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

(11) EP 2 436 574 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**04.04.2012 Bulletin 2012/14**

(51) Int Cl.:
***B61F 9/00** (2006.01)* ***B61L 15/00** (2006.01)*

(21) Application number: **11250239.8**

(22) Date of filing: **02.03.2011**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**

(30) Priority: **01.10.2010 JP 2010223884**

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(54) **State monitoring apparatus and state monitoring method of railway car, and railway car**

(57) The invention provides a state monitoring apparatus and a state monitoring method of a railway car, and a railway car capable of detecting or sensing a defect prior to the occurrence of a serious defect without having to set up thresholds corresponding to various traveling speed patterns. The railway car comprises a vibration detector for detecting a vibration of the railway car, and a defect detection system for detecting defect of the railway car using a signal output from the vibration detector, wherein the vibration detector includes a vibration detection means for detecting the vibration of the railway car from a vibration acceleration of the car body, and the defect detection system includes a filtering means for detecting two or more different frequency band components based on the car body vibration acceleration from the vibration detection means, an amplitude ratio computing means for computing an amplitude ratio of two or more car body vibration accelerations detected via the filtering means, and a defect determination processing means for determining defect based on the result of the amplitude ratio computing means.

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# Description

## BACKGROUND OF THE INVENTION

### Field of the invention

**[0001]** The present invention relates to a state monitoring apparatus and a state monitoring method of a railway car for monitoring a defective state of a railway car traveling on tracks, especially the defect of tracks and cars, and a railway car.

### Description of the related art

**[0002]** The prior art state monitoring apparatus (defect detection system) of a railway car teaches detecting a vibration acceleration in a perpendicular direction via a sensor disposed on a floor of a car body above a spring device of the car, detecting a maximum value of the absolute value within a predetermined frequency range of the detected vibration acceleration, comparing the maximum value with threshold limit values (hereinafter abbreviated as threshold) stored in response to respective traveling speed patterns, wherein when the maximum value of the absolute value of the vibration acceleration in the perpendicular direction within the frequency range exceeds a threshold limit value corresponding to the traveling speed detected during driving of the car, it is determined that the railway car has derailed (refer for example to patent document 1; WO 00/09379).

**[0003]** However, the disclosed prior art is aimed at detecting derailing of the railway car, and it does not consider detecting any defect of the car prior to detecting derailing. Further, according to the prior art, the threshold values corresponding to the traveling speeds are values obtained by driving the cars in the respective tracks according to respective driving patterns. In other words, the railway car must be driven along predetermined tracks while changing the traveling speed thereof to acquire the threshold limit values of the perpendicular acceleration (threshold) determined for each of the predetermined speeds as thresholds for detecting derailing, which requires time, and the storage means for storing the thresholds must have a large capacity, and the system becomes complex since traveling speed is required for selecting the threshold. A predetermined threshold refers to a defect detection reference value for determining the state of the railway car, that is, the defect of the railway car.

## SUMMARY OF THE INVENTION

**[0004]** In consideration of the problems of the prior art mentioned above, the present invention aims at solving the problems of the prior art by providing a state monitoring apparatus and a state monitoring method of a railway car capable of detecting any defect to be set before a serious defect occurs, without requiring thresholds for respective traveling speed patterns, and a railway car.

**[0005]** In order to achieve the above object, the present invention provides a railway car comprising a vibration detector for detecting a vibration of the railway car, and a defect detection system for detecting defect of the railway car using a signal output from the vibration detector, wherein the vibration detector includes a vibration detection means for detecting the vibration of the railway car from a vibration acceleration of the car body, and the defect detection system includes a filtering means for detecting two different frequency band components based on the car body vibration acceleration from the vibration detectionmeans, an amplitude ratio computingmeans for computing an amplitude ratio of two or more car body vibration accelerations detected via the filtering means, and a defect determination processing means for determining defect based on the result of the amplitude ratio computing means.

**[0006]** Further, the railway car characterizes in that the amplitude ratio computing means of the defect detection system comprises a window filer for extracting a fixed amount of acceleration signals from the car body vibration acceleration, and a computing section for computing an RMS (root mean square) value of the car body acceleration signals extracted via the window filter or a maximum value thereof, wherein the filtering means includes a bandpass filter.

**[0007]** Further, the railway car comprises a defect determination processing means for determining whether the amplitude ratio has exceeded a threshold of a predetermined number of times within a predetermined time.

**[0008]** According further to the railway car, the defect detection system is equipped with a filtering means for detecting three or more frequency band components from the car body vibration acceleration detected via the vibration detecting means, an amplitude ratio computingmeans for computing the amplitude ratio from a combination of three or more of said car body accelerations detected via the filtering means, and a defect determination means for determining defect from the result of the amplitude ratio computing means.

**[0009]** Further, the railway car is equipped with a traveling speed detector for detecting the traveling speed, and a filter coefficient conversion unit for automatically setting a cutoff frequency of the filtering means of the detect detection system using signals detected via the traveling speed detector.

**[0010]** According to the present invention, the defect of the state of a railway car can be monitored accurately and reliably.

**[0011]** Further, the monitoring of the defect can be performed without determining thresholds corresponding to respective traveling speed patterns as according to the prior art.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]**

FIG. 1 is a system con figuration diagram of a state monitoring apparatus of a railway car according to one preferred embodiment (embodiment 1) of the present invention;

Fig. 2 is a flow chart of the defect detection/determination process showing the flow of signal processing of the defect detection system according to Fig. 1;

Fig. 3 illustrates an example of applying a window filter to the signal of the state monitoring apparatus and an example of computing an amplitude ratio of the RMS value in a railway car according to the present invention;

Fig. 4 is a view showing a threshold determination process and a defect determination process according to one embodiment of the state monitoring apparatus of a railway car according to the present invention;

Figs. 5 (a) and 5 (b) show the traveling speed of a car and the time history waveform of a car body lateral vibration acceleration including an impulse vibration when the car passes a branch;

Figs. 6 (a) , 6 (b) and 6 (c) are views showing the time history waveform of a car body lateral vibration acceleration including an abnormal vibration caused by the failure of a bogie component or the like, and power spectral densities;

Fig. 7 is a view showing the time history waveform of the car body lateral vibration acceleration including an abnormal vibration caused by the failure of a bogie component or the like being subjected to filtering process, and the RMS values;

Fig. 8 is a view showing an example of application of the RMS value amplitude ratio to the RMS values of Fig. 7;

Figs. 9 (a) , 9 (b) and 9 (c) are views showing the traveling speed of the car, the time history waveform of a car body lateral vibration acceleration including an abnormal vibration caused by meandering or the like, and power spectral densities;

Fig. 10 shows the time history waveform of the car body lateral vibration acceleration including an abnormal vibration caused by meandering or the like being subjected to filtering process, and the RMS values;

Fig. 11 shows an example of application of the RMS value amplitude ratio to the RMS values of Fig. 10;

Fig. 12 shows a threshold determination process and a defect determination process of a state monitoring apparatus of a railway car according to yet another embodiment (embodiment 2) of the present invention;

Fig. 13 shows an example of application of the RMS value amplitude ratio to the vibration waveform of Fig. 12;

Fig. 14 is a system configuration diagram of a state monitoring apparatus of a railway car showing yet another embodiment (embodiment 3) of the present invention;

Fig. 15 is a flow chart of the defect detection/determination process illustrating the flow of signal processing of the defect detection system according to Fig. 14;

Fig. 16 is a view showing a filter application example corresponding to traveling speed conditions;

Fig. 17 is a system configuration diagram of a state monitoring apparatus of a railway car showing yet another embodiment (embodiment 4) of the present invention;

Fig. 18 is a flow chart of the defect detection/determination process illustrating the flow of signal processing of the defect detection system according to Fig. 17;

Fig. 19 is a view showing an example of applying a window filter to the signal of the state monitoring apparatus and an example of computing an amplitude ratio of the RMS value in a railway car shown in Fig. 17;

Fig. 20 is a system configuration diagram of a state monitoring apparatus of a railway car showing yet another embodiment (embodiment 5) of the present invention;

Fig. 21 is a flow chart of the defect detection/determination process illustrating the flow of signal processing of the defect detection system according to Fig. 20;

Figs. 22(a) and 22(b) are views showing an example of application of filters corresponding to command signals; and

Fig. 23 is a view showing an example of application of filters corresponding to command signals, wherein a normal state and an abnormal state are illustrated.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

**[0013]** Now, the preferred embodiments of the present invention will be described in detail with reference to the drawings. In the drawings, the components having common functions are denoted by the same reference numbers, and detailed descriptions thereof are omitted.

[Embodiment 1]

**[0014]** Fig. 1 is a system configuration diagram showing an example of configuration of a state monitoring apparatus of a railway car according to a preferred embodiment (embodiment 1) of the present invention.

**[0015]** In Fig. 1, a car 7 driven on tracks (railway tracks) 1 is composed of a car body 6 and a bogie 5. The car body 6 is mounted on bogies 5 (only one bogie is shown) via air springs 4. The bogie 5 is composed of a bogie frame 3 and wheelsets 2. An axle box 9 as bearing housing for the wheelset 2 is attached via an axle spring 8 to the bogie frame 3. The wheelsets 2 are capable of performing rotary motion.

**[0016]** An acceleration meter can be disposed on the car body 6, the bogie 5 or other components, but in the present embodiment, the acceleration meter is disposed on the car body 6.

**[0017]** Furthermore, the direction of acceleration can be in any of the following directions, front and rear (lengthwise) sides in the horizontal direction, left and right (lateral) sides in the horizontal direction, or perpendicular direction, but in the present embodiment, the acceleration in the left and right (lateral) sides in the horizontal direction is described.

**[0018]** The present invention can be equipped with a filtering section for detecting two or more different frequency band components, but in the present embodiment, the railway car is equipped with a filtering section for detecting two different frequency band components.

**[0019]** Moreover, the present invention can be equipped with a pluralityof vibrationdetectors, but in the present embodiments, a single vibration detector is disposed.

**[0020]** A car body acceleration meter 100 is disposed above a floor surface of the car body 6 of the car 7 for measuring a lateral vibration acceleration of the car body 6. The car body acceleration meter 100 is equipped with a car body acceleration detector 11 for detecting a voltage 21a of the car body acceleration meter 100. The voltage 21a of the car body acceleration meter 100 is detected as a car body lateral vibration acceleration signal 22a via the car body acceleration detector 11. In other words, the car body acceleration detector 11 including the car body acceleration meter 100 constitutes a vibration detecting means for detecting the vibration of the car 7.

**[0021]** A defect detection system 20 for detecting the defect of the car 7 is electrically connected to the car body acceleration detector 11 and receives a car body lateral vibration acceleration signal 22a from the car body acceleration detector 11, based on which the defect of the car is detected.

**[0022]** In other words, the system is a defect detection system for detecting the defect of a railway car based on the car body lateral vibration acceleration signal including the vibration information of the car body of the railway car, wherein the actual example of the system is composed of a filtering section A 12 and a filtering section B 13 connected to the car body acceleration detector 11 and receiving car body lateral vibration acceleration signals 22a, RMS value computing sections A 14 and B 15 for receiving a car body lateral vibration acceleration signal 23a and a car body lateral vibration acceleration signal 24a of varied frequency bands extracted via these filtering sections, an amplitude ratio computing section 16 for computing the amplitude ratio of an RMS signal 25a and an RMS signal 26a computed via the RMS value computing sections and outputting an amplitude ratio signal 27a, a threshold determination section 17 for receiving the amplitude ratio signal 27a and a threshold signal 30a stored in advance in a threshold storage section 10 to execute a threshold determination process and outputting a threshold determination process signal 28a, a defect determination section 18 for receiving the threshold determination process signal 28a to execute a defect determination process and outputting a defect determination process signal 29a, and a determination result output section 19 for receiving the defect determination process signal 29a and outputting the determination result. The defect detection system 20 is disposed on the car body 6, but the installation position can be any position as long as the determination result can be confirmed. When performing processing via the RMS value computing sections A14 and B15, the car body lateral vibration acceleration is extracted for a predetermined time via a window filter (described in detail later) from the signals having passed through the filtering sections A 12 and B 13.

**[0023]** Now, the amplitude ratio computing section 16 of the defect detection system 20 constitutes an amplitude ratio computing means for computing an amplitude ratio between the car body lateral vibration acceleration signal 23a and the car body lateral vibration acceleration 24a, based on the RMS signal 25a from the RMS value computing section A14 and the RMS signal 26a from the RMS value computing section B15. The threshold determination section 17 constitutes a threshold determination process means for determining the above-mentioned amplitude ratio and the threshold signal 30a stored in advance in the threshold storage section 10 based on the amplitude ratio signal 27a from the amplitude ratio computing section 16, and the defect determination section 18 and the determination result output section 19 constitutes a defect determination process means for determining defect from the result obtained via the threshold determination process signal 28a of the threshold determination section 17 and the defect determination process signal 29a of the defect determination section 18.

**[0024]** Regarding the threshold determination process via the threshold determination section 17, a storage means is disposed for storing a threshold (described in detail later) for performing comparison with the amplitude ratio signal obtained via the amplitude ratio computing process. Now, the value of RMS (root mean square) is a square root of an arithmetic average of the squares of original values, and the calculation process thereof is well known, so it will not be described in detail.

**[0025]** Next, with reference to Figs. 2 through 4, the process flow of the operation of a defect detection system 20 in a state monitoring apparatus of a railway car according to one preferred embodiment of the present invention, including a filtering process, an RMS value computing process, an amplitude ratio computing process, a threshold determination process and a defect determination process, will be described in detail.

**[0026]** Fig. 2 is a flow showing the defect detecting/determining process of the defect detection system 20. The flow from input of the car body acceleration signal to the output of the defect detection result will be described with reference to the drawing. In Fig. 2, "s" refers to steps.

**[0027]** At first, the defect detection system 20 receives input (s1) of the car body lateral vibration acceleration signal 22a from the car body acceleration detector 11 in the filtering sections A 12 and B 13, executes a filtering process A for extracting a certain frequency bandwidth A from the signal (s2), executes a filtering process B for extracting a certain frequency bandwidth B from the signal (s3), and executes a process for filtering a certain amount of signal counts using a window filter (s4).

**[0028]** Next, the defect detection system 20 executes an RMS value computing process to the car body lateral vibration acceleration signals 23a and 24a extracted via the filtering sections 12A and 13A in the RMS computing sections A14 and B15 (s5). The RMS value is the square root of an arithmetic average of the squares of original values from a group of signals as object, which shows one index of the magnitude of variation.

**[0029]** Further, the defect detection system 20 executes calculation in the amplitude ratio computing section 16 (S6) of the amplitude ratio of the RMS value of the car body lateral vibration acceleration signal 23a and the RMS value of the car body lateral vibration acceleration signal 24a based on the RMS values 25a and 26a of the car body lateral vibration acceleration signals computed via the RMS computing sections A14 and B15, and outputs an amplitude ratio computing signal 27a.

**[0030]** Next, the defect detection system 20 executes a threshold determination process in the threshold determination section 17 for the amplitude ratio signal 27a based on the amplitude ratio computed in the amplitude ratio computing section 16 and the threshold determined in advance (s7) , and outputs a threshold determination process signal 28a. Now, the predetermined threshold set in advance refers to a defect determination threshold set to determine whether the amplitude ratio falls within a normal range or within a defect range. The actual examples of which will be described in detail later.

**[0031]** Finally, the defect detection system 20 determines whether defect has occurred or not based on the threshold determination result (threshold determination process signal 28a) with respect to the amplitude ratio signal 27a in the defect detection section 18 (s8), and outputs a defect determination process signal 29a. Then, the determination result output section 19 outputs a defect determination result based on the defect determination process signal 29a (s9). The defect determination result is notified via a means not shown for outputting an alarm signal indicating the defect determination result to a device for confirming defect disposed at a location where the defect can be confirmed within the car 7, that is, in the driver's cabin of the car body 6 where the driver can easily confirm the defect. The notice of defect can be performed for example by displaying a notice on a display unit or by outputting an alarm sound via a speaker disposed on an apparatus.

**[0032]** Fig. 3 shows an example of application of filtering processing and application of a widow filter to the aforementioned car body lateral vibration acceleration signal (waveform) 22a and an example of computing the amplitude ratio of the RMS value, which corresponds to processes s2 through s6 of Fig. 2.

**[0033]** A filter A 42 of the filtering section A 12 and a filter B 43 of the filtering section B 13 are bandpass filters each having certain frequency bandwidths for extracting a car body lateral vibration acceleration A 51 (corresponding to the car body lateral vibration acceleration signal 23a of Fig. 1) and a car body lateral vibration acceleration B 52 (corresponding to the car body lateral vibration acceleration signal 24a of Fig. 1) from a car body lateral vibration acceleration 41 (corresponding to the car body lateral vibration acceleration signal 22a of Fig. 1).

**[0034]** In other words, according to the present embodiment, the filtering section constituting the filtering means for extracting two varied frequency band components from the car body vibration acceleration signal is composed of at least two filters. These filters are composed of bandpass filters having different frequency band regions (frequency bandwidths). In the present embodiment, the frequency band uses bandpass filters having frequency bands with portions thereof overlapped, but is not restricted thereto. Window filters 50 and 50 are used in the subsequent stage of bandpass filters A 42 and B 43 of filtering sections A 12 and B 13.

**[0035]** The window filter 50 has a certain length (time) , and within that length, car body lateral vibration acceleration RMS values A 53 and B 54 are computed based on the car body lateral vibration acceleration signals A 51 and B 52 having certain frequency bandwidths.

**[0036]** An RMS value amplitude ratio 55 is computed as a ratio (Y/X) of a car body lateral vibration acceleration RMS value B 54 (Y, for example) with respect to a car body lateral vibration acceleration RMS value A 53 (X, for example). Further, the acceleration signal within the window filter 50 is varied momentarily, so that the car body lateral vibration acceleration RMS value A 53, the car body lateral vibration acceleration RMS value B 54 and the RMS value amplitude ratio 55 are varied momentarily without taking fixed values.

**[0037]** Here, the RMS value is taken as an example, but the same process can be applied for computing the maximum value, wherein if a maximum value of amplitude ratio is to be computed, the maximum value is computed based on the absolute values of car body lateral vibration acceleration signal A 51 and car body lateral vibration acceleration signal B 52 to obtain the amplitude ratio.

**[0038]** In order to execute the abovementioned calculation, the system is equipped with a computing section for computing the RMS value or the maximum value of the acceleration signal extracted via the window filter.

**[0039]** Fig. 4 shows an example of a threshold determination process and a defect determination process with respect to the RMS value amplitude ratio 55, corresponding to processes s7 through s9 of Fig. 2. In the drawing, a determination section 90 compares and determines the magnitude relation of the RMS value amplitude ratio 55 (RMS value amplitude ratio: A) and a given threshold $\alpha$. For example, the threshold $\alpha$ is computed in advance via a driving test or an analysis result the amplitude ratio of vibration of a sound car, and the value is set based on the computed result. This threshold $\alpha$ is stored in a storage unit 10 composed for example of a RAM. The storage unit can be composed of a memory with only a small capacity for storing only the threshold, and defect can be detected easily since setting of threshold levels corresponding to each driving speed pattern, which was required in the prior art, is not required. Since the capacity of the storage means for storing the threshold can be small, defect detection can be performed easily with high accuracy via a simple system configuration.

**[0040]** The determination section 90 determines that there is "no defect" 92 when the RMS value amplitude ratio 55 is smaller than the predetermined threshold $\alpha$, and determines that there is "defect" 91 when the RMS value amplitude ratio 55 is greater than the predetermined threshold $\alpha$.

**[0041]** Fig. 4 takes the RMS value amplitude ratio 55 as an example, but a similar determination process can be applied using the maximum amplitude ratio. In that case, a predetermined value must be set as the threshold.

**[0042]** Next, a defect detection processing method will be described with reference to Figs. 5 through 11 regarding the defect detection system 20 in a state monitoring apparatus of a railway car according to one preferred embodiment of the present invention.

**[0043]** First, Figs. 5(a) and 5(b) show a general traveling speed 44 (including the car body acceleration) and a time history waveform of the car body acceleration 45 (including the vibration waveform/ impulse disturbance 4 6 when passing a branched section) , in which the horizontal axis represents time [S] and the vertical axis represents traveling speed [km/h] or the horizontal axis represents time [S] and the vertical axis represents car body acceleration [m/s$^2$].

**[0044]** In the drawing, car 7 is accelerated from a stopped state (0 km/h) to a constant speed section, and then the car is decelerated from the constant speed section to the deceleration section and stopped. At this time, the car body lateral vibration acceleration 45 of Fig. 5 (b) depends on the traveling speed 44 of Fig. 5(a). Therefore, the car body lateral vibration acceleration 45 is gradually increased during acceleration, takes a vibration level corresponding to the traveling speed 44 in the constant speed section, and is gradually reduced during deceleration. Further, an impulse-like vibration waveform 46 occurs when the car passes a branched section or a junction (impulse disturbance when passing a branch).

**[0045]** Now, an example for calculating an amplitude ratio with respect to a vibration occurring via a defect of a bogie component or the like will be described with reference to Figs. 6 through 8.

**[0046]** Fig. 6 (a), 6 (b) and 6 (c) are waveforms showing the traveling speed 44', the car body lateral vibration acceleration 49 and the power spectral densities 60, 63 and 64 thereof.

**[0047]** The car body lateral vibration acceleration 49 in Fig. 6 (b) assumes that the abnormal vibration caused in an abnormal vibration occurrence section is the abnormal vibration caused by the defect of a bogie component or the like. The power spectral densities (hereinafter abbreviated as PSD) 60, 63 and 64 (refer to Fig. 6c) are computed at a time interval 60' of the car body lateral vibration acceleration 49 including the branched section and time intervals 63' and 64' where abnormal vibration occurs. The PSD 60 includes a peak that rises instantly when the car passes a branch, and the PSD 63 includes a peak caused by the detect of a bogie component or the like. The overall value of PSD 64 is small since the traveling speed of the car is small (slow).

**[0048]** At this time, filters A 42' and B 43' applied for computing the amplitude ratio are described. In order to capture the peak frequency of PSD 60, the filter A42' uses a bandpass filter to set up a cutoff frequency $f_{A1}$ and a cutoff frequency $f_{A2}$ having a certain frequency bandwidth from the peak frequency at the center.

**[0049]** Next, in order to capture the peak frequency of PSD 63, the filter B 43' uses a bandpass filter to set up a cutoff frequency $f_{B1}$ and a cutoff frequency $f_{B2}$ having a frequency bandwith including all the peak frequencies.

**[0050]** Fig. 7 shows a time history waveform and RMS values extracted via the filters A 42' and B 43'. In the drawing, the car body lateral vibration acceleration 70 is a time history waveform extracted via the filter A 42' , and the RMS values 72 are obtained by applying the RMS value calculation to the car body lateral vibration acceleration 70. Similarly, the car body lateral vibration acceleration 71 is a time history waveform extracted via the filter B 43', and the RMS values 73 are obtained by applying the RMS value calculation to the car body lateral vibration acceleration 71. By applying filters A 42' and B 43', the car body lateral vibration acceleration 70 and the car body lateral vibration acceleration 71 become substantially equal in the branched section, and the RMS value 72 and the RMS value 73 also becomes substantially equal. Further, in the abnormal vibration section, only the vibration components caused via the defect of a bogie component are extracted in the car body lateral vibration acceleration 71, and the vibration levels of the car body lateral vibration acceleration 70 and the car body lateral vibration acceleration 71 are reduced accompanying the acceleration and deceleration of the car. The RMS values 72 and 73 are also reduced in the same manner.

**[0051]** Fig. 8 shows an example of applying the RMS value amplitude ratios with respect to the RMS values of Fig. 7. In the drawing, the amplitude ratios 74 represent the ratio (Y/X) of the RMS values 73 (Y, for example) with respect to the RMS values 72 (X, for example). In the branched section, the RMS values 72 and 73 are substantially equal, and the amplitude ratio is not different from the ratios in the other sections. Further, in the abnormal vibration section, the RMS value 73 is calculated as a greater value than the RMS value 72, so the amplitude ratio 74 is calculated as a high value corresponding to the ratio of the RMS values 73 and 72. Further, when the traveling speed is small, the RMS values 73 and 72 are also small, so that the amplitude ratio 74 will not become small and the speed dependency can be eliminated. At this time, by setting up a threshold 150, for example, defect of only the vibration waveform within the abnormal vibration section can be detected. In the drawing, the amplitude ratio 66 has been applied to the car body lateral acceleration 45 (refer to Fig. 5).

**[0052]** Next, the example of computing an amplitude ratio with respect to a meandering vibration occurring at a certain speed or higher will be described with reference to Figs. 9 through 11.

**[0053]** Figs. 9 (a), 9 (b) and 9 (c) show waveforms of traveling speed 44', car body lateral vibration acceleration 47 and power spectral densities 60 through 62 thereof.

**[0054]** At first, the car body lateral vibration acceleration 47 of Fig. 9 will be described. The abnormal vibration generated in the abnormal vibration generation section assumes a meandering vibration waveform that occurs at a certain speed or higher. The PSD 60, 61 and 62 (refer to Fig. 9c) are calculated from the car body lateral vibration acceleration 47 at a time interval 60' including the branched section, a time interval 61' of a section where abnormal vibration occurs, and a time interval 62' of a section where the car speed is slow, wherein the PSD 60 has a peak that rises instantly when the car passes a branch, and the PSD 61 has a peak that rises by the meandering vibration characteristics occurring at a certain speed or higher. The PSD 62 corresponds to a section where no abnormal vibration occurs and where traveling speed is slow, so that the PSD is small.

**[0055]** At this time, filters A 42' and B 43' applied for computing the amplitude ratio are described. In order to capture the peak frequency of PSD 60, the filter A42' uses a bandpass filter to set up a cutoff frequency $f_{A1}$ and a cutoff frequency $f_{A2}$ having a certain frequency bandwidth from the peak frequency set as center. Next, in order to capture the peak frequency of PSD 61, the filter B 43' uses a bandpass filter to set up a cutoff frequency $f_{B1}$ and a cutoff frequency $f_{B2}$ having a frequency bandwith including all the peak frequencies.

**[0056]** Fig. 10 shows a time history waveform and an RMS value extracted via the filters A 42' and B 43'. In the drawing, the car body lateral vibration acceleration 75 is a time history waveform extracted via the filter A 42', and the RMS value 77 is obtained by applying the RMS value calculation to the car body lateral vibration acceleration 75. Similarly, the car body lateral vibration acceleration 76 is a time history waveform extracted via the filter B 43' , and the RMS value 78 is obtained by applying the RMS value calculation to the car body lateral vibration acceleration 76. In the abnormal vibration section, only the meandering vibration component is extracted in the car body lateral vibration acceleration 76, and the same applies for the RMS value 78.

**[0057]** Fig. 11 shows an example of applying the RMS value amplitude ratio with respect to the RMS value of Fig. 9. In the drawing, the amplitude ratios 79 represents the ratio (Y/X) of the RMS values 78 (Y, for example) with respect to the RMS values 77 (X, for example). In the branched section, the RMS values 75 and 76 are substantially equal, and the amplitude ratio 79 is not different from the ratios in the other sections. Further, in the abnormal vibration section, the RMS value 78 is computed as a greater value than the RMS value 77, so that the amplitude ratio 79 is calculated as a high value corresponding to the ratio of the RMS values 77 and 78 . At this time, by setting up a threshold 150, for example, only the vibration wave form within the abnormal vibration section can be detected as a defect. In the drawing, the amplitude ratio 66 has been applied to the car body lateral acceleration 45.

**[0058]** According to the above-described embodiment, two car body acceleration amplitude ratios of different frequency bands extracted from a single car body acceleration are used to execute a threshold determination process with respect to a predetermined threshold, according to which the influence of traveling speed dependency can be eliminated, and since there is no need to set up thresholds corresponding to respective traveling speed patterns, the capacity of the storage unit for storing the threshold can be made small and defect can be detected with high accuracy via a simple system configuration.

[Embodiment 2]

**[0059]** Next, another embodiment (embodiment 2) according to the present invention will be described. Fig. 12 shows a flow of the threshold determination process and the defect determination process of a state monitoring apparatus of a railway car according to embodiment 2 of the present invention, and Fig. 13 shows an application example of the threshold determination of embodiment 2 of the present invention with respect to the amplitude ratio. Embodiment 2 adds a threshold determination process corresponding to the number of exceedance of the amplitude ratio in the threshold determination process of embodiment 1.

**[0060]** The present embodiment adds a determination section 93 in the determination flow to embodiment 1 of Fig. 4 as shown in Fig. 12. The determination section 93 observes the number of times N in which the RMS value amplitude ratio 55 exceeding the threshold $\alpha$ 81 of a certain amplitude ratio in the determination section 90 has exceeded the threshold $\alpha$ (threshold with respect to the amplitude ratio level) of the amplitude ratio within a certain time, and compares the same with a threshold $\beta$ (threshold with respect to a number of exceedance of level $\alpha$ of the amplitude ratio) of a predetermined number of exceedance of a threshold. If the number of exceedance N of amplitude ratio with respect to threshold $\alpha$ is smaller than threshold $\beta$ showing the predetermined number of exceedance of the threshold, it is determined that there is "no defect" 92, and if the number of exceedance N of amplitude ratio with respect to threshold $\alpha$ is greater than threshold $\beta$ showing the predetermined number of exceedance of the threshold, it is determined that there is "defect" 91. In another example, the determination section 93 can observe an excess time T of amplitude ratio with respect to threshold $\alpha$ in which the RMS value amplitude ratio 55 exceeds the threshold $\alpha$ of a certain amplitude ratio in the determination section 90, and compares the same with a predetermined threshold $\Upsilon$ of the threshold excess time. For example, if the excess time T of the amplitude ratio with respect to threshold $\alpha$ is smaller than a certain threshold $\Upsilon$ of threshold excess time, it is determined that there is "no defect", and if the excess time T of the amplitude ratio with respect to threshold $\alpha$ is greater than a certain threshold $\Upsilon$ of a threshold excess time, it is determined that there is "defect".

**[0061]** Further, as shown in the application example of a threshold determination with respect to the amplitude ratio of Fig. 13, when the RMS value amplitude ratio 80 exceeds a predetermined threshold 81, in section 85 the number of the RMS value amplitude ratio 83 is greater than a predetermined threshold (when assuming that the threshold is 3) within a predetermined time 82 so that it is determined that there is "defect", and in section 86 the number 84 of the RMS value amplitude ratio is smaller than a predetermined value (when assuming that the threshold is 3) so that it is determined that there is "no defect".

**[0062]** According to the present embodiment, by adding a threshold determination process function for determining whether the values have exceeded the threshold for a predetermined number of times or greater within the predetermined time in addition to the threshold determination process with respect to the level of the RMS value amplitude ratio 55, it becomes possible to improve the detection accuracy even when the amplitude ratio has exceeded the threshold instantly due to noise or disturbance, for example.

[Embodiment 3]

**[0063]** Next, we will describe another embodiment (embodiment 3) according to the present invention. Fig. 14 corresponds to the system configuration diagram of the state monitoring apparatus of a railway car according to embodiment 1 of the present invention, and Fig. 15 corresponds to the defect detection/determination process flow of the state monitoring apparatus of a railway car according to embodiment 1 of the present invention. Fig. 16 shows the filter application example of embodiment 1 of the present invention, wherein according to embodiment 3, a car speed information is newly added and a function for automatically changing a filter coefficient of filtering of the defect detection system is also added with respect to embodiment 1.

**[0064]** As shown in Fig. 14, the present embodiment has added to embodiment 1 of Fig. 1 in the system configuration a car speed detector 101 for detecting the car speed via a car information system disposed on the car on the car 6, and adds to the defect detection system 20 a filter conversion processing section 102 for automatically changing the filter coefficients such as the cutoff frequencies of the filtering sections A 12 and B 13 based on the traveling speed signal 110a from the car speed detector 101.

**[0065]** In the drawing, the filter conversion processing section 102 receives input of the traveling speed signal 110a output from the car speed detector 101 disposed on the car 7 and outputs a filter conversion signal 111a to the filtering section A 13 and the filtering section B 14. The filtering section A 13 and the filtering section B 14 applies a bandpass filter using a cutoff frequency assigned by the filter conversion signal 111a to the car body lateral vibration acceleration signal 22a.

**[0066]** Further, as shown in Fig. 15, with respect to embodiment 1 shown in Fig. 2, the defect detection/determination process flow executes after input of the car body lateral vibration acceleration signal 22a from the car body acceleration detector 11 (s1) a coefficient conversion process (s2-1) regarding the cutoff frequencies or the like of the filtering process A 42 and the filtering process B 43 based on the car traveling speed.

**[0067]** Further, as shown in Fig. 16, with respect to embodiment 1 shown in Figs. 9, 10 and 11, when a certain car speed condition $V_1$ is changed to another car speed condition $V_2$ and the PSD 121 is changed to PSD 121' by the influence of the car speed, the bandpass filter 120 is automatically changed to bandpass filter 120' to correspond to the peak frequencies of the PSD 121 and PSD121' . At this time, the frequency band of the bandpass filter is shifted from fc1 - fc2 to fD1 - fD2, and the frequency band is not overlapped.

**[0068]** The present embodiment illustrated an example in which the filtering processes A 42 and B 43 are applied to the car body lateral vibration acceleration, but the same can be applied to a car body lengthwise acceleration or a car body vertical acceleration.

**[0069]** According to the present embodiment, by adding a filter conversion processing section 102 for automatically changing the filter coefficient such as the cutoff frequencies of the filtering sections A 12 and B 13 based on the traveling speed of the car, for example, a filter can be constantly applied to the vibration component having its frequency varied due to the wheel rotation frequency, according to which the detection accuracy can be improved.

[Embodiment 4]

**[0070]** Next, yet another embodiment (embodiment 4) of the present invention will be described. Fig. 17 shows a system configuration diagram of a state monitoring apparatus of a railway car according to embodiment 4, Fig. 18 shows a defect detection/determination process flow of the state monitoring apparatus of the railway car according to embodiment 4, and Fig. 19 shows the filtering process, the RMS value computing process and the amplitude ratio computing process according to embodiment 4 of the present invention, wherein embodiment 4 adds to embodiment 1 an amplitude ratio computing process of two vibration accelerations in different directions (such as the lateral vibration acceleration and the vertical vibration acceleration).

**[0071]** As shown in Fig. 17, the present embodiment adds to the system configuration of embodiment 1 shown in Fig. 1 a voltage 21a' , a car body acceleration detector 11' and a car body vertical vibration acceleration signal 22a'.

**[0072]** In the drawing, voltages 21a and 21a' are of different directions, which are respectively detected in the car body acceleration detectors 11 and 11' as a car body lateral vibration acceleration signal 22a and a car body vertical vibration acceleration signal 22a' , for example, and the car body lateral vibration acceleration signal 22a is sent to the filtering section A 12 and the car body vertical vibration acceleration signal 22a' is sent to the filtering section B 13.

**[0073]** As for the defect detection/determination process flow shown in Fig. 18, with respect to embodiment 1 of Fig. 2 after entering the car body lateral vibration acceleration signal 22a and the car body vertical vibration acceleration 22a' from the car body acceleration detectors 11 and 11' (s1-3), a filtering process A 42 is performed to the car body lateral vibration acceleration signal 22a (s2-3) and a filtering process B 43 is performed to the car body lateral vibration acceleration signal 22a' (s3-3).

**[0074]** Regarding the filtering process, the RMS value computing process and the amplitude ratio computing process shown in Fig. 19, with respect to embodiment 1 shown in Fig. 3, the car body lateral vibration acceleration 41 is applied to the filter A 42 by which an RMS value 53 (X, for example) is extracted, and the car body vertical vibration acceleration 41' is applied to the filter B 43 by which an RMS value 54 (Y, for example) is extracted, according to which the amplitude ratio (Y/X) is calculated.

**[0075]** Further, if the car body lateral acceleration or the car body vertical acceleration is influenced by the a vibration component depending on the car speed, such as the wheel rotation frequency, the amplitude ratio can be computed by performing control to automatically change the cutoff frequency of the bandpass filter in response to the change of condition of car speed, for example.

**[0076]** Further according to the present embodiment, the amplitude ratio was computed for the respective RMS values of the car body lateral vibration acceleration and the car body vertical vibration acceleration, but the same can be computed for the respective RMS values of the car body lateral vibration acceleration and the car body lengthwise vibration acceleration, or the car body lengthwise vibration acceleration and the car body vertical vibration acceleration.

**[0077]** According to the present embodiment, by computing the amplitude ratio regarding the RMS values of two vibration accelerations whose measurement directions differ, it becomes possible to detect the balance of vibration components in different directions and to detect the defect by determining that the balance is not normal.

[Embodiment 5]

**[0078]** Next, we will describe another embodiment (embodiment 5) of the present invention. Fig. 20 is a system configuration of a state monitoring apparatus of a railway car regarding a power supply car 200 equipped with a facility for obtaining electric power by driving a power generator 202 via the driving force of an engine 201, wherein embodiment 5 differs from embodiment 3 in that the present embodiment assumes a case in which the vibration source is on the car, caused by the defect of the engine 201 or the power generator 202 or other reasons related to the engine 201 or the power generator 202. The power generator 202 is disposed above the engine 201. Further, the present embodiment can be applied not only to the engine and the power generator disposed on the car body but to cases in which the vibration is caused by car-mounted equipments such as a bogie motor, a drive unit or a journal bearing.

**[0079]** The present embodiment illustrates an example in which the filtering processes A 42 and B 43 are applied to the car body lateral vibration acceleration, but the present embodiment can similarly be applied to the car body lengthwise acceleration or the car body vertical acceleration.

**[0080]** As shown in Fig. 20, the present embodiment adds to the system configuration of embodiment 3 shown in Fig. 14 a power supply car 200 equipped with a facility for obtaining power by driving a power generator 202 via the driving force of an engine 201, and provides to the filter conversion processing section 102 a command signal 220a from a command unit 203 for controlling the number of rotations of the engine 201.

**[0081]** In the drawing, the filter conversion processing section 102 receives input of a traveling speed signal 110a output from a car speed detector 101 disposed on the power supply car 200, and outputs a filter conversion signal 111a to the filtering sections A 13 and B 14. The filtering sections A 13 and B 14 apply a bandpass filters using cutoff frequencies assigned by the filter conversion signal 111a to the car body lateral vibration acceleration signal 22a.

**[0082]** Further, in addition to embodiment 1 shown in

Fig. 2, the defect detection/determination process flow shown in Fig. 21 executes a coefficient conversion process of the filtering process A 42 and the filtering process B 43 based on a command signal 20a (s2-4) after input of the car body lateral vibration acceleration signal 22a from the car body acceleration detector 11 (s1).

**[0083]** Further, with respect to embodiment 1 shown in Figs. 9, 10 and 11, the present embodiment illustrates in Fig. 22 a filter application example in which when a command signal $s_1$ is changed in a discontinuous manner to command signal $s_2$, even if the PSD 221 is changed via the command signal to PSD 221' , the bandpass filter 220 is automatically changed to a bandpass filter 220' in response to the peak frequencies of PSD 221 and PSD 221'. Further, the amplitude ratio computes a ratio (Y/X) of the RMS value of the car body lateral vibration acceleration extracted via the bandpass filters 220 and 220' (Y, for example) to the RMS value of the car body lateral vibration acceleration extracted via the bandpass filter 222 (X, for example), and thresholds regarding the respective command signals $s_1$ and $s_2$ are selected in advance, so that switching can be performed to correspond to the states of command signals $s_1$ and $s_2$. As shown in Fig. 23, when the PSD is varied from a normal condition 231 to an abnormal condition 232, the amplitude ratio is increased, so that defect can be detected by comparing the same with a threshold determined in advance.

**[0084]** The present embodiment adds a filter conversion processing section 102 capable of automatically changing the filter coefficient such as the cutoff frequencies of the filtering sections A 12 and B 13 based on the traveling speed of the car, so that the filter can be constantly applied to a vibration component having its frequencies varied due for example to the wheel rotation frequency, and thus, the detection accuracy can be improved.

**[0085]** According to the respective embodiments of the present invention described above, the meandering vibration of the railway car or the defect of suspensions such as the air spring or the lateral vibration damper can be monitored accurately and reliably. Further, the present embodiments do not require setting of threshold levels corresponding to various traveling speed patterns as in the prior art to monitor the defect, so that the system configuration can be simplified, and the influence of traveling speed of the car can be eliminated without increasing the storage capacity for storing thresholds.

## Claims

1. A railway car having a car body, a bogie frame and wheelsets, comprising:

    a vibration detector for detecting a vibration of the railway car, and a defect detection system for detecting a defect of the railway car using a signal output from the vibration detector,
    wherein the vibration detector includes a vibration detection means for detecting the vibration of the railway car from a vibration acceleration of the car body; and
    the defect detection system includes a filtering means for detecting two or more different frequency band components based on the car body vibration acceleration from the vibration detectionmeans, an amplitude ratio computingmeans for computing an amplitude ratio of two or more car body vibration accelerations detected via the filtering means, and a defect determination processing means for determining the defect based on the result of the amplitude ratio computing means.

2. The railway car according to claim 1, wherein the vibration detector includes a vibration detecting means for detecting vibration of a bogie frame or a vibration of an axle box of the car body.

3. The railway car according to claim 1 or claim 2, wherein the amplitude ratio computing means of the defect detection system comprises:

    a window filer for extracting a fixed amount of acceleration signals from the car body vibration acceleration;
    a computing section for computing an RMS value of a time history waveform or a maximum value thereof based on the acceleration signals extracted via the window filter; and
    an amplitude ratio computing section for computing the amplitude ratio; wherein
    the filtering means is a bandpass filter capable of passing frequency bands of varied ranges.

4. The railway car according to claims 1 through 3, wherein the defect determination processing means determines whether the amplitude ratio has exceeded a threshold for a predetermined number of times within a predetermined time, or the defect determination processing means determines whether an excess time of the amplitude ratio having exceeded a predetermined threshold has exceeded a threshold of a predetermined time.

5. The railway car according to claims 1 through 4, further comprising

    a traveling speed detector for detecting a traveling speed of the railway car, and a filter coefficient conversion processing system for automatically setting a cutoff frequency of the filtering means of the defect detection system using a signal detected form the traveling speed detector.

6. A state monitoring method of a railway car having a car body, a bogie frame and wheelsets for detecting vibration of the railway car and detecting a defect of the railway car using the detection signal, the method comprising:

an amplitude ratio computing step for computing an amplitude ratio of acceleration having two or more different frequency band components detected from a single car body vibration acceleration of the railway car;
a threshold determination step for determining whether the amplitude ratio is greater than a predetermined threshold or not; and
a defect determination step for determining the defect based on the determination result of the threshold determination step.

7. The state monitoring method according to claim 6, further comprising

a computing step for computing an RMS value of a time history waveform or a maximum value thereof based on acceleration signals extracted via a window filter for extracting a fixed amount of acceleration signals from the car body vibration acceleration; and
a step for setting a cutoff frequency with a frequency bandwidth for capturing a peak frequency of the acceleration signal extracted via a bandpass filter of the filtering means.

8. The sate monitoring method of a railway car according to claims 6 or 7, further comprising:

a defect determination process computing step for determining whether the amplitude ratio has exceeded a threshold for a predetermined number of times or greater within a predetermined time, or a defect determination process computing step for determining whether an excess time of the amplitude ratio having exceeded the threshold has exceeded a threshold of a predetermined time.

9. The state monitoring method of a railway car according to any one of claims 6 through 8, further comprising:

a traveling speed detecting step for detecting a traveling speed of the railway car, and a filter coefficient conversion step for automatically setting a cutoff frequency of the filtering means of the defect detection system using a signal detected from the traveling speed detector.

FIG. 1

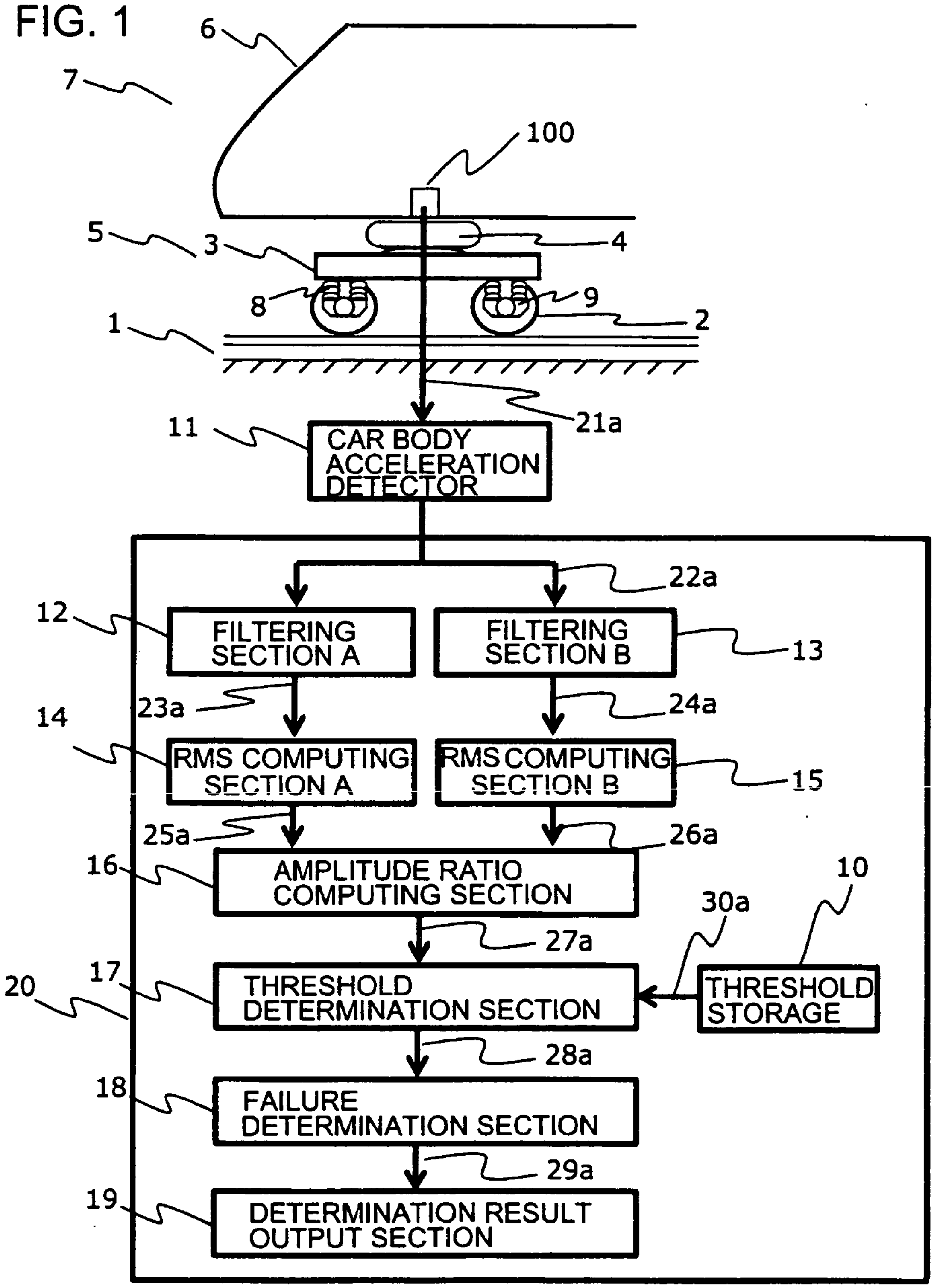
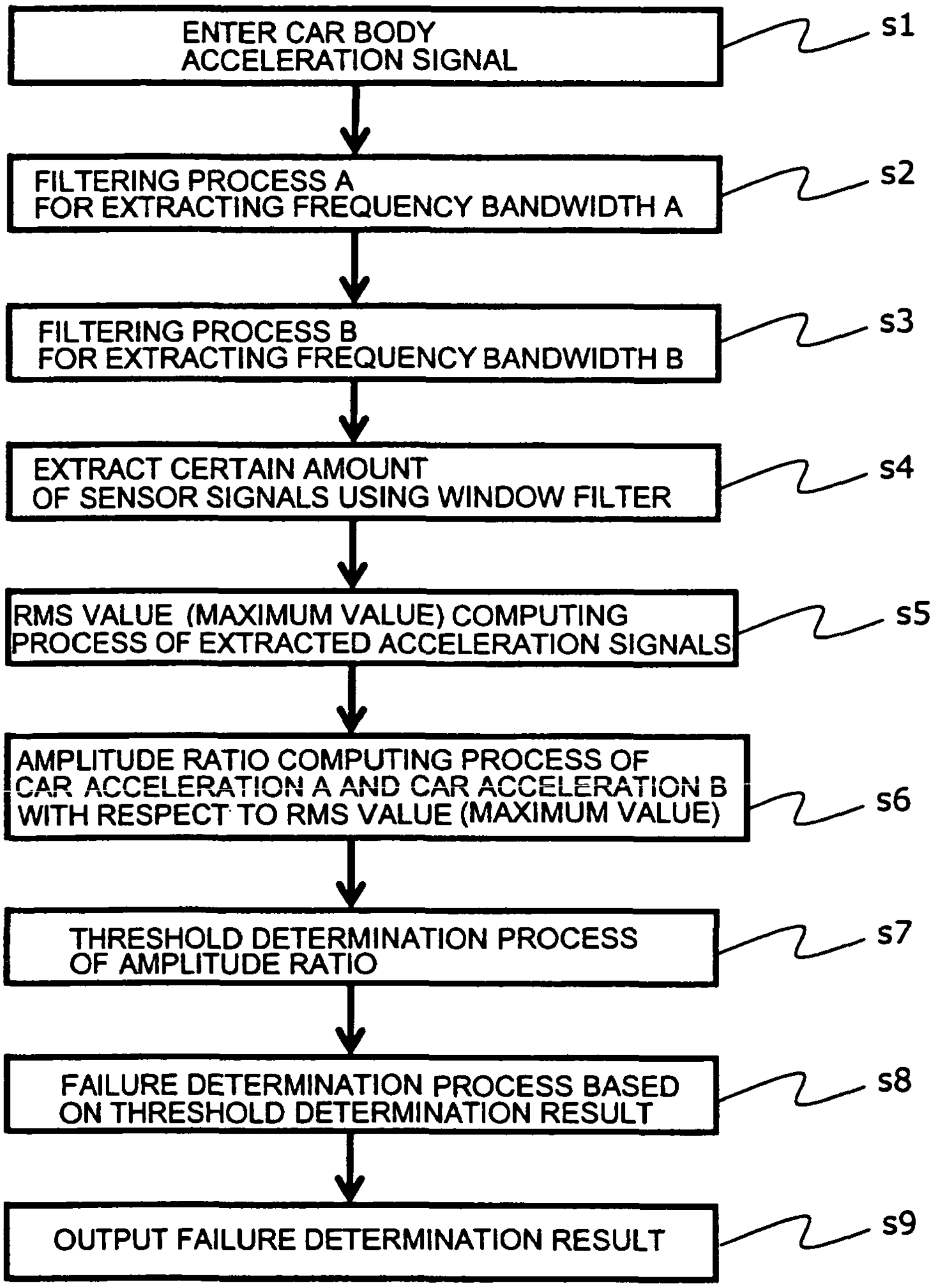
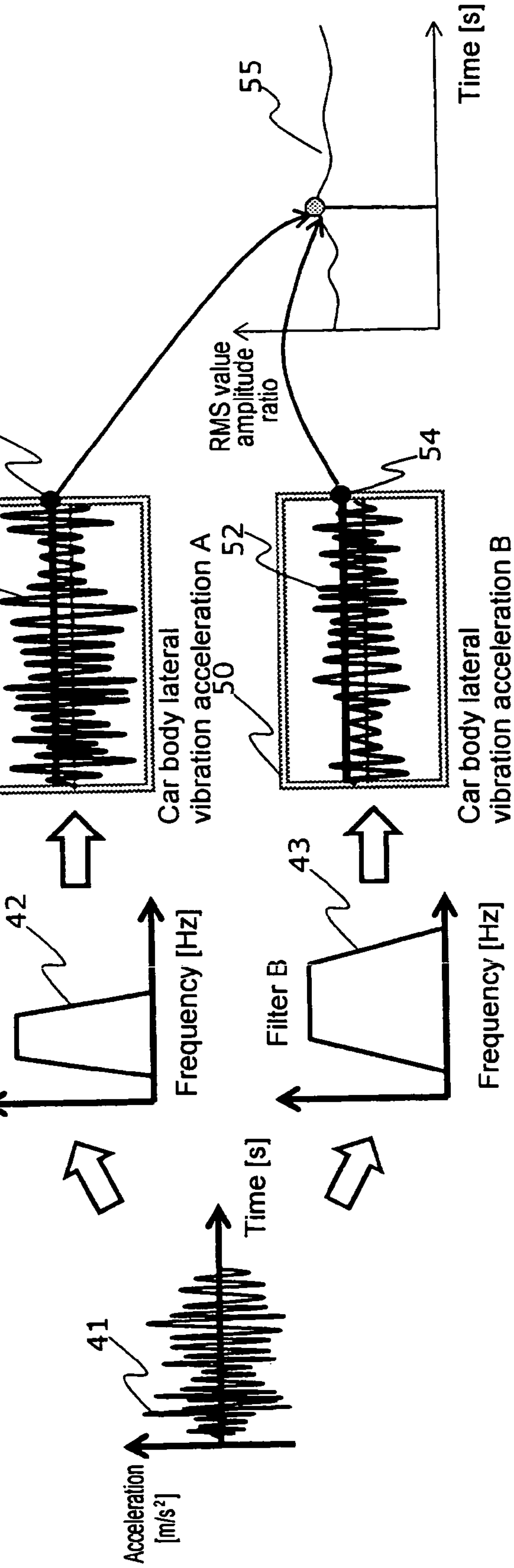

6
7
100
5
3
4
8
9
2
1
21a
11
CAR BODY ACCELERATION DETECTOR
22a
12
FILTERING SECTION A
FILTERING SECTION B
13
23a
24a
14
RMS COMPUTING SECTION A
RMS COMPUTING SECTION B
15
25a
26a
16
AMPLITUDE RATIO COMPUTING SECTION
10
30a
27a
20
17
THRESHOLD DETERMINATION SECTION
THRESHOLD STORAGE
28a
18
FAILURE DETERMINATION SECTION
29a
19
DETERMINATION RESULT OUTPUT SECTION

FIG. 2



ENTER CAR BODY ACCELERATION SIGNAL
s1
FILTERING PROCESS A FOR EXTRACTING FREQUENCY BANDWIDTH A
s2
FILTERING PROCESS B FOR EXTRACTING FREQUENCY BANDWIDTH B
s3
EXTRACT CERTAIN AMOUNT OF SENSOR SIGNALS USING WINDOW FILTER
s4
RMS VALUE (MAXIMUM VALUE) COMPUTING PROCESS OF EXTRACTED ACCELERATION SIGNALS
s5
AMPLITUDE RATIO COMPUTING PROCESS OF CAR ACCELERATION A AND CAR ACCELERATION B WITH RESPECT TO RMS VALUE (MAXIMUM VALUE)
s6
THRESHOLD DETERMINATION PROCESS OF AMPLITUDE RATIO
s7
FAILURE DETERMINATION PROCESS BASED ON THRESHOLD DETERMINATION RESULT
s8
OUTPUT FAILURE DETERMINATION RESULT
s9

FIG. 3



Acceleration [m/s²]
41
Time [s]
Filter A
42
Frequency [Hz]
Filter B
43
Frequency [Hz]
50
51
Car body lateral vibration acceleration A
50
52
Car body lateral vibration acceleration B
53
54
RMS value amplitude ratio
55
Time [s]

FIG. 4

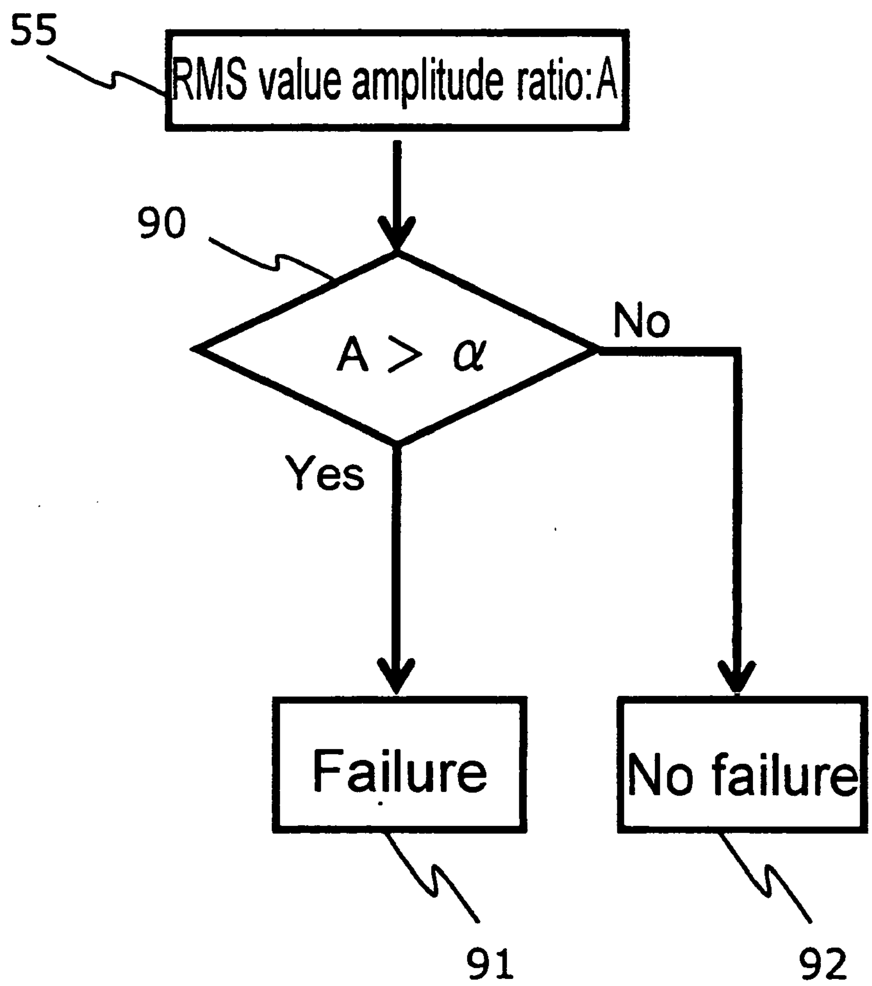
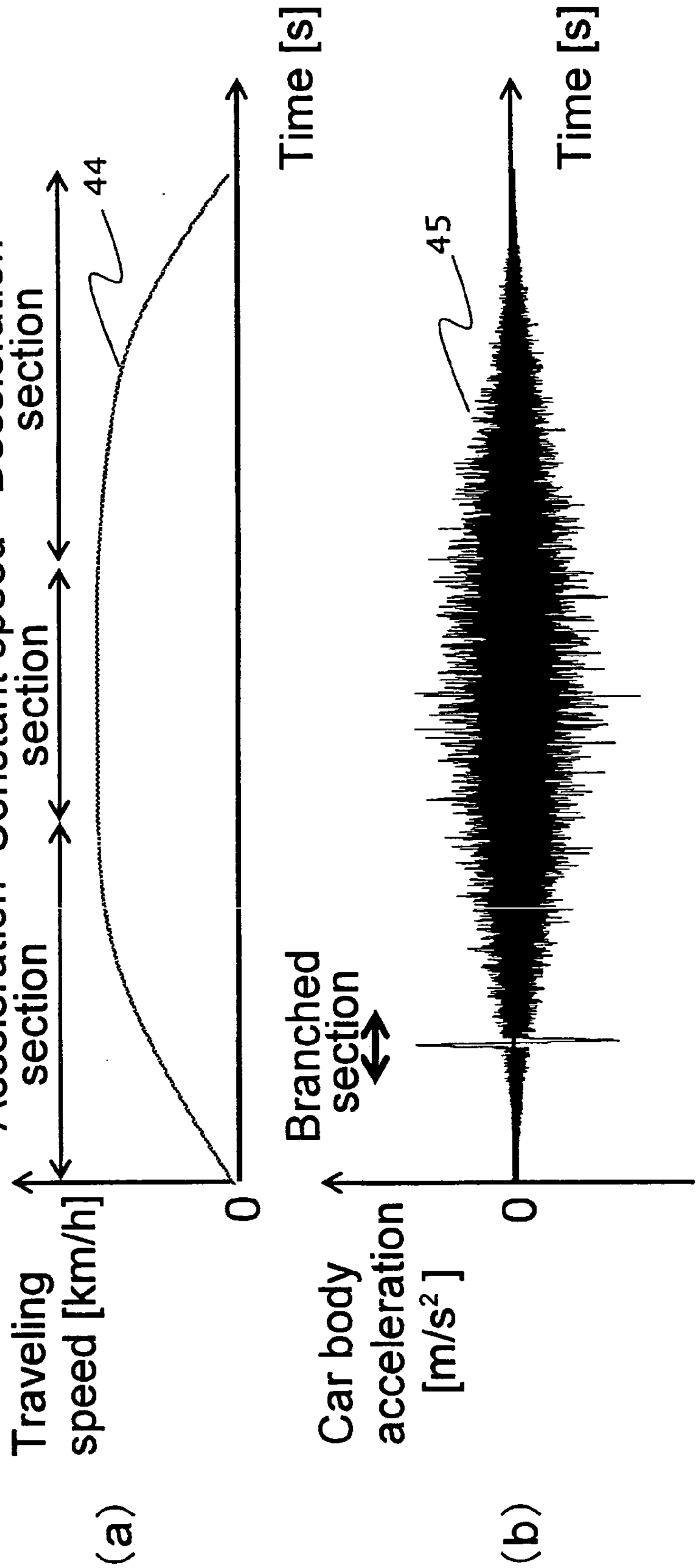

55
RMS value amplitude ratio:A
90
A > α
No
Yes
Failure
No failure
91
92

FIG. 5


(a)
Traveling speed [km/h]
0
Acceleration section
Constant speed section
Deceleration section
44
Time [s]
(b)
Car body acceleration [m/s²]
0
Branched section
45
Time [s]

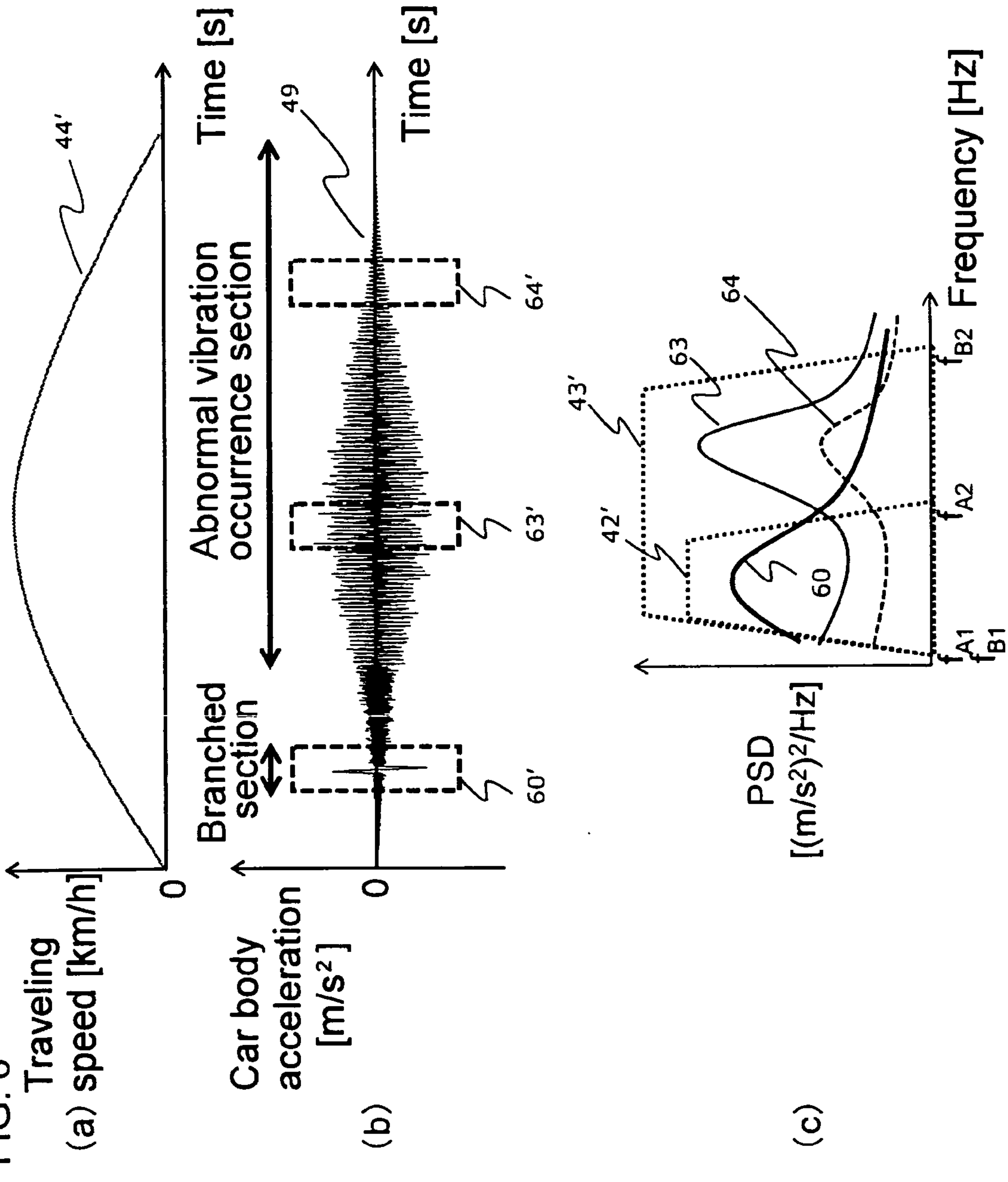

(a) Traveling speed [km/h]
0
44'
Time [s]
(b) Car body acceleration [m/s²]
0
Branched section
Abnormal vibration occurrence section
49
60'
63'
64'
Time [s]
(c) PSD [(m/s²)²/Hz]
42'
43'
60
63
64
fA1
fB1
fA2
fB2
Frequency [Hz]

FIG. 6

FIG. 7

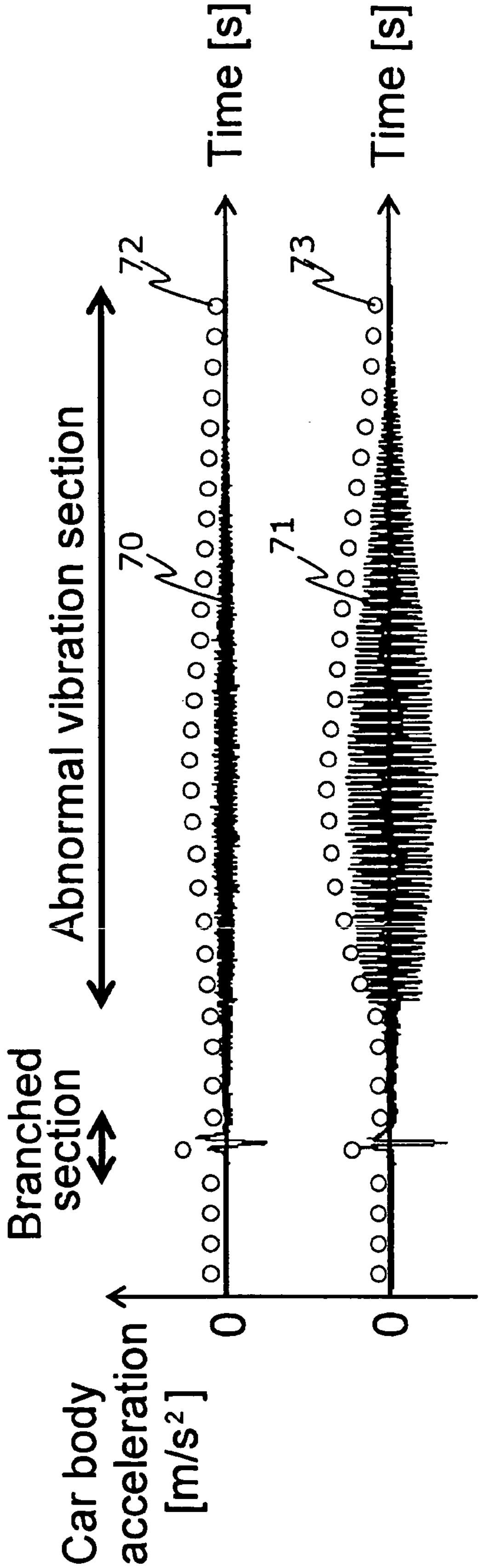

Car body acceleration [m/s²]
0
0
Branched section
Abnormal vibration section
70
71
72
73
Time [s]
Time [s]

FIG. 8

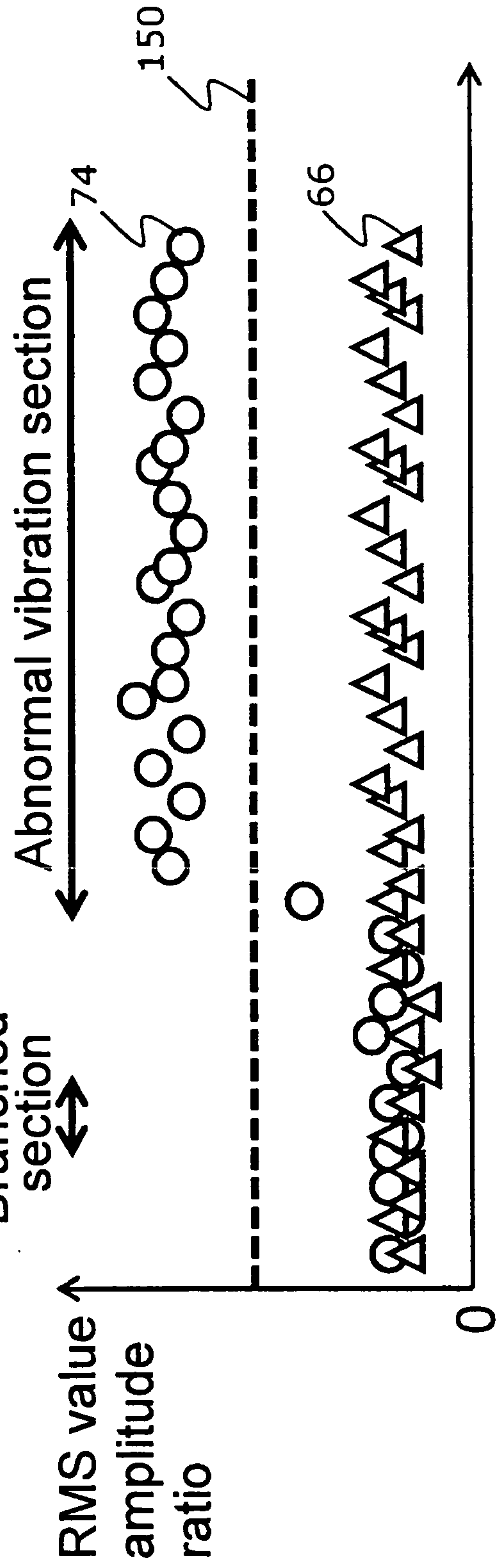

RMS value amplitude ratio
0
Branched section
Abnormal vibration section
74
66
150

FIG. 9

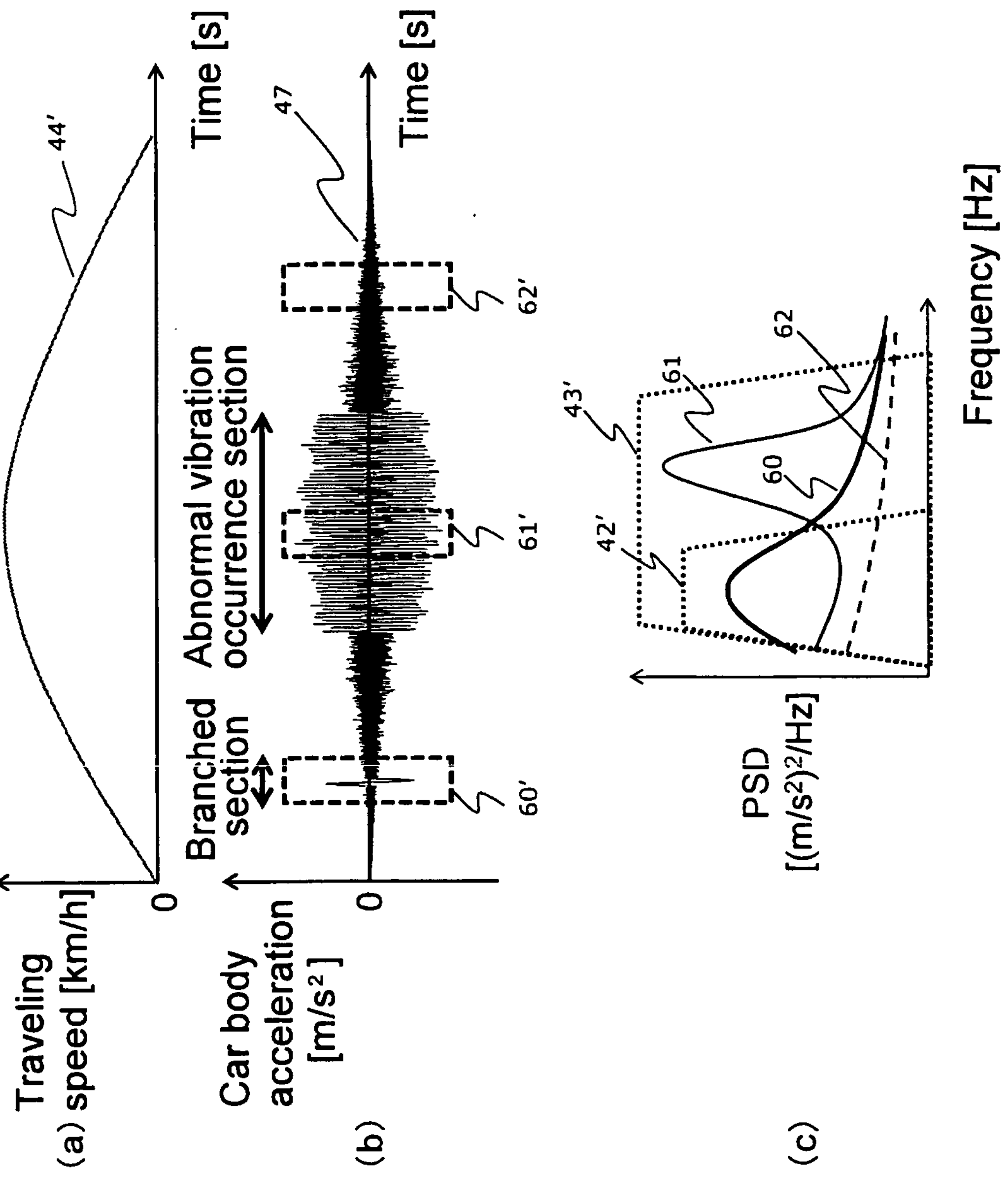

(a) Traveling speed [km/h]
0
Time [s]
44'
(b) Car body acceleration [m/s²]
0
Branched section
Abnormal vibration occurrence section
Time [s]
47
60'
61'
62'
(c) PSD [(m/s²)²/Hz]
Frequency [Hz]
42'
43'
60
61
62

FIG.10

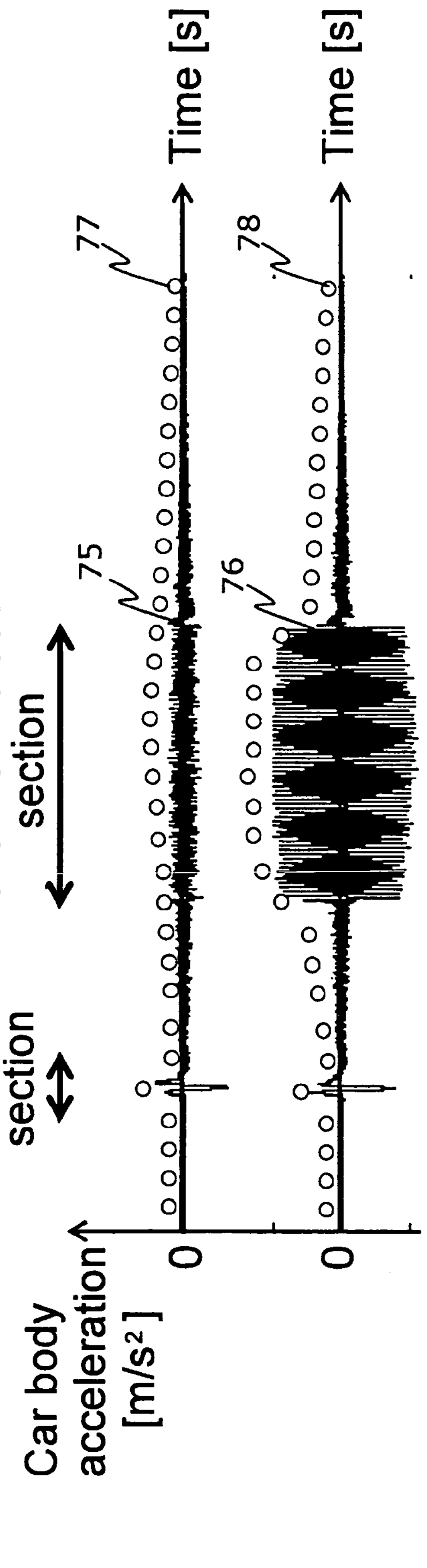

Car body acceleration [m/s²]
0
0
Branched section
Abnormal vibration section
75
76
77
78
Time [s]
Time [s]

FIG.11

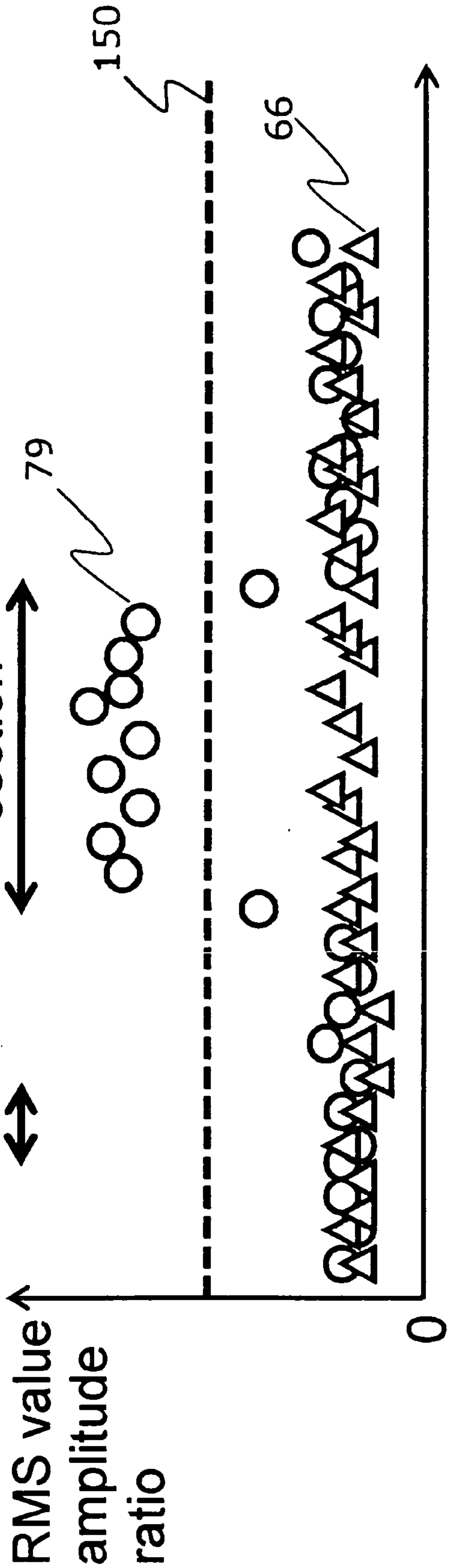

RMS value amplitude ratio
0
Branched section
Abnormal vibration section
79
150
66

FIG.12

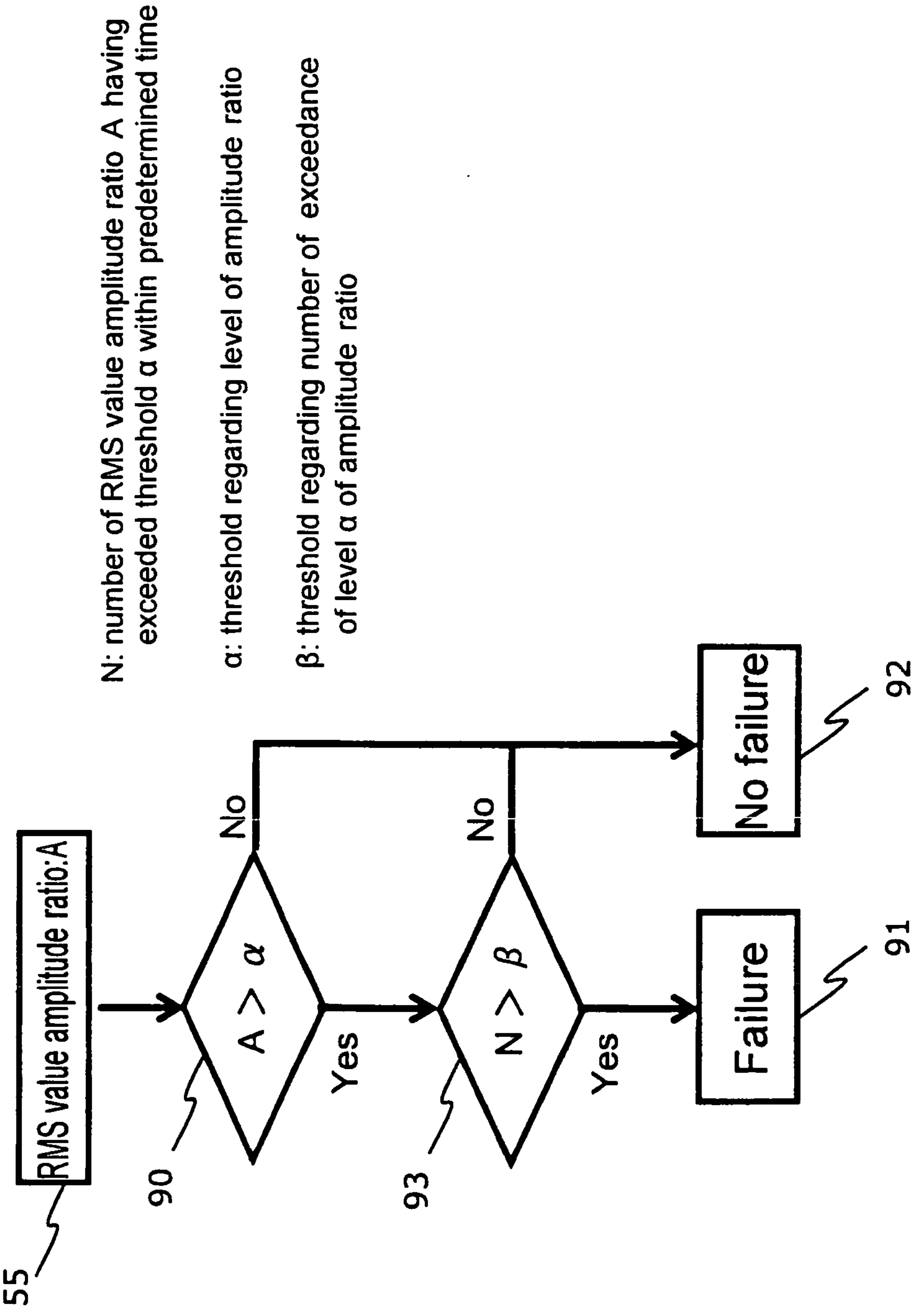

RMS value amplitude ratio:A
55
A > α
90
No
Yes
N > β
93
No
Yes
Failure
91
No failure
92
N: number of RMS value amplitude ratio A having exceeded threshold α within predetermined time
α: threshold regarding level of amplitude ratio
β: threshold regarding number of exceedance of level α of amplitude ratio

FIG.13

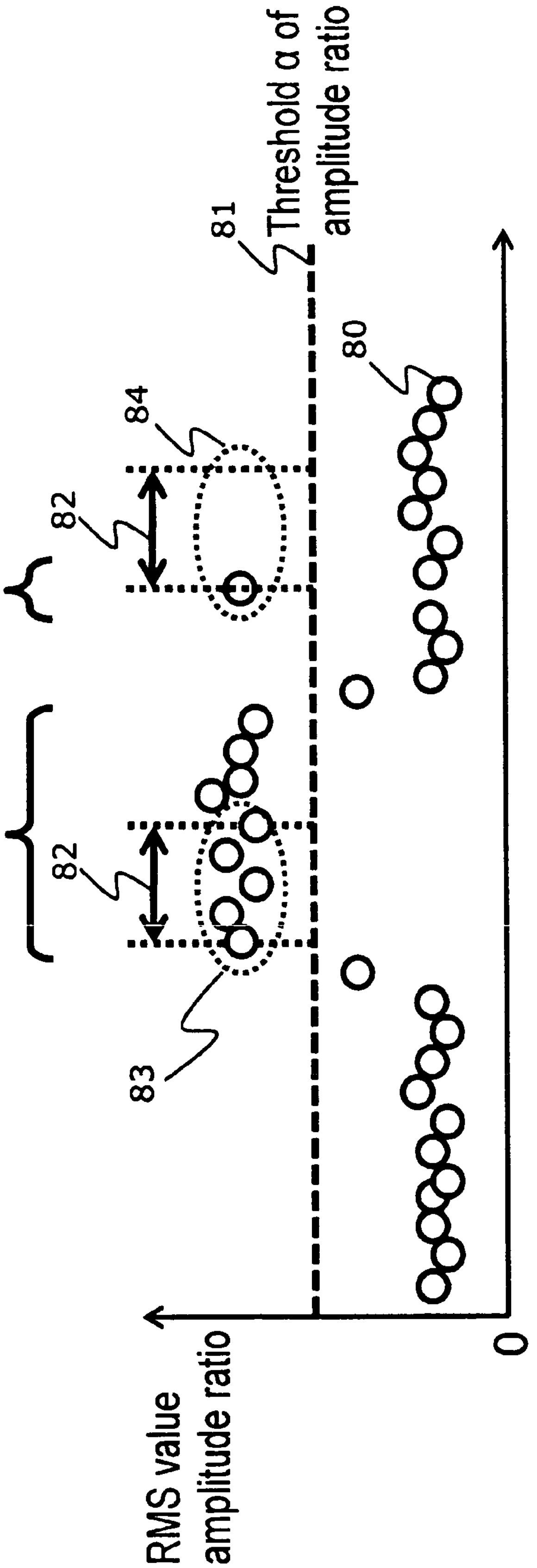
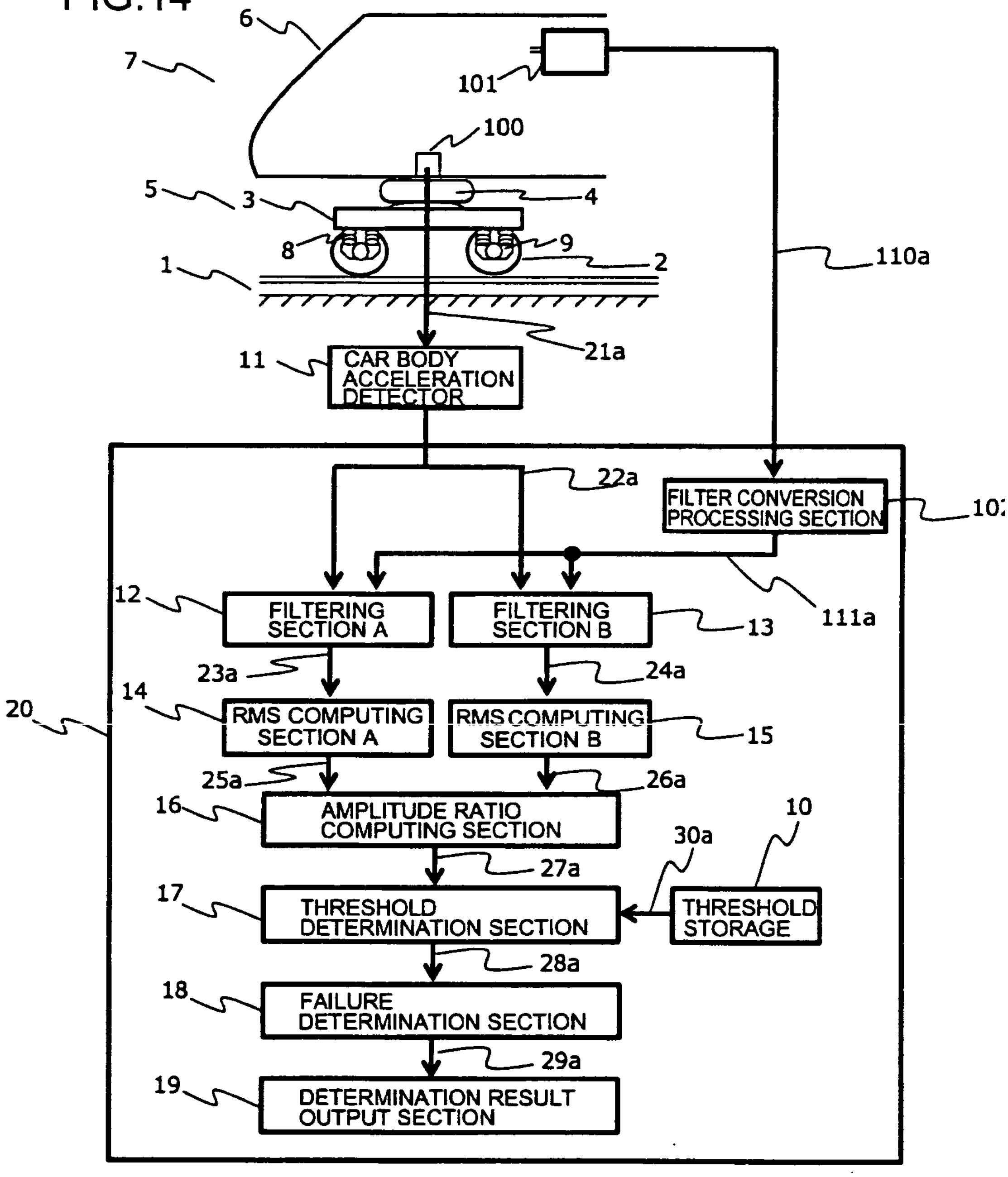

RMS value amplitude ratio
0
Threshold α of amplitude ratio
80
81
82
82
83
84
85
86

FIG.14



6
7
101
100
5
3
4
8
9
2
1
110a
21a
11
CAR BODY ACCELERATION DETECTOR
22a
FILTER CONVERSION PROCESSING SECTION
10:
111a
12
FILTERING SECTION A
FILTERING SECTION B
13
23a
24a
14
20
RMS COMPUTING SECTION A
RMS COMPUTING SECTION B
15
25a
26a
16
AMPLITUDE RATIO COMPUTING SECTION
10
30a
27a
17
THRESHOLD DETERMINATION SECTION
THRESHOLD STORAGE
28a
18
FAILURE DETERMINATION SECTION
29a
19
DETERMINATION RESULT OUTPUT SECTION

FIG.15

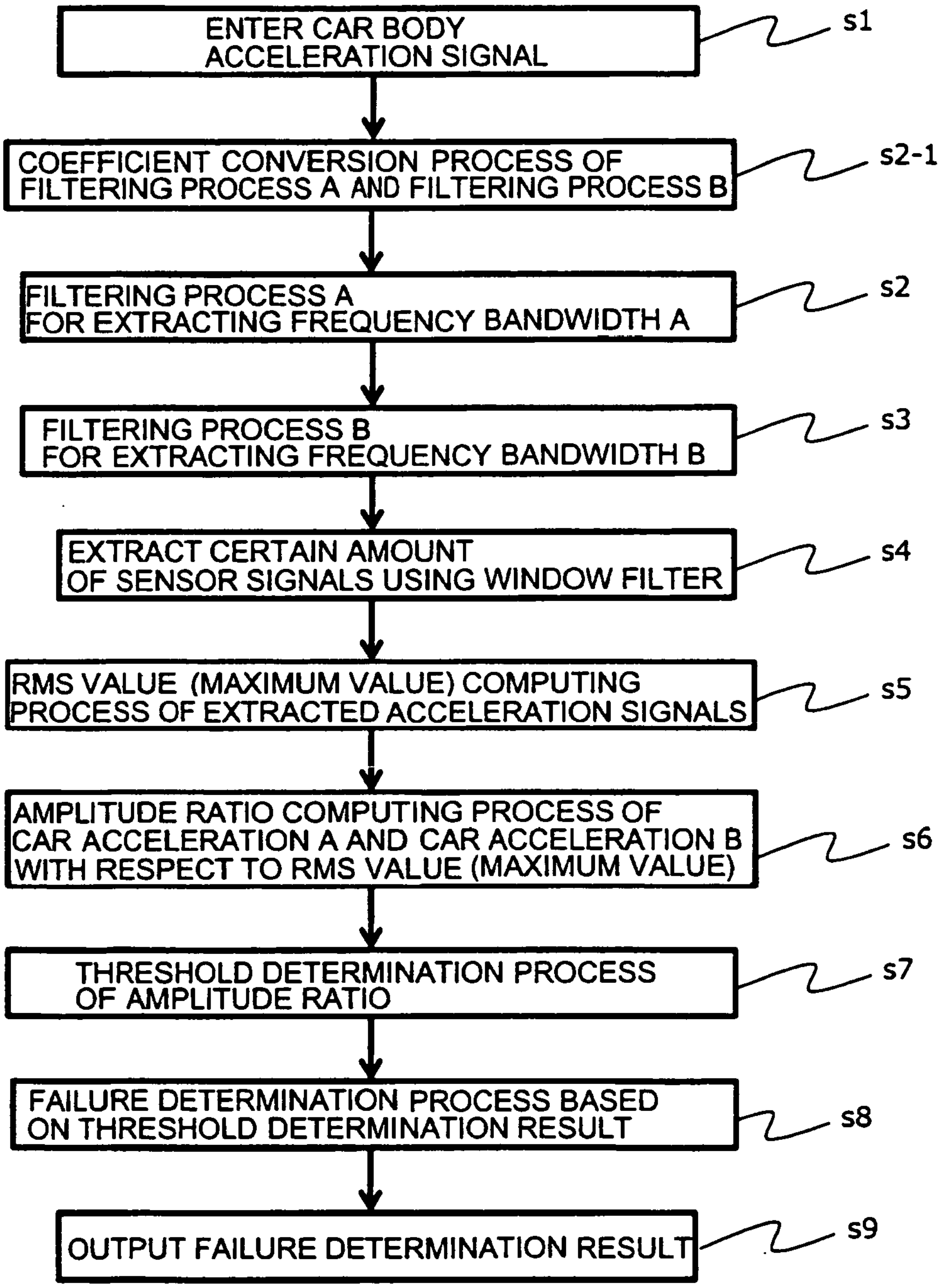

ENTER CAR BODY ACCELERATION SIGNAL
s1
COEFFICIENT CONVERSION PROCESS OF FILTERING PROCESS A AND FILTERING PROCESS B
s2-1
FILTERING PROCESS A FOR EXTRACTING FREQUENCY BANDWIDTH A
s2
FILTERING PROCESS B FOR EXTRACTING FREQUENCY BANDWIDTH B
s3
EXTRACT CERTAIN AMOUNT OF SENSOR SIGNALS USING WINDOW FILTER
s4
RMS VALUE (MAXIMUM VALUE) COMPUTING PROCESS OF EXTRACTED ACCELERATION SIGNALS
s5
AMPLITUDE RATIO COMPUTING PROCESS OF CAR ACCELERATION A AND CAR ACCELERATION B WITH RESPECT TO RMS VALUE (MAXIMUM VALUE)
s6
THRESHOLD DETERMINATION PROCESS OF AMPLITUDE RATIO
s7
FAILURE DETERMINATION PROCESS BASED ON THRESHOLD DETERMINATION RESULT
s8
OUTPUT FAILURE DETERMINATION RESULT
s9

FIG.16

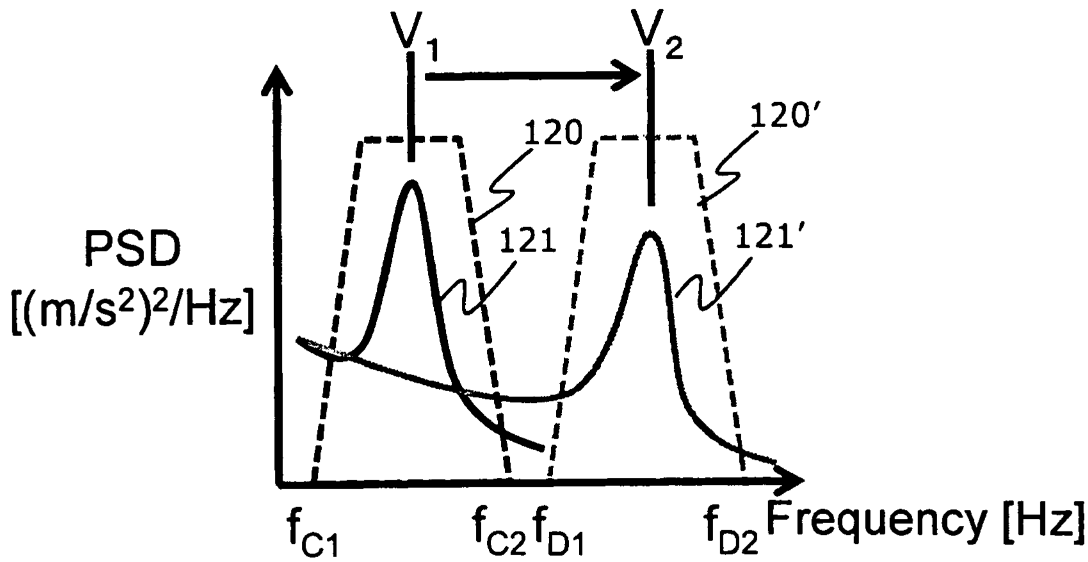


FIG.17

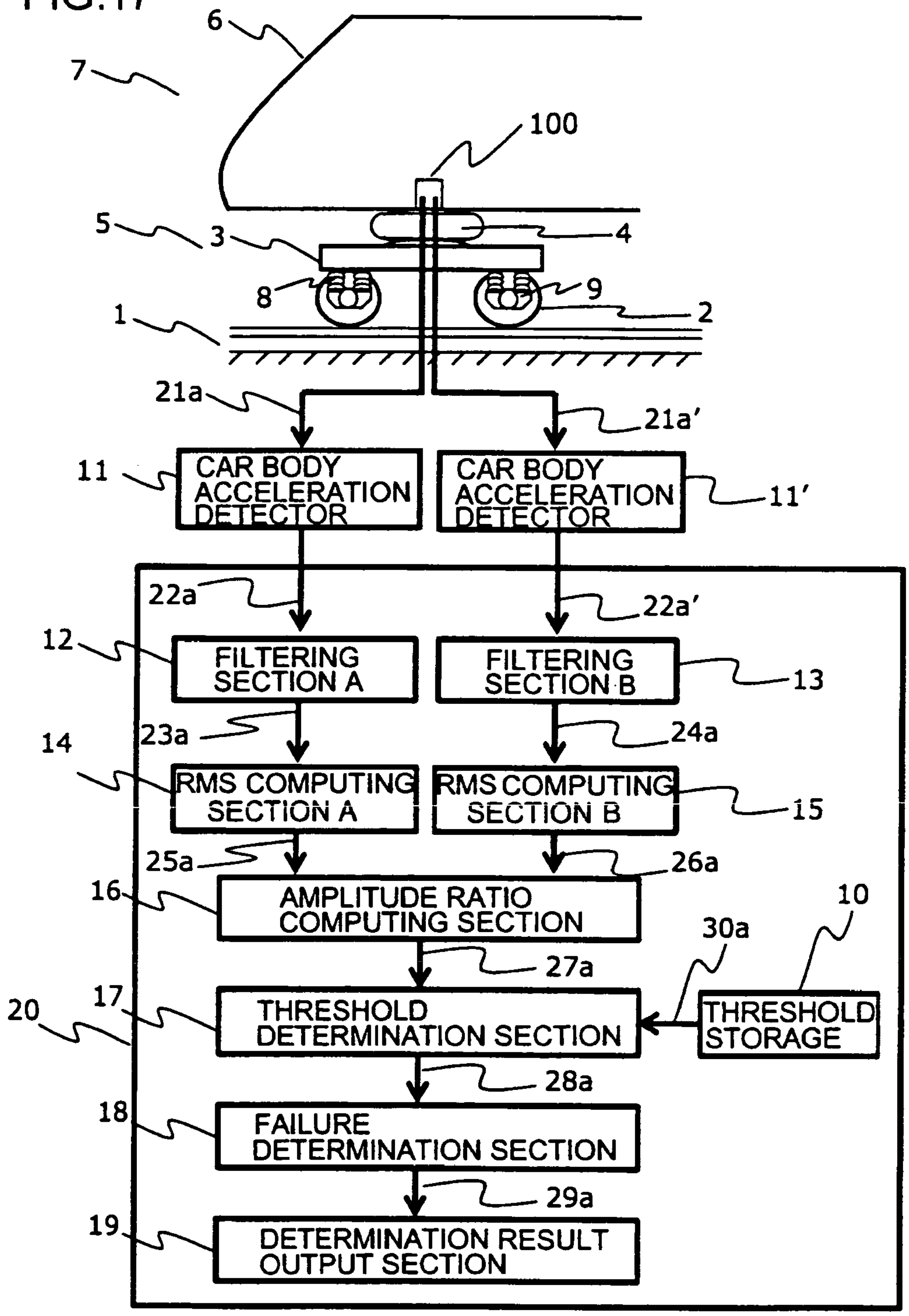

6
7
100
5
3
4
8
9
1
2
21a
21a'
11
CAR BODY ACCELERATION DETECTOR
CAR BODY ACCELERATION DETECTOR
11'
22a
22a'
12
FILTERING SECTION A
FILTERING SECTION B
13
23a
24a
14
RMS COMPUTING SECTION A
RMS COMPUTING SECTION B
15
25a
26a
16
AMPLITUDE RATIO COMPUTING SECTION
10
30a
27a
20
17
THRESHOLD DETERMINATION SECTION
THRESHOLD STORAGE
28a
18
FAILURE DETERMINATION SECTION
29a
19
DETERMINATION RESULT OUTPUT SECTION

FIG.18

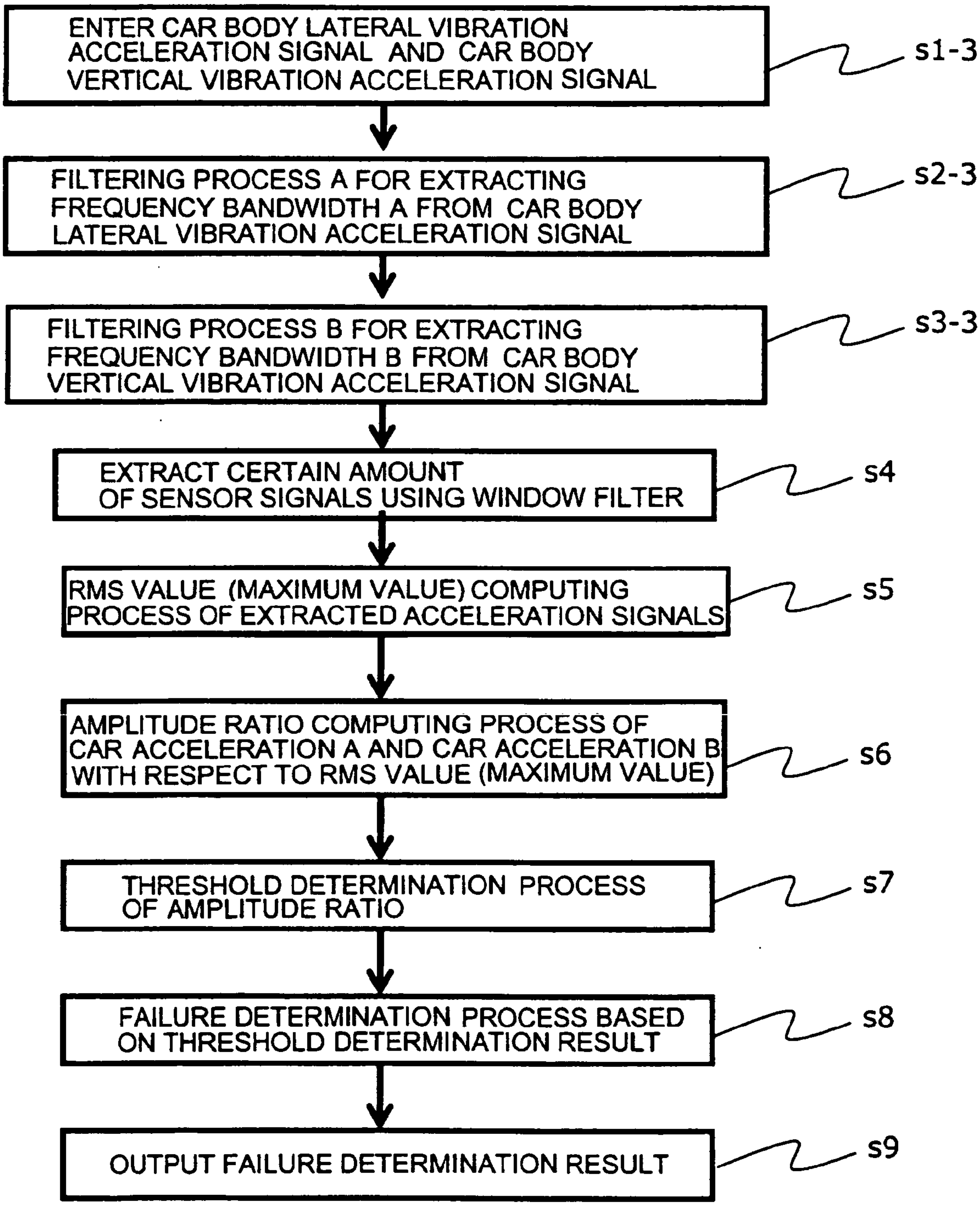

ENTER CAR BODY LATERAL VIBRATION ACCELERATION SIGNAL AND CAR BODY VERTICAL VIBRATION ACCELERATION SIGNAL
s1-3
FILTERING PROCESS A FOR EXTRACTING FREQUENCY BANDWIDTH A FROM CAR BODY LATERAL VIBRATION ACCELERATION SIGNAL
s2-3
FILTERING PROCESS B FOR EXTRACTING FREQUENCY BANDWIDTH B FROM CAR BODY VERTICAL VIBRATION ACCELERATION SIGNAL
s3-3
EXTRACT CERTAIN AMOUNT OF SENSOR SIGNALS USING WINDOW FILTER
s4
RMS VALUE (MAXIMUM VALUE) COMPUTING PROCESS OF EXTRACTED ACCELERATION SIGNALS
s5
AMPLITUDE RATIO COMPUTING PROCESS OF CAR ACCELERATION A AND CAR ACCELERATION B WITH RESPECT TO RMS VALUE (MAXIMUM VALUE)
s6
THRESHOLD DETERMINATION PROCESS OF AMPLITUDE RATIO
s7
FAILURE DETERMINATION PROCESS BASED ON THRESHOLD DETERMINATION RESULT
s8
OUTPUT FAILURE DETERMINATION RESULT
s9

FIG.19

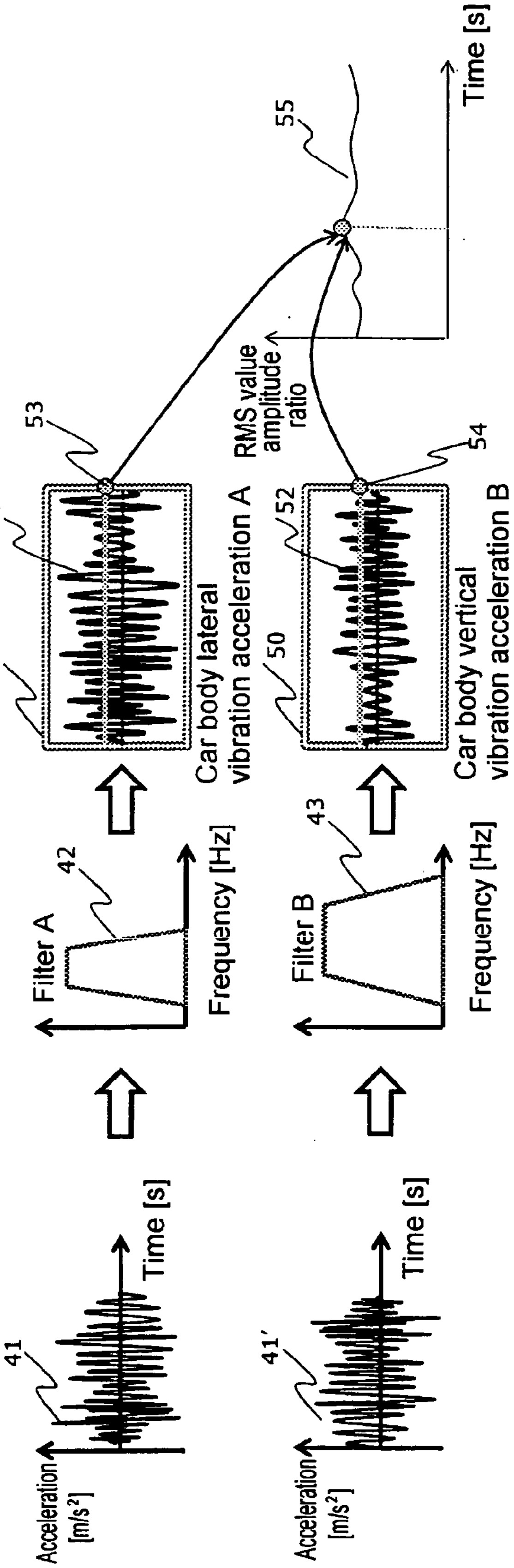
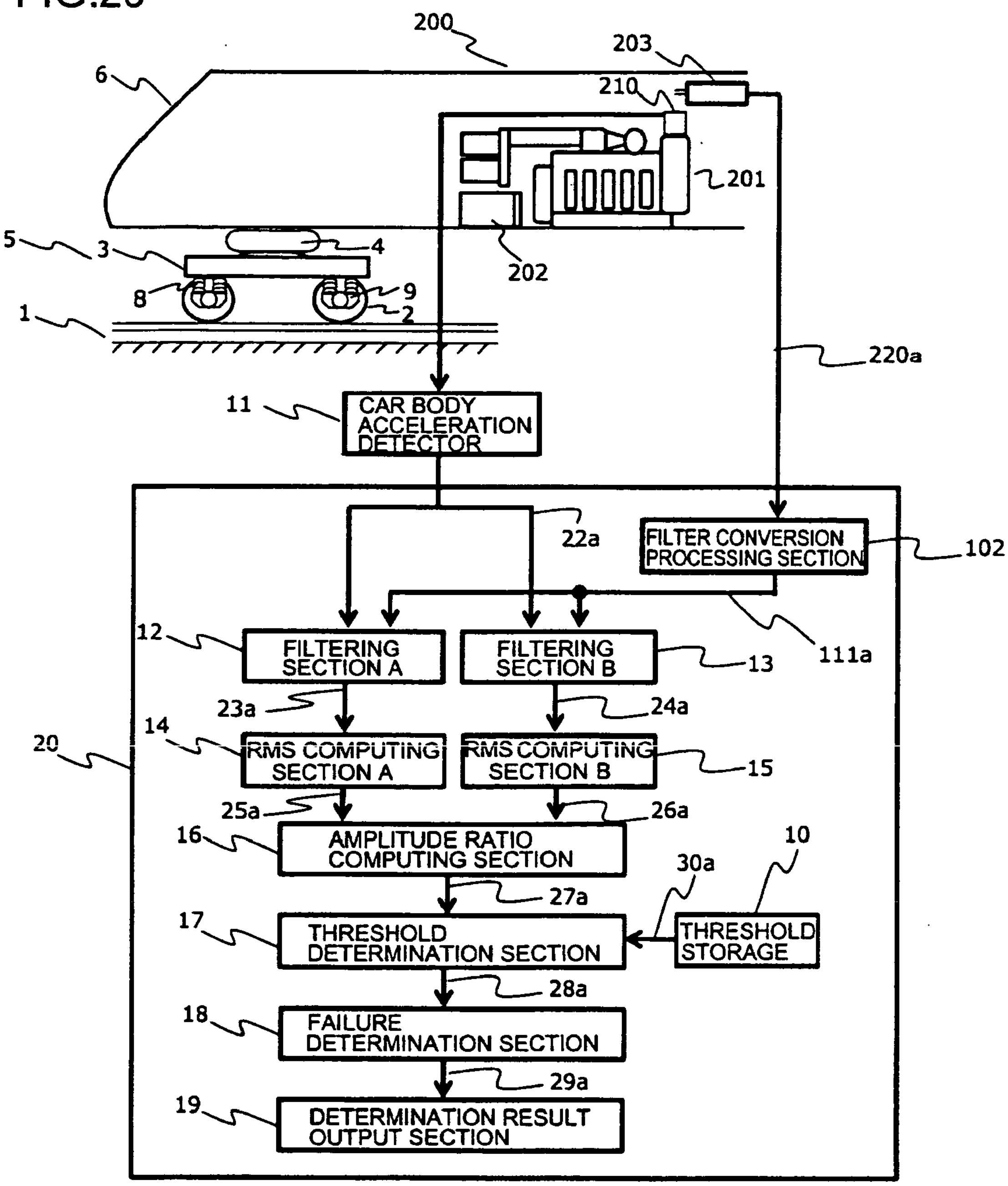

Acceleration [m/s²]
Time [s]
41
41'
Filter A
42
Frequency [Hz]
Filter B
43
Frequency [Hz]
50
51
53
Car body lateral vibration acceleration A
50
52
54
Car body vertical vibration acceleration B
RMS value amplitude ratio
55
Time [s]

FIG.20



200
203
6
210
201
5
3
4
202
8
9
1
2
220a
11
CAR BODY ACCELERATION DETECTOR
22a
FILTER CONVERSION PROCESSING SECTION
102
111a
12
FILTERING SECTION A
FILTERING SECTION B
13
23a
24a
14
20
RMS COMPUTING SECTION A
RMS COMPUTING SECTION B
15
25a
26a
16
AMPLITUDE RATIO COMPUTING SECTION
10
30a
27a
17
THRESHOLD DETERMINATION SECTION
THRESHOLD STORAGE
28a
18
FAILURE DETERMINATION SECTION
29a
19
DETERMINATION RESULT OUTPUT SECTION

FIG.21

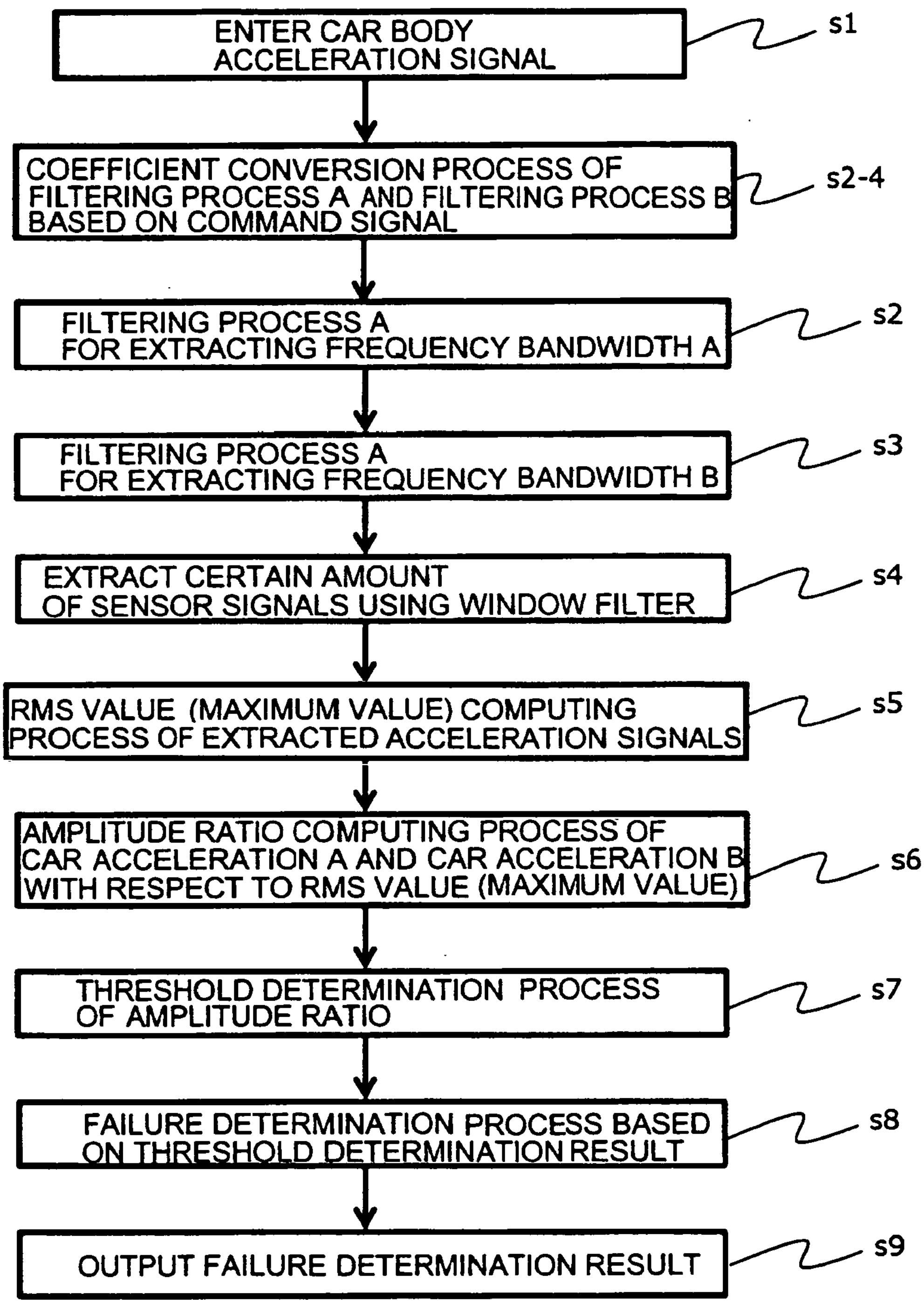

ENTER CAR BODY ACCELERATION SIGNAL
s1
COEFFICIENT CONVERSION PROCESS OF FILTERING PROCESS A AND FILTERING PROCESS B BASED ON COMMAND SIGNAL
s2-4
FILTERING PROCESS A FOR EXTRACTING FREQUENCY BANDWIDTH A
s2
FILTERING PROCESS A FOR EXTRACTING FREQUENCY BANDWIDTH B
s3
EXTRACT CERTAIN AMOUNT OF SENSOR SIGNALS USING WINDOW FILTER
s4
RMS VALUE (MAXIMUM VALUE) COMPUTING PROCESS OF EXTRACTED ACCELERATION SIGNALS
s5
AMPLITUDE RATIO COMPUTING PROCESS OF CAR ACCELERATION A AND CAR ACCELERATION B WITH RESPECT TO RMS VALUE (MAXIMUM VALUE)
s6
THRESHOLD DETERMINATION PROCESS OF AMPLITUDE RATIO
s7
FAILURE DETERMINATION PROCESS BASED ON THRESHOLD DETERMINATION RESULT
s8
OUTPUT FAILURE DETERMINATION RESULT
s9

FIG.22

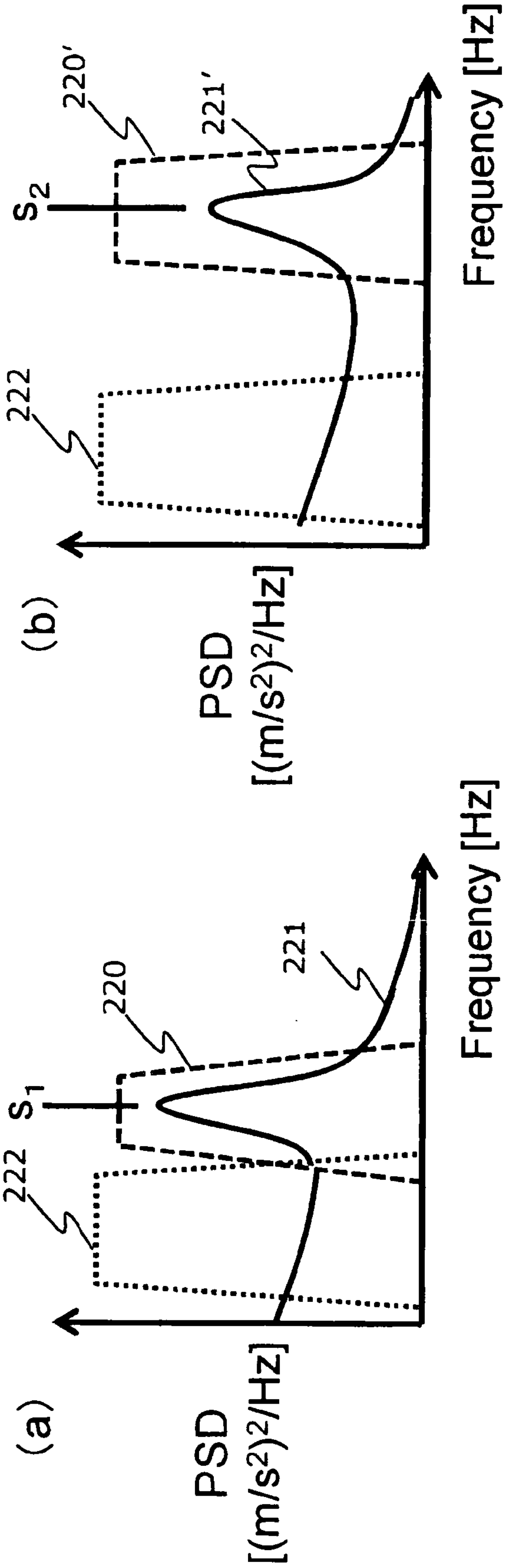
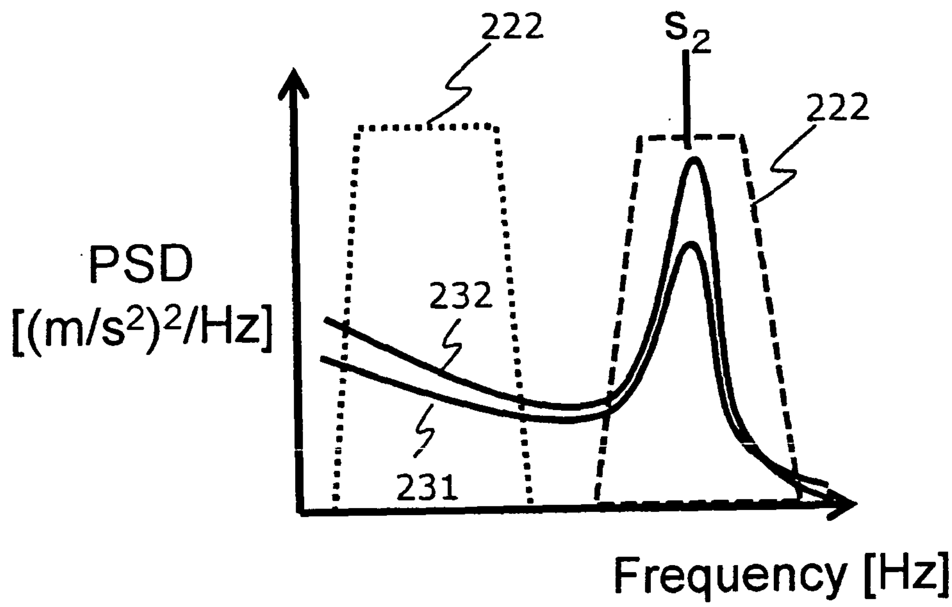

(a)
PSD [(m/s²)²/Hz]
Frequency [Hz]
S1
220
221
222
(b)
PSD [(m/s²)²/Hz]
Frequency [Hz]
S2
220'
221'
222

FIG.23



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Application Number
EP 11 25 0239

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B61K
B61F
B61L

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 17 January 2012 | Awad, Philippe |

CATEGORY OF CITED DOCUMENTS

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17-01-2012

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