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(54) **Distortion reduction for small loudspeakers by band limiting**

Verzerrungsverringerung für kleine Lautsprecher durch Bandbegrenzung

Réduction de la distorsion pour petits haut-parleurs par la limitation de bandes

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to the field of signal processing, especially audio signal processing, and more specifically processing of audio signals for playback by small loudspeakers. More specifically, the invention provides a processor and a method for reducing distortion produced by small loudspeakers, and/or increasing the possible acoustic output for such loudspeakers, and/or possibly reducing the risk of damaging the loudspeakers.

BACKGROUND OF THE INVENTION

[0002] Small loudspeaker units are used in many devices today for reproducing audio signals in compact portable audio devices, e.g. mobile phones, media players, car audio systems and the like. Due to the small size, such loudspeakers have a limited maximum acoustic output, a limited dynamic range, and especially a limited low frequency output. When the dynamic capability of a small loudspeaker is exceeded, the result is a severely distorted audio signal. Especially, the distortion is clearly audible on audio signal including a few pure tones, e.g. as popular ring tones used by many Japanese in their mobile phones.

[0003] A number of known solutions exist for processing the electric signal applied to a small loudspeaker in order to remedy the limited capacity of the loudspeaker, if a low distortion signal is required: reduce the overall level and accept a low acoustic output, sharply filter out low frequency content, or limit the level by means of a compressor.

[0004] An example of such a processing of an audio signal is given by JP2000253484.

SUMMARY OF THE INVENTION

[0005] Thus, according to the above description, it is an object of the present invention to provide a simple and effective processor and processing method for preprocessing an audio signal before applying it to a small loudspeaker, so as to increase the acoustic output of the loudspeaker without severely affecting sound quality due to distortion. Alternatively, the goal is to maintain an acoustic output while lower the distortion.

[0006] In a first aspect, the invention provides a device arranged for application to an associated loudspeaker acoustically mounted such that it exhibits a lower resonance frequency. The device comprises

- an input arranged to receive an audio input signal,
- a filter section arranged to receive the audio input signal and to attenuate a limited frequency band thereof and generate a modified audio signal accordingly, wherein the limited frequency band includes said lower resonance frequency of the associated loudspeaker, and
- an output arranged to output the modified audio signal as an audio output signal.

[0007] Such device is advantageous, since it allows reproduction of sound with a miniature or micro-speaker with reduced distortion. Typical loudspeakers where the invention is advantageous are loudspeaker with a small diaphragm area and which are mounted such that its lower resonance frequency Fc is rather high, e.g. 1 kHz, as in many mobile phones and the like. The free air resonance frequency of the loudspeaker is typically lower, but due to a small back volume the resulting lower resonance frequency Fc often becomes rather high. The invention is based on the insight that by attenuating a limited frequency band including the Fc, e.g. centred around Fc (on a logarithmic frequency scale), it is possible to limit large diaphragm excursions of the loudspeaker which occurs when applying sound around Fc. Such large excursions of the diaphragm will at higher signal levels lead to severe audible non-linear distortion, and potentially they may damage the loudspeaker. Such severe distortion can be reduced or even eliminated by proper attenuation of the limited frequency band around Fc. Since the attenuated frequency band is limited, e.g. only 1 octave wide or even narrower such as 1/3-2/3 octaves wide, the negative audible effect of such attenuation is very limited, and in many cases not even audible. Such as 3-6 dB of attenuation at high signal levels in said frequency band can dramatically reduce distortion from a small loudspeaker, thus leading to either improved sound quality and/or increased effective acoustic output from the small loudspeaker at audio frequencies above Fc, but in many cases also below Fc.

[0008] In a digital signal processing chain, the invention should preferably be present just prior to digital to analog conversion resulting in the analog signal to drive the loudspeaker.

[0009] In preferred embodiments, the limited frequency band has a bandwidth of less than 2 octaves, such as less than 1 octave, such as less than 2/3 octaves, such as less than 1/3 octave. The limited frequency band may be centred around said lower resonance frequency of the associated loudspeaker. The bandwidth optimal in each case will depend on the loudspeaker and the acoustical environment where it is mounted. A more effective distortion protection can be achieved with a rather wide bandwidth, whereas the most inaudible processing is obtained with a narrow bandwidth.

[0010] The invention comprises a gain control unit arranged to control said attenuation in the limited frequency band. The gain control unit may be arranged to detect a level of the audio input signal within the limited frequency band and to provide said attenuation according to a predetermined attenuation scheme. Said scheme may include detecting whether a peak level of the audio input signal within the limited frequency band exceeds a pre-

determined maximum level, and determining said attenuation accordingly to ensure that the modified audio signal does not exceed the predetermined maximum level. Said predetermined maximum level is preferably selected such in relation to the associated loudspeaker that the audio output signal will not cause the loudspeaker to perform a diaphragm excursion exceeding its limit.

[0011] The gain control unit is preferably designed such, that zero attenuation is provided most of the time when signal levels are low enough to ensure that the loudspeaker diaphragm will not reach excursions causing severe distortion. Especially, an attenuation Att (in dB) should preferably be determined in response to a detected peak signal level P (in dB) such that a predetermined maximum allowable level ML (in dB), determined in accordance with the capability of the loudspeaker, e.g. according to:

$$Att = P - ML \text{ (all in dB)},$$

[0012] Thus, with ML = 100 dB, and a detected peak level P exceeding this, e.g. P = 110 dB, an attenuation of A = 10 dB will be determined, thus leading to a resulting signal level in the frequency band which has a peak level equal to the maximum allowed, i.e. ML. ML can be selected according to the application to include a safety margin to ensure that the loudspeaker is never overloaded, or it can be set to a more aggressive value allowing slightly overloading the loudspeaker. As mentioned, for many signals, the attenuation will preferably be zero, thus leaving the processing inactive. However, in case of signals with high levels within the frequency band including Fc, especially tone complexes with large onsets, the attenuation can effectively ensure that severe audible distortion is avoided.

[0013] It is to be understood, that the filter section may be implemented in various ways, using various types of filters with various cut off slope steepness etc. In one implementation, the filter section may comprise a band pass filter arranged to band pass filter the audio input signal to said limited frequency band, and a band stop filter arranged to band stop filter the audio input signal with the stop band being said limited frequency band. Outputs from the band pass filter and the band stop filter may then be summed to generate the audio output signal.

[0014] The device may be designed to accept an audio input signal with a plurality of audio channels, such as a stereo signal, and wherein the audio channels are processed to form an audio output signal with a corresponding plurality of audio channels. The audio input signal may be analog or digital, and also the audio output signal may be analog or digital. Preferably, the filter section and the attenuation is implemented by means of a digital processor programmed to perform the required signal processing.

[0015] The device may comprise a loudspeaker acoustically mounted such that it exhibits said lower resonance frequency, and a power amplifier connected to drive the loudspeaker according to the audio output signal. Especially, the device may be a mobile device, such as portable audio device, portable video devices, and portable players. More specifically, the device may be one of: a mobile phone, a tablet, a laptop, and a personal navigation device. However, it is to be understood that the invention may be useful in combination to any application where an acoustic output from a small loudspeaker is required with a minimum of audible distortion. Especially, the loudspeaker is small, i.e. has a diaphragm area of less than 10 cm^2, such as less than 5 cm^2, such as less than 2 cm^2, such as less than 1 cm^2. The loudspeaker may be further acoustically mounted, e.g. a closed or vented cabinet, such that the lower resonance frequency is above 100 Hz, such as above 300 Hz, such as above 500 Hz, such as above 800 Hz, such as above 1 kHz. Especially, the lower resonance frequency may be between 500 Hz and 2 kHz, such as between 700 Hz and 1.5 kHz.

[0016] In a second aspect, the invention provides a method for reducing distortion from an associated loudspeaker acoustically mounted such that it exhibits a lower resonance frequency, the method comprising attenuating a limited frequency band of an audio input signal, wherein the limited frequency band includes said lower resonance frequency.

[0017] In a third aspect, the invention provides a computer executable program code arranged to perform the method according to the second aspect, such as a computer executable program code stored on a data carrier. The program code may be implemented on any type of audio processing platform, e.g. a sound card in a computer, a general processor in a mobile device e.g.

[0018] It is appreciated that the same advantages and embodiments described for the first aspect apply as well for the second and third aspects. Further, it is appreciated that the described embodiments can be intermixed in any way between all the mentioned aspects.

BRIEF DESCRIPTION OF THE FIGURES

[0019] The invention will now be described in more detail with regard to the accompanying figures of which

Fig. 1 illustrates a block diagram of a possible implementation of the invention,

Fig. 2 illustrates another block diagram of a stereo device embodiment,

Fig. 3 illustrates examples of frequency band attenuations for an example of a loudspeaker with Fc = 1 kHz, and

Fig. 4 illustrates calculated total harmonic distortion versus frequency for a loudspeaker with Fc = 1.3

kHz.

[0020] The figures illustrate specific ways of implementing the present invention and are not to be construed as being limiting to other possible embodiments falling within the scope of the attached claim set.

DETAILED DESCRIPTION OF EMBODIMENTS

[0021] Fig. 1 illustrates a device embodiment in block diagram form taking an audio signal A_in as input. A miniature loudspeaker L with lower resonance frequency Fc = 1 kHz, e.g. resulting from the loudspeaker L being mounted in a mobile device cabinet which causes the lower resonance frequency Fc to be higher than the free air resonance frequency of the loudspeaker L. The large box illustrates the signal processing which is preferably implemented as program code of a processor system, e.g. the main processor of a mobile device. This processing is preferably the last part of a digital audio processing chain, since it is important that the correct signal level is detected to ensure that the resulting output signal A_out is the actual signal reaching the loudspeaker L, e.g. taking into account a possible gain in an intermediate power amplifier PA driving the loudspeaker L.

[0022] The signal processing according to the invention can be interpreted as a "band limiter", since it basically detects and attenuates, i.e. limits signal level, in a narrow frequency band around the lower resonance frequency Fc of the loudspeaker L. Thus, it is possible, within this narrow frequency range, e.g. 1/3-2/3 octave wide, to control the signal level in this range to ensure that the large diaphragm excursions which occur around Fc will be limited such that the diaphragm will not reach its maximum amplitude - not even during onsets of demanding sound signals with high energy level in the range around Fc. This reduces distortion of the loudspeaker L. Thus, better sound quality can be obtained, and/or more acoustic output can be obtained from a small loudspeaker. Interfering only with a narrow frequency band, normally only within short periods during demanding signal onsets, the audible degrading due to the attenuation is minimal if audible at all. Even if slightly audible, this effect is preferred to the severe non-linear distortion otherwise resulting.

[0023] In the example shown in Fig. 1, the band limiter is implemented as a band pass filter BPF and a band stop filter BSF, both operating on the same frequency range, namely a frequency range with a bandwidth BW of less than 1 octave, e.g. 2/3 octaves, and centred around Fc. The input signal A_in is applied to both filters BPF, BSF, and a gain control unit GC detects a peak level of an output of the band pass filter BPF, i.e. the peak level of the signal present within the frequency range around Fc. With a predetermined maximum allowed band pass peak level MBPP (e.g. -10 dB re. full scale), the gain control unit GC determines the gain factor to be applied to the output of the band pass filter BPF so as to obtain a resulting attenuation of the signal level within this band according to a predetermined attenuation scheme. The rest of the input signal A_in, i.e. the output of the band stop filter BSF, is finally added to the attenuated version of the output of the band pass filter BPF to form the output signal A_out. This output signal A_out is then digital to analog converted and applied to the power amplifier PA driving the loudspeaker L.

[0024] The attenuation scheme applied by the gain control unit GC can be selected differently, however it may be preferred that the attenuation can be graduated and adjusted based on the detected peak level. Preferably, such that a minimum possible attenuation is selected to ensure that MBPP is not exceeded, e.g. by determining the attenuation Att continuously along with the detected peak level P e.g. according to: Att = P - MBPP (all in dB), when P exceeds MBPP, otherwise Att = 0 dB is selected. Alternatively, a simple scheme is to apply zero attenuation at low signal levels and then apply a fixed attenuation, e.g. 10 dB attenuation, when the detected peak level exceeds MBPP. During most normal operation, the attenuation will thus be zero dB, i.e. the resulting processing is inactive and thus does not influence sound quality. However, during onsets with high signal levels at frequencies around Fc, the processing will effectively protect the loudspeaker L from large diaphragm excursions, and thus severe audible distortion can be eliminated.

[0025] Fig. 2 shows an example with a band limiter BL as explained in connection with Fig. 2 with Fc, BW, and MBPP as input parameters. The band limiter BL is here implemented on a processor P which also handles a pre-equalizing Eq, e.g. to compensate unequal frequency response of the loudspeakers used, of the audio input signal, here shown as a stereo PCM signal. In such case, the band limiter BL has separate path ways for the two stereo signals, here illustrated as a stereo PCM output signal to be applied to a stereo power amplifier PA which drives a set of stereo loudspeakers.

[0026] Fig. 3 shows an example of different curves of attenuation of an embodiment of a band limiter. In the illustrated example, a loudspeaker with Fc = 1 kHz is used, and thus attenuation of the input signal can be applied in a rather narrow band around this frequency, so as to obtain a resulting output signal without severe signal peaks around Fc which can lead to distortion. The upper curve show zero attenuation (0 dB), whereas the lowest curve illustrates 10 dB attenuation (-10 dB).

[0027] Fig. 4 shows a result of a calculation of total harmonic distortion THD for a miniature loudspeaker mounted in a cabinet resulting in a lower resonance frequency of Fc = 1.3 kHz (dashed vertical line). The loudspeaker plays a single tone with a duration of 200 ms, i.e. a tone burst. As seen, the maximum distortion about 7.5 %, occurs for tones with a frequency near Fc, i.e. a clearly audible distortion. Thus, attenuation of the input signal to the loudspeaker in this frequency range helps to reduce the resulting distortion. However, what is not

illustrated, and potentially more audible, is the non-linear distortion resulting from even a temporally short overload of the loudspeaker diaphragm, e.g. during onset of a tone or complex of tones in the frequency range near Fc, which will lead to a severe audible distortion clearly exceeding 10 %. Such severe distortion can be eliminated with application of the invention.

[0028] To sum up: the invention provides a method and a device for reducing distortion from an associated loudspeaker acoustically mounted such that it exhibits a lower resonance frequency Fc. A limited frequency band, including Fc, of an audio input signal is attenuated. Hereby distortion due to large diaphragm excursions in the frequency range around Fc can be eliminated. Especially, the amount of attenuation to be applied to this limited signal frequency range is determined in response to the peak signal level in this limited signal frequency range so as to only apply an attenuation when the signal level in this frequency range exceeds a predetermined level. Hereby, it is possible to take into account the properties of a miniature loudspeaker and ensure that sufficient attenuation is applied so as to avoid maximum diaphragm excursions which result in severe audible distortion. Thus, by controlling this attenuation in a narrow frequency band, e.g. 1 octave or even down to such as 1/3 octave, severe audible distortion can be eliminated, and the negative audible effect of such "band limitation" is hardly audible since the frequency range is so narrow. Most of the time the attenuation effect is completely inactive, since its effect is only required when large peak levels occur in the range near Fc.

[0029] Although the present invention has been described in connection with the specified embodiments, it should not be construed as being in any way limited to the presented examples. The scope of the present invention is to be interpreted in the light of the accompanying claim set. In the context of the claims, the terms "including" or "includes" do not exclude other possible elements or steps. Also, the mentioning of references such as "a" or "an" etc. should not be construed as excluding a plurality. The use of reference signs in the claims with respect to elements indicated in the figures shall also not be construed as limiting the scope of the invention. Furthermore, individual features mentioned in different claims, may possibly be advantageously combined, and the mentioning of these features in different claims does not exclude that a combination of features is not possible and advantageous.

Claims

1. A device arranged for application to an associated loudspeaker (L) acoustically mounted such that it exhibits a lower resonance frequency (Fc),

- an input arranged to receive an audio input signal (A_in),
- a filter section (BPF, BSF) arranged to receive the audio input signal (A_in) and to provide an attenuation in a limited frequency band thereof and generate a modified audio signal accordingly, wherein the limited frequency band includes said lower resonance frequency (Fc) of the associated loudspeaker (L),
- an output arranged to output the modified audio signal as an audio output signal (A_out), and
- a gain control unit (GC) arranged to control said attenuation in the limited frequency band, wherein the gain control (GC) unit is arranged to detect a level of the audio input signal (A_in) within the limited frequency band and to provide said attenuation according to a predetermined attenuation scheme, wherein said scheme includes detecting whether a peak level of the audio input signal (A_in) within the limited frequency band exceeds a predetermined maximum level (MBPP), and determining said attenuation accordingly to ensure that the modified audio signal does not exceed the predetermined maximum level (MBPP).

2. Device according to claim 1, wherein the limited frequency band has a bandwidth (BW) of less than 2 octaves.

3. Device according to claim 2, wherein the limited frequency band is centred around said lower resonance frequency (Fc) of the associated loudspeaker (L).

4. Device according to any of the preceding claims, wherein said predetermined maximum level (MBPP) is selected such in relation to the associated loudspeaker (L) that the audio output signal (A_out) will not cause the loudspeaker (L) to perform a diaphragm excursion exceeding its limit.

5. Device according to any of the preceding claims, wherein the filter section (BPF, BSF) comprises a band pass filter (BPF) arranged to band pass filter the audio input signal (A_in) to said limited frequency band, and a band stop filter (BSF) arranged to band stop filter the audio input signal (A_in) with the stop band being said limited frequency band.

6. Device according to any of the preceding claims, wherein the audio input signal (A_in) includes a plurality of audio channels, and wherein the audio channels are processed to form an audio output signal (A_out) with a corresponding plurality of audio channels.

7. Device according to any of the preceding claims, comprising a loudspeaker (L) acoustically mounted such that it exhibits said lower resonance frequency (Fc), and a power amplifier (PA) connected to drive

the loudspeaker (L) according to the audio output signal (A_out).

8. Device according to claim 7, wherein the loudspeaker (L) has a diaphragm area of less than 10 cm^2.

9. Device according to claim 8, wherein the loudspeaker is acoustically mounted such that the lower resonance frequency is above 100 Hz.

10. Device according to any of the preceding claims, wherein the device is one of: a portable audio device, a portable video device, and a portable player, such as a mobile phone, a tablet, a laptop, or a personal navigation device.

11. A method for reducing distortion from an associated loudspeaker (L) acoustically mounted such that it exhibits a lower resonance frequency (Fc), the method comprising attenuating a limited frequency band of an audio input signal (A_in), wherein the limited frequency band includes said lower resonance frequency (Fc), wherein the method further comprises controlling said attenuation in the limited frequency band, detecting a level of the audio input signal (A_in) within the limited frequency band and providing said attenuation according to a predetermined attenuation scheme, wherein said scheme includes detecting whether a peak level of the audio input signal (A_in) within the limited frequency band exceeds a predetermined maximum level (MBPP), and determining said attenuation accordingly to ensure that the modified audio signal does not exceed the predetermined maximum level (MBPP).

12. Computer executable program code arranged to perform the method according to claim 11.

Patentansprüche

1. Vorrichtung, die zur Anwendung an einem zugehörigen Lautsprecher (L) angeordnet ist, der akustisch montiert ist, sodass er eine niedrigere Resonanzfrequenz (Fc) aufweist,

- ein Eingang, der angeordnet ist, ein Audioeingangssignal (A_in) zu empfangen,
- ein Filterabschnitt (BPF, BSF), der angeordnet ist, das Audioeingangssignal (A_in) zu empfangen und eine Dämpfung in einem begrenzten Frequenzband davon bereitzustellen und ein entsprechend modifiziertes Audiosignal zu erzeugen, wobei das begrenzte Frequenzband die niedrigere Resonanzfrequenz (Fc) des zugehörigen Lautsprechers (L) einschließt,
- ein Ausgang, der angeordnet ist, das modifizierte Audiosignal als ein Audioausgangssignal (A_out) auszugeben, und
- eine Verstärkungssteuereinheit (GC), die angeordnet ist, die Dämpfung im begrenzten Frequenzband zu steuern, wobei die Verstärkungssteuereinheit (GC) angeordnet ist, einen Pegel des Audioeingangssignals (A_in) innerhalb des begrenzten Frequenzbandes zu ermitteln und die Dämpfung entsprechend einem vorbestimmten Dämpfungsschema bereitzustellen, wobei das Schema das Ermitteln, ob ein Spitzenpegel des Audioeingangssignals (A_in) innerhalb des begrenzten Frequenzbandes einen vorbestimmten Maximalpegel (MBPP) übersteigt, und das entsprechende Bestimmen der Dämpfung einschließt, um sicherzustellen, dass das modifizierte Audiosignal nicht den vorbestimmten Maximalpegel (MBPP) übersteigt.

2. Vorrichtung nach Anspruch 1, wobei das begrenzte Frequenzband eine Bandbreite (BW) von weniger als 2 Oktaven aufweist.

3. Vorrichtung nach Anspruch 2, wobei das begrenzte Frequenzband um die niedrigere Resonanzfrequenz (Fc) des zugehörigen Lautsprechers (L) herum zentriert ist.

4. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der vorbestimmte Maximalpegel (MBPP) so in Bezug auf den zugehörigen Lautsprecher (L) ausgewählt ist, dass das Audioausgangssignal (A_out) den Lautsprecher (L) nicht veranlasst, eine seine Grenze überschreitende Membranauslenkung auszuführen.

5. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der Filterabschnitt (BPF, BSF) einen Bandpassfilter (BPF), der angeordnet ist, das Audioeingangssignal (A_in) auf das begrenzte Frequenzband zu bandpassfiltern, und einen Bandsperrfilter (BSF) umfasst, der angeordnet ist, das Audioeingangssignal (A_in) zu sperrbandfiltern, wobei das Sperrband das begrenzte Frequenzband ist.

6. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei das Audioeingangssignal (A_in) eine Vielzahl von Audiokanälen einschließt, und wobei die Audiokanäle verarbeitet werden, um ein Audioausgangssignal (A_out) mit einer entsprechenden Vielzahl von Audiokanälen zu bilden.

7. Vorrichtung nach einem der vorhergehenden Ansprüche, die einen Lautsprecher (L), der akustisch montiert ist, sodass er eine niedrigere Resonanzfrequenz (Fc) aufweist, und einen Leistungsverstärker (PA) umfasst, der verbunden ist, um den Lautsprecher (L) entsprechend dem Audioausgangssignal (A_out) anzutreiben.

8. Vorrichtung nach Anspruch 7, wobei der Lautsprecher (L) eine Membranfläche von weniger als 10 cm^2 aufweist.

9. Vorrichtung nach Anspruch 8, wobei der Lautsprecher akustisch montiert ist, sodass die niedrigere Resonanzfrequenz über 100 Hz liegt.

10. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung eines von Folgendem ist: eine tragbare Audiovorrichtung, eine tragbare Videovorrichtung und ein tragbarer Player, wie zum Beispiel ein Mobiltelefon, ein Tablet, ein Laptop oder eine persönliche Navigationsvorrichtung.

11. Verfahren zum Verringern der Verzerrung von einem zugehörigen Lautsprecher (L), der akustisch montiert ist, sodass er eine niedrigere Resonanzfrequenz (Fc) aufweist, wobei das Verfahren das Dämpfen eines begrenzten Frequenzbandes eines Audioeingangssignals (A_in) umfasst, wobei das begrenzte Frequenzband die niedrigere Resonanzfrequenz (Fc) einschließt, wobei das Verfahren ferner das Steuern der Dämpfung im begrenzten Frequenzband, das Ermitteln eines Pegels des Audioeingangssignals (A_in) innerhalb des begrenzten Frequenzbandes und das Bereitstellen der Dämpfung entsprechend einem vorbestimmten Dämpfungsschemas umfasst, wobei das Schema das Ermitteln, ob ein Spitzenpegel des Audioeingangssignals (A_in) innerhalb des begrenzten Frequenzbandes einen vorbestimmten Maximalpegel (MBPP) übersteigt, und das entsprechende Ermitteln der Dämpfung einschließt, um sicherzustellen, dass das modifizierte Audiosignal nicht den vorbestimmten Maximalpegel (MBPP) übersteigt.

12. Computerausführbarer Programmcode, der angeordnet ist, das Verfahren nach Anspruch 11 auszuführen.

Revendications

1. Dispositif prévu pour application à un haut-parleur associé (L) étant monté de manière acoustique de façon à ce qu'il présente une fréquence de résonance inférieure (Fc),

- un signal agencé pour recevoir un signal d'entrée audio (A_in),
- une section de filtre (BPF, BSF) agencée pour recevoir le signal d'entrée audio (A_in) et pour fournir une atténuation dans une bande de fréquence limitée de celui-ci et générer un signal audio modifié en conséquence, dans laquelle la bande de fréquence limitée comprend ladite fréquence de résonance inférieure (Fc) du haut-parleur associé (L),
une sortie agencée pour faire sortir le signal audio modifié comme un signal de sortie audio (A_out), et
- une unité de contrôle de gain (CG) agencée de manière à contrôler ladite atténuation dans la bande de fréquence limitée, dans laquelle l'unité de contrôle de gain (CG) est agencée pour détecter un niveau du signal d'entrée audio (A_in) dans la bande de fréquence limitée et pour fournir ladite atténuation selon un schéma d'atténuation prédéterminé, dans lequel ledit schéma comprend la détection si un niveau le plus haut du signal d'entrée audio (A_in) dans la bande de fréquence limitée dépasse un niveau maximum prédéterminé (MBPP), et déterminer ladite atténuation en conséquence pour assurer que le signal audio modifié n'excède pas le niveau maximum prédéterminé (MBPP).

2. Dispositif selon la revendication 1, dans lequel la bande de fréquence limitée comprend une largeur de bande (BW) de moins de deux octaves.

3. Dispositif selon la revendication 2, dans lequel la bande de fréquence limitée est centrée autour de ladite fréquence de résonance inférieure (Fc) du haut-parleur associé (L).

4. Dispositif selon l'une quelconque des revendications précédentes, dans lequel ledit niveau maximum prédéterminé (MBPP) est choisi par rapport au haut-parleur associé (L) pour éviter que le signal de sortie audio (A_out) ne cause pas une excursion de la membrane du haut-parleur (L) dépassant sa limite.

5. Dispositif selon l'une quelconque des revendications précédentes, dans lequel la section de filtre (BPF, BSF) comprend un filtre passe-bande (BPF) agencé pour filtrer en passe-bande le signal d'entrée audio (A_in) pour ladite bande de fréquence limitée, et un filtre coupe-bande (BSF) agencé pour filtrer en coupe-bande le signal d'entrée audio (A_in) avec la coupe-bande qui est ladite bande de fréquence limitée.

6. Dispositif selon l'une quelconque des revendications précédentes, dans lequel le signal d'entrée audio (A_in) comprend plusieurs voies audios, et dans lequel les voies audios sont traitées pour réaliser un signal de sortie audio (A_out) avec plusieurs voies audios correspondantes.

7. Dispositif selon l'une quelconque des revendications précédentes comprenant un haut-parleur (L) étant monté de manière acoustique de façon à ce qu'il présente ladite fréquence de résonance inférieure (Fc), et un amplificateur de puissance (AP) connecté pour piloter le haut-parleur (L) selon le signal de sor-

tie audio (A_out).

8. Dispositif selon la revendication 7, dans lequel le haut-parleur (L) comprend une surface de membrane inférieure à 10 cm^2.

9. Dispositif selon la revendication 8, dans lequel le haut-parleur est monté de manière acoustique de façon à ce que ladite fréquence de résonance inférieure soit supérieure à 100 Hz.

10. Dispositif selon l'une quelconque des revendications précédentes, dans lequel le dispositif est l'un des suivants : un appareil audio portable, un appareil vidéo portable et un lecteur portable, tel qu'un téléphone portable, une tablette, un ordinateur portable ou un appareil de navigation personnel.

11. Procédé pour réduire la distorsion d'un haut-parleur associé (L) qui est monté de manière acoustique de façon à ce qu'il présente une fréquence de résonance inférieure (Fc), le procédé comprend une atténuation dans une bande de fréquence limitée d'un signal d'entrée audio (A_in), dans lequel la bande de fréquence limitée comprend ladite fréquence de résonance inférieure (Fc), dans lequel le procédé comprend encore un contrôle de ladite atténuation dans la bande de fréquence limitée, et détecter un niveau du signal d'entrée audio (A_in) dans la bande de fréquence limitée et fournir ladite atténuation selon un schéma d'atténuation prédéterminé, dans lequel ledit schéma comprend la détection si un plus haut niveau du signal d'entrée audio (A_in) dans la bande de fréquence limitée dépasse un niveau maximum prédéterminé (MBPP), et par conséquent déterminer ladite atténuation pour assurer que le signal audio modifié ne dépasse pas le niveau maximum prédéterminé (MBPP).

12. Code de programme exécutable par ordinateur pour réaliser le procédé selon la revendication 11.

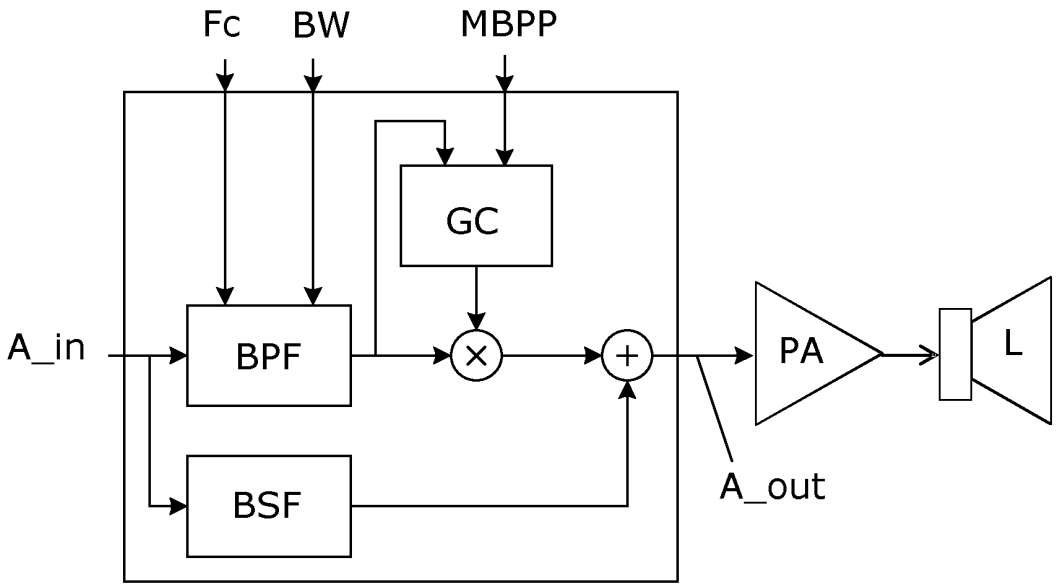
Fc
BW
MBPP
GC
A_in
BPF
BSF
PA
L
A_out

Fig. 1

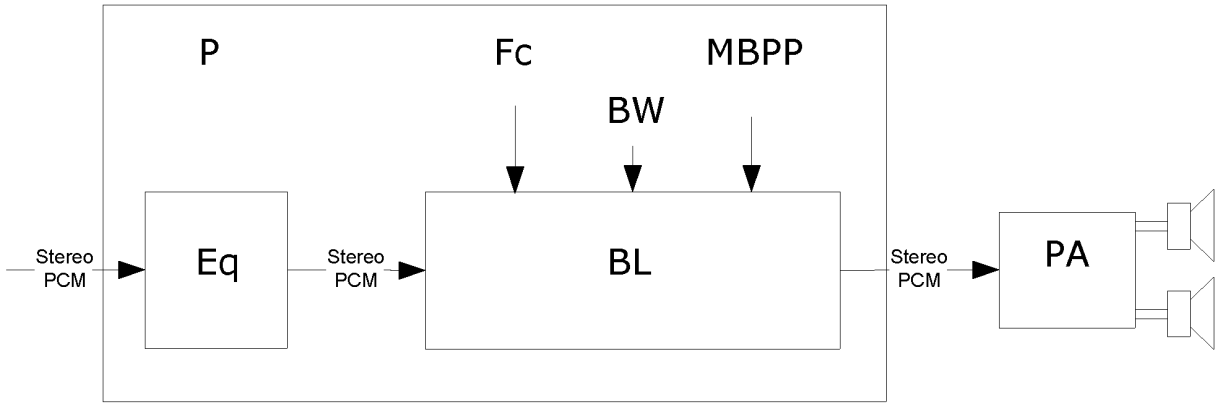
P
Fc
MBPP
BW
Stereo PCM
Eq
Stereo PCM
BL
Stereo PCM
PA

Fig. 2

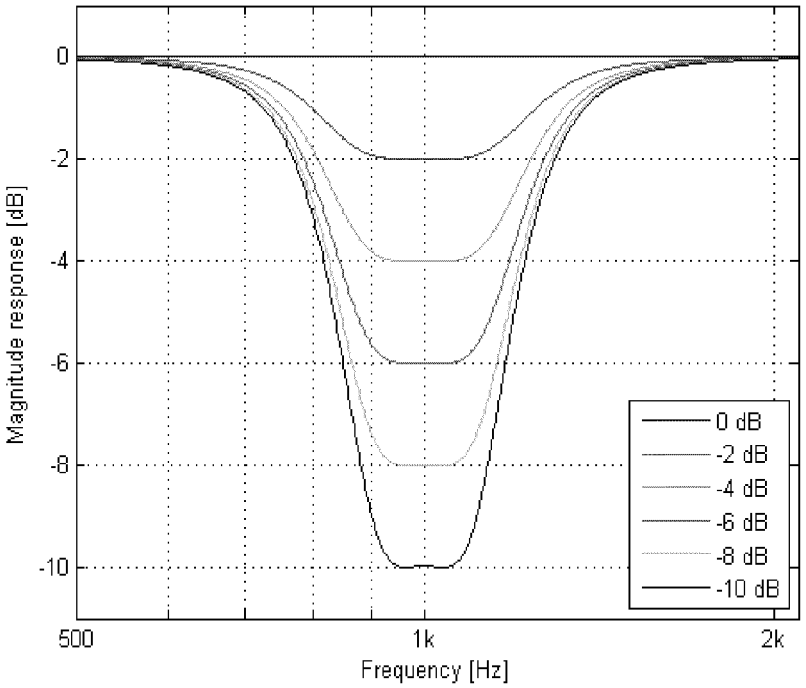
0
-2
-4
-6
-8
-10
Magnitude response [dB]
500
1k
2k
Frequency [Hz]
0 dB
-2 dB
-4 dB
-6 dB
-8 dB
-10 dB

Fig. 3

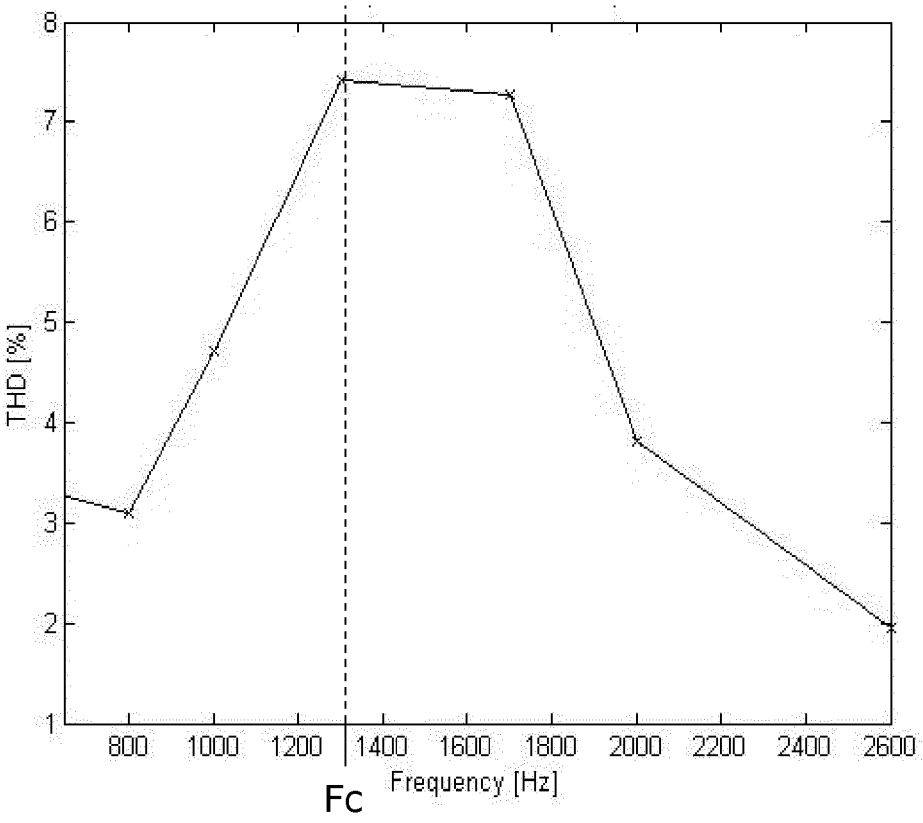
8
7
6
5
4
3
2
1
THD [%]
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
Frequency [Hz]
Fc

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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