(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 128 360 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
29.08.2001 Bulletin 2001/35

(51) Int Cl.7: **G10K 15/02**

(21) Application number: **01830129.1**

(22) Date of filing: **23.02.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **24.02.2000 IT TO000180**

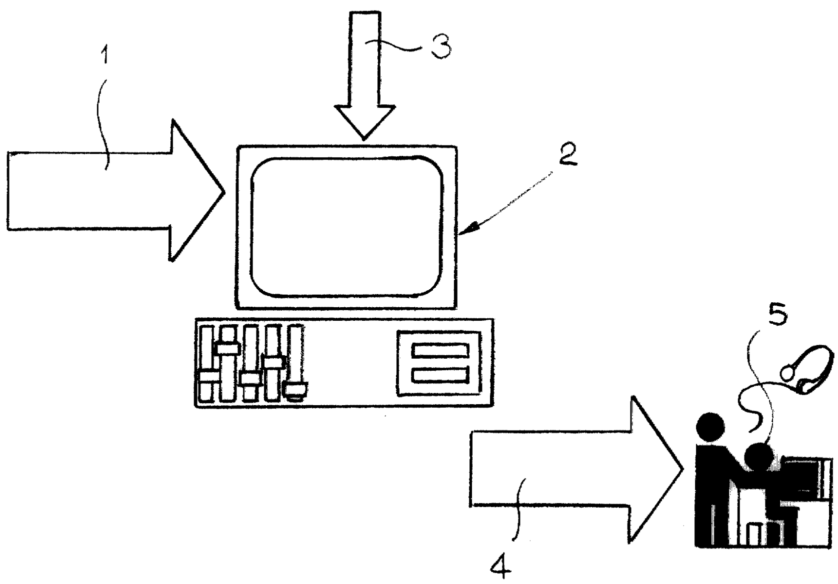
(71) Applicant: **C.R.F. Società Consortile per Azioni**
10043 Orbassano (TO) (IT)

(72) Inventor: **Irato, Giorgio,**
CRF Societa Consortile per Azioni
10043 Orbassano, Torino (IT)

(74) Representative: **Notaro, Giancarlo et al**
c/o Buzzi, Notaro & Antonielli d'Oulx srl,
Corso Fiume 6
10133 Torino (IT)

(54) Method for optimizing the acoustic quality of an acoustic signal on the basis of psyscho-acoustic parameters

(57) Procedure for the optimisation of the acoustic quality, comprising the steps of arranging media (1) for playing a recorded sound or for synthesising an artificial sound, manipulating (2, 3) the sound thus generated so to confer a predefined value of at least one psycho-acoustic parameter, such as, for example, roughness, loudness, sharpness or impulsiveness, subjecting the sound thus manipulated to the subjective judgement of a plurality of panels of statistically representative experimental individuals, processing the subjective evaluations of the panels, in association to the psycho-acoustic parameters conferred to the sounds which are the object of the evaluation, in such a way to identify optimisation values of the perceived sound quality. In the case of application to the sound perceived inside the passenger compartment of a moving motor vehicle, sound processing media are arranged inside the motor vehicle for conferring optimal values of one or more previously defined psycho-acoustic parameters to the perceived sound.



EP 1 128 360 A2

Description

[0001] This invention relates to a procedure for optimising the acoustic quality of an acoustic signal. The procedure is particularly suitable for being applied to the optimisation of the sound perceived inside the passenger compartment of a moving motor vehicle, also if naturally other applications are not excluded.

[0002] The optimisation of acoustic quality in the passenger compartment of a motor vehicle has been demonstrated as being determining both from an "aesthetic" point of view, consequently influencing the purchasing decision of the potential customer, and in terms of comfort and safety, considering that it contributes towards reducing the stressing components in the interaction between humans and motor vehicles.

[0003] Purpose of this invention is to permit a substantial progress in the design and optimisation of the acoustic quality of an acoustic signal.

[0004] The main characteristic of the procedure according to this invention is illustrated in the accompanying claim 1. The specific application of optimisation to the sound perceived inside the passenger compartment of a motor vehicle, on the other hand, is illustrated in accompanying claim 2.

[0005] The fundamental concept underlying this invention consists in comprehending that a development is required from the traditional sound synthesis method, based on controlling the physical properties of sound, to a procedure based on directly controlling the psycho-acoustic characteristics of sound. In practice, in addition to the usual interventions on frequency, amplitude, development in time, additional interventions according to this invention include psycho-acoustic parameters such as loudness, roughness, sharpness, impulsiveness and any other psycho-acoustic variables.

[0006] A form of embodiment according to this invention focuses on the "roughness" parameter. This parameter is discussed and defined in literature as a "sensation of dissonance" (R. Plomp, *Aspects of tone sensation,* Academic Press, 1976). On the basis of experimental results, the applicant identified a set of physical characteristics on which to intervene to control the output roughness. Particularly, algorithms have been selected for operating on amplitude modulations. The fundamental principle of roughness synthesis is based on a particular filtering operation which separates the area of the frequencies concerned from the residual part of the spectrum. This "isolated" area is manipulated by means of active or passive roughness component filtering, on the basis of the so-called "roughness curve" defined by Plomp (see above).

[0007] The portion with increased or decreased roughness is then combined again with its completion to obtain the complete sample with the new overall value of roughness. The necessary filtering algorithms can be optimised in terms of computation and in terms of filtering quality, to obtain a practically "perfect" signal after manipulation without any form of phase distortion nor filter output "contour effects".

[0008] The following details on the theoretical bases of the procedure according to this invention for better understanding.

[0009] The classic definition of "roughness" (considered as an extension of the musical concept of "dissonance") is based on the presence of beats (amplitude modulations) overlaying a sinusoidal background sound (fundamental), with a modulation frequency which is smaller than the width of the critical band to which the fundamental belongs (see publication mentioned above). According to Plomp, the maximum roughness curve which can be obtained by the interference between two pure sounds is reached when the relationship of their frequencies is 0.23 times the width of the critical band of the fundamental (in musical terms: one semitone).

[0010] In a recent work (D. Pressnitzer, S. McAdams, *Influence of phase effects of roughness modelling,* Proceedings I.C.M.C. 97, Toessaloniki, Greece, September 1997), some effects of the phase relationships on the perception of roughness, by overlaying three pure sounds (pseudo amplitude modulation), at least under 8 kHz.

[0011] Currently, no satisfying perceptive model of roughness of complex sounds (narrow band sounds and quasi harmonic sounds) is currently described in literature.

[0012] The procedure according to this invention employs a roughness synthesis module which is based on the following logical steps:

1. Extraction of a frequency band: the frequency band which is analysed and manipulated is extracted in an efficient way from the "original" acoustic signal (recorded or synthesised). The band amplitude is determined according to Plomp's roughness curve.
2. Analysis of the components of a phase modulation and of an amplitude modulation: this step is required to permit intervening on the physical characteristics responsible for the most known effects on roughness perception (as mentioned above, there is currently no available, satisfying explanation of "phase roughness"). In fact, this splitting of the signal offers the possibility of operating also on phase modulation, once that its relationship with perception is sufficiently clear.
3. Extraction of the roughness component: the roughness component in the defined band is extracted using Plomp's roughness curve as a filter.
4. Quantification of the roughness component. At this point, defining a correct measurement of the "amplitude roughness" in the extracted band is relatively simple. The relationship between the values of the roughness component alone and inside the signal can be considered as a starting point.

5. Modification of the roughness value: the local roughness can consequently be modified by recomposing the roughness component and the "non roughness" component after setting a variable gain on the roughness component alone. This operation (particularly if repeated across different bands) requires subsequent overall correction of loudness of the signal.

[0013] The procedure according to this invention may be firstly applied in laboratory. Its use in this case requires interfacing with systems for playing recorded sounds or systems for the synthesis of artificial sounds (inputs) and with other systems for playing sounds for the administration of sounds obtained after manipulation to the ears of a listener (output).

[0014] The accompanying figure schematically illustrates the system used. In the figure, number 1 indicates the input acoustic signal to a processor 2 by means of which the required psycho-acoustic characteristics (3) are introduced (controlled), according to the criteria illustrated above, as an example, in the case of the roughness parameter. The acoustic signal 4 thus manipulated, output from the processor 2, is submitted to the subjective judgement of a plurality of panels formed by statistically representative experimental individuals 5. For this purpose, very high fidelity stereophonic headphones can be used with suitable amplification and sound signal conditioning systems.

[0015] The method of use of this system is based on subjective listening test and sound evaluation methods. In essence, these methods consist in interviewing the panel members by means of specific questionnaires or other subjective evaluation sampling instruments, on the experimental physiological/psychological effects during listening to acoustic specimens played employing the selected instruments. Such data are the base for subsequent statistic processing which form a description of the mean behaviour, the deviations and the predictive models of the subjective reactions of the chosen population. The results of such investigations provide the information required to defined "acoustic design" specifications of the product, aimed at improving the perceived quality. In this context, dominated by subjective behavioural variables, the use of instruments such as the one described above, capable of manipulating the acoustic signal (by a laboratory operator or by the experimental individual) directly on the parameters conceived for quantifying characteristics of subjective acoustic perception, is crucial.

[0016] When applying the procedure according to this invention to the optimisation of the acoustic quality perceived inside the passenger compartment of a motor vehicle, a suitably programmed and interfaced digital signal processor (DSP) is employed to introduce in the sound perceived inside the passenger compartment the required psycho-acoustic characteristics. In this way, the parameteric management of the qualitative characteristics of the sound means that the user can modify the sound, at least in part, according to personal tastes and requirements, obtaining a direct access to the physiological and psychological effects of the acoustic environment in driving conditions.

[0017] The results thus obtained, in addition to having an "aesthetic" value which can effect the purchasing choice of the potential buyer, also invest the context of comfort and safety, since the results would allow reduction of the stressing components in the interaction between humans and motor vehicles.

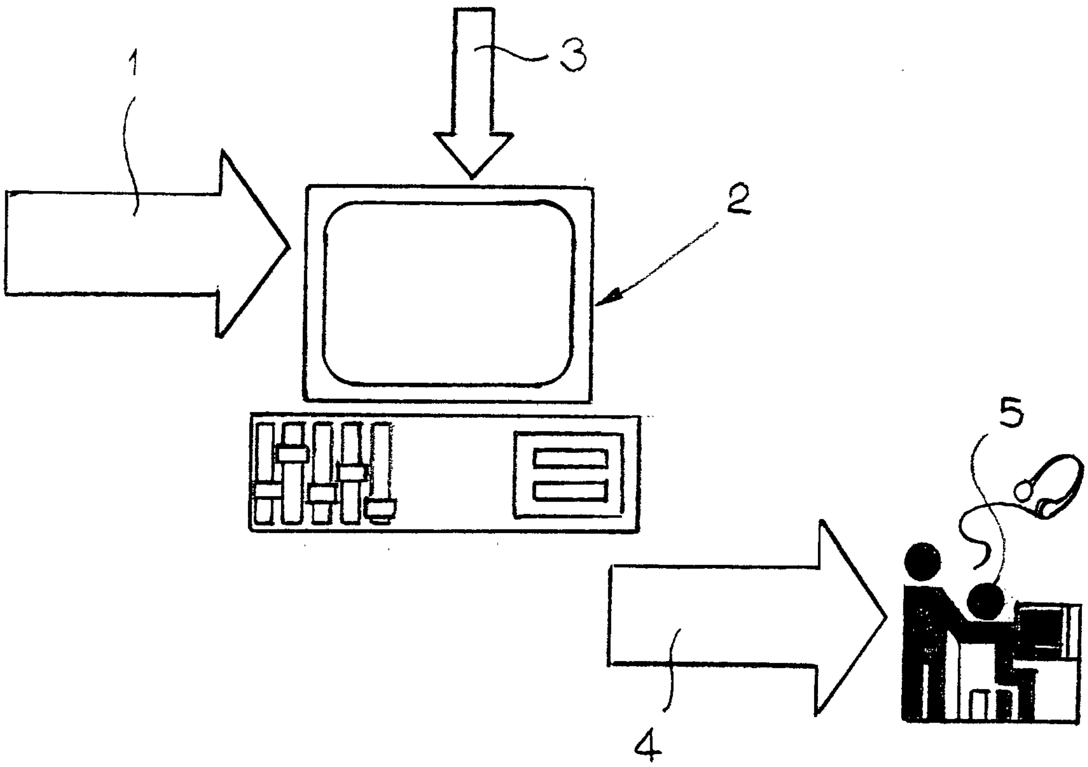
[0018] Naturally, numerous changes can be implemented to the forms of embodiment of the invention herein envisaged, all comprised within the context of the concept characterising this invention, as defined by the following claims.

Claims

1. Procedure for the optimisation of the acoustic quality of an acoustic signal characterised in that it comprises the steps of:

- arranging media (1) for playing a recorded sound or for synthesising an artificial sound,
- manipulating the sound thus generated (2, 3) so to confer a predefined value of at least one psycho-acoustic parameter, such as roughness, loudness, sharpness or impulsiveness,
- subjecting the sound thus manipulated to the subjective judgement of a plurality of panels of statistically representative experimental individuals,
- processing the subjective evaluations of the panels, in association to the psycho-acoustic parameters conferred to the sounds which are the object of the evaluation, in such a way to identify optimisation values of the perceived sound quality.

2. Procedure according to claim 1 characterised in that it is applied to the sound perceived inside the passenger compartment of a moving motor vehicle and by the fact that sound processing media are arranged inside the motor vehicle for conferring optimal values of one or more psycho-acoustic parameters to the perceived sound previously defined according to the procedure described in claim 1.


1
2
3
4
5