



(11) **EP 2 040 614 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
27.01.2016 Bulletin 2016/04

(51) Int Cl.:
A61B 5/00 (2006.01) A61B 5/02 (2006.01)
A61B 5/04 (2006.01) A61B 5/08 (2006.01)
A61B 5/11 (2006.01)

(21) Application number: **07840352.4**

(86) International application number:
PCT/US2007/072854

(22) Date of filing: **05.07.2007**

(87) International publication number:
WO 2008/024561 (28.02.2008 Gazette 2008/09)

(54) **A SYSTEM FOR DETECTING AND MONITORING VITAL SIGNS**

SYSTEM ZUR ERKENNUNG UND ÜBERWACHUNG VON VITALZEICHEN

SYSTÈME DE DÉTECTION ET DE CONTRÔLE DE SIGNES VITAUX

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR

• **DIONNE, Jean-Paul**
Levis, Québec G6V 7A6 (CA)

(30) Priority: **05.07.2006 US 818699 P**
05.07.2007 US 773714

(74) Representative: **Coyle, Philip Aidan et al**
F. R. Kelly & Co.
27 Clyde Road
Ballsbridge
Dublin 4 (IE)

(43) Date of publication of application:
01.04.2009 Bulletin 2009/14

(73) Proprietor: **STRYKER CORPORATION**
Kalamazoo, MI 49002 (US)

(56) References cited:
JP-A- 2003 210 434 JP-A- 2005 177 471
US-A- 4 595 016 US-A- 5 620 003
US-A1- 2006 028 350 US-B1- 6 280 392
US-B1- 6 450 957

(72) Inventors:
• **WAN FONG, David Kim Soui**
St-romuald, Québec G6W 8K6 (CA)

EP 2 040 614 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to patient support apparatuses, such as beds, stretchers, cots, or the like, and more particularly to patient support apparatuses that monitor one or more conditions of the patient while the patient is positioned on the support apparatus.

[0002] A patient's health status is typically evaluated by reference to a plurality of vital signs, such as a pulse rate and breathing rate. When these vital signs fall below or rise above normal readings, a patient is usually in distress and requires quick attention by healthcare professionals. It is therefore desirable for health care professionals to know these vital sign readings.

[0003] U.S. Patent 5,620,003 issued to Sepponen discloses a measuring support, which may be applied in a domestic bathroom scale. The measuring support includes a transforming element T, which may be a strain gauge transducer, that is used to detect both a person's weight and the person's pulse. With the appropriate integration and/or multiplication, the pulse rate can be converted to measurements of stroke volume (SV) and cardiac output (CO) as well. As shown in FIG. 1 and described in col. 2, lines 26-35, the pulse rate is able to be detected by the transforming element T because of the turns in the person's aorta. This turn produces a force FO directed toward the head P of the patient. Because this force is directed in a direction perpendicular to the plane of support S, this force will cause compression or expansion of transforming element T, which is detected by element T and processed into a pulse rate. Measuring a person's breathing rate is not disclosed.

[0004] Japanese patent publication 2005 177471 discloses a bed having number of strain gauges 40a and 40b that are incorporated into a head section 3 of the bed. The strain gauges are used to detect biological activity of a patient supported thereon, such as breathing rate and/or heart rate. In all of the different embodiments, the strain gauges 40a and 40b are incorporated into the surface constitutive member 2--specifically into the head section 3 of member 2. The strain gauges do not measure the forces exerted by a load frame thereon wherein the load frame supports a support deck having multiple sections.

[0005] Japanese patent publication 2003 210434 discloses a bio-information acquiring device that has a hermetically closed pneumatic sound chamber. The sound chamber senses vibrations that are due to respiration, heartbeat, and other causes. The sound chamber includes an omnidirectional microphone for detecting variations in the pneumatic pressure therein. The sound sensors may be attached to the leg of a chair or bed, or they may be incorporated into the floor.

[0006] US patent publication 2006/0028350 discloses a hospital bed having a plurality of load cells that are used to determine the location and movement of a patient on

the bed. A controller reads the load cells and detects changes in the distribution of patient weight among the plurality of load cells. The controller may also account for the installation or removal of medical equipment or other tare weights on the bed. The load cells do not detect any vital signs of the patient.

[0007] According to the present invention, there is provided a patient support apparatus as claimed in Claim 1.

DESCRIPTION OF THE DRAWINGS

[0008]

FIG. 1 is a perspective view of a patient support apparatus according to one aspect of the present invention shown with a head section of a patient support deck pivoted to an elevated position;

FIG. 2 is a side, elevational view of the patient support apparatus of FIG. 1 shown with the patient support deck pivoted to a horizontal orientation and with various components removed for clarity, such as the side rails and head rails;

FIG. 3 is a perspective view of an intermediate frame of the patient support apparatus of FIG. 1 illustrating the location of four load cells;

FIG. 4 is a perspective, exploded view similar to that of FIG. 3 showing a load frame positioned above the intermediate frame;

FIG. 5 is a perspective view of a portion of the load frame and intermediate frame of FIGS. 3 and 4 illustrating an electronic controller;

FIG. 6 is a graph of weight versus time generated by the measurements of one of the load cells taken when no person was supported on the patient support apparatus;

FIG. 7 is a graph of the Fast Fourier Transform of the graph of FIG. 6;

FIG. 8 is a graph of weight versus time generated by the measurements of one of the load cells taken when a person was lying substantially motionless on his back on the patient support apparatus;

FIG. 9 is a graph of the Fast Fourier Transform of the graph of FIG. 8 taken over an interval of 6.35 seconds;

FIG. 10 is a graph of the Fast Fourier Transform of the graph of FIG. 8 taken over an interval of 12.75 seconds;

FIG. 11 is a graph of the Fast Fourier Transform of the graph of FIG. 8 taken over an interval of 204.8 seconds;

FIG. 12 is a graph of weight versus time generated by the measurements of one of the load cells taken when a person was lying substantially motionless on his side on the patient support apparatus;

FIG. 13 is a graph of the Fast Fourier Transform of the graph of FIG. 12 taken over an interval of 40.95 seconds;

FIG. 14 is a graph of weight versus time generated

by the measurements of one of the load cells taken when a person was lying substantially motionless on his stomach on the patient support apparatus; FIG. 15 is a graph of the Fast Fourier Transform of the graph of FIG. 14 taken over an interval of 40.95 seconds; FIG. 16 is a graph of weight versus time generated by the measurements of one of the load cells taken when a person was in the sitting-up position on the patient support apparatus; and FIG. 17 is a graph of the Fast Fourier Transform of the graph of FIG. 16 taken over an interval of 40.95 seconds.

DETAILED DESCRIPTION OF THE INVENTION

[0009] The present invention will now be described with reference to the accompanying drawings wherein the reference numerals appearing in the following written description correspond to like-numbered elements in the several drawings. The methods and systems of the present invention may be incorporated into any known bed, stretcher, cot, or other type of patient support apparatus having one or more force sensors, as will be discussed in greater detail below. One such patient support apparatus that may incorporate the systems and methods of the present invention is patient support apparatus 20, depicted in FIG. 1. Patient support apparatus 20 includes a base 22, an intermediate frame 24, a load frame 26, and a support deck 28. Base 22 may include one or more casters 30 and a fifth wheel 32 that is moveable between a raised position out of contact with the ground and a lowered position in contact with the ground, the latter position facilitating steering of patient support apparatus 20. Intermediate frame 24 is supported on base 22 by way of a pair of lift arms 34. Lift arms 34 are pivotably coupled to base 22 such that their pivoting enables the height and angular orientation of intermediate frame 24 to be adjusted with respect to base 22. Load frame 26 is supported on intermediate frame 24 and load frame 26 supports support deck 28. Support deck 28 is adapted to support a mattress or other type of sleep surface that comfortably supports a patient. Support deck 28 includes a head section 36, a seat section 38, a thigh section 40, and foot section 42. Sections 36, 38, 40, and 42 are all pivotably coupled to each other and/or load frame 26 such that they can articulate between the flat, horizontal orientation of FIG. 2 and various raised orientations, one of which is illustrated in FIG. 1. Further details of the construction of patient support apparatus 20 can be found in commonly-assigned, copending U.S. application Serial No. 11/362,543 filed February 23, 2006 by applicants Guy Lemire et al., and entitled Hospital Patient Support.

[0010] Patient support apparatus 20 includes a plurality of force sensors 44 positioned between intermediate frame 24 and load frame 26 (FIGS. 3-4). Force sensors 44 may be any type of sensors that are capable of de-

tecting the forces exerted by load frame 26 onto intermediate frame 24. In one embodiment, force sensors 44 may be any type of conventional load cell, such as, but not limited to, hydraulic load cells, pneumatic load cells, mechanical load cells, strain gauge load cells, bending beam load cells, shear beam load cells, canister load cells, ring and pancake load cells, button and washer load cells, helical load cells, fiber optic load cells, and piezoelectric load cells.

[0011] Force sensors 44 are positioned at each of four corners 46 of intermediate frame 24 (FIGS. 3-4). Force sensors 44 each include a pair of vertical fastener apertures 48 that receive corresponding fasteners 50, such as, but not limited to, screws and/or bolts and nuts. Fasteners 50 also pass through a pair of fastener apertures 52 on intermediate frame 24, thereby securing force sensors 44 to intermediate frame 24. Force sensors 44 are dimensioned to fit within a rectangular opening 54 defined at each end of a longitudinal support rail 56. Intermediate frame 24 includes a pair of longitudinal support rails 56 that are parallel to each other and positioned along the sides of patient support apparatus 20.

[0012] In the illustrated embodiment, each force sensor 44 includes an aperture 58 having a generally horizontal axis. A pair of collars 60 are inserted into either side of aperture 58 and positioned therein. A fastener 62, such as, but not limited to, a screw and/or a bolt and nut, is inserted through a horizontal fastener aperture 64 positioned generally on the underside of load frame 26. Fastener 62 also passes through collars 60, thereby securing load frame 26 to intermediate frame 24. Load frame 26 is supported on intermediate frame 24 only at the corners 46 of intermediate frame 24. More specifically, load frame 26 is completely supported on intermediate frame 24 by way of force sensors 44. Thus, the entire weight of load frame 26, as well as all the other structures supported by load frame 26 (including any patient on support deck 28) will be measured by force sensors 44. Force sensors 44 can thus be used to measure the weight of a patient positioned on support deck 28 by simply subtracting the tare weight of the non-patient items from the gross weight measured by the force sensors 44. The resulting net weight is the weight of the patient.

[0013] Each of the force sensors 44 includes a cable 66 over which electrical signal indicative of the forces sensed by force sensors 44 are transmitted. The electrical signals carried by cables 66 are transmitted to a controller 68 (FIG. 5). The transmitted signals may be amplified by an amplifier (not shown) prior to being transmitted over cables 66, or they may be amplified by an amplifier adjacent to, or part of, controller 68, or they may not need to be amplified at all. Once controller 68 receives the electrical signals from cables 66, it processes them in a manner that will be described below in order to gather and determine various characteristics about a patient lying on support deck 28, such as the patient's heart rate, breathing rate, and/or whether the patient is experiencing a seizure or not.

[0014] The basic principle of various aspects of the present invention is that a person lying on a sleep surface positioned on support deck 28 will exert changing forces onto one or more of force sensors 44, and those changes can be monitored to determine useful information about the patient. For example, the beating of the patient's heart will exert small forces that are transferred to the support deck, and from the support deck to load frame 26 where they are detected by the force sensors 44. As another example, the patient's breathing creates forces that are transferred to the patient support deck 28 and load frame 26, where they are detected by force sensors 44. Still further, if a patient experiences a seizure, the movement of the patient's limbs and/or body will generate forces on support deck 28 that are transferred, via load frame 26, to force sensors 44. Force sensors 44 detect all of these various kinds of forces and convert them into electrical signals 70 (see, e.g. FIG. 6), which are then passed by cables 66 to controller 68 which performs an analysis of the data contained within the electrical signals 70.

[0015] Controller 68 may do several things with the electrical signals 70, one of which is the calculation of Fast Fourier Transforms. As is known in the art, the calculation of a Fourier Transform generates a spectrum illustrating the various frequency components of a time domain signal. As will be discussed below, the frequency spectrum generated by the Fast Fourier Transforms can be utilized by controller 68 in order to determine various characteristics about the patient. In addition to calculating the Fast Fourier Transforms of the electrical signals 70 from cables 66, controller 68 may also perform low-pass and band-pass filtering of signals 70. The low-pass filtering may be designed to remove those frequency components that are not needed for the analyses described herein. As will be discussed more below, the frequencies of interest for determining the patient's heart rate are primarily the second and third harmonics of the patient's heart rate. Thus, the low-pass filter should not, at a minimum, eliminate frequencies less than three times that of the maximum heart rate desired to be detected. The band-pass filtering may be used to remove the sixty hertz electrical noise from the electrical power supply.

[0016] Controller 68 may also combine the signals 70 from two or more of the force sensors 44 as part of the data analysis carried out by controller 68. The choice of which signals 70 to combine may be based upon changes in the center of gravity of the patient on support deck 28. The center of gravity of the patient may be determined by controller 68, or some other processing device, based upon the force signals generated by force sensors 44. One method by which controller 68, or another processing device, may determine the patient's center of gravity from force sensors 44 is disclosed in commonly-assigned U.S. Patent No. 5,276,432, issued to Travis on January 4, 1994.

[0017] FIGS. 6-17 depict data that was generated from the measurements of a single force sensor 44 implemented as a load cell and positioned at the left, head end of

a patient support apparatus. The patient support apparatus upon which these readings were taken was substantially similar to support apparatus 20. The various data depicted in these drawings correspond to different locations of a patient, as well as different time intervals for the various Fast Fourier Transforms illustrated therein, as will be discussed in greater detail below.

[0018] FIG. 6 depicts a graph of the signal 70 output from a single force sensor 44 taken when no patient was positioned on the support deck of the patient apparatus. As can be seen, the load cell measures a force of approximately 59.75kg (131.7 lbs), with very minor variations, over the course of a ten second time interval. This graph indicates the baseline fluctuation of the force sensor 44 when no patient is present.

[0019] FIG. 7 depicts the Fast Fourier Transform of the graph of FIG. 6. FIG. 7 thus shows the frequency components of the graph of FIG. 6. As can be seen from FIG. 7, the frequency spectrum is almost uniformly close to zero for substantially all frequencies.

[0020] FIG. 8 depicts the graph of the signal 70 output from a single force sensor 44 taken when a patient was lying down on his back on the support deck. As can be seen in FIG. 8, the signal 70 has eleven peaks 72 and ten valleys 74 over the forty second time interval depicted in FIG. 8. Peaks 72 and valleys 74 correspond to the breathing rate of a patient positioned on support deck 28. Controller 68 may be programmed to calculate a breathing rate from these peaks and valleys. In the graph of FIG. 8, the first peak 72 occurs at about 101 seconds, while the last valley 74 occurs at about 138.5 seconds. Thus, between 101 and 138.5 seconds, there are ten complete cycles illustrated in FIG. 8. This corresponds to a breathing rate of approximately 3.75 seconds per breath $[(138.5 - 101)/10 = 3.75]$. A breathing rate of 3.75 seconds per breath translates into a breathing rate of sixteen breaths per minute $[(1/3.75) * 60 = 16]$. A person skilled in the art would be able to program controller 68, which may include one or more conventional microprocessors with suitable RAM and/or other memory, to analyze the time domain signal 70 of force sensor 44 in order to calculate a breathing rate of the patient.

[0021] FIG. 9 illustrates a Fast Fourier Transform of the time domain signal 70 of FIG. 8 taken over a time interval of 6.35 seconds. Controller 68 may be programmed to carry out this Fast Fourier Transform, or another controller having one or more microprocessors and suitable memory, may be programmed to calculate this Fast Fourier Transform. As can be seen in FIG. 9, the chart has three major peaks. The leftmost peak 76 corresponds to a breathing rate of the patient. The second to leftmost peak 78 corresponds to a second harmonic of the patient's heart beat. The rightmost peak 80 corresponds to the third harmonic of the patient's heart beat.

[0022] Controller 68 may be programmed to automatically analyze the Fast Fourier Transforms of the signals 70 generated by force sensors 44, such as the Fast Fourier Transform depicted in FIG. 9. Such analysis may be

used to determine the patient's heart rate and/or breathing rate. Using FIG. 9 as an example, the patient's breathing rate can be determined from the breathing rate peak 76. In FIG. 9, breathing rate peak 76 occurs at approximately 0.28 hertz. This corresponds to a breathing rate of about 16.8 breathes per minute [$60 * 0.28 = 16.8$]. This matches closely with the breathing rate of 16 breathes per minute that was calculated above using the time domain signal 70 of FIG. 8. (The discrepancy can be accounted for due to the different time periods over which the breathing rate was measured: the FIG. 8 calculation used a time period of 37.5 seconds while the FIG. 9 calculation used a time period of 6.35 seconds).

[0023] In addition to determining a patient's breathing rate, controller 68 may further be programmed to determine the patient's heart rate using the Fast Fourier Transform of signal 70. This can be accomplished by looking at the peaks 78 and 80, which, as noted, correspond to the second and third harmonics of the patient's heart beat, respectively. Using FIG. 9 as an example, peak 78 occurs approximately at 2.2 hertz and peak 80 occurs approximately at 3.9 hertz. Since these peaks represent the second and third harmonics of the patient's heart beat, the first harmonic can be easily calculated by either dividing the second harmonic frequency by two, or dividing the third harmonic frequency by three. If the results of these two different computations differ, it may be beneficial to compute an average of the two.

[0024] In the example of FIG. 9, the patient's heart rate can be calculated by dividing the frequency at peak 78 (approximately 2.2 hertz) by two to obtain a value of 1.1 hertz. Alternatively, the patient's heart rate can be calculated by dividing the frequency at peak 80 (approximately 3.9) by three to obtain a value of 1.3 hertz. Because this value differs from the 1.1 hertz value calculated using peak 78, the two values can be averaged together. Such an averaging would yield a heart rate of 1.2 hertz [$(1.3 + 1.1) \% 2 = 1.2$], which translates into a heart rate of 72 beats per minute.

[0025] FIG. 10 illustrates a Fast Fourier Transform of the signal 70 of FIG. 7 taken over a time interval of 12.75 seconds, which is greater than the time interval of FIG. 8. While this graph shows that the peak 80 of the third harmonic has been diminished, it is still possible for controller 68 to calculate both the patient's heart rate and breathing rate from this graph. The breathing rate is defined by peak 76 which, in FIG. 8, is located at approximately 0.24 hertz, corresponding to a breathing rate of about 14.4 breathes per minute. The heart rate can be determined by dividing the frequency of the second harmonic peak 78 by two. In FIG. 10 this yields a heart rate of approximately 1.125 hertz [$2.25/2 = 1.125$], or 67.5 beats per minute. Alternatively, the heart rate can be calculated using the frequency at the third harmonic peak 80, which occurs approximately at 3.9 hertz. Dividing this frequency by three, yields a heart rate of 1.3 hertz, which can either be used alone as the heart rate, or can be combined with the heart rate generated from the frequen-

cy of second peak 78. The combination of the two heart rates can be done by averaging, or by any other suitable mathematical technique.

[0026] FIG. 11 illustrates another Fast Fourier Transform of the time domain signal 70 of FIG. 8 taken over a time interval of 204.8 seconds. As can be seen, peaks 76, 78, and 80 are clearly defined and the breathing rate and/or heart rate of a patient can be determined from these peaks using any of the methods described above. While the peaks of FIG. 11 are clearly defined, this clarity comes at a cost of a relatively lengthy time interval of 204.8 seconds. In some situations, this "cost" may be perfectly acceptable, and in other situations, this "cost" may desirably be avoided. In general, the longer the time period used for the Fast Fourier Transform, the clearer the peaks. However, in general, the longer the time period used in the Fast Fourier Transforms, the less often one can determine the heart rate and/or breathing rate. Thus, longer time intervals can be useful for accurately determining relatively steady heart rates and/or breathing rates, while longer time intervals may be less effective for determining short term trends and/or changes. A person skilled in the art would be able to choose the most suitable time interval for a given situation, and the present invention contemplates, in addition to using a single time interval, using time intervals of different durations at different times, as well as using different time intervals for two or more of the force sensors 44.

[0027] FIG. 12 illustrates a time domain signal 70 generated by a force sensor 44 while a patient was lying on his side on top of the support deck of a patient support apparatus. The peaks 72 and valleys 74 corresponding to the patient's breathing rate are evident, and controller 68 could be programmed to determine the patient's breathing rate directly from time domain signal 70. Alternatively or additionally, controller 68 could be programmed to determine the patient's breathing rate using a Fast Fourier Transform of the time domain signal.

[0028] FIG. 13 illustrates a Fast Fourier Transform of the time domain signal 70 of FIG. 12 taken over a time interval of 40.95 seconds. Peaks 76, 78, and 80 are clearly visible and can be used to determine heart rate and/or breathing rate in the manner described above.

[0029] FIG. 14 illustrates a time domain signal 70 generated by a force sensor 44 while a patient was lying on his stomach on top of the support deck of a patient support apparatus. The peaks 72 and valleys 74 are evident, and controller 68 could determine a patient's breathing rate directly from the time domain signal 70 of FIG. 14.

[0030] FIG. 15 illustrates a Fast Fourier Transform of the time domain signal 70 of FIG. 14 taken over a time interval of 40.95 seconds. Peaks 76 and 78 are clearly visible, and these are sufficient for controller 68 to determine either or both of the patient's heart rate and breathing rate in the manner described above.

[0031] FIG. 16 illustrates a time domain signal 70 generated by a force sensor 44 while a patient was sitting up on top of the support deck of a patient support appa-

ratus. This data was generated when the person's torso was not in contact with the head section 36 of the patient support deck. Thus, the vibrations of the patient's heart beat were likely muted by the patient's body, thereby explaining the lack of clear second and third harmonic heart beat peaks 78 and 80 (FIG. 17). FIG. 18, however, does show a breathing rate peak 76, and FIG. 17 also shows peaks and valleys 72 and 74. Consequently, a patient's breathing rate could be calculated either from the direct time domain signal 70 or a Fast Fourier Transform of those signals.

[0032] The charts of FIGS. 6-17 demonstrate the viability of using one or more force sensors 44 to determine and monitor one or more of a patient's conditions. While FIG. 17 suggests that it may be difficult to determine a patient's heart rate while the person is sitting up on the patient support apparatus, additional signal processing could be done to mitigate this difficulty. The charts of FIGS. 6-17 thus confirm the usefulness of monitoring the fluctuations of force sensors to determine one or more characteristics about a patient positioned on a support apparatus, such as patient support apparatus 20.

[0033] In addition to monitoring the breathing rate and/or heart rate of a patient, controller 68 can also be configured to determine if a patient is experiencing a seizure or not. In order to detect seizures, controller 68 monitors the amplitude of signals 70 for repetitive fluctuations that exceed a predetermined magnitude over a predetermined time period. Such monitoring may be done on signals that are not filtered, or that are filtered in a different manner than is done to the signals used to monitor the patient's heart rate and/or breathing rate. The predetermined magnitude and predetermined time that the fluctuations of signal 70 has to exceed in order to qualify as a seizure may be adjustably set by a health care attendant so as to be able to be specifically tailored to a particular patient. Alternatively, the predetermined magnitude of the changes from one or more force sensors 44 may be based upon a percentage of the patient's resting weight such that a lighter patient won't have to cause as great of amplitude variations in signal 70 as a heavier person would before controller 68 determined a seizure was occurring. Because the movements of a patient experiencing a seizure generally occur at random, it is not necessary to calculate a Fast Fourier Transform of the signals 70 in order to detect a seizure.

[0034] Controller 68 may further be configured so as to issue one or more alerts or alarms if one or more of a variety of conditions occur. Controller 68 may be programmed to issue an alert or alarm if either of the breathing rate and/or pulse rate rises above, or drops below, predetermined levels. The predetermined levels may be adjustable by a health care attendant either through a control panel (not shown) on patient support apparatus 20 having a user interface that allows the attendant to input desired levels, or through a connection to a remote computer, or computer network, to which patient support apparatus 20 may be in electronic communication. Ad-

ditionally or alternatively, controller 68 may be configured to issue an alert if either of the breathing rate or heart rate experiences a change that exceeds a specified amount over a specified time period, wherein the specified amount and specified time period may be set by health care attendants. Further, controller 68 may desirably be configured to issue an alert if forces are detected on one or more force sensors 44 that are indicative of a potential seizure. Controller 68 may also issue an alert if it is unable to detect a heart rate and/or a breathing rate. The particular alert or alarm issued by controller 68 can take on any form that is suitable for a given environment, and may include visual and/or audio indications generated by patient support apparatus 20, or it may include the transmission of an alert or alarm signal to a remote location, such as a hospital computer network, that then processes the signal in the correct manner, such as by forwarding it to a nurse's station.

[0035] Controller 68 may determine heart rate, breathing rate, and seizure status of a patient based upon the output of only a single force sensor 44, or it may make one or more of those determinations based upon the output (i.e. signals 70) of more than one force sensor 44. In the cases where more than one force sensor 44 is used to determine heart rate, breathing rate, and/or patient seizure status, the processing of signals 70 from each force sensor 44 can be accomplished through any suitable combinations of the signals, such as by processing each signal individually and then combining the results in an appropriate manner (such as averaging), or by combining one or more of the signals prior to processing, or at some point prior to the final processing of the signals.

[0036] Still further, the particular manner in which controller 68 processes the signals may vary depending upon other circumstances or conditions of patient support apparatus 20. For example, if controller 68 is adapted to determine the patient's center of gravity, controller 68 could be configured to assign a greater weight to the signals 70 coming from the force sensor 44 closest to the center of gravity. Alternatively, controller 68 may assign a greater weight to the two closest force sensors 44 to the center of gravity. Additionally, controller 68 may be in communication with one or more angle sensors that determine the angle of one or more of the sections 36, 38, and 40 of support deck 28. This angular information could be used to alter the processing of the signals 70. Still other circumstances or conditions of patient support apparatus 20 can be taken into account when processing the signals 70, if desired.

[0037] In addition to, or in lieu of, the Fast Fourier Transform calculations made by controller 68 on the signals 70 coming from one or more force sensors 44, controller 68 may perform other processing beyond that described above to usefully enhance the data generated by force sensors 44. One such type of processing may involve digital signal processing that does not utilize any Fast Fourier Transforms at all. Another such possible processing may involve the computation of one or more

Fast Fourier Transforms of a previously computed Fast Fourier Transform. Such a multiple calculation of Fourier Transforms is known as a cepstrum, and may provide additional data that can be used to refine or assist in the determination of the patient's heart rate and/or breathing rate. Controller 68 may also perform processing to separate or minimize the impact of normal patient movement upon the calculations of heart rate, breathing rate, and/or seizure detection. Such processing may take into account changes in the location of the patient's center of gravity, the angular orientation of support deck sections 36, 38, 40 and 42, or still other factors.

[0038] Controller 68 may also store the data of signals 70 and/or the Fast Fourier Transforms in a memory (not shown) which can be read for displaying to attendant personnel so that they can look at and manually analyze the raw data. The memory may be located on patient support apparatus 20, or it may be located at a location remote from patient support apparatus, or both. If located remotely, controller 68 may communicate the data by any known means, such as a wire or cable connection, or via any of a variety of different conventional wireless communication techniques. Controller 68 may also be located remotely from patient support apparatus 20 and receive signals 70 via a wired or wireless connection to patient support apparatus 20.

[0039] Because of the computational resources necessary for calculating Fast Fourier Transforms, and/or performing other computationally heavy digital signal processing, controller 68 may include one or more processors specifically dedicated to the functions of monitoring the force sensors 44. Alternatively, the one or more processors of controller 68 may perform other patient support apparatus functions besides the monitoring of force sensors 44, such as the control of various motors, the monitoring of other medical equipment and/or patient support apparatus sensors, and other tasks. Still further, controller 68 may have some components physically located on patient support apparatus 20 and some components located remotely that communicate in any suitable manner with each other. However controller 68 is implemented, it is configured to carry out one or more of the functions described herein.

[0040] In addition to determining a patient's heart rate, breathing rate, and or seizure status, controller 68 can also be configured to determine a patient's weight from force sensors 44. Such a determination of weight can be carried out in a known manner by analyzing the signals 70 from the various force sensors 44. The monitoring of the patient's weight may also be performed as part of, or separately from, a patient bed exit system in which controller 68 issues an alert when it detects that the patient's weight has substantially or completely been lifted off of patient support deck 28. Such a lifting of the patient's weight indicates the patient has left, or is about to leave, patient support apparatus 20, and such information may desirably be communicated to remote locations.

[0041] The system of one or more force sensors 44

and controller 68 can be implemented on any patient support apparatus, not just the patient support apparatus 20 illustrated and described herein. Any patient support apparatus, such as a bed, cot, stretcher, or the like, in which one or more force sensors can be placed and their outputs analyzed can be adapted to include the monitoring system of the present invention. Such force sensors may be placed in any location where they are capable of detecting force changes caused by the breathing and heart beating of the patient.

[0042] While the systems and methods discussed herein have been previously described with reference to calculations of Fast Fourier Transforms, it will be understood by those skilled in the art that other mathematical techniques besides Fast Fourier Transforms can be used to carry out the systems and methods of the present invention.

[0043] Another embodiment of the present invention includes a method for analyzing forces exerted by a patient on a patient support, such as patient support apparatus 20, or any other patient support. The method includes the simultaneous monitoring of one or more patient conditions of interest (e.g. heart rate, breathing rate, seizure status, or others) via two sensors; or two sets of sensors. The first sensor or sensor set is a sensor specifically adapted to measure the condition of interest (such as a sleeve that directly measures a patient's heart rate, for example). The second sensor or sensor set is the one or more force sensors 44. After readings from the force sensors 44 are taken over a suitable time period, those readings are compared with the measurements from the first sensor (or first sensor set). The comparison involves looking for correlations between the readings from the first sensor (or first sensor set) and the second sensor (or second sensor set). After such a correlation is determined, the second sensor (or second sensor set) can thereafter be used to determine the condition of interest without the first sensor (or first sensor set) by examining the data from the second sensor (or sensor set) and using the known correlation between that data and the outputs of the first sensor (or sensor set). This method is a generalized method that allows correlations between force sensors 44 and various patient conditions to be discovered and refined, such as the patient heart rate, breathing rate, and seizure status, as well as other patient conditions.

[0044] While the present invention has been described herein in terms of several embodiments, it will be understood by those skilled in the art that the present invention is not limited to these particular embodiments, but includes any and all modification that are within the scope and spirit of the invention as defined in the following claims.

Claims

1. A patient support apparatus (20) comprising:

- a support deck (28) adapted to support a patient, said support deck (28) including a plurality of sections (36, 38, 40, or 42) pivotable with respect to each other such that a position of a patient's body supported on said support deck (28) may be changed;
- a load frame (26) supporting said support deck (28);
- an intermediate frame (24) secured to said load frame (26);
- force sensors (44) and a controller (68) in communication with said force sensors (44), **characterized in that** the force sensors are positioned at each of four corners (46) of intermediate frame (24), said force sensors being positioned intermediate said load frame and said intermediate frame, said force sensors (44) adapted to detect forces exerted from said load frame (26) onto said force sensors (44), said force sensors (44) outputting signals corresponding to said forces; and
- said controller (68) adapted to determine from said signals a weight of the patient, a breathing rate, and a heart rate of a patient positioned on said support deck (28).
2. The apparatus (20) of claim 1 wherein said controller (68) is adapted to calculate a Fast Fourier Transform of said signals and use said Fast Fourier Transform to determine the breathing rate and the heart rate.
 3. The apparatus (20) of claim 2 wherein said controller (68) determines the patient's breathing rate by identifying a peak frequency in said Fast Fourier Transform.
 4. The apparatus (20) of claim 2 wherein said controller (68) determines the patient's heart rate by analyzing a peak in said Fast Fourier Transform in order to determine the heart rate.
 5. The apparatus (20) of claim 4 wherein said controller (68) calculates the heart rate by dividing said peak by an integer.
 6. The apparatus (20) of claim 4 wherein said controller (68) analyzes a plurality of peaks in said Fast Fourier Transform to determine the heart rate, said plurality of peaks located at integer multiples of the heart rate.
 7. The apparatus (20) of claim 1 further including a low pass filter adapted to filter out frequencies in said signals that exceed a selected frequency.
 8. The apparatus (20) of any preceding claim wherein said controller (68) is further adapted to analyze said signals to determine if the patient is experiencing a seizure.

9. The apparatus (20) of claim 1 wherein said controller (68) is further adapted to monitor at least one of the breathing rate and heart rate and issue a notification to an attendant if the at least one of the breathing rate and heart rate meets a criteria that may be set by an attendant.
10. The apparatus (20) of claim 1 further including a plurality of lifting arms (34) pivotably coupled to the base (22) such that their pivoting enables the height and angular orientation of the intermediate frame (24) to be adjusted with respect to the base (22).
11. The apparatus (20) of claim 1 wherein said controller (68) is further adapted to determine a center of gravity of a patient using said force sensors (44), and to use said center of gravity to weight said signals when determining said breathing rate and heart rate.
12. The apparatus (20) of claim 1 wherein said controller (68) issues an alert when it detects that the patient's weight has substantially or completely been lifted off of the support deck.

Patentansprüche

1. Patiententragevorrichtung (20), umfassend:

eine Trägerfläche (28), die dazu angepasst ist, einen Patienten zu tragen, wobei die Trägerfläche (28) eine Vielzahl von Abschnitten (36, 38, 40 oder 42) beinhaltet, die in Bezug aufeinander drehbar sind, derart, dass eine Position eines Körpers eines Patienten, der auf der Trägerfläche (28) getragen wird, geändert werden kann;

einen Lastrahmen (26), der die Trägerfläche (28) trägt;

einen Zwischenrahmen (24), der an dem Lastrahmen (26) gesichert ist;

Kraftsensoren (44) und eine Steuereinrichtung (68) in Kommunikation mit den Kraftsensoren (44), **dadurch gekennzeichnet, dass** die Kraftsensoren an jeder von vier Ecken (46) des Zwischenrahmens (24) angeordnet sind, wobei die Kraftsensoren zwischen dem Lastrahmen und dem Zwischenrahmen angeordnet sind, wobei die Kraftsensoren (44) dazu angepasst sind, Kräfte zu detektieren, die von dem Lastrahmen (26) auf die Kraftsensoren (44) ausgeübt werden, wobei die Kraftsensoren (44) Signale ausgeben, die den Kräften entsprechen; und

wobei die Steuereinrichtung (68) dazu angepasst ist, anhand der Signale ein Gewicht des Patienten, eine Atmungsfrequenz und eine Herzfrequenz eines Patienten zu bestimmen, der auf der Trägerfläche (28) positioniert ist.

2. Vorrichtung (20) nach Anspruch 1, wobei die Steuereinrichtung (68) dazu angepasst ist, eine schnelle Fourier-Transformation der Signale zu berechnen und die schnelle Fourier-Transformation zum Bestimmen der Atmungsfrequenz und der Herzfrequenz zu verwenden. 5
3. Vorrichtung (20) nach Anspruch 2, wobei die Steuereinrichtung (68) die Atmungsfrequenz des Patienten durch Identifizieren einer Spitzenfrequenz in der schnellen Fourier-Transformation bestimmt. 10
4. Vorrichtung (20) nach Anspruch 2, wobei die Steuereinrichtung (68) die Herzfrequenz des Patienten durch Analysieren einer Spitze in der schnellen Fourier-Transformation bestimmt, um die Herzfrequenz zu bestimmen. 15
5. Vorrichtung (20) nach Anspruch 4, wobei die Steuereinrichtung (68) die Herzfrequenz durch Teilen der Spitze durch eine Ganzzahl berechnet. 20
6. Vorrichtung (20) nach Anspruch 4, wobei die Steuereinrichtung (68) eine Vielzahl von Spitzen in der schnellen Fourier-Transformation analysiert, um die Herzfrequenz zu bestimmen, wobei die Vielzahl von Spitzen an ganzzahligen Vielfachen der Herzfrequenz angeordnet ist. 25
7. Vorrichtung (20) nach Anspruch 1, ferner aufweisend einen Tiefpassfilter, der dazu angepasst ist, Frequenzen in den Signalen herauszufiltern, die eine ausgewählte Frequenz übersteigen. 30
8. Vorrichtung (20) nach einem der vorangehenden Ansprüche, wobei die Steuereinrichtung (68) ferner dazu angepasst ist, die Signale zu analysieren, um zu bestimmen, ob der Patient einen Anfall erleidet. 35
9. Vorrichtung (20) nach Anspruch 1, wobei die Steuereinrichtung (68) ferner dazu angepasst ist, wenigstens eine von der Atmungsfrequenz und der Herzfrequenz zu überwachen und eine Meldung an einen Pfleger auszugeben, wenn die wenigstens eine von der Atmungsfrequenz und der Herzfrequenz ein Kriterium erfüllt, das von einem Pfleger festgelegt werden kann. 40
10. Vorrichtung (20) nach Anspruch 1, ferner aufweisend eine Vielzahl von Hebearmen (34), die drehbar an die Basis (22) gekoppelt ist, derart, dass 10 ihr Drehen ein Anpassen der Höhe und Winkelausrichtung des Zwischenrahmens (24) in Bezug auf die Basis (22) ermöglicht. 50
11. Vorrichtung (20) nach Anspruch 1, wobei die Steuereinrichtung (68) ferner dazu angepasst ist, einen Schwerpunkt eines Patienten mithilfe der Kraftsen-

soren (44) zu bestimmen und den Schwerpunkt zum Gewichten der Signale zu verwenden, wenn die Atmungsfrequenz und Herzfrequenz bestimmt werden.

12. Vorrichtung (20) nach Anspruch 1, wobei die Steuereinrichtung (68) einen Alarm ausgibt, wenn sie detektiert, dass das Gewicht des Patienten im Wesentlichen oder vollständig von der Trägerfläche gehoben wurde. 55

Revendications

1. Dispositif (20) pour supporter un patient comprenant : 15
 - un plan de couchage (28) adapté pour supporter un patient, ledit plan de couchage (28) comprenant une pluralité de segments (36, 38, 40 ou 42) pouvant pivoter les uns par rapport aux autres de manière à pouvoir changer la position du corps du patient supporté sur ledit plan de couchage (28) ;
 - un châssis de charge (26) supportant ledit plan de couchage (28) ;
 - un châssis intermédiaire (24) fixé audit châssis de charge (26) ;
 - des capteurs de force (44) et un contrôleur (68) en communication avec lesdits capteurs de force (44), **caractérisé en ce que** les capteurs de force sont placés à chacun des quatre coins (46) du châssis intermédiaire (24), lesdits capteurs de force étant placés entre ledit châssis de charge et ledit châssis intermédiaire, lesdits capteurs de force (44) étant adaptés pour détecter les forces exercées par ledit châssis de charge (26) sur lesdits capteurs de force (44), lesdits capteurs de force (44) émettant des signaux correspondant auxdites forces ; et
 - ledit contrôleur (68) étant adapté pour déterminer, d'après lesdits signaux, le poids du patient, la fréquence respiratoire et la fréquence cardiaque d'un patient placé sur ledit plan de couchage (28). 25
2. Dispositif (20) selon la revendication 1, dans lequel ledit contrôleur (68) est adapté pour calculer la transformée de Fourier rapide desdits signaux et utiliser ladite transformée de Fourier rapide pour déterminer la fréquence respiratoire et la fréquence cardiaque. 30
3. Dispositif (20) selon la revendication 2, dans lequel ledit contrôleur (68) détermine la fréquence respiratoire du patient en identifiant une fréquence pic dans ladite transformée de Fourier rapide. 35
4. Dispositif (20) selon la revendication 2, dans lequel 40

- ledit contrôleur (68) détermine la fréquence cardiaque du patient en analysant un pic dans ladite transformée de Fourier rapide afin de déterminer la fréquence cardiaque. 5
5. Dispositif (20) selon la revendication 4, dans lequel ledit contrôleur (68) calcule la fréquence cardiaque en divisant ledit pic par un entier. 5
6. Dispositif (20) selon la revendication 4, dans lequel ledit contrôleur (68) analyse une pluralité de pics dans ladite transformée de Fourier rapide pour déterminer la fréquence cardiaque, ladite pluralité de pics étant située au niveau des multiples entiers de la fréquence cardiaque. 10
15
7. Dispositif (20) selon la revendication 1, comprenant en outre un filtre passe-bas adapté pour filtrer les fréquences dans lesdits signaux qui excèdent la fréquence sélectionnée. 20
8. Dispositif (20) selon l'une quelconque des revendications précédentes, dans lequel ledit contrôleur (68) est en outre adapté pour analyser lesdits signaux afin de déterminer si le patient est en crise convulsive. 25
9. Dispositif (20) selon la revendication 1, dans lequel ledit contrôleur (68) est en outre adapté pour surveiller au moins une constante parmi la fréquence respiratoire et la fréquence cardiaque et émettre une alerte pour un auxiliaire de soins si au moins la fréquence respiratoire ou la fréquence cardiaque répond à un critère pouvant être paramétré par l'auxiliaire de soins. 30
35
10. Dispositif (20) selon la revendication 1, comprenant en outre une pluralité de bras de levage (34) couplés de manière pivotante à la base (22) de telle sorte que leur pivotement permette de régler la hauteur et l'orientation angulaire du châssis intermédiaire (24) par rapport à la base (22). 40
11. Dispositif (20) selon la revendication 1, dans lequel ledit contrôleur (68) est en outre adapté pour déterminer le centre de gravité du patient en utilisant lesdits capteurs de force (44) et utiliser ledit centre de gravité afin de pondérer lesdits signaux au moment de déterminer ladite fréquence respiratoire et ladite fréquence cardiaque. 45
50
12. Dispositif (20) selon la revendication 1, dans lequel ledit contrôleur (68) émet une alerte lorsqu'il détecte que le poids du patient s'est sensiblement ou complètement soulevé du plan de couchage. 55

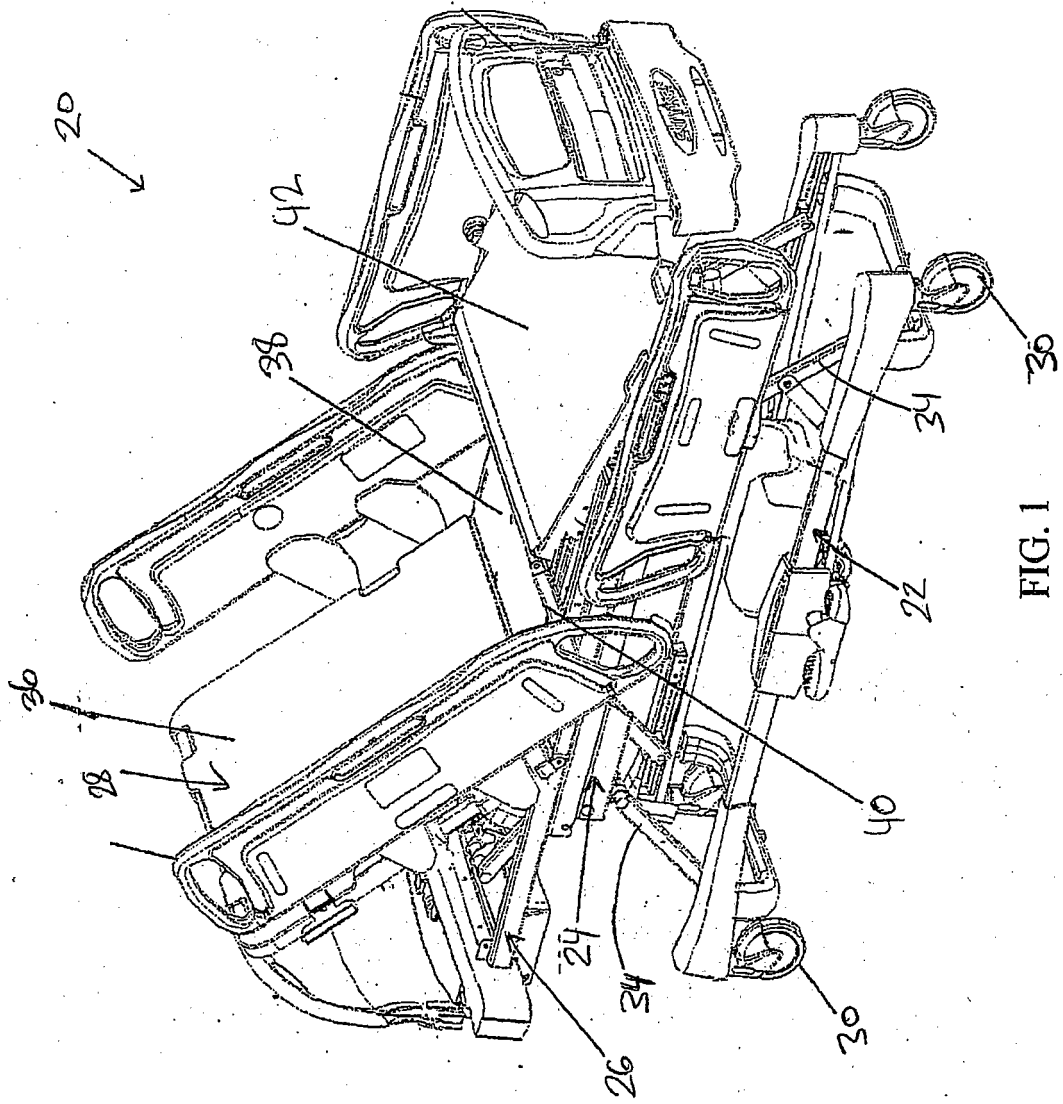


FIG. 1

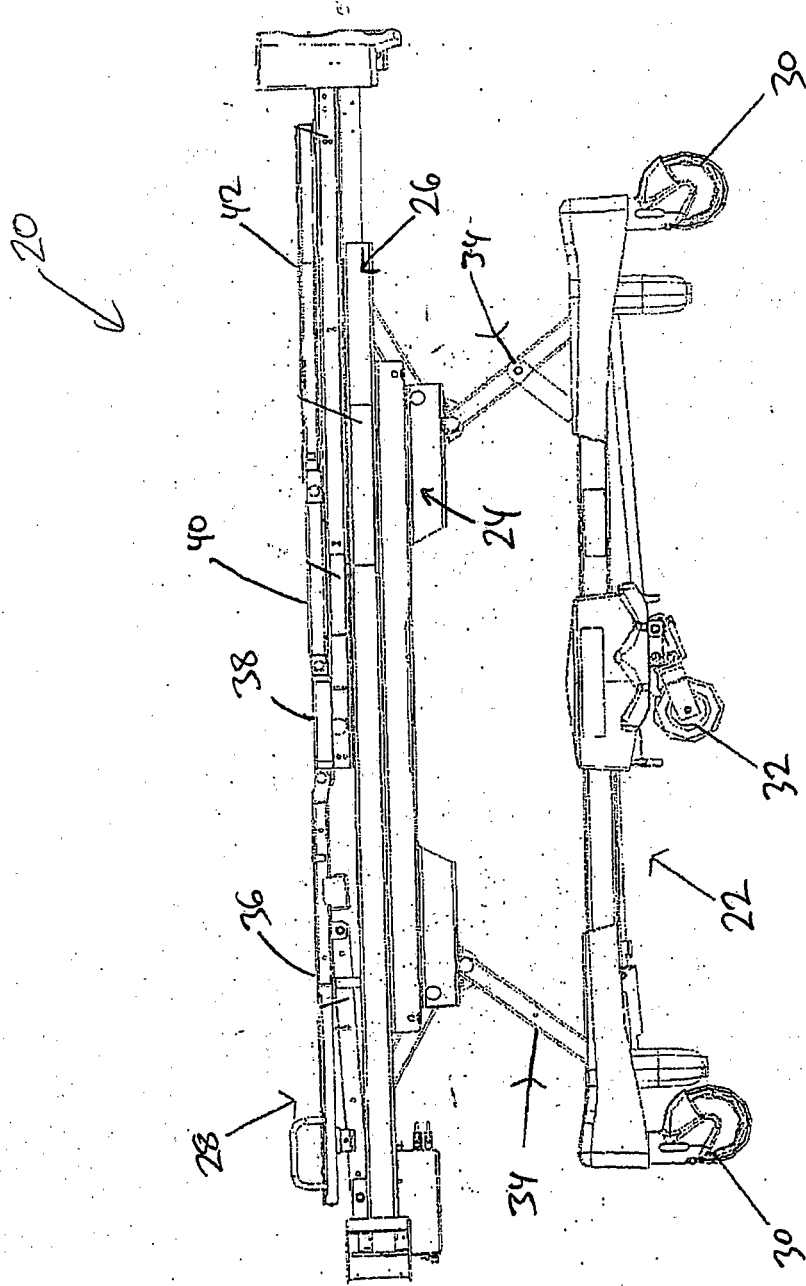


FIG. 2

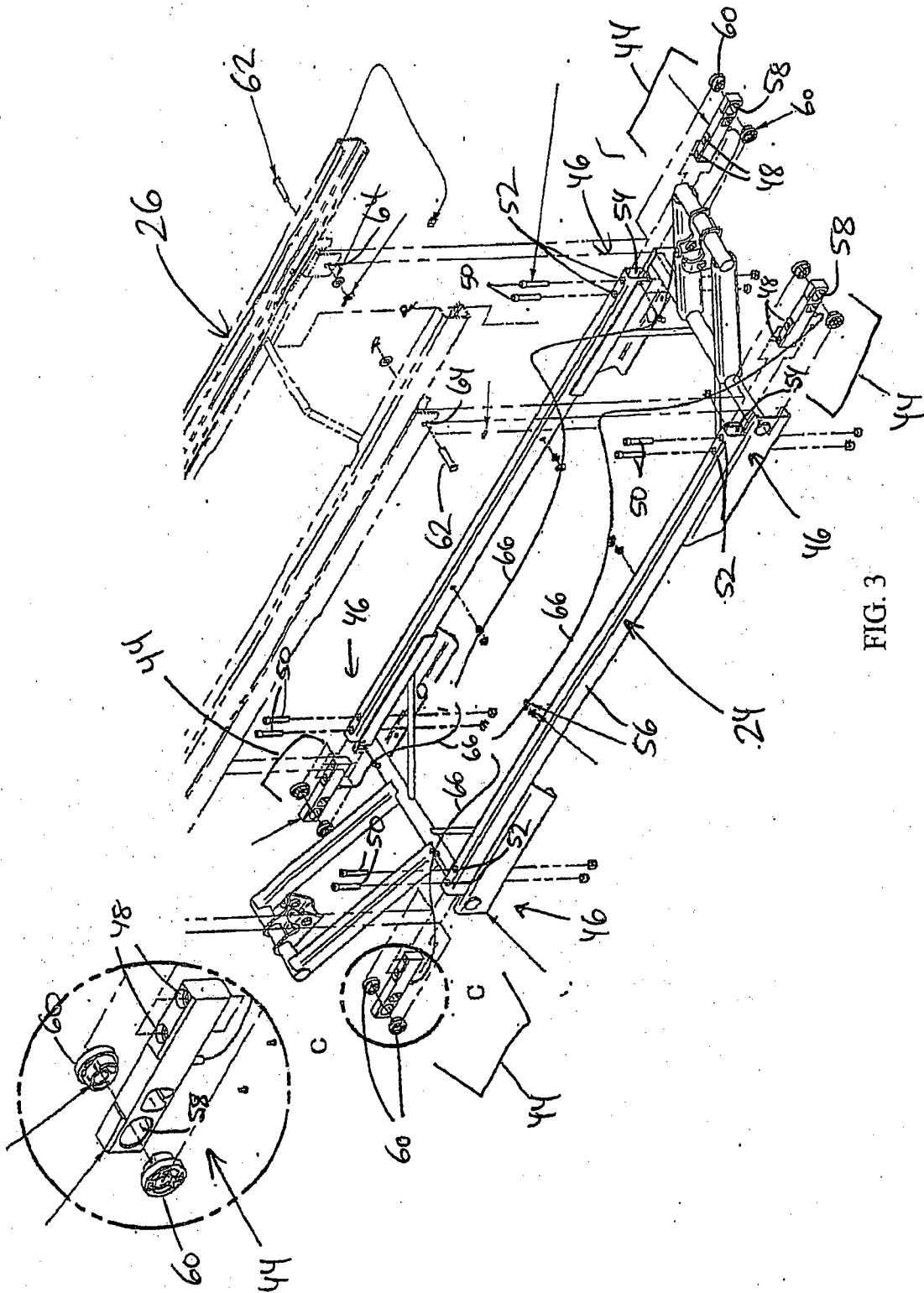


FIG. 3

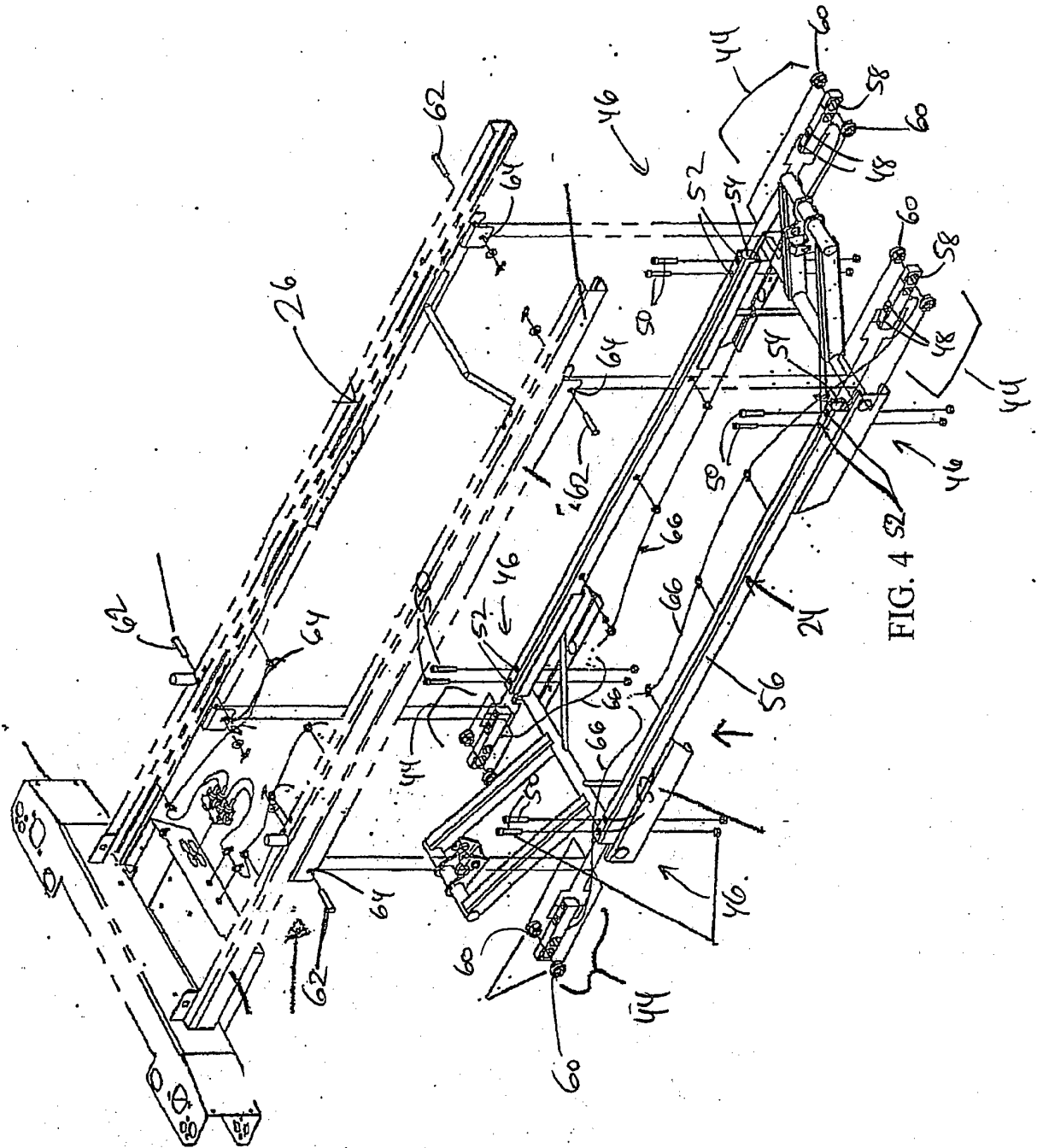


FIG. 4

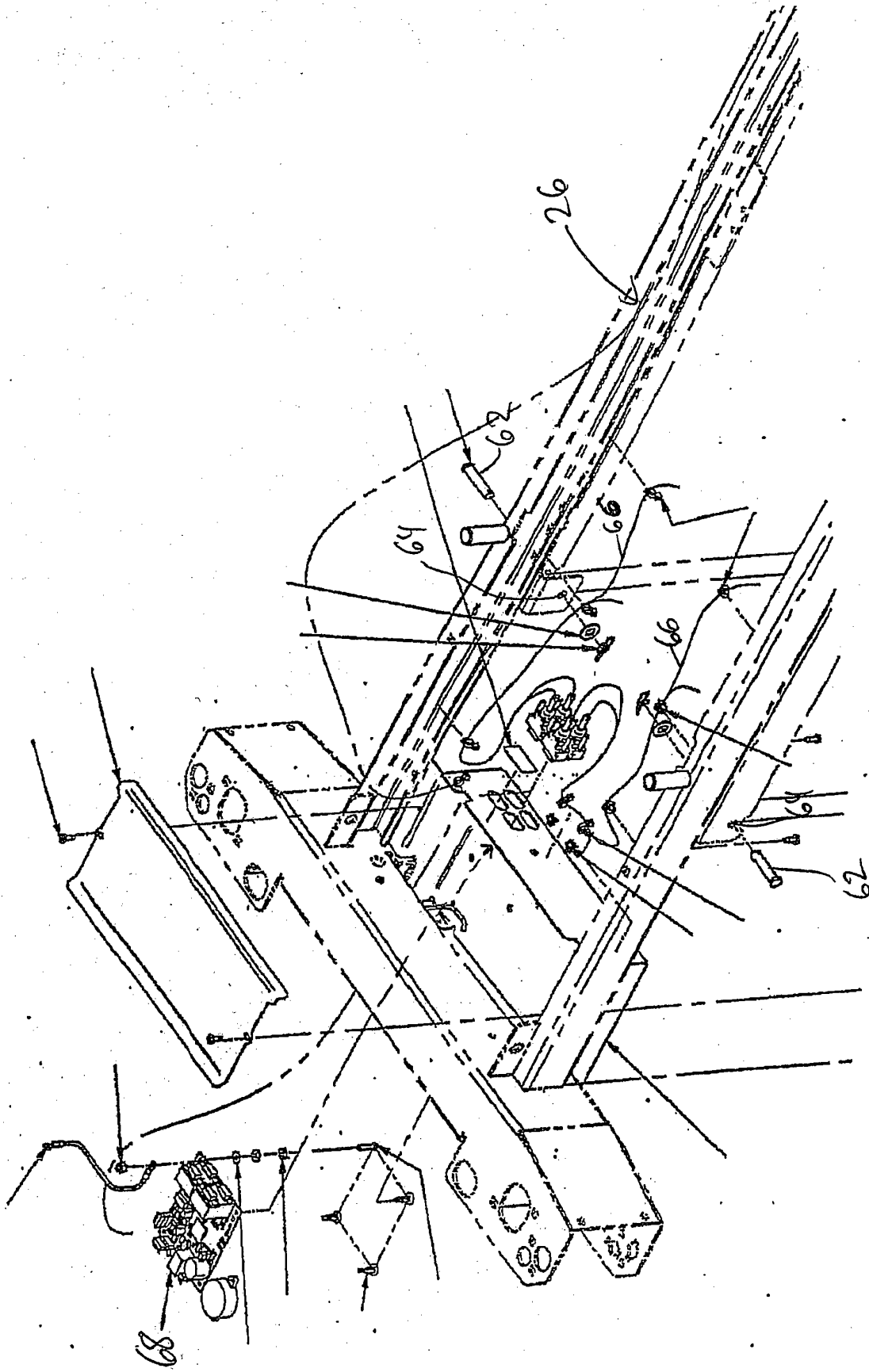


FIG. 5

Graph 1, Load Cell I, left Side Head End:
Time and weight metrics without patient

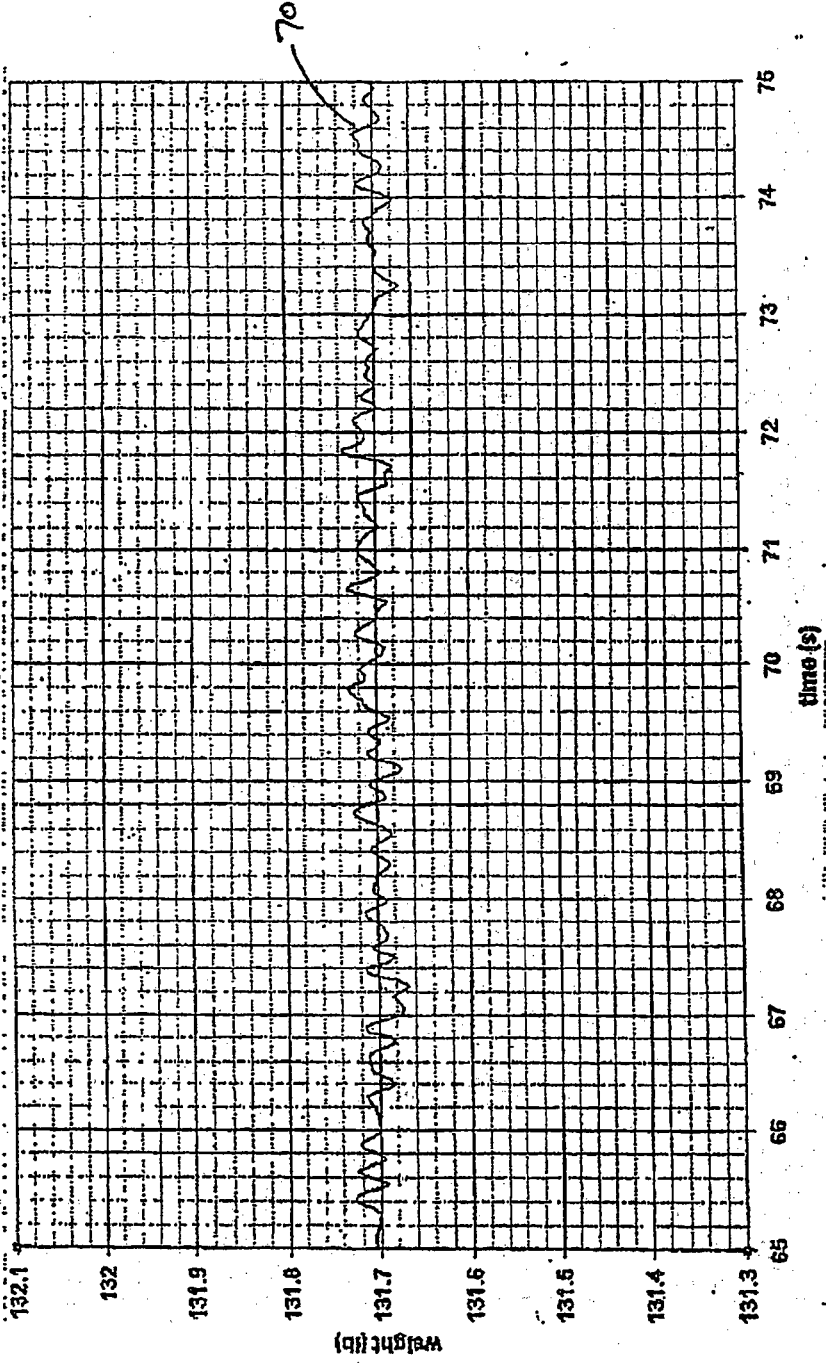


FIG. 6

Graph 2. Load Cell Left Side Head End: FFT
Harmonic and weight metrics without patient

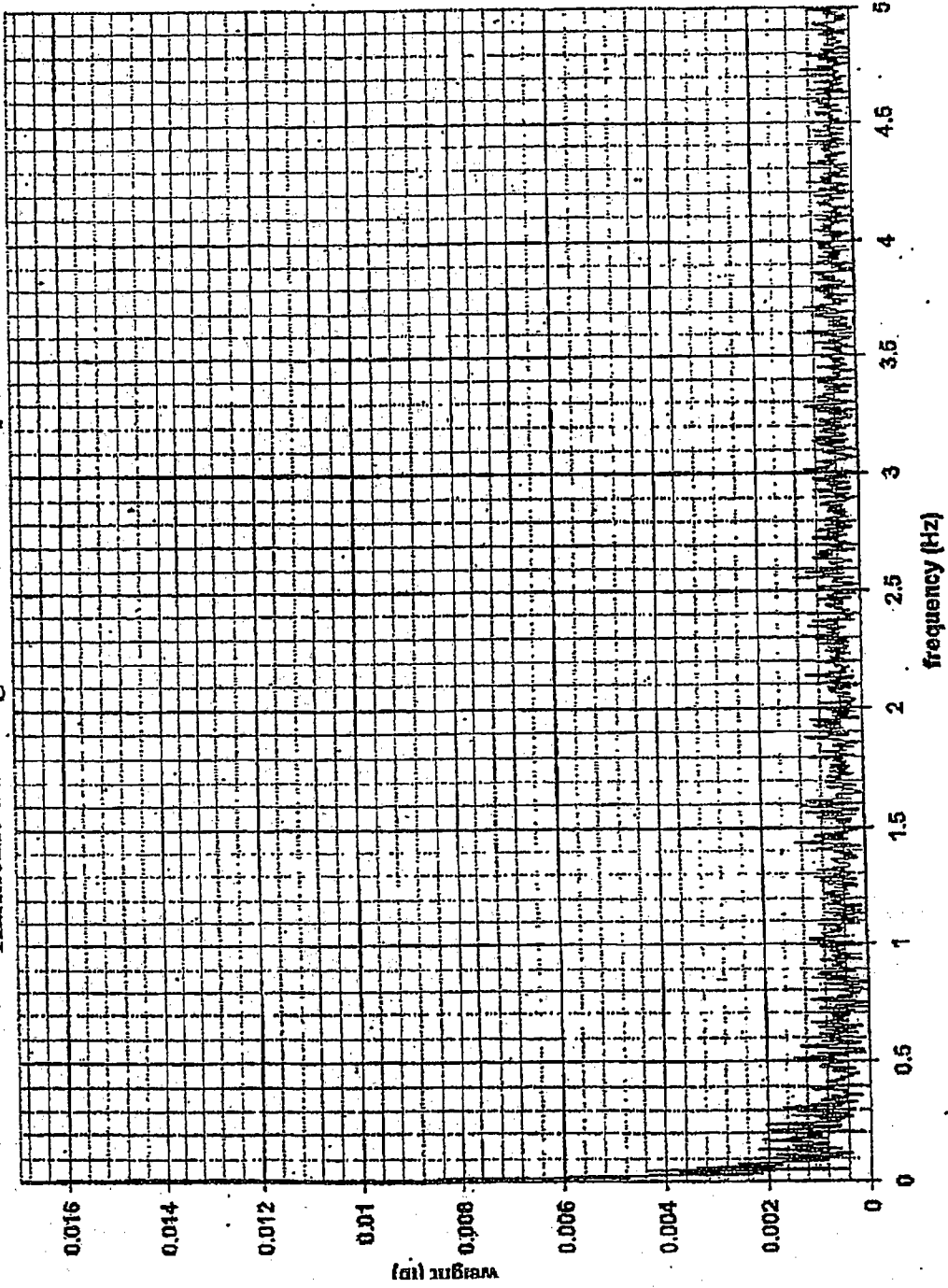


FIG. 7

Graph 3. Load Cell Left Side Head End:
Time and weight metrics of a motionless patient lying down on the back

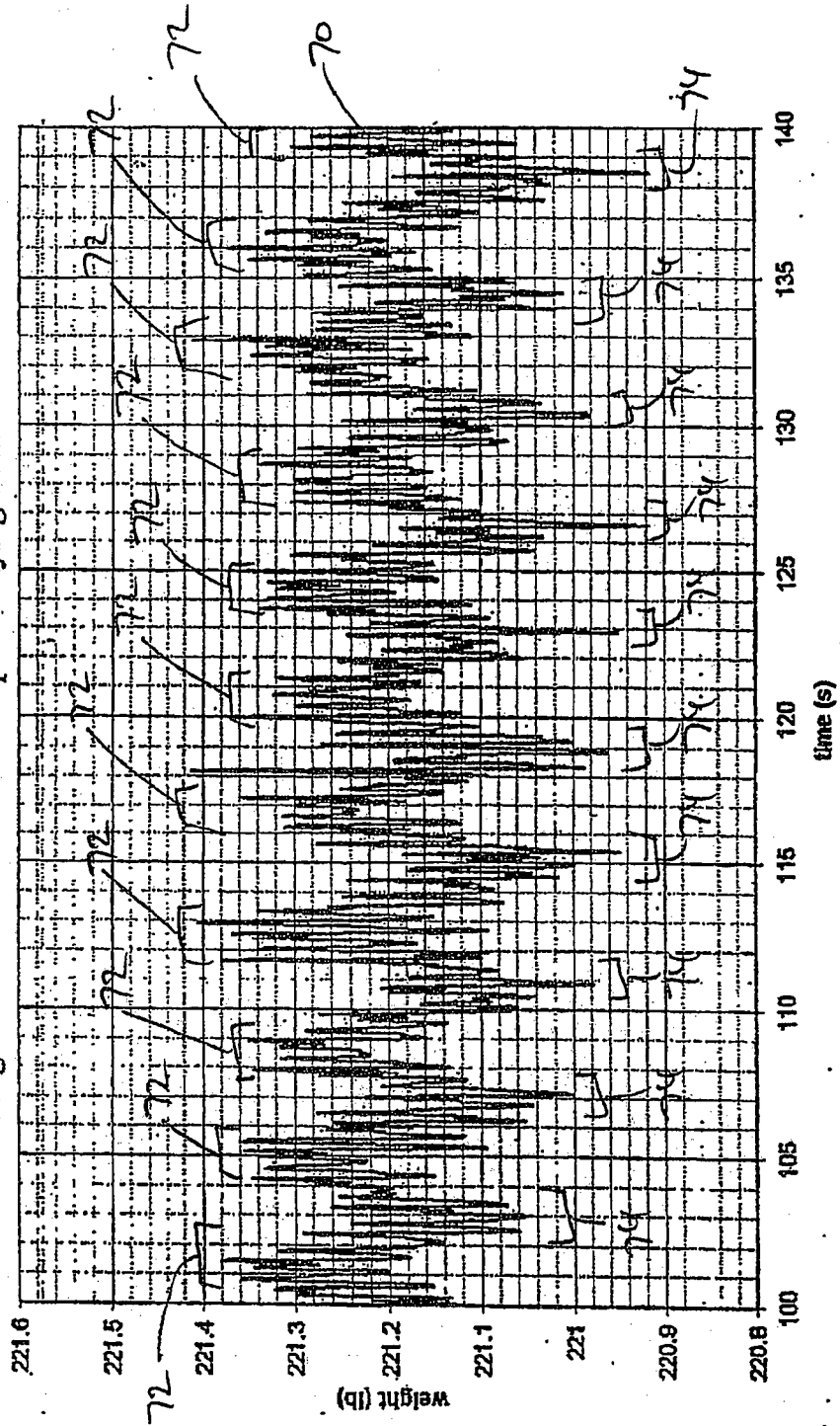


FIG. 8

Graph 6. Load Cell Left Side Head End: FFT
Harmonic and weight metrics of a motionless patient lying down on the back in interval of 6.35s

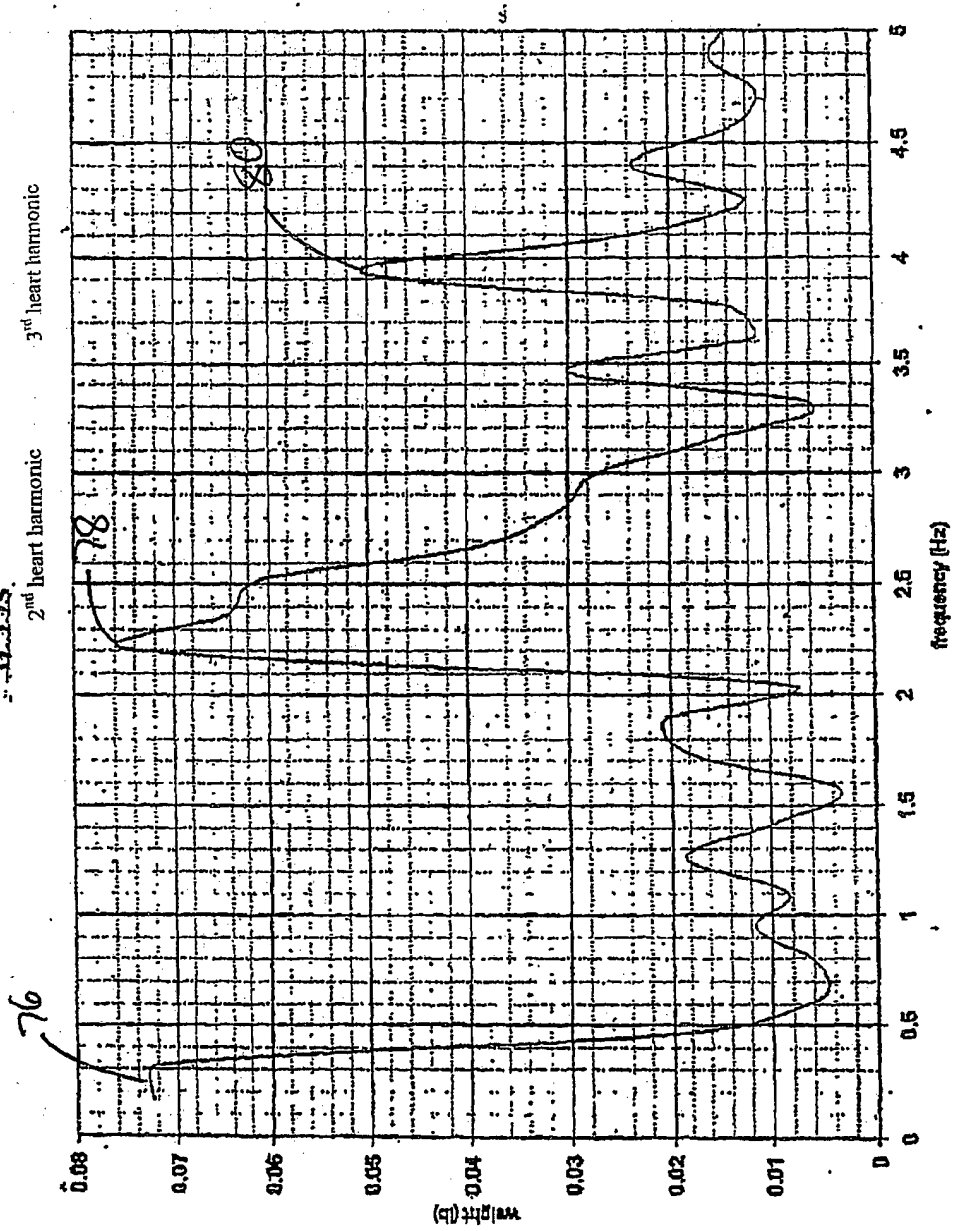


FIG. 9

Graph 5. Load Cell Left Side Head End: FFT
Harmonic and weight metrics of a motionless patient lying down on the back in interval of 12.75s

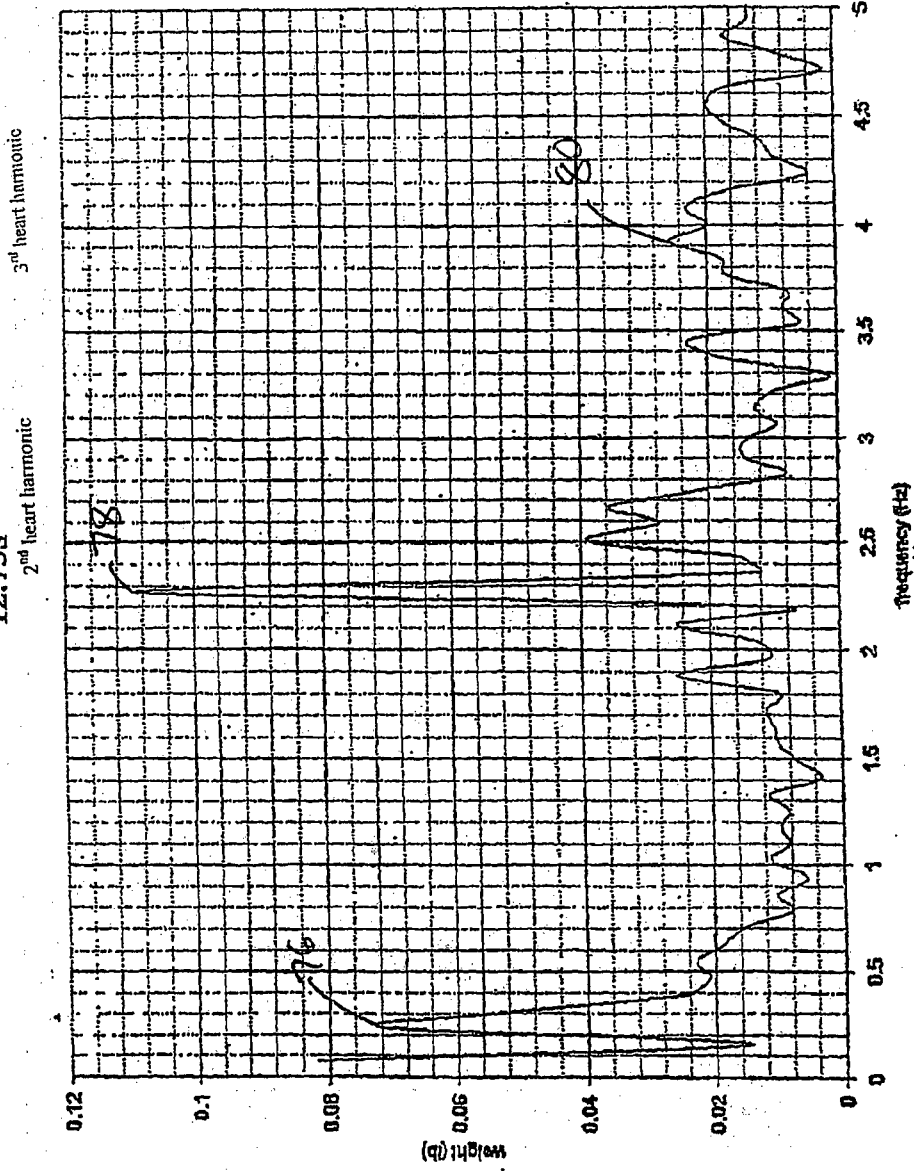


FIG. 10

Graph 4. Load Cell Left Side Head End: FFT
Harmonic and weight metrics of a motionless patient lying down on the back in interval of 204.8s

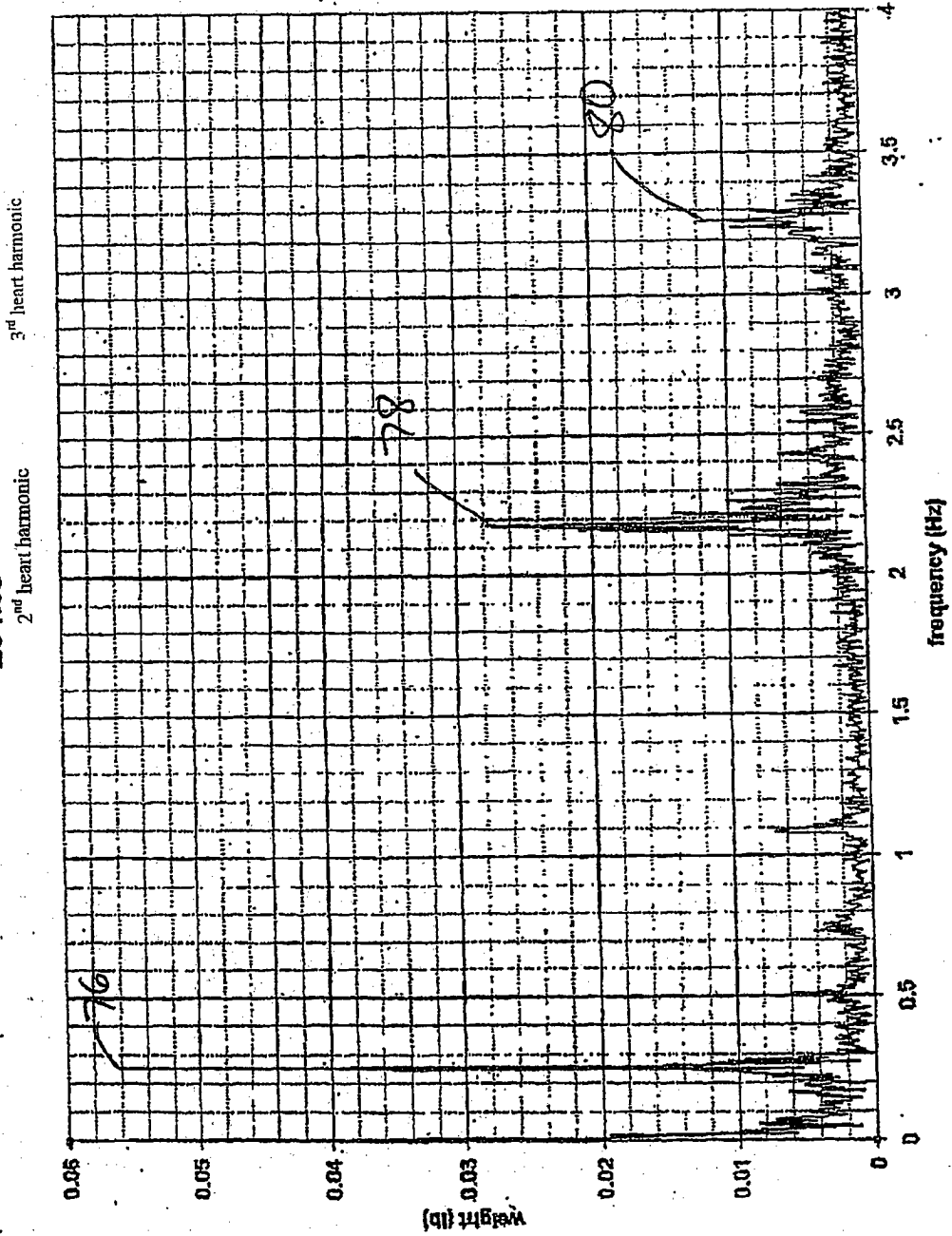


FIG. 11

Graph 9. Load Cell Left Side Head End:
Time and weight metrics of a motionless patient lying down on the side

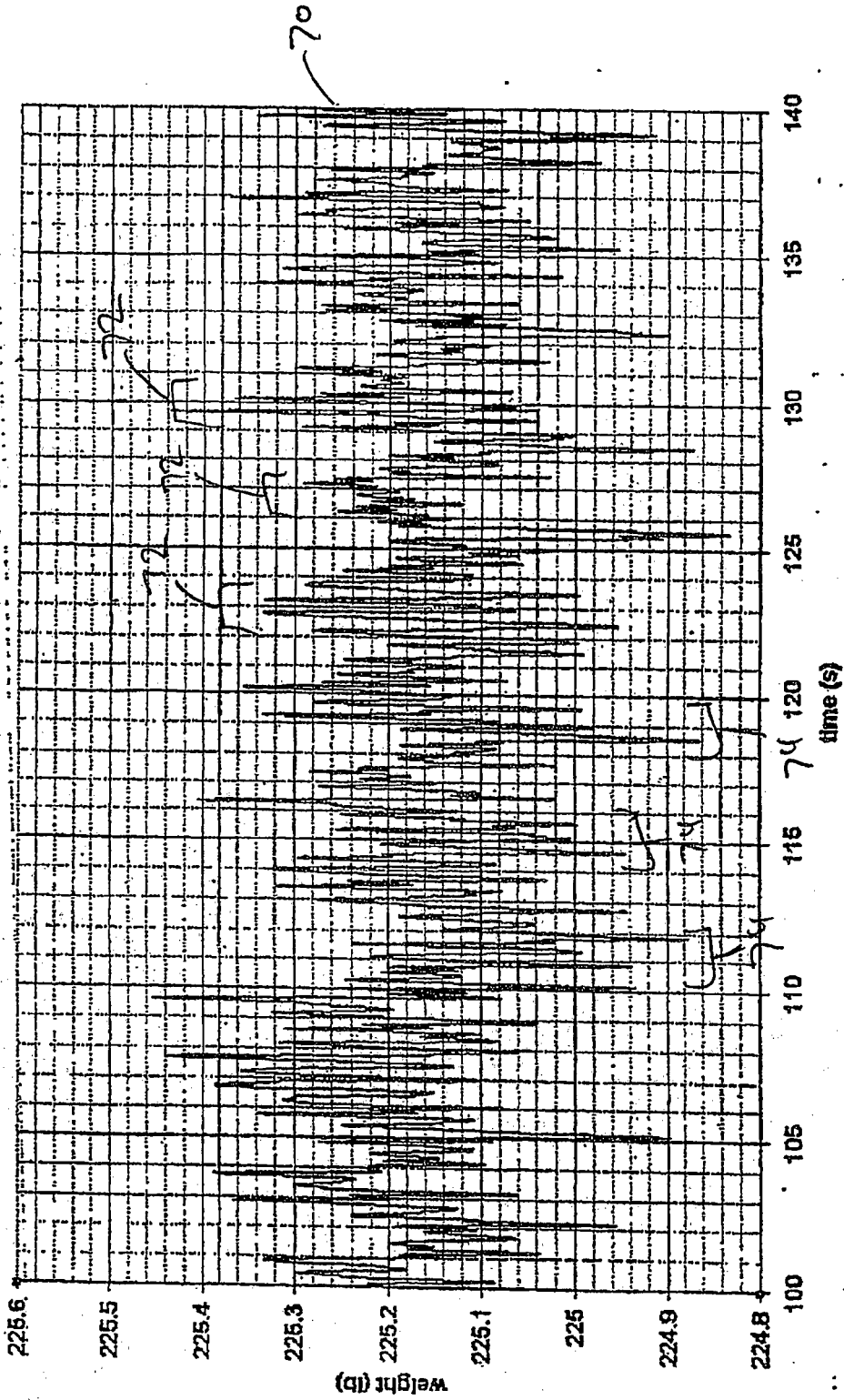


FIG. 12

Graph 10. Load Cell Left Side Head End: FFT
Harmonic and weight metrics of a motionless patient lying down on the side in interval of 40.95s

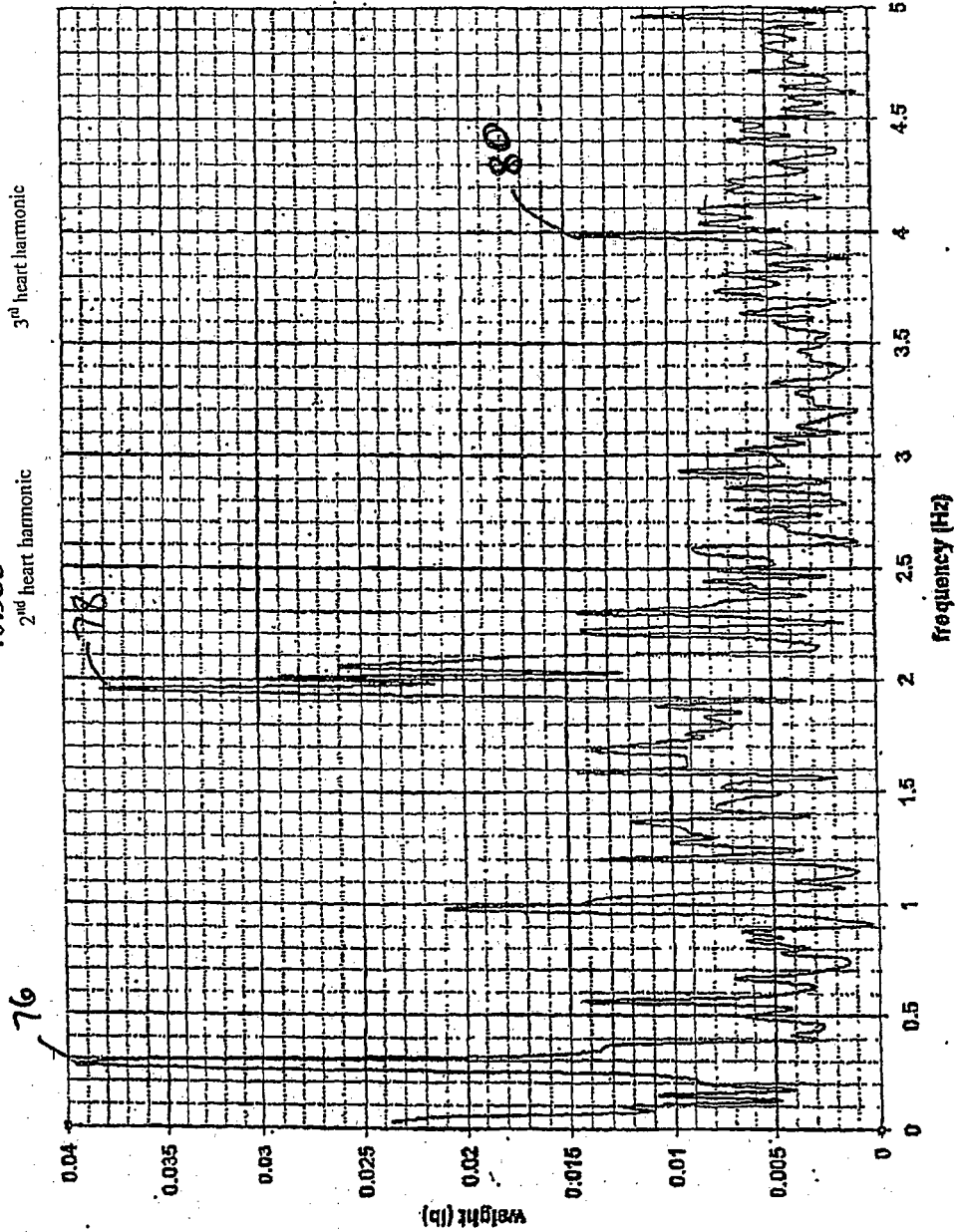


FIG. 13

Graph 7. Load Cell Left Side Head End:
Time and weight metrics of a motionless patient lying down on stomach

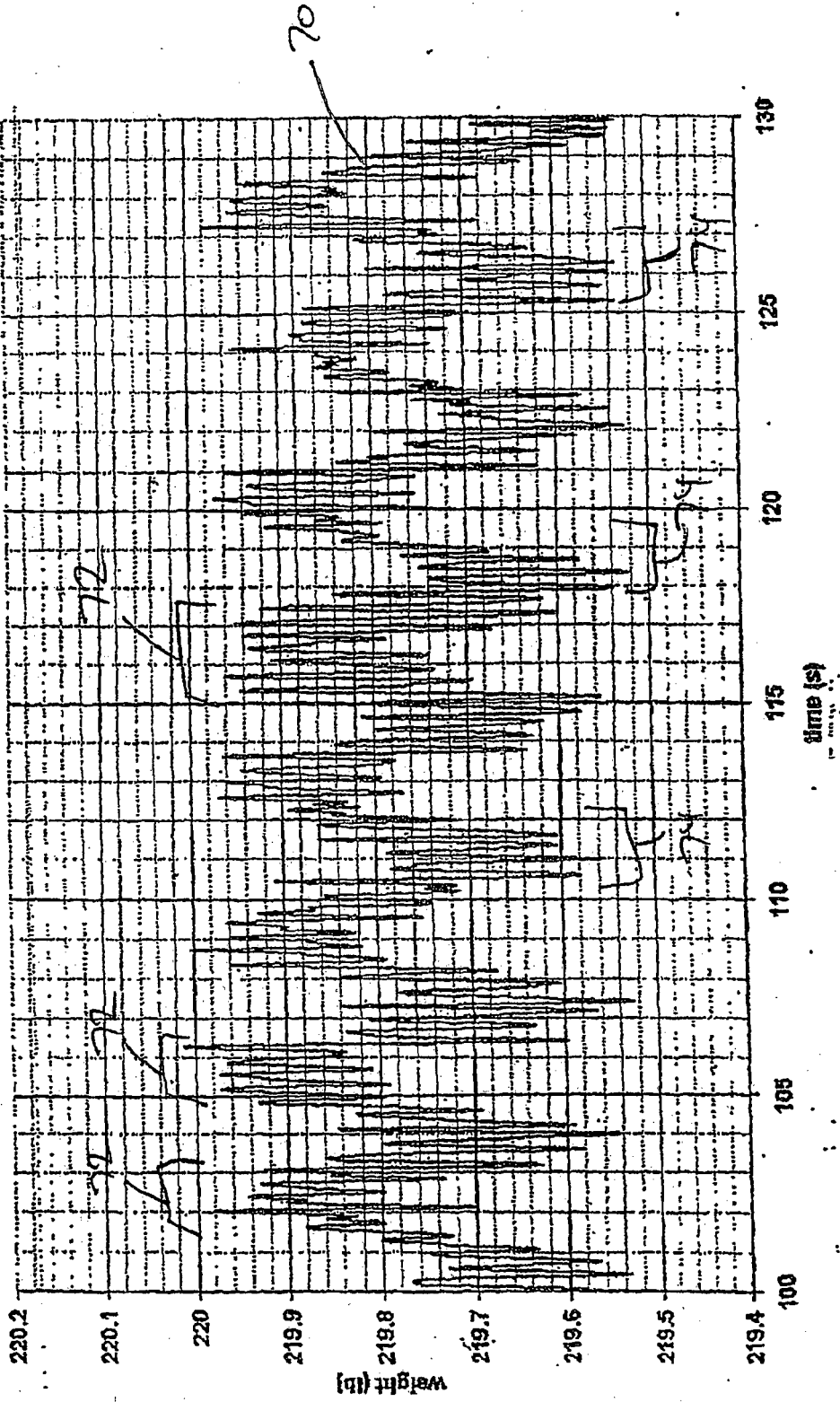


FIG. 14

Graph 8. Load Cell Left Side Head End: FFT
Harmonic and weight metrics of a motionless patient lying down on stomach in interval of
40.95s

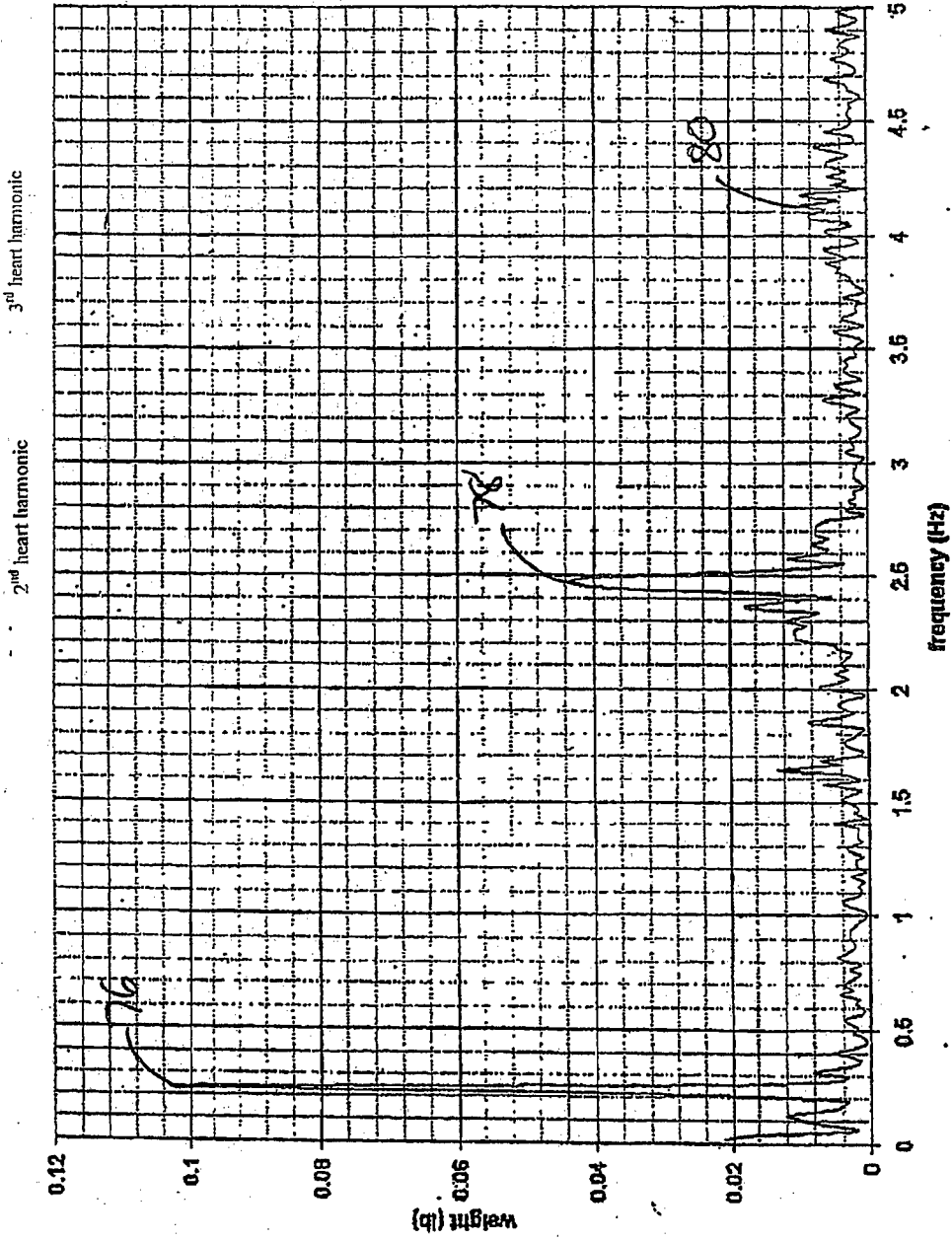


FIG. 15

Graph 11. Load Cell Left Side Head End:
Time and weight metrics of a motionless patient seating

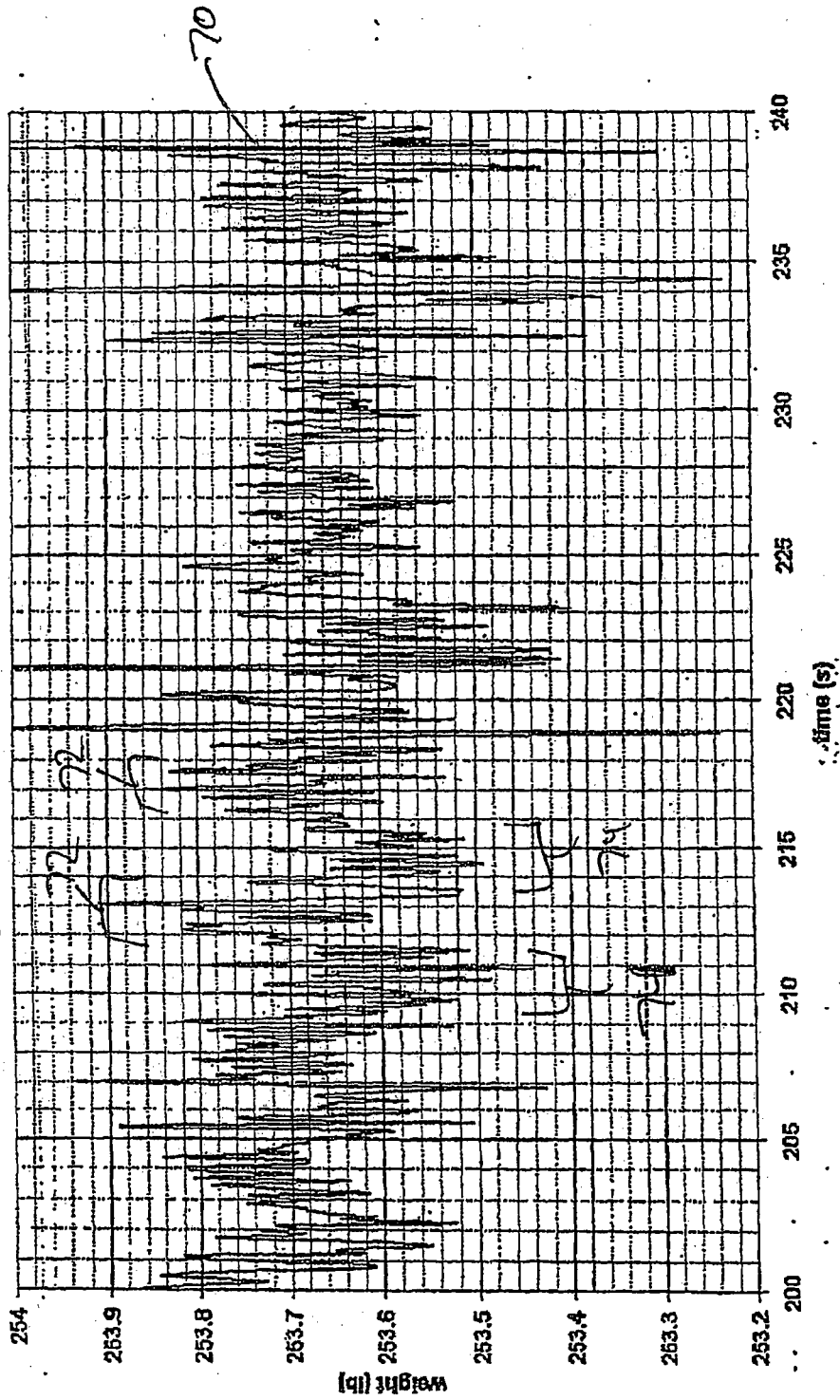


FIG. 16

Graph 12. Load Cell Left Side Head End: FFT
Harmonic and weight metrics of a motionless patient seating in interval of 40.95s

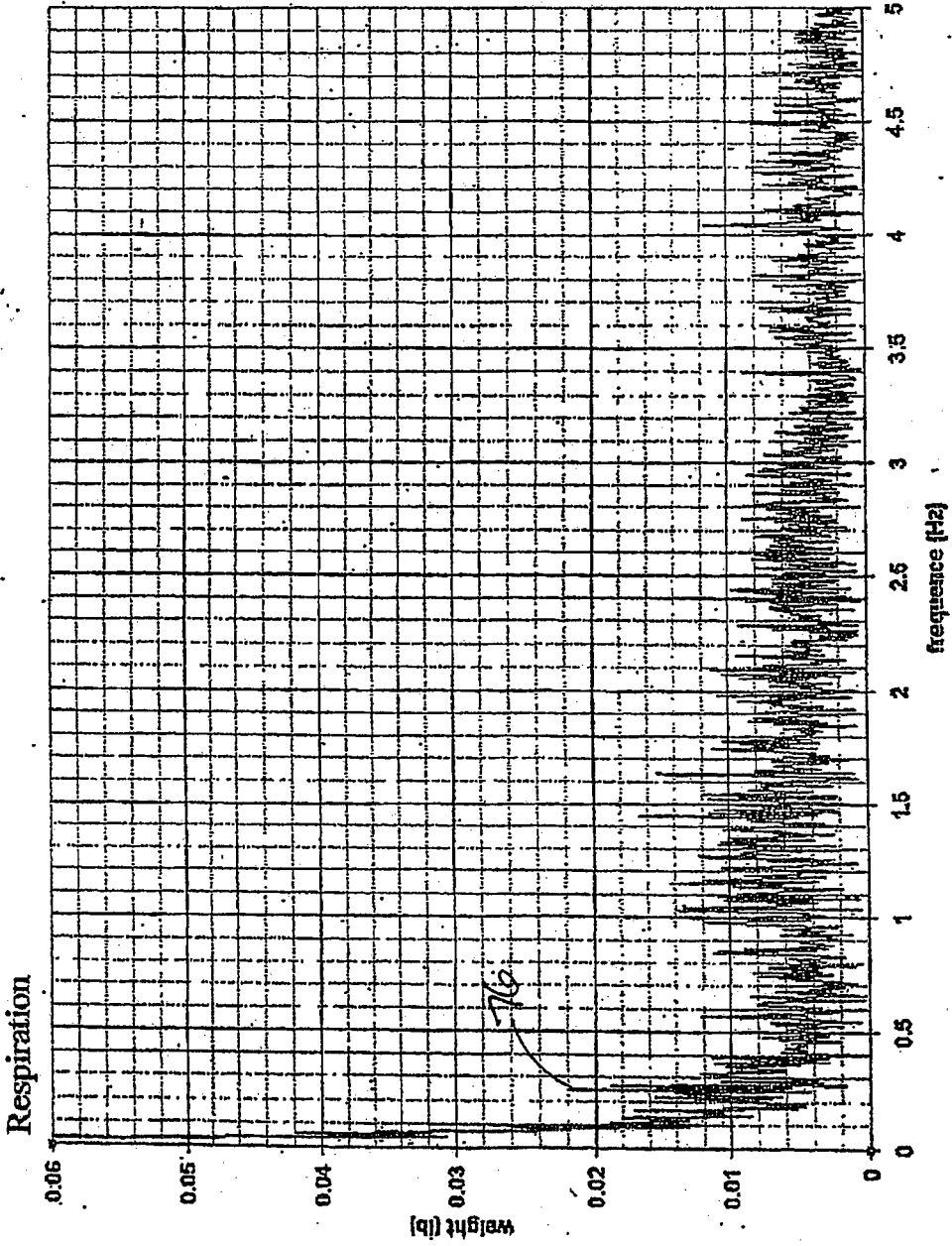


FIG. 17

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 5620003 A, Sepponen **[0003]**
- JP 2005177471 A **[0004]**
- JP 2003210434 A **[0005]**
- US 20060028350 A **[0006]**
- US 36254306 A, Guy Lemire **[0009]**
- US 5276432 A, Travis **[0016]**

专利名称(译)	用于检测和监测生命体征的系统		
公开(公告)号	EP2040614B1	公开(公告)日	2016-01-27
申请号	EP2007840352	申请日	2007-07-05
[标]申请(专利权)人(译)	史赛克公司		
申请(专利权)人(译)	史赛克公司		
当前申请(专利权)人(译)	史赛克公司		
[标]发明人	WAN FONG DAVID KIM SOUI DIONNE JEAN PAUL		
发明人	WAN FONG, DAVID KIM SOUI DIONNE, JEAN-PAUL		
IPC分类号	A61B5/00 A61B5/02 A61B5/04 A61B5/08 A61B5/11		
CPC分类号	A61B5/1102 A61B5/02444 A61B5/113 A61B5/4094 A61B5/6887 A61B5/7257 A61G2203/32		
优先权	11/773714 2007-07-05 US 60/818699 2006-07-05 US		
其他公开文献	EP2040614A4 EP2040614A2		
外部链接	Espacenet		

摘要(译)

公开了一种用于确定和监测位于患者支撑设备（例如床，担架或婴儿床）上的患者的各种特征的系统和方法。该系统和方法涉及监测患者施加在一个或多个力传感器上的力，该力传感器可以是支撑装置上的称重传感器。这些力传感器将检测对应于患者的各种状况的振动，包括患者的心率，呼吸速率和/或患者的癫痫发作状态。可以例如通过快速傅里叶变换分析这些振动，以便确定患者的各种状况。

