

**Method for the reduction of an interference signal in a
room, and application of said method**

The present invention relates to a method for reducing a
5 noise signal in a room according to the preamble of claim
1, a use of the method, a device according to the preamble
of claim 9 as well as a use of the device.

Sources of noise are increasingly perceived as
10 environmental pollution and are regarded as reduction of
life quality. Because sources of noise often cannot be
avoided, methods to reduce noises have already been
proposed, which are based on the principle of wave
cancelling.

15 The principle of active noise reduction (ANC or "Active
Noise Cancelling") is based on the cancelling of sound
waves by interferences. These interferences are generated
by one or several electro-acoustic converters, for example
20 by loudspeakers. The signal emitted by the electro-acoustic
converters is calculated on the basis of a suitable
algorithm and is corrected continuously. As basis for the
calculation of the signal emitted by the electro-acoustic
converters, information is used that is provided by one or
25 several sensors. This is, on the one hand, information on
the composition of the signal to be minimized. Thereto, a
microphone, for example, can be used that records the sound
to be minimized. On the other hand, information is also



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necessary on the remaining residual signal. Microphones can also be used thereto.

5 The basic principle implemented for active noise reduction has been described by Dr. Paul Lueg in a patent specification going back to the year 1935 having a publication no. AT-141 998 B. This printed publication discloses how noise can be cancelled in a tube by generating a signal having opposite phase.

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An algorithm for active noise reduction needs information of at least one sensor (for example a microphone), which determines the residual error - in the following also called error signal. Dependent on implementation and
15 implemented algorithm, a further sensor is added, which provides information on the composition of the signal to be minimized, which in the following is called noise signal. Furthermore, an adaptive noise reduction system needs one or several actuators (typically electro-acoustic converters
20 are applied for example in the manner of loudspeakers being pointed out explicitly that also other suitable actuators or converters for the respective use can be applied) in order to output the correcting signal.

25 The information of the sensors must be converted in a corresponding format by an analog-to-digital converter. The signal is converted by a digital-to-analog converter after processing by the algorithm and transmitted to the actuators.

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A problem that is related to the active noise reduction with the aid of adaptive processes is the fact that the adaptive process needs a certain time for the processing of the signals. Thus, all signals to be processed are subject
5 to a time delay caused by the adaptive process. This time delay represents a limitation and is co-decisive if a signal of the adaptive process can be processed at all.

If an noise signal can be adapted by an adaptive algorithm
10 in order to determine a correcting signal suitable for minimizing the noise signal, is among other things also dependant on that the adaptive process can compute the correcting signal faster than the noise signal arrives into the area to be calmed, considering that the actuators and
15 converters are also subject to a time delay.

If the noise signal arrives chronologically before the determined correcting signal (of the adaptive algorithm for reducing the noise signal) in the area to be processed, the
20 signal cannot be minimized anymore.

Noise signals are often acoustic signals, which are not transmitted by air path but by fixed structures like floor grounds, steel girders or heating pipes, and these
25 materials have a greater acoustic velocity in comparison to acoustic signals, which are transmitted by air path. As these signals are not only detected by that sensor, which is in charge of detecting the noise signals, but also by

that sensor, which detects the error signal, this can lead to an instability of the overall system as a consequence.

The present invention has therefore the object to provide a
5 method that does not have the afore-mentioned drawbacks or problems.

This object is resolved by the features given in the
characterizing part of claim 1. Further embodiments of the
10 invention, a use, a device as well as a use of the device are given in further claims.

It is explicitly pointed out that the number of the sensors and actuators mentioned in the following description can
15 differ from the actual used number, and that it must not be mandatory microphones and loudspeakers, even if in the following, it is started from microphones or from loudspeakers, respectively, for reasons of comprehensibility.

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The present invention is related to a method for reducing an noise signal in a room with the aid of an adaptive noise reduction system. The method consists in

- detecting the noise signal with the aid of at least
25 one sensor unit,
- estimating a transmission path of the room with the aid of an adaptive process by minimizing an error signal, the error signal being a superimposition of an

actual output signal in the room with the aid of the transmission path of the estimated signal, and

- feeding the error signal of the adaptive process to the continuous optimization.

5 The method according to the present invention is characterized in

- feeding the error signal to a further filter unit for the generation of an output signal,
- adjusting a transfer function of the further filter
10 unit with the aid of a further adaptive process in dependence on the error signal and
- subtracting the output signal together with the estimated output signal from the actual output signal.

15 As one of the advantages of the method according to the present invention, is the increase in efficiency based on the fact that in particular signals can be processed very efficiently having different delays, i.e. which spread differently fast.

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Another characteristic of the present invention, is the effect of the increase of stability at systems, by which signals are processed with adaptive processes having different delays, or a portion of the signals being faster
25 than the available control structure and can therefore not or only insufficiently be processed by the actual adaptive process without this favorable extension and accordingly could have a destabilizing effect as a consequence. Thus,

the present invention offers possibilities how certain signal portions can be detected such that

- the stability of the adaptive process is not affected by signals having great velocity ,
- 5 - and signals, which in order to minimize an noise signal, as a result of the transmission velocity cannot be processed by the adaptive process correctly, can be considered at the processing.

10 An embodiment of the present invention consists in detecting the noise signal outside of the room.

A further embodiment of the present invention consists in feeding an actual existing noise signal to the adaptive
15 process for continuous optimizing.

Another further embodiment of the present invention consists in that signal portions being in the noise signal are excluded from the noise reduction.

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A further embodiment of the present invention consists in presetting the excluded signal portions in a piecewise manner.

25 Another further embodiment of the present invention consists in carrying the output signal over a filter, in

which the excluded signals portions are damped. Therefore, an adaptive control structure is given, by which with the aid of an additional filter determined frequency ranges are excluded from the processing by the adaptive process.

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Finally, a further embodiment of the present invention consists in subtracting a desired signal in the room from the error signal.

10 The present invention is in particular suitable for the active noise reduction in a vehicle in mentioning explicitly that this invention cannot only be applied in systems for active noise reduction but also for others uses in connection with adaptive processes.

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Furthermore, a device according to the present invention for reducing an noise signal in a room with the aid of an adaptive noise reduction system is given. The device comprises:

- 20 - at least one sensor unit for detecting the noise signal and
- an adaptive process unit for estimating a transmission path of a room by minimizing an error signal, the error signal being a superimposition of an actual
- 25 output signal in the room and a signal with the aid of the transmission path and being fed to the adaptive process unit.

According to the present invention the device is characterized by

- a further filter unit, to which the error signal is fed for the generation of the output signal,
- 5 - a further adaptive process unit, which is operatively connected to a further filter unit for the adjustment of its transfer function, the error signal being fed to the further adaptive process unit, and
- 10 - means for subtracting the output signal and the estimated signal from the actual output signal.

An embodiment of the present invention consists in arranging at least one sensor unit outside of the room.

- 15 A further embodiment of the present invention consists in feeding the actual existing noise signal to the adaptive process unit.

- 20 Another further embodiment of the present invention consists in that a filter is provided via which the output signal, at least levels reducing in the filter from signal portions to be excluded.

- 25 Finally, an embodiment of the present invention consists in providing means for subtracting a desired signal in the room from an error signal.

The device according to the present invention is in particular suitable for active noise reduction in a vehicle.

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The present invention will be further described with the aid of exemplified embodiments by referring to drawings. It is shown in:

10 Fig. 1 a simplified block diagram of a method according to the present invention,

Fig. 2 a simplified block diagram of a further method according to the present invention,

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Fig. 3 a simplified block diagram of an embodiment of a known method,

20 Fig. 4 a simplified block diagram of a further embodiment of a method according to the present invention.

25 Fig. 5 a simplified block diagram of another further embodiment of a method according to the present invention.

Fig. 6 a use of a method according to the present invention (in a motor vehicle), in schematic representation.

Fig. 3 shows a block circuit diagram of a known active noise reduction system. An noise signal x to be minimized is fed to a transmission path 1 (a room for example) with a transfer function H . The noise signal x in the room covers a certain path. The noise signal x usually is changed by the transfer function H delaying in particular the noise signal x by the transfer function H . The transmission path 1 forming the room contains, for example air, and one or several walls dividing the room completely or partly. If the noise signal x is a noise, which originates outside of the room and which is loud enough to be perceived inside of this room and hence, to be detected from a sensor unit contained in the room (a microphone for example), thus, this noise is changed in the frame of the characteristic of the transmission path 1.

Furthermore, the noise signal x existing outside of the room is according to Fig. 3, fed to a filter unit 2, and to an adaptive process unit 3, the adaptive process unit 3 being operatively connected to the filter unit 2.

For the generation of an error signal e , an actual output signal of the transmission path 1 and a correcting signal y estimated by the filter unit is summarized in an addition unit 6, inverting the estimated correcting signal y beforehand. The error signal e is fed to the adaptive process unit 3 as a consequence.

Only then, the algorithm is stable used in the adaptive process unit 3 and can as a consequence only then be operated in an active noise reduction system, if the delay of the noisesignal x being greater by the transmission path 1 than the delay caused by the filter unit 2 and by the adaptive process unit 3.

Thus, the adaptive process unit 3 mandatory must calculate the necessary correcting signal y for minimizing the noisesignal x in shorter time than the time for the transition of the transmission path 1 needed by the noisesignal x .

In applying two sensor units in the room for the detection of the signals, for example, detecting the noisesignal x by one of the sensor units, which is fed to the adaptive process unit 3 and the filter unit 2, and the other sensor unit detects the error signal e , which is fed to the adaptive process unit 3, then a correcting signal y must be computed faster mandatory than the delay needed by the noisesignal x , which is necessary for covering the distance between the two sensor units.

Fig. 1 shows a block diagram of an embodiment of the present invention, in feeding the error signal e not only to the filter unit 2 actuating the adaptive process unit 3, but in which in addition to a further filter unit 4 and a further adaptive process unit 5, in which a further adaptive process for the adjustment in a further filter

unit 4 is used for an adjustable transfer function. In the following, a generated signal in a further filter unit 4 is referred to as y_2 . In a further addition unit 7, a sum is formed out of the two signals y and y_2 , which is added to
5 the actual output signal of the transmission path 1 in the addition unit 6 after being inverted in known manner beforehand. In the adaptive process units 3 and 5, adjustments are carried out in the particular filter units 2 or 4, respective, such that the error signal e is
10 minimal.

The further adaptive process unit 5 being operatively connected to the further filter unit 4 operates in a feedback method, thus, without notice of the error signal x
15 beforehand. The further adaptive process unit 5 adapts only the remaining error signal e , thus, is not subject to the time delays effected by the adaptive process unit 3.

Fig. 2 shows a block diagram of a further embodiment of the present invention. The signal y_2 is filtered by a filter 13
20 for generating a signal y_2' , in addition to the embodiment as depicted in Fig. 1. Therefore, this filtering is necessary, because the further adaptive process unit 5 would minimize the entire error signal e without the filter
25 13, which is not desired mostly. The reasons can be by nature of safety engineering - for example a klaxon - or by the necessity of verbal communication, if people remain in the area to be calmed, i.e. in the room. Thus always, when certain signals should not or are not allowed to be

minimized, respectively, within the area to be calmed. Signals, which are excluded from processing, are the signals, which cannot pass the filter 13 and accordingly are not fed to the further adaptive process unit 5. Thus, 5 this embodiment allows in an advantageous manner to exclude signals from the processing by the further process unit 5 being operatively connected to the filter unit 4 having certain characteristics.

- 10 Accordingly to the explanations as aforesaid in connection with the exclusion of certain signals, which should not be eliminated in the room, the characteristic of the filter 13 has to be chosen.
- 15 Fig. 4 shows a block diagram of a further embodiment of the present invention. In amendment to the embodiment as depicted in Fig. 2, a desired signal 14 is fed to the room 1 to be calmed. The desired signal 14 is subtracted in the addition units 15 and 16 from the error signal e or in the 20 addition unit 29 from the error signal x to be minimized, respectively, making sure that the adaptive process units 3 and 5 do not include the desired signal 14. Thereby the desired signal 14 is not minimized.
- 25 Fig. 5 shows a block diagram of another further improved embodiment of the present invention. Either by reasons of stability or by insufficient computing power in the adaptive process units 3 and 5 as well as in the filter

units 2 and 4, the desired signal 14 can also be subtracted directly after the addition unit 6 in the addition unit 17 from the residual error e.

5 Fig. 6 shows a practical use of the method according to the present invention, in a motor vehicle 20, in schematic representation. In the following, the use is described in detail only in connection with the noise of engines in pointing explicitly out that also other noises can be taken
10 into account, like rolling noises of wheels on a roadway, for example.

The noise signal 8 to be reduced is the noise of engines produced by the motor 18 and the area to be calmed may be a
15 passenger cell 19 included in a motor vehicle 20. The noise signal x - the noise of engines -, which is caused by the motor 18 and is detected by a microphone 22, is dispersed by different ways and accordingly gets also by different ways into the passenger cell 19. On the one hand, the noise
20 signal x is dispersed by air, thus gets via holes between passenger cell and motor compartment also into the passenger cell 19, for example. In this case, the noise of engines moves with the velocity of propagation known for air from the motor compartment into the passenger cell 19.
25 On the other hand, the noise of engines moves over fixed structures, as for example the car body of the motor vehicle 20 having a considerable higher velocity (as by air path) from the motor 18 into the passenger cell 19.

As a further advantageous characteristic of the present invention presented here, the noise generated in the rear end 24 by the rolling resistance of the motor vehicle, which is propagated in direction of the driving direction 5 25, thus in the opposite direction mentioned in the first use, can be kept away from processing by suitable means, as described in the first use - noise of engines.

It is explicitly pointed out here that in the described use 10 it is a matter of the example of a motor vehicle having front-wheel drive, the invention in turn can be used for other modes of drive as for example in a car having rear-wheel drive.

15 Further, here should be mentioned that the presented invention can be implemented also to other noises emerging in a vehicle but that this description refers to the noise of engines of a motor vehicle having a front-wheel drive for reasons of comprehensibility. Furthermore, the 20 applicability of the invention is not restricted to motor vehicles.

The portion of the noise of engines generated by the motor 18, which is propagated by air path, is adapted in the 25 passenger cell 19 with the algorithm generated in the adaptive process 3 and the filter unit 2 in order to minimize the noise of engines in the passenger cell 19 as depicted in Fig. 1 and Fig. 2. The portion propagating over

the car body with greater velocity than in the case of air and the portion of noise of engines generated by the motor 18 attaining the passenger cell 19 is adapted with the aid of the algorithm from the further adaptive process unit 5
5 and the further filter unit 4 consisting portion, as depicted in Fig. 1 and Fig. 2, in order to minimize the noise of engines in the passenger cell 19.

Music, speech or an ulterior signal, which is detected by
10 one the microphones 23 and emitted by loudspeakers 21 into the passenger cell 19, can be excluded from the processing being the portion of the further adaptive process unit 5 and the further filter unit 4, like the shown measures in Fig. 4 and Fig. 5, or from the adaptive process unit 3 and
15 filter unit 2, like the algorithms shown in Fig. 1 and Fig. 2, respectively.

Claims

1. Method for reducing an noise signal (x) in a room
with the aid of an adaptive noise reduction system,
5 the method consisting in
 - detecting the noise signal (x) with the aid of at
least one sensor unit (22),
 - estimating a transmission path (1) of the room
10 with the aid of an adaptive process by minimizing
an error signal (e), the error signal being (e) a
superimposition of an actual output signal in the
room and a signal (y) estimated with the aid of
the transmission path (1), and
 - feeding the error signal (e) of the adaptive
15 process for the continuous optimization,
characterized by
 - feeding the error signal (e) to a further filter
unit (4) for the generation of an output signal
20 (y2),
 - adjusting a transfer function of the further
filter unit (4) with the aid of a further
adaptive process in dependence on the error
signal (e), and
 - subtracting the output signal (y2) together with
25 the estimated signal (y) from the actual output
signal.
2. Method according to claim 1, characterized in that
the noise signal (x) is detected outside the room.

3. Method according to claim 1 or 2, characterized in
that the actual existing noise signal (x) is fed to
the adaptive process for the continuous
5 optimization.
4. Method according to one of the claims 1 to 3,
characterized in that signal portions being in the
error signal (x) are excluded from the noise
10 reduction.
5. Method according to claim 4, characterized in that
the excluded signal portions are preset in a
piecewise manner.
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6. Method according to claim 4 or 5, characterized in
that the output signal (y2) is fed via the filter
(13), in which the excluded signal portions are
damped.
20
7. Method according to one of the claims 1 to 6,
characterized in that a desired signal (14) in the
room is subtracted from the error signal (e).
- 25 8. Use of the method according to one of the claims 1
to 7 for active noise reduction in a vehicle.

9. Device for reducing an error signal (x) in a room with the aid of an adaptive noise reduction system the device comprising:

- 5 - at least one sensor unit (22) for the detection of the noise signal (x) and
- an adaptive process unit (3) for estimating a transmission path (1) of the room by minimizing an error signal (e), the error signal (e) being a
- 10 superimposition of an actual output signal in the room and a signal (y) estimated with the aid of the transmission path (1) and being fed to the adaptive process unit (3),

characterized by

- 15 - a further filter unit (4), to which the error signal (e) is fed for generating a output signal (y2),
- a further adaptive process unit (5), which is operatively connected to a further filter unit
- 20 (4) for adjusting its transfer function, the error signal (e) being fed to the further adaptive process unit (5), and
- means for subtracting the output signal (y2) and the estimated signal (y) from the actual output
- 25 signal.

10. Device according to claim 9, characterized in that at least one sensor unit (22) is arranged outside the room.
- 5 11. Device according to claim 9 or 10, characterized in that the actual existing noise signal (x) is fed to the adaptive process unit (3).
- 10 12. Device according to one of the claims 9 to 11, characterized in that a filter (13) is provided via which the output signal (y2) is fed, at least reducing levels in the filter (13) from signal portions to be excluded.
- 15 13. Device according to one of the claims 9 to 12, characterized in that means are provided for subtracting a desired signal (14) in the room from an error signal (e).
- 20 14. The device according to claim 9 to 13 for active noise reduction in a vehicle.