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(54) Method and apparatus for controlling the performance of a loudspeaker in a room

Verfahren und Vorrichtung zur Leistungsregelung eines Lautsprechers in einem Raum

Procédé et appareil pour contrôler la performance d'un haut-parleur dans une salle

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WO-A-84/00274 **DE-A1- 4 334 040**

- **PATENT ABSTRACTS OF JAPAN vol. 1996, no. 02, 29 February 1996 (1996-02-29) & JP 07 274282 A (SUZUKI MOTOR CORP), 20 October 1995 (1995-10-20)**

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Description

[0001] The invention relates to a method and apparatus for controlling the performance of a loudspeaker in a room.

[0002] The actual performance of a loudspeaker is known to be highly dependent on the acoustics of the actual listening room and the actual loudspeaker position within this room. In particular the performance of a loudspeaker will change very noticeably when it is in proximity to the boundaries of the room. This is caused by the loading of the room on the loudspeaker as a radiator, or in other words due to the changing radiation resistance. A change of listener position changes the perceived performance of the loudspeaker, in particular due to early reflections and standing waves. However some boundary effects are universal in the room, in particular in the bass frequency range, and hence the perception of this range is less influenced by the listener position.

[0003] Loudspeaker designers experience this fact by having to make a compromise when optimizing the timbre of the loudspeaker so that the perceived sound will be acceptable under a number of different conditions, i.e. different room acoustics, loudspeaker positions, and listening positions. Even though making this compromise, the designer cannot ensure that the customer will always experience the intended quality. Thus, the listener will experience a performance of the loudspeaker that depends on the acoustic properties of the actual listening room and the position chosen for both loudspeaker and listener. There is a risk that an expensive loudspeaker which performs very well in the shop, will turn out performing badly or at least disappointingly when placed in a different environment and/or in a different position.

[0004] In order to compensate for this problem it is known to fit a switch in the cross-over filter unit in the loudspeaker in order that the bass response may be modified to suit a particular placement of the loudspeaker. At best, this must be considered a poor compromise, and if at all possible, the precise adjustment will be dependent on a measurement of the room characteristics. Some automatic systems are based on measuring the transfer function from the input of the loudspeaker to an omnidirectional microphone, placed at the preferred listening position or a number of representative positions. An equalizing filter is then inserted so that the resulting transfer function approximates a target function, which e.g. can be flat in the frequency range of interest. A major problem of such systems is the sensitivity to changes in the position of the sound source as well as the receiver. If the position of the loudspeaker or the listener is changed after calculating the equalizing filter, the effects can be severe colouration, pre-echoes, etc. Another problem of such systems is the choice of a suitable target function, where a flat function may not be found to be optimal.

[0005] The patent application WO84/00274 recognizes that high fidelity reproduction is adversely affected by normal room acoustics and the relative position of a loudspeaker system with respect to the room boundaries. To provide optimum results WO84/00274 proposes an environment-adaptive loudspeaker system, which uses pressure-sensing means and velocity sensing means mounted to determine the instantaneous pressure and velocity at the surface of a loudspeaker diaphragm and supply signals to a processor which controls the transfer characteristic of a correction filter iva which input signals are fed to the loudspeaker. The problem with such a system is the choice of appropriate transfer characteristics.

[0006] It has in the present invention been realized that since all the involved acoustic phenomena's are considered to be linear, what is actually compensated through the apparently sensible procedures discussed above is the superposition of several phenomena, such as standing waves/natural frequencies of the room, early reflections, reverberation and the reduction of angular space angle due to the boundary effect, and it is considered that this is the reason why the known procedures will only function for one listening position.

[0007] It is the purpose of the invention to provide an improved method and apparatus for controlling the performance of a loudspeaker in a room in order that it becomes independent of the placement of the loudspeaker. This is obtained in a method according to the invention which is particular in that the listening room is divided into zones of e.g. 30 cm by 30 cm, each having a correction filter transfer function assigned to it, and that information on the particular zone is fed to the correcting filter in the electrical signal path to the loudspeaker. By this means it is possible to accomodate a a number of typical placements of a loudspeaker and to obtain a large degree of the improvement according to the invention, without having to perform a measurement. In a first acoustic environment the movement, e.g. velocity, of the diaphragm of the loudspeaker driver and the force, arising from the sound field, acting on it are determined by measuring suitable parameters, defining thereby a first complex transfer function, that in a second acoustic environment a second complex transfer function is determined by measuring the same or different parameters of the loudspeaker driver, relating to the room, that the ratio between the real parts of the first and second transfer functions is used to define the performance of a correcting filter, that the filter is applied in the signal chain to the loudspeaker driver.

[0008] There is a strong link between the way the loudspeaker sounds, in particular in the bass range, and its radiation resistance as a function of frequency, being the real part of the radiation impedance. Implementing the invention for a loudspeaker has proved to significantly increase the certainty that the customer will always experience the quality intended by the loudspeaker designer. The loudspeaker in a first step is put in a reference room environment where it performs to a standard to be determined, and during which a reference radiated power output (real, i.e. active) or reference radiation resistance

of a driver as a function of frequency is measured, and in that in a second step the loudspeaker is put in its room of usage where its attendant radiated power output or radiation resistance is measured, the ratio between the said real (active) power outputs or radiation resistances respectively being used to define the transfer function of a correcting filter in order to obtain said standard of performance determined in said reference room environment, and that in a third step said correcting filter is introduced in the electrical signal path to the driver. In principle a multi-driver loudspeaker should have each driver subjected to such a measurement, however one or several may be selected as representative. At the time of measurement of one particular driver or a group of drivers, the other drivers may either be short-circuited, disconnected or connected to the signal.

[0009] When the loudspeaker is placed in a position which is not identical to the reference position/room, the bass performance changes. However, the method according to the invention is able to detect a major part of this change in the acoustic environment of the loudspeaker and to correct accordingly. Switching on and off an apparatus working according to the principles of the invention can lead to dramatic changes of the bass performance of the loudspeaker depending on how different the actual position and room are from the reference conditions. If a loudspeaker is designed to operate away from the walls of a room, then when placing such a loudspeaker close to a corner of the listening room, the bass performance becomes boomy, coloured, and the sound pressure level increases. In such a situation the apparatus according to the principles of the invention corrects the timbre in such a way that the perceived timbre is almost the same as in the reference position. The effect of the apparatus in this situation has been described by listeners as quite startling. The bass performance then was not plagued by the rumble which is traditionally a characteristic of a corner position, and the bass performance becomes more even and neutral without becoming "thin". In a corner position this is perceived as a dramatic improvement of the bass performance.

[0010] An advantageous embodiment is particular in that the loudspeaker is permanently fitted with measurement means, the ratio between reference and use measurements being used to define the parameters of the correcting filter. This enables a measurement to be initiated by a user or in the event that some predefined conditions are met, e.g. power up of the apparatus. This measurement cycle could be performed using a dedicated measuring signal, e.g. obtained from a particular Compact Disc.

[0011] A further advantageous embodiment of the invention is particular in that the loudspeaker is permanently fitted with measurement means, and the complex transfer function, which corresponds to the situation during usage, is continuously measured during operation of the apparatus. The ratio between reference and usage measurements being used to define the parameters of the correcting filter. This means that the loudspeaker will be automatically and continuously adaptable to any new listening room environment, e.g. using the played music as the stimuli when measuring the complex transfer functions. In this case the transfer function in the usage situation is continuously measured, and e.g. a digital signal processor in the signal chain calculates and performs the filtering which provides a sound from the loudspeaker which is very similar to the sound in the reference position/room and which presumably was judged positively during the design of the loudspeaker.

[0012] A simpler arrangement is obtained by instructing the user to activate switches according to a schematic showing various typical placements of a loudspeaker in a room. This functions in practice, provided the loudspeaker is of the same type as the loudspeaker used in the reference environent.

[0013] An apparatus according to the invention is particular in that it comprises a filter, the transfer function of which is controllable by electronic/numerical signals, said signals being obtained from a unit which determines the ratio between a stored reference radiation resistance or active power output (real) as a function of frequency and a measured radiation resistance or active power output (real) in the usage situation. This ratio basically defines the amplitude response of the correction filter, and various filter implementations, e.g. minimum phase can be obtained from this. However various operation might be performed to modify the ratio before implementation, e.g. smoothing, convolution, frequency limiting, correction limiting, logarithm, exponential, multiplication, addition etc. and combinations of these. For instance, defining the amplitude response of the correction filter as the square root of the ratio seems to be a reasonable choice.

[0014] The invention will be further described in the following with reference to the drawing, in which

Fig. 1 shows the electrical, mechanical and acoustical signal paths associated with a loudspeaker placed in a room,

Fig. 2 shows a loudspeaker with a driver and measuring transducers, and

Fig. 3 shows a schematic of how the correction filter can be inserted in the signal chain according to one embodiment of the invention.

[0015] By way of example Fig. 1 shows the signal path and transfer functions relating to a loudspeaker in a room. The electrical signal from the source is fed to a power amplifier A which drives the loudspeaker which is designated B and comprises the electrical and mechanical parts of the loudspeaker driver unit and the acoustic influence of the cabinet enclosure. The output from the loudspeaker is transformed by the transfer function C from the acceleration of the diaphragm to the sound pressure in front of the diaphragm which may be measured by a microphone D as one example of how to obtain the force, arising from the sound field, acting on the dia-

phragm. An accelerometer E for example may measure the diaphragm acceleration directly. At point 1 the source signal is provided, at point 2 the electrical input signal to the loudspeaker driver is available, point 3 refers to the acceleration of the diaphragm of the loudspeaker, and at point 4 the sound pressure at some predetermined and fixed point in front of the driver is available. After being converted by the microphone D an electrical signal representing the sound pressure is available at point 5, and correspondingly, an electrical signal representing the membrane acceleration is available at point 6.

[0016] Fig. 2 shows one embodiment of the invention where the loudspeaker B with one of a multitude of possible placements of a microphone D and an accelerometer E.

[0017] Fig. 3 shows how a measurement of the radiation resistance of the loudspeaker is used when calculating the filter F, which is switched into the signal path. The signal processing may occur through any means available to the skilled person, the result will be a linear pre-distortion of the signal to the power amplifier in order that the loudspeaker provides an excitation of the listening room so that the perceived sound is a good approximation to the quality determined during the design phase. The advantage of making the measurement continuous is that the system will automatically compensate e.g. for an influx of listeners or a changed placement of furniture or the loudspeaker placement itself, which disturbs the sound distribution in the room. Such a disturbance is now compensated so that the perceived sound is essentially unchanged.

Claims

1. A method for controlling the performance of a loudspeaker (B) in a listening room environment, whereby in a reference room environment the resultant movement of the loudspeaker driver diaphragm and the associated force, arising from the sound field in said reference room environment, acting on it are determined by measuring suitable parameters defining a first complex transfer function, whereby in said listening room environment a second complex transfer function is determined by measuring the same or different parameters of the loudspeaker driver relating to said listening room environment, whereby the ratio between the real parts of the first and second transfer functions is used to define the transfer function of a correcting filter, whereby said correcting filter is applied in the signal chain to the loudspeaker driver, said method **characterized in that** the listening room environment is divided into zones, each zone having said correcting filter (F) transfer function defined and assigned to it, and that information about the particular zone is fed to the loudspeaker in the electrical signal path to the loudspeaker (B).

2. A method for controlling the performance of a loudspeaker (B) in a listening room environment according to claim 1, **characterized in that** the loudspeaker (B) in a first step is put in a reference room environment where it performs to a standard to be determined, and during which a reference radiated power output and reference radiation resistance of a driver or any similar physical parameter are measured as a function of frequency, and **in that** in a second step the loudspeaker (B) is put in the listening room environment where a usage radiated power output and usage radiation resistance of the same driver or any similar physical parameter are measured, and **in that** in a third step the ratio between the real part of said power outputs, radiation resistances or any similar physical parameters respectively are being used to define the transfer function of said correcting filter (F) in order to obtain said standard of performance determined in said reference room environment, and that in a fourth step said correcting filter is introduced in the electrical signal path to the driver.

3. A method according to claim 1 or 2, **characterized in that** the loudspeaker (B) is permanently fitted with measurement means, the ratio between said reference and said usage measurements being used to define the parameters of the correcting filter.

4. A method according to claim 1 or 2, **characterized in that** the loudspeaker (B) is permanently fitted with measurement means and is continuously measuring the second complex transfer function, the ratio between said reference and said usage measurements being used to define the parameters of the correcting filter.

5. A method according to claim 3, **characterized in that** the measurement means are activated by a user or in the event that some predefined conditions are met such as power up of said correcting filter.

6. A method according to claim 3 or 4, **characterized in that** a multi-driver system should have each driver subjected to a measurement according to claim 1 or 2.

Patentansprüche

1. Verfahren zur Steuerung der Leistung eines Lautsprechers (B) in einer Hörraumumgebung, wobei in einer Bezugsraumumgebung die resultierende Bewegung der Lautsprechertreibermembran und die assoziierte Kraft, herrührend aus dem Schallfeld in der genannten Bezugsraumumgebung, die darauf einwirken, durch Messung geeigneter Parameter bestimmt werden, die eine erste komplexe Übertra-

gungsfunktion definieren, wobei in der genannten Hörraumumgebung eine zweite komplexe Übertragungsfunktion durch Messung der gleichen oder anderer Parameter des Lautsprechertreibers in Bezug auf die Hörraumumgebung ermittelt wird, wobei das Verhältnis zwischen den reellen Teilen der ersten und zweiten Übertragungsfunktionen zum definieren der Übertragungsfunktion eines korrigierenden Filters verwendet wird, wobei das genannte korrigierende Filter in der Signalkette zu dem Lautsprechertreiber angewandt wird wobei das genannte Verfahren **dadurch gekennzeichnet ist, dass** die Hörraumumgebung in Zonen aufgeteilt ist, wobei jede Zone die genannte korrigierende Filterübertragungsfunktion (F) hat, die definiert und derselben zugeordnet ist, und dass Information über die betreffende Zone dem Lautsprecher in der elektrischen Signalstrekke zu dem Lautsprecher (B) zugeführt wird.

2. Verfahren zur Steuerung der Leistung eines Lautsprechers (B) in einer Hörraumumgebung nach Anspruch 1, **dadurch gekennzeichnet, dass** der Lautsprecher (B) in einem ersten Schritt in eine Bezugsraumumgebung gesetzt wird, wo er entsprechend einem zu bestimmenden Standard funktioniert, und wobei ein als Bezugswert ausgestrahlter Leistungsausgang und ein Bezugsstrahlungswiderstand eines Treibers oder eines beliebigen ähnlichen physikalischen Parameters als eine Funktion der Frequenz gemessen wird, und dass in einem zweiten Schritt der Lautsprecher (B) in die Hörraumumgebung gesetzt wird, wo ein üblicher ausgestrahlter Leistungsausgang und ein üblicher Ausstrahlungswiderstand desselben Treibers oder eines beliebigen ähnlichen physikalischen Parameters gemessen werden, und dass in einem dritten Schritt das Verhältnis zwischen dem reellen Teil der genannten Leistungsausgänge, Strahlungswiderstände bzw. beliebiger ähnlicher physikalischer Parameter zum Definieren der Übertragungsfunktion des genannten korrigierenden Filters (F) verwendet werden, und zwar zum Erhalten des genannten Leistungsstandards, ermittelt in der genannten Bezugsraumumgebung, und dass in einem vierten Schritt das genannte korrigierende Filter in die elektrische Signalstrecke zu dem Treiber eingeführt wird.

3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Lautsprecher (B) mit Messmitteln ständig verbunden ist, wobei das Verhältnis zwischen dem genannten Bezugswert und den genannten üblichen Messungen zum Definieren der Parameter des korrigierenden Filters verwendet wird.

4. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Lautsprecher (B) mit Messmitteln ständig verbunden ist und die zweite komplexe Übertragungsfunktion ständig gemessen wird, wobei das Verhältnis zwischen dem genannten Bezugswert und den üblichen Messungen zum Definieren der Parameter des korrigierenden Filters verwendet wird.

5. Verfahren nach Anspruch 3, **dadurch gekennzeichnet, dass** die Messmittel durch einen Benutzer aktiviert werden, oder in dem Fall, dass einige vorher definierte Bedingungen, wie das Einschalten des genannten korrigierenden Filters, erfüllt werden.

6. Verfahren nach Anspruch 3 oder 4, **dadurch gekennzeichnet, dass** ein Mehrfachtreibersystem jeden Treiber einer Messung nach Anspruch 1 oder 2 aussetzen soll.

Revendications

1. Procédé pour commander la performance d'un haut-parleur (B) dans un environnement de pièce d'écoute, cas dans lequel dans un environnement de pièce de référence le mouvement qui résulte du diaphragme du dispositif d'attaque de haut-parleur et la force associée provenant du champ sonore dans ledit environnement de pièce de référence qui y agit sont déterminés par la mesure de paramètres appropriés définissant une première fonction complexe de transfert, cas dans lequel dans ledit environnement de pièce d'écoute une deuxième fonction complexe de transfert est déterminée par la mesure des mêmes ou des paramètres différents du dispositif d'attaque de haut-parleur qui se rapportent audit environnement de pièce d'écoute, cas dans lequel le rapport entre les parties réelles des première et deuxième fonctions de transfert est utilisé pour définir la fonction de transfert d'un filtre de correction, cas dans lequel ledit filtre de correction est appliqué dans la chaîne de signal au dispositif d'attaque de haut-parleur, ledit procédé étant **caractérisé en ce que** l'environnement de pièce d'écoute est divisé en des zones, chaque zone ayant définie et assignée à elle ladite fonction de transfert du filtre de correction (F), et **en ce que** l'information relative à la zone particulière est acheminée vers le haut-parleur dans le chemin de signal électrique au haut-parleur (B).

2. Procédé pour commander la performance d'un haut-parleur (B) dans un environnement de pièce d'écoute selon la revendication 1, **caractérisé en ce qu'**à une première étape le haut-parleur (B) est positionné dans un environnement de pièce de référence où il fonctionne à une norme à déterminer et pendant laquelle une sortie de puissance rayonnée de référence et une résistance de rayonnement de référence d'un dispositif d'attaque ou de n'importe quel paramètre physique similaire sont mesurées en fonction

d'une fréquence, et **en ce qu'**à une deuxième étape le haut-parleur (B) est positionné dans l'environnement de pièce d'écoute où il est mesuré une sortie de puissance rayonnée d'usage et une résistance de rayonnement d'usage du même dispositif d'attaque ou de n'importe quel paramètre physique similaire, et **en ce qu'**à une troisième étape le rapport entre la partie réelle desdites sorties de puissance, desdites résistances de rayonnement ou des paramètres physiques similaires quelconques, respectivement, est en cours d'être mesuré pour définir la fonction de transfert dudit filtre de correction (F) afin d'obtenir ladite norme de performance qui est déterminée dans ledit environnement de pièce de référence et **en ce qu'**à une quatrième étape ledit filtre de correction est introduit dans le chemin de signal électrique au dispositif d'attaque.

3. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** le haut-parleur (B) est équipé en permanence de moyens de mesure, le rapport entre ladite référence et lesdites mesures d'usage étant utilisé pour définir les paramètres du filtre de correction.

4. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** le haut-parleur (B) est équipé en permanence de moyens de mesure et est en cours de mesurer continûment la deuxième fonction complexe de transfert, le rapport entre ladite référence et lesdites mesures d'usage étant utilisé pour définir les paramètres du filtre de correction.

5. Procédé selon la revendication 3, **caractérisé en ce que** les moyens de mesure sont activés par un utilisateur ou dans le cas où quelques conditions prédéfinies seraient remplies, telles que la mise sous tension dudit filtre de correction.

6. Procédé selon la revendication 3 ou 4, **caractérisé en ce qu'**un système de dispositifs d'attaque multiples devrait effectuer que chaque dispositif d'attaque est soumis à une mesure selon la revendication 1 ou 2.

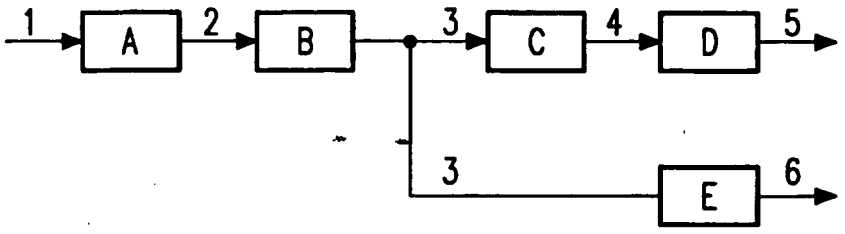


FIG. 1

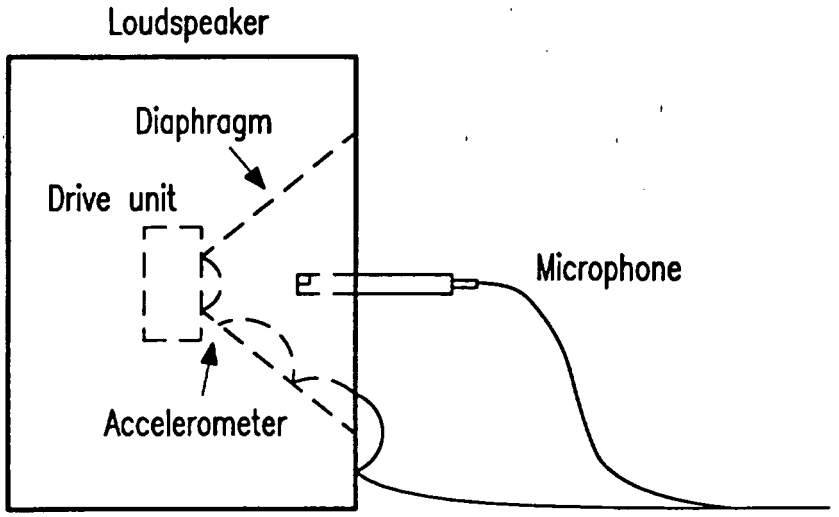


FIG. 2

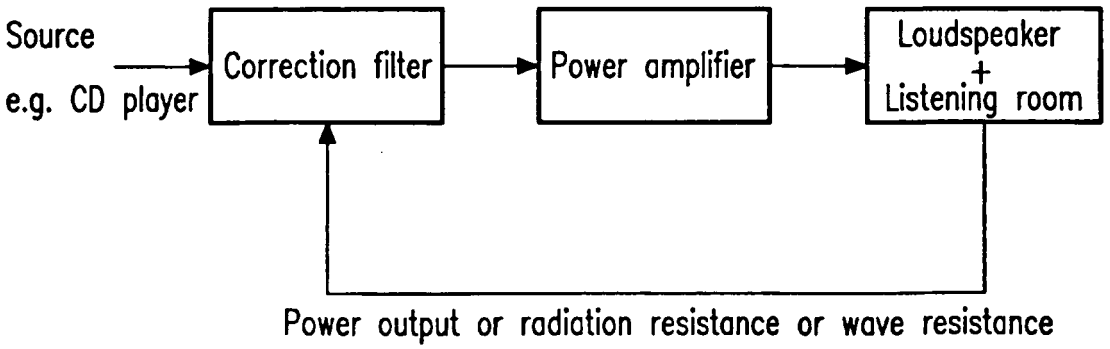


FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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