Aktuator (4'), der mit der Näherung der Admittanz des Schallfeldes eingestellt wurde, berücksichtigt wird.

4. Verfahren gemäß Anspruch 1, **dadurch gekennzeichnet, daß** der Schalldruck (p) des Schallfeldes gemessen wird, und ein Dipol-Aktuator (4) im wesentlichen direkt mittels des Schalldrucks (p) gesteuert wird, und ein Monopol-Aktuator (4') mittels des Schalldrucks (p), der mit der Näherung der Admittanz des Schallfeldes eingestellt wurde, gesteuert wird.

5. Verfahren gemäß Anspruch 1, **dadurch gekennzeichnet, daß** die Schallschnelle (u_x) des Schallfeldes gemessen wird, und ein Monopol-Aktuator (4') im wesentlichen direkt mittels der Schallschnelle (u_x) gesteuert wird, und ein Dipol-Aktuator (4) mit dem Wert der Schallschnelle (u_x), die mittels der Näherung der Impedanz des Schallfeldes eingestellt wurde, gesteuert wird.

6. Verfahren gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, daß** der Restschalldruck (p_{res}) im wesentlichen kontinuierlich gemessen wird.

7. Verfahren gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, daß** der Restschalldruck (p_{res}) an verschiedenen unterschiedlichen Stellen gemessen wird.

8. Vorrichtung zum Dämpfen von Schall, die mindestens eine Einrichtung, die eine Komponente eines Schallfeldes mißt, und mindestens einen Aktuator, der Schalldämpfung auf der Grundlage des Meßergebnisses erzeugt, umfaßt, **dadurch gekennzeichnet, daß** die Vorrichtung mindestens eine Einrichtung (7), die Restschalldruck mißt, und eine Einrichtung (6), die ein Korrektursignal erzeugt, umfaßt, und die Einrichtung (6) angeordnet ist, um die zu erzeugende Schalldämpfung mittels der Näherung der Impedanz oder Admittanz des Schallfeldes einzustellen, die auf der Grundlage des gemessenen Restschalldrucks (p_{es}) eingestellt wurde.

9. Vorrichtung gemäß Anspruch 8, **dadurch gekennzeichnet, daß** die Vorrichtung einen Schalldruckdetektor (2), einen Schallschnellendetektor (3) und einen Dipol-Aktuator (4), der Schalldämpfung erzeugt, umfaßt, wobei der Schalldruckdetektor (2) angeordnet ist, um den Dipol-Aktuator (4) im wesentlichen direkt zu steuern, und der Schallschnellendetektor (3) angeordnet ist, um den Dipol-Aktuator (4) über die Einrichtung (6), die ein Korrektursignal erzeugt, zu steuern, und die Einrichtung (6) angeordnet ist, um das Korrektursignal mittels der Näherung der Impedanz des Schallfeldes zu erzeugen.

10. Vorrichtung gemäß Anspruch 8, **dadurch gekennzeichnet, daß** die Vorrichtung einen Schalldruckdetektor (2), einen Schallschnellendetektor (3) und einen Monopol-Aktuator (4'), der angeordnet ist, um Schalldämpfung zu erzeugen, umfaßt, wobei der Schallschnellendetektor (3) angeordnet ist, um den Monopol-Aktuator (4') im wesentlichen direkt zu steuern, und der Schalldruckdetektor (2) angeordnet ist, um den Monopol-Aktuator (4') über die Einrichtung (6), die ein Korrektursignal erzeugt, zu steuern, und die Einrichtung (6) angeordnet ist, um das Korrektursignal mittels der Näherung der Admittanz des Schallfeldes zu erzeugen.

11. Vorrichtung gemäß Anspruch 8, **dadurch gekennzeichnet, daß** die Vorrichtung einen Schalldruckdetektor (2), und einen Dipol-Aktuator (4) und einen Monopol-Aktuator (4'), die Schalldämpfung erzeugen, umfaßt, wobei der Schalldruckdetektor (2) angeordnet ist, um den Dipol-Aktuator (4) im wesentlichen direkt und den Monopol-Aktuator (4') über die Einrichtung (6), die ein Korrektursignal erzeugt, zu steuern, und die Einrichtung (6) angeordnet ist, um das Korrektursignal mittels der Näherung der Admittanz des Schallfeldes zu erzeugen.

12. Vorrichtung gemäß Anspruch 8, **dadurch gekennzeichnet, daß** die Vorrichtung einen Schallschnellendetektor (3), und einen Dipol-Aktuator (4) und einen Monopol-Aktuator (4'), die Schalldämpfung erzeugen, umfaßt, wobei der Schallschnellendetektor (3) angeordnet ist, um den Monopol-Aktuator (4') im wesentlichen direkt und den Dipol-Aktuator (4) über die Einrichtung (6), die ein Korrektursignal erzeugt, zu steuern, und die Einrichtung (6) angeordnet ist, um das Korrektursignal mittels der Näherung der Impedanz des Schallfeldes zu erzeugen.

13. Vorrichtung gemäß einem der Ansprüche 8 bis 12, **dadurch gekennzeichnet, daß** die Vorrichtung verschiedene Einrichtungen (7) zum Messen von

Restschalldruck (p_{res}) umfaßt.

14. Vorrichtung gemäß einem der Ansprüche 8 bis 13, **dadurch gekennzeichnet, daß** mindestens eine Einrichtung (7) zum Messen von Restschalldruck (p_{res}) angeordnet ist, um von einer Person in dem Schallfeld getragen zu werden.

Revendications

1. Procédé d'atténuation du son, comprenant la mesure d'au moins une composante d'un champ sonore, et la génération d'un son d'atténuation au moyen d'au moins un transducteur, et l'ajustement du résultat de la mesure avec un coefficient, **caractérisé en ce que** le résultat de la mesure est ajusté avec l'approximation de l'impédance ou de l'admittance du champ sonore, et l'approximation est ajustée en se fondant sur la pression sonore résiduelle mesurée (p_{res}).

2. Procédé selon la revendication 1, **caractérisé en ce que** la pression (p) et la vitesse particulaire (u_x) du champ sonore sont mesurées, et un transducteur dipolaire (4) est commandé sensiblement directement par la pression sonore (p), et l'influence de la vitesse particulière (u_x) sur le transducteur dipolaire (4) est prise en compte, ajustée avec l'approximation de l'impédance du champ sonore.

3. Procédé selon la revendication 1, **caractérisé en ce que** la vitesse particulaire (u_x) et la pression sonore (p) du champ sonore sont mesurées, et un transducteur monopolaire (4') est commandé sensiblement directement par la vitesse particulaire (u_x), et l'influence de la pression sonore (p) sur le transducteur monopolaire (4') est prise en compte, ajustée avec l'approximation de l'admittance du champ sonore.

4. Procédé selon la revendication 1, **caractérisé en ce que** la pression sonore (p) du champ sonore est mesurée, et un transducteur dipolaire (4) est commandé sensiblement directement par la pression sonore (p), et le transducteur monopolaire (4') est commandé par la pression sonore, ajustée avec l'approximation de l'admittance du champ sonore.

5. Procédé selon la revendication 1, **caractérisé en ce que** la vitesse particulaire (u_x) du champ sonore est mesurée, et un transducteur monopolaire (4') est commandé sensiblement directement par la vitesse particulaire (u_x), et le transducteur dipolaire (4) est commandé avec la valeur de la vitesse particulaire (u_x), qui a été ajustée avec l'approximation de l'impédance du champ sonore.

6. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la pression sonore résiduelle (p_{res}) est mesurée sensiblement en continu.

7. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la pression sonore résiduelle (p_{res}) est mesurée en plusieurs endroits différents.

8. Appareil d'atténuation du son, comprenant au moins un dispositif de mesure d'une composante d'un champ sonore et au moins un transducteur générant un son d'atténuation en se fondant sur le résultat de la mesure, **caractérisé en ce que** l'appareil comprend au moins un dispositif (7) de mesure de la pression sonore résiduelle et un dispositif (6) de génération d'un signal de correction, et le dispositif (6) est destiné à ajuster le son d'atténuation à générer au moyen de l'approximation de l'impédance ou de l'admittance du champ sonore, qui est ajustée en se fondant sur la pression sonore résiduelle mesurée (p_{res}).

9. Appareil selon la revendication 8, **caractérisé en ce que** l'appareil comprend un détecteur de pression sonore (2), un détecteur de vitesse particulaire (3), et un transducteur dipolaire (4) générant un son d'atténuation, d'où il résulte que le détecteur de pression sonore (2) est destiné à commander le transducteur dipolaire (4) sensiblement directement, et le détecteur de vitesse particulaire (3) est destiné à commander le transducteur dipolaire (4) via le dispositif (6) de génération d'un signal de correction, et le dispositif (6) est prévu pour générer un signal de correction au moyen de l'approximation de l'impédance du champ sonore.

10. Appareil selon la revendication 8, **caractérisé en ce que** l'appareil comprend un détecteur de pression sonore (2), un détecteur de vitesse particulaire (3), et un transducteur monopolaire (4') destiné à générer un son d'atténuation, d'où il résulte que le détecteur de vitesse particulaire (3) est destiné à commander le transducteur monopolaire (4') sensiblement directement, et le détecteur de pression sonore (2) est destiné à commander le transducteur monopolaire (4') via le dispositif (6) de génération d'un signal de correction, et le dispositif (6) est destiné à générer le signal de correction au moyen de l'approximation de l'admittance du champ sonore.

11. Appareil selon la revendication 8, **caractérisé en ce que** l'appareil comprend un détecteur de pression sonore (2), un transducteur dipolaire (4) et un transducteur monopolaire (4') générant un son d'atténuation, d'où il résulte que le détecteur de pression sonore (2) est destiné à commander le trans-

ducteur dipolaire (4) sensiblement directement, et le transducteur monopolaire (4') via le dispositif (6) de génération d'un signal de correction, et le dispositif (6) est destiné à générer le signal de correction au moyen de l'approximation de l'admittance du champ sonore.

12. Appareil selon la revendication 8, **caractérisé en ce que** l'appareil comprend un détecteur de vitesse particulaire (3), un transducteur dipolaire (4) et un transducteur monopolaire (4') générant un son d'atténuation, d'où il résulte que le détecteur de vitesse particulaire (3) est destiné à commander le transducteur monopolaire (4') sensiblement directement et le transducteur dipolaire (4) via le dispositif (6) de génération d'un signal de correction, et le dispositif (6) est destiné à générer le signal de correction au moyen de l'approximation de l'impédance du champ sonore.

13. Appareil selon l'une quelconque des revendications 8 à 12, **caractérisé en ce que** l'appareil comprend plusieurs dispositifs (7) pour mesurer la pression sonore résiduelle (p_{res}).

14. Appareil selon l'une quelconque des revendications précédentes 8 à 13, **caractérisé en ce qu'**au moins un dispositif (7) pour mesurer la pression sonore résiduelle (p_{res}) est destiné à être porté par une personne dans le champ sonore.

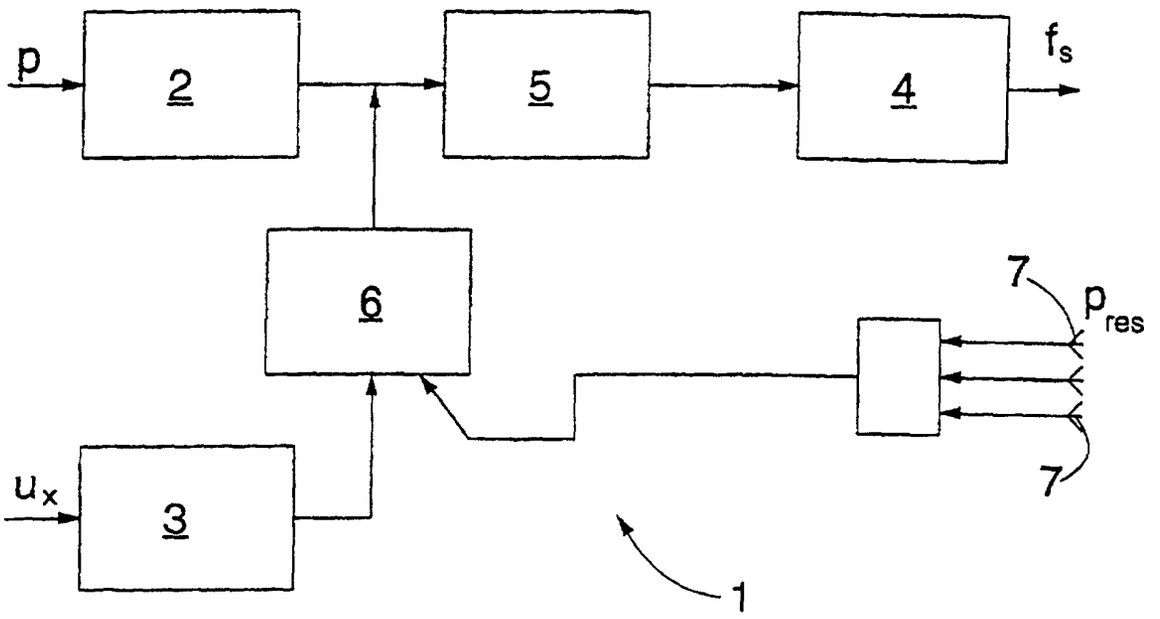

FIG. 1

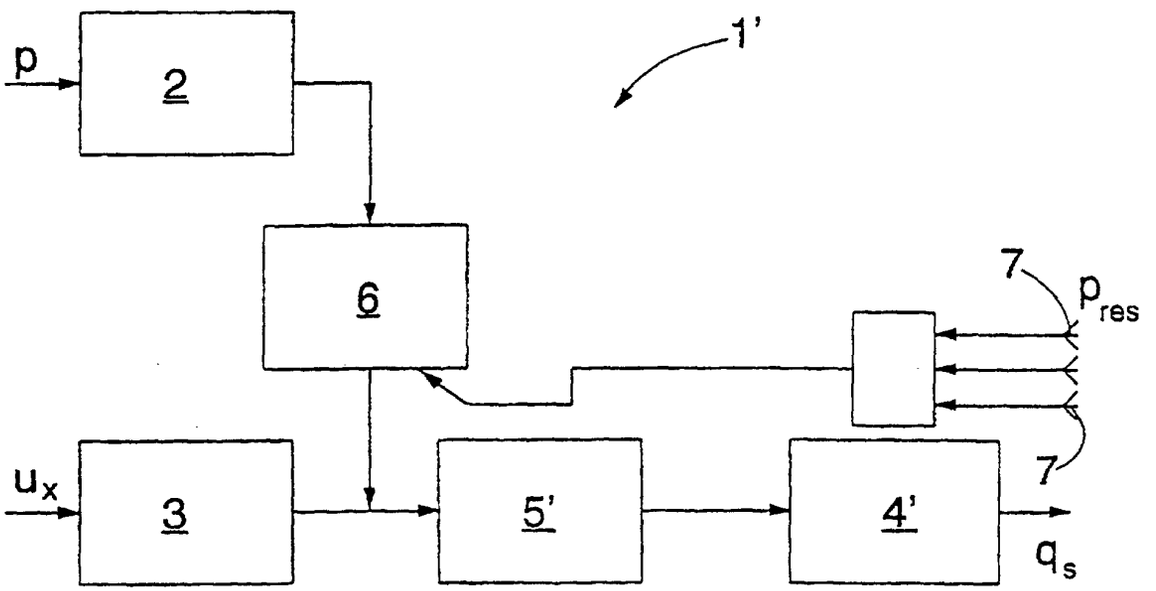

FIG. 2

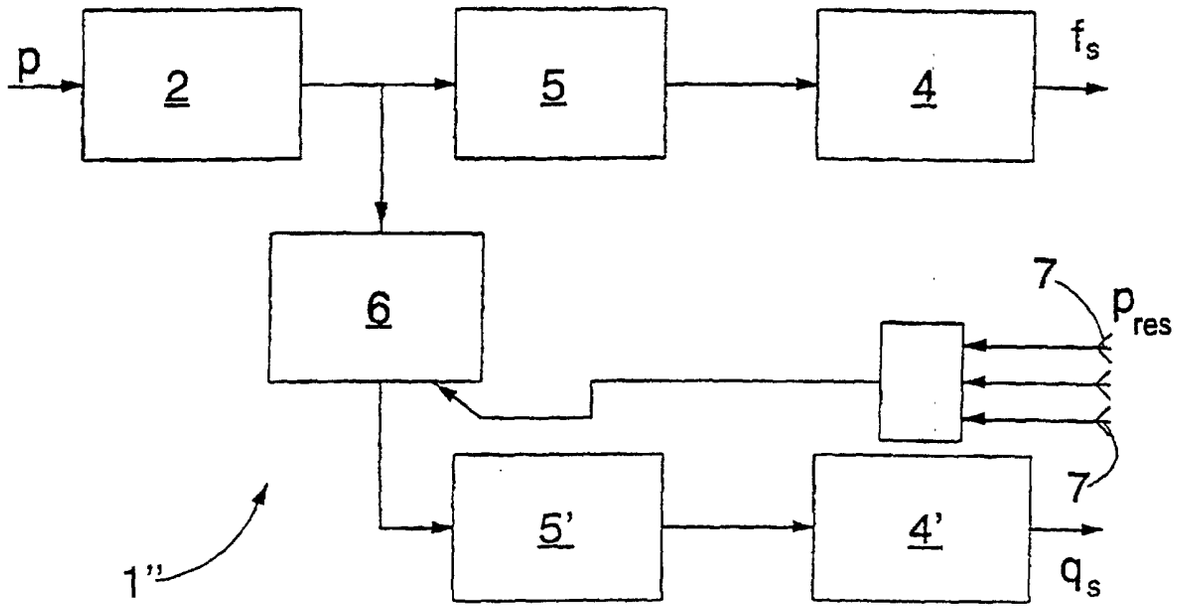

FIG. 3

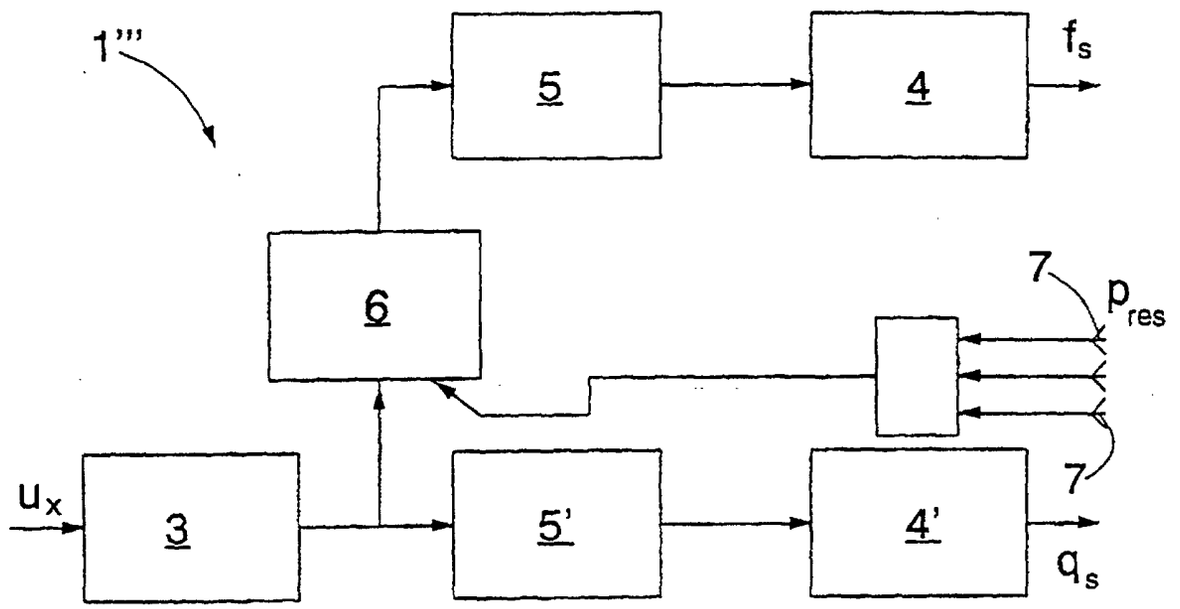

FIG. 4

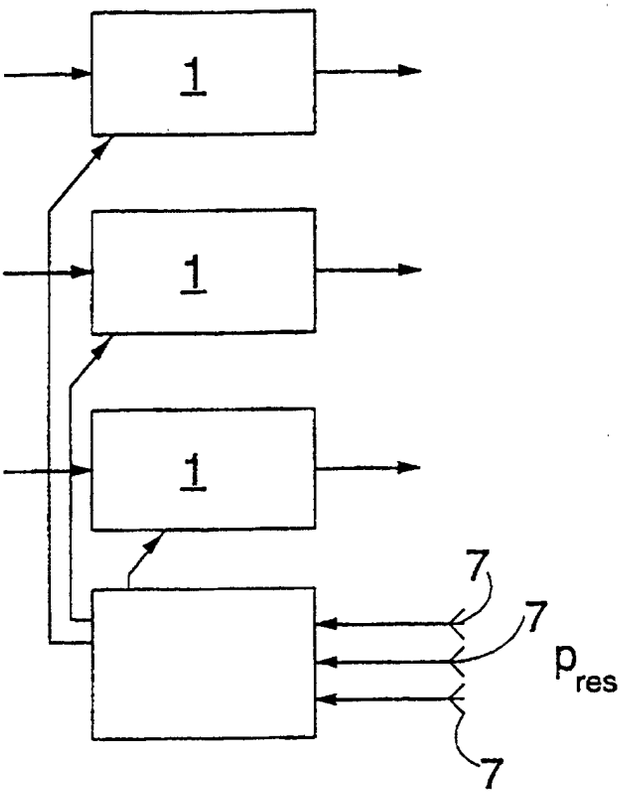

FIG. 5