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(54) **A METHOD AND AN ARRANGEMENT FOR DETERMINING THE SPEED OF A RAIL VEHICLE**

(57) An arrangement for determining the speed of a rail vehicle (2) moving along a track (3) with rails (4, 5) resting on sleepers (6) mutually separated by a distance (d) known comprises a sensor (7) sensing vertical oscillations of the vehicle. A processing member (10) is treating measuring signals obtained by the sensor for deter-

mining the frequency of oscillations therein emanating from passages of sleepers by a wheel set (20) of the vehicle. A calculating unit (11) multiplies the frequency determined by the processing member by the distance (d) between adjacent sleepers for determining the speed of the vehicle.

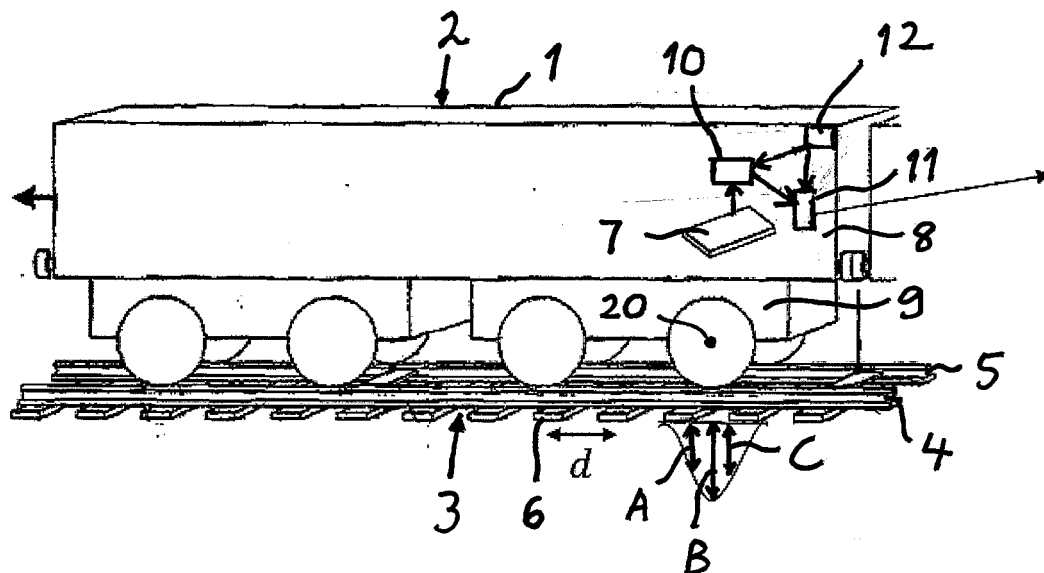


Fig 1

Description

TECHNICAL FIELD OF THE INVENTION AND BACKGROUND ART

[0001] The present invention relates to a method for determining the speed of a rail vehicle moving along a track with rails resting on sleepers mutually separated by a distance known, as well as an arrangement for obtaining such speed determination.

[0002] The rail vehicle may be any type of tracks-bound vehicle driven on railways.

[0003] All such rail vehicles or trains need reliable information about the actual speed of the rail vehicle, and for all rail vehicles having an ATP (Automatic Train Protection) system it is a requirement to be able to all the time deliver reliable speed information. Would in any situation reliable speed information not be available the control system of the rail vehicle has to assume that the rail vehicle is driven at a maximum acceleration as of the moment the speed data is missing, which means that the system will react far too early to different traffic information received so that the number of rail vehicles operating within a certain railway section or region may not be as high as would the actual speed of the rail vehicle be known.

[0004] A number of different arrangements for determining the speed of a rail vehicle are known, and they are all associated with different types of drawbacks. Tachometers measuring the rate at which one set of train wheels rotate are often used, and they give a good speed measurement in most cases, if the wheel circumference is known. However, tachometers provide inaccurate information about the train speed when the wheels slip and slide, which is becoming a more frequent occurrence for modern trains. On such trains, it is necessary to complement tachometers with another wheel-independent sensor. Doppler radar speedometers are also used, but these may not deliver reliable speed information when covered by ice or snow. Speedometers based on inertial navigation measuring accelerations of the rail vehicle for integration of the measurement values may not be used alone but have to be combined with other speed measuring devices.

[0005] Another option is to use satellite aided navigation, such as a GPS, but such sensors may neither be used alone and they will encounter problems when the rail vehicle is driving through tunnels or in cities with high buildings, besides the fact that speed measuring systems including these may be rather complex.

SUMMARY OF THE INVENTION

[0006] The object of the present invention is to provide a method and an arrangement of the type defined in the introduction being improved in at least some aspect with respect to such methods and arrangements already known by addressing any of the problems mentioned

above.

[0007] This object is with respect to the method obtained by providing such a method with the features listed in the characterizing part of appended patent claim 1.

[0008] Thus, the invention is based on the understanding that a rail vehicle will carry out vertical oscillations caused by the passage of sleepers by each wheel axle thereof. These oscillations may not be noticeable for the passengers inside the rail vehicle, but a rail vehicle axle moving along a railway will oscillate up and down with the peaks occurring when the axle is directly above a sleeper and the troughs occurring when the axle is exactly half-way between two sleepers. Accordingly, these vertical oscillations are sensed when the rail vehicle is moving over a railway and the measuring signals are treated to filter out oscillations emanating from passages of sleepers by a wheel set of the rail vehicle for by that determine the frequency of the oscillations filtered out. The speed of the rail vehicle may then be determined by multiplying the frequency determined by the distance between adjacent sleepers. Distance does here of course mean centre to centre distance of two consecutive sleepers. This distance is mostly known for a certain railway section and may even be the same in a large region such as within one country. This way of determining the speed of a rail vehicle will not be dependent upon the type of wheels on the rail vehicle and not encounter problems associated with the existence of tunnels or high buildings, and the method may be carried out by simple and cost efficient means as explained further below. However, the method may preferably be combined with arrangements measuring speeds of a rail vehicle in other ways, not at least since the rail vehicle may reach railway sections having no sleepers, for instance where the rails are resting on a concrete ground.

[0009] According to an embodiment of the invention it is vertical accelerations of a rail vehicle part that are sensed for sensing said vertical oscillations caused by sleeper passages of rail vehicle axles. Thus, when the rail vehicle has an inertial navigation system normally used to measure accelerations of the rail vehicle in the direction of movement of the rail vehicle this system may be used to determine the speed of the rail vehicle by carrying out the method according to the invention while using data available anywhere from this system.

[0010] According to another embodiment of the invention a Fourier transformation of the measuring signals is carried out in step d) to obtain a signal of oscillation amplitudes versus frequency. This constitutes a useful way of filtering out the oscillations to be used for the speed determination.

[0011] According to another embodiment of the invention oscillations within a restricted frequency window are considered when carrying out said filtering out of oscillations in step b). This will facilitate the search for and discrimination of the oscillations to be found from other possible oscillations not associated with sleeper passages of rail vehicle axles.

[0012] According to another embodiment of the invention said frequency window is established by determining a lower limit as the frequency of sleeper passages of a wheel axle of the rail vehicle at a lower threshold speed, such as 5 m/sec or 10 m/sec, and an upper limit as a frequency of sleeper passages of the wheel axle at a maximum speed of the rail vehicle. This measure will facilitate a reliable detection of the oscillations useful for determining the speed of the vehicle.

[0013] According to another embodiment of the invention accelerations of the rail vehicle in the direction of movement of the vehicle are measured and the result of these measurements are used to restrict said frequency window.

[0014] According to another embodiment of the invention data relating to the speed of the rail vehicle is collected from devices providing such information, such as a tachometer arranged on board the rail vehicle or a GPS-device, and these data are used to define lower and upper limits of said frequency window. This will make it very easy to reliably find the oscillations associated with sleeper passages of rail vehicle axles.

[0015] According to another embodiment of the invention in step b) the amplitude of peaks of oscillations in said measuring signals within a frequency window are compared and a peak is determined to derive from wheel axle sleeper passages when having an amplitude exceeding other peaks within said frequency window by at least a predetermined amount, such as 100 %, and otherwise to not derive from wheel axle sleeper passages. This constitutes an efficient way of discriminating peaks emanating from the oscillations searched for from peaks emanating from possible noise. According to another embodiment of the invention the speed determined in step d) is compared with speed data collected by a said other device and it is determined that the speed information obtained in step d) is not credible if the difference of that speed and said speed data exceeds a predetermined level. This will guard against a change of sleeper distance making the actual sleeper distance unknown and by that the speed determination incorrect. This possibility also applies for another embodiment of the method in which speed values determined by carrying out step d) are used to calculate values of accelerations of the rail vehicle in the direction of movement of the vehicle and acceleration values so calculated are compared with possible accelerations of the rail vehicle in said direction and if an acceleration value calculated exceeds a highest possible acceleration value for the rail vehicle it is determined that the actual sleeper distance deviates from said sleeper distance assumed to be known and that the speed determined in step d) is not credible.

[0016] The object of the invention is with respect to the arrangement obtained by providing an arrangement with the features listed in the characterizing part of the appended independent arrangement claim. The advantages of such an arrangement appears clearly from the above discussion of embodiments of the method accord-

ing to the invention.

[0017] In an embodiment of the invention the sensor of the arrangement is an inertial navigation sensor configured to obtain measuring signals by measuring vertical accelerations of a rail vehicle part to which it is secured. Such an inertial navigation sensor may already be arranged in the rail vehicle for measuring accelerations of the rail vehicle in the moving direction thereof and for integration of these measurements for obtaining speed values, so that the arrangement according to the invention does then only use data already available from this sensor but with a new approach to consider vertical accelerations of the rail vehicle.

[0018] According to another embodiment of the invention the inertial navigation sensor is configured to also measure accelerations of the rail vehicle in the direction of movement of the vehicle, the processing member is configured to use the results of the acceleration measurements last mentioned to define a frequency window, and the processing member is configured to consider oscillations in the measuring signals of a frequency within this frequency window.

[0019] According to another embodiment of the invention the sensor is configured to be secured to a rail vehicle part close to a wheel axle of the rail vehicle, and it may be configured to be secured to a vehicle body or a wheel bogie of the rail vehicle.

[0020] According to another embodiment of the invention the sensor is realized in the form of a MEMS (Micro Electro Mechanical System) device or a piezo-electric sensor available at a competitive cost.

[0021] The invention also relates to a computer program, which when executed by a computer causes the computer to carry out the method according to the invention. A computer-readable medium comprising instructions, which when executed by a computer, cause the computer to carry out the method according to the invention is also covered. Moreover, the invention also covers an electronic control unit comprising an execution means, a memory connected to the execution means, and a computer-readable medium which is connected to the execution means and on which the computer program code of a computer program according to the invention is stored. Use of an inertial navigation sensor arranged onboard a rail vehicle to measure vertical accelerations of the rail vehicle emanating from passages of sleepers by a wheel set of the rail vehicle for determining the speed of the rail vehicle through knowledge of the distance (d) separating adjacent sleepers of a track along which the rail vehicle is moving, and a rail vehicle provided with an arrangement for determining the speed of the rail vehicle or an electronic control unit according to the invention are also covered.

[0022] Further advantages as well as advantageous features of the invention will appear from the description following below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] With reference to the appended drawings below follows a specific description of an embodiment of the invention cited as an example.

[0024] In the drawings:

- Fig. 1 is a schematic view illustrating a rail vehicle provided with an arrangement according to an embodiment of the invention,
- Fig. 2 is a graph of vertical accelerations of a rail vehicle part versus time for a rail vehicle moving over a railway with rails resting on sleepers,
- Fig. 3 is a graph of amplitude versus frequency obtained by carrying out a Fourier transformation of the function shown in Fig. 2, and
- Fig. 4 is a schematic view illustrating an electronic control unit for implementing a method according to the invention.

DETAILED DESCRIPTION OF AN EMBODIMENT OF THE INVENTION

[0025] Fig. 1 illustrates schematically a railway wagon 1 of a rail vehicle 2 moving over a railway 3 with rails 4, 5 resting on sleepers 6 mutually separated by a distance d known, such as 0.6 m.

[0026] The rail vehicle is provided with an arrangement for determining the speed of the rail vehicle according to an embodiment of the invention, and this arrangement has at least one sensor 7 configured to be secured to a part of the rail vehicle, such as the vehicle body 8 or a wheel bogie 9. This sensor would when Fig. 1 were drawn to scale not be visible, since it is preferably but not necessarily a MEMS device in the form of a semiconductor device, and it is configured to sense vertical oscillations of the vehicle part to which it is secured within a time window for producing measuring signals of oscillations versus time as shown in Fig. 2 in the form of vertical acceleration V_a versus time t . The sensor is arranged close to a wheel axle 20 to improve the sensitivity to the ups and downs thereof when passing a sleeper. It is illustrated by arrows A, B, C how the wheel axle moving along the railway oscillates up and down with peaks occurring when the axle is directly above a sleeper and a trough (arrow B) occurring when the axle is halfway between two sleepers.

[0027] The arrangement comprises further a processing member 10 configured to treat measuring signals obtained through the sensor 7 and shown in Fig. 2 so as to determine the frequency of oscillations therein emanating from passages of sleepers by a wheel axle of the rail vehicle, and the processing member will do this by carrying out a Fourier transformation of the measuring signals, which will then result in a graph shown in Fig. 3 of

oscillation amplitudes A_m versus frequency f . The processing member 10 may then be configured to compare the amplitude of peaks of oscillations in the measuring signals within a frequency window and determine that the highest peak at the frequency f_1 emanates from sleeper passages of the axle under the condition that the highest peak exceeds the second highest peak by a predetermined amount. The processing member may consider the measurement unreliable if this is not the case, since sensing said vertical accelerations should indicate a distinct, continuous oscillation, which can be discriminated from other types of oscillations deriving from noise.

[0028] A calculating unit 11 will receive the information shown in Fig. 3 from the processing member and is configured to determine the speed of the rail vehicle by multiplying the frequency f_1 determined by the processing member by the distance d between adjacent sleepers. Thus, the arrangement according to the invention determines the speed of the rail vehicle by counting sleepers passed per time unit. A frequency f_1 of for instance 92.5 Hz as obtained by testing the arrangement on a railway section in the Czech Republic means that 92.5 sleepers were passed per second. The sleeper distance was in this case 0.6 m, which translates to a speed of $92.5 \times 0.6 = 55.5$ m/s. This did exactly correlate to the rail vehicle speed sensed by the vehicle's regular speedometer. When moving at such a high speed a time window of 0.1 s will do for obtaining an accurate speed value, so that the speed determined will substantially be the instantaneous speed, whereas a longer time window may be necessary for lower speeds.

[0029] The processing member and the calculating unit may very well be combined in the same on-board computer of the rail vehicle.

[0030] The arrangement for determining the speed by "sleeper counting" according to the present invention may be combined with other speed measuring devices 12, such as a tachometer arranged on board the rail vehicle or a GPS-device, for collecting data relating to speed of the rail vehicle from such a device. These data may be used to define lower and upper limits of said frequency window and also to decide if the speed determined by the arrangement according to the invention is credible or not. These devices are external in the sense that they are not influenced by the function of the sensor 7 measuring vertical accelerations, whereas use of the inertial navigation sensor 7 to measure accelerations in the moving direction of the vehicle for being used to check the proper function of the arrangement according to the invention will be dependent upon the function of the sensor 7 included in the arrangement according to the invention.

[0031] Computer program code for implementing a method according to the invention is with advantage included in a computer program, which can be read into the internal memory of a computer, e.g. the internal memory of an electronic control unit of a motor vehicle. Such a computer program is with advantage provided via a

computer program product comprising a data storage medium, which can be read by a computer and which has the computer program stored on it. Said data storage medium is for example an optical data storage medium in the form of a CD ROM disc, a DVD disc etc., a magnetic data storage medium in the form of a hard disc, a diskette, a cassette tape etc., or a flash memory or a memory of the ROM, PROM, EPROM or EEPROM type. Fig. 4 illustrates very schematically an electronic control unit 13 comprising an execution means 14, e.g. a central processor unit (CPU), for execution of computer software. The execution means 14 communicates with a memory 15, e.g. of the RAM type, via a data bus 16. The control unit 13 comprises also a non-transitory computer-readable medium 17, e.g. in the form of a flash memory or a memory of the ROM, PROM, EPROM or EEPROM type. The execution means 14 communicates with the computer-readable medium 17 via the data bus 16. A computer program comprising computer program code for implementing a method according to the invention is stored on the computer-readable medium 17.

[0032] Alternatively, the method according to the invention may be realized using an Application Specific Integrated Circuit (ASIC) or a Field Programmable Gate Array (FPGA) configured using Hardware Description Language (HDL).

[0033] The invention is of course in no way restricted to the embodiments described above, since many possibilities for modifications thereof are likely to be obvious to one skilled in the art without having to deviate from the scope of invention defined in the appended claims.

[0034] The rail vehicle may have more than one said sensor sensing vertical oscillations associated with different wheel axles for redundancy.

[0035] "Sleepers" as used in this disclosure is to be interpreted to also cover other supportive features of a rail track with regular known mutual distances.

Claims

1. A method for determining the speed of a rail vehicle (2) moving along a track (3) with rails (4, 5) resting on sleepers (6) mutually separated by a known distance (d), **characterized by** the following steps:
 - a) sensing vertical oscillations of a part (8, 9) of the rail vehicle within a time window for producing measuring signals of oscillations versus time,
 - b) treating said measuring signals to filter out oscillations emanating from passages of sleepers (6) by a wheel set (20) of the rail vehicle,
 - c) determining the frequency of the oscillations filtered out, and
 - d) determining the speed of the rail vehicle by multiplying the frequency determined in step c) by said distance between adjacent sleepers.
2. A method according to claim 1, **characterized in that** it is vertical accelerations of said rail vehicle part that are sensed in step a).
3. A method according to claim 1 or 2, **characterized in that** a Fourier transformation of said measuring signals is carried out in step b) to obtain a signal of oscillation amplitudes (A_m) versus frequency (f).
4. A method according any of the preceding claims, **characterized in that** oscillations within a restricted frequency window are considered when carrying out said filtering out of oscillations in step b).
5. A method according to claim 4, **characterized in that** said frequency window is established by determining a lower limit as the frequency of sleeper passages of a wheel axle of the rail vehicle at a lower threshold speed, such as 5 m/sec or 10 m/sec, and an upper limit as a frequency of sleeper passages of the wheel axle at a maximum speed of the rail vehicle.
6. A method according to claim 4 or 5, **characterized in that** accelerations of the rail vehicle in the direction of movement of the vehicle are measured and the result of these measurements are used to restrict said frequency window.
7. A method according to any of claims 4-6, **characterized in that** data relating to the speed of the rail vehicle is collected from devices (12) providing such information, such as a tachometer arranged on board the rail vehicle or a GPS-device, and these data are used to define lower and upper limits of said frequency window.
8. A method according to any of the preceding claims, **characterized in that** in step b) the amplitude of peaks of oscillations in said measuring signals within a frequency window are compared and a peak is determined to derive from wheel axle sleeper passages when having an amplitude exceeding other peaks within said frequency window by at least a predetermined amount, such as 100 %, and otherwise to not derive from wheel axle sleeper passages.
9. A method according to claim 7, **characterized in that** the speed determined in step d) is compared with speed data collected by a said other device (12) and it is determined that the speed information obtained in step d) is not credible if the difference of that speed and said speed data exceeds a predetermined level.
10. A method according to any of the preceding claims, **characterized in that** speed values determined by carrying out step d) are used to calculate values of

accelerations of the rail vehicle in the direction of movement of the vehicle and acceleration values so calculated are compared with possible accelerations of the rail vehicle in said direction and if an acceleration value calculated exceeds a highest possible acceleration value for the rail vehicle it is determined that the actual sleeper distance deviates from said sleeper distance (d) assumed to be known and that the speed determined in step d) is not credible.

11. An arrangement for determining the speed of a rail vehicle (2) moving along a track (3) with rails (4, 5) resting on sleepers (6) mutually separated by a known distance (d), **characterized in that** it comprises:
- a sensor (7) configured to be secured to a part (8, 9) of the rail vehicle and to sense vertical oscillations of that vehicle part within a time window for producing measuring signals of oscillations versus time,
 - a processing member (10) configured to treat said measuring signals so as to determine the frequency of oscillations therein emanating from passages of sleepers (6) by a wheel set (20) of the rail vehicle, and
 - a calculating unit (11) configured to determine the speed of the rail vehicle by multiplying said frequency (f_1) determined by the processing member (10) by said distance (d) between adjacent sleepers.
12. An arrangement according to claim 11, **characterized in that** said sensor (7) is an inertial navigation sensor configured to obtain said measuring signals by measuring vertical accelerations of a rail vehicle part (8, 9) to which it is secured.
13. An arrangement according to claim 12, **characterized in that** said inertial navigation sensor (7) is configured to also measure accelerations of the rail vehicle (2) in the direction of movement of the vehicle, that the processing member (10) is configured to use the results of the acceleration measurements last mentioned to define a frequency window, and that the processing member (10) is configured to consider oscillations in the measuring signals of a frequency within this frequency window.
14. An arrangement according to any of claims 11-13, **characterized in that** said sensor (7) is configured to be secured to a rail vehicle part (8, 9) close to a wheel axle (20) of the rail vehicle.
15. An arrangement according to any of the preceding claims, **characterized in that** said sensor (7) is configured to be secured to a vehicle body (8) or a wheel bogie (9) of the rail vehicle.

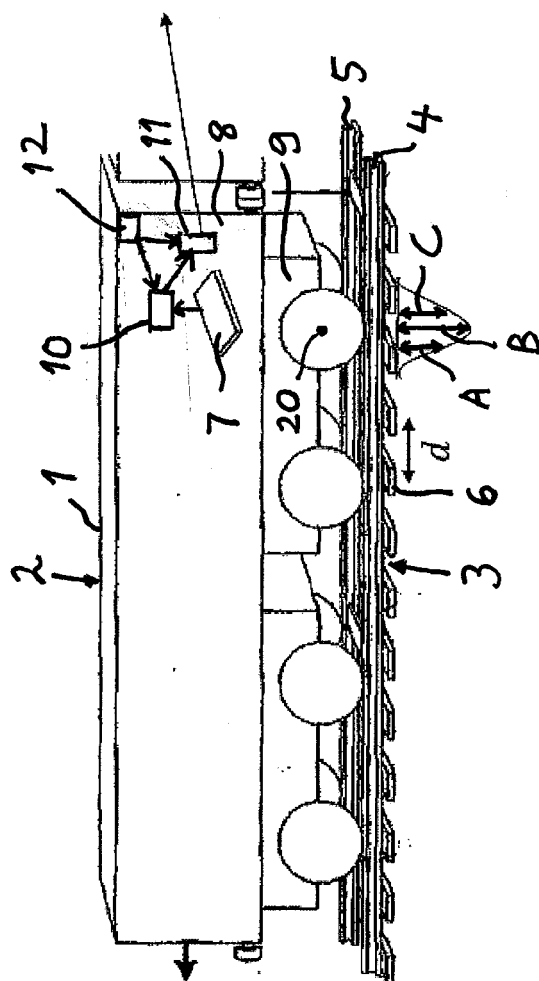


Fig 1

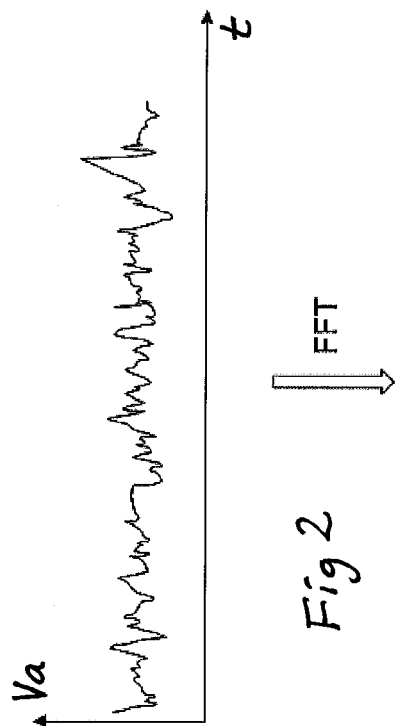


Fig 2

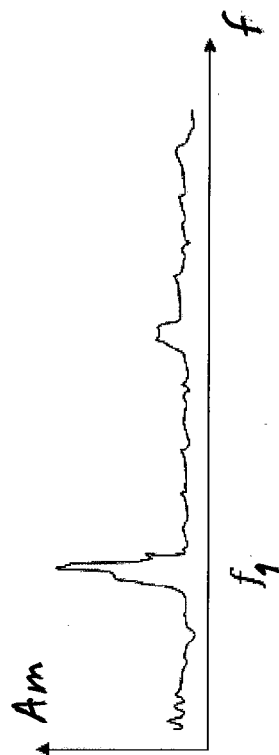


Fig 3

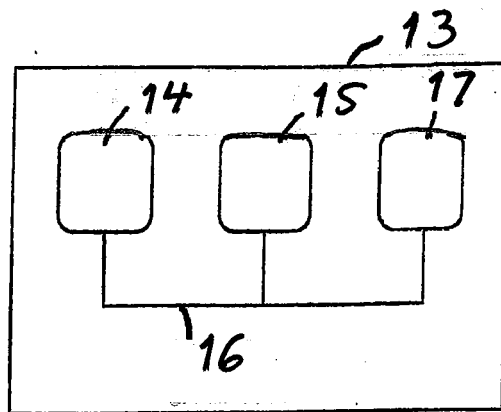


Fig 4



EUROPEAN SEARCH REPORT

 Application Number
 EP 17 16 2797

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	* paragraph [0010] - paragraph [0016] * * paragraph [0019] - paragraph [0028] * * paragraph [0040] - paragraph [0051] * * figure 1 *	6	
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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 September 2017	Examiner Janssen, Axel
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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