(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 December 2005 (15.12.2005)

PCT

(10) International Publication Number
WO 2005/118366 A1

(51) International Patent Classification[7]: B61K 9/08, B61L 23/04

(21) International Application Number: PCT/GB2005/001600

(22) International Filing Date: 28 April 2005 (28.04.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0412215.6 2 June 2004 (02.06.2004) GB

(71) Applicant *(for all designated States except US)*: **AEA TECHNOLOGY PLC** [GB/GB]; 329 Harwell, Didcot, Oxfordshire OX11 0QJ (GB).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **PATKO, Sandor, Matyas** [HU/GB]; 18 New Zealand Square, Derby, Derbyshire DE22 3BZ (GB).

(74) Agents: **MANSFIELD, Peter, Turquand** et al.; Accentus plc, Patents Dept, 329 Harwell, Didcot, Oxfordshire OX11 0QJ (GB).

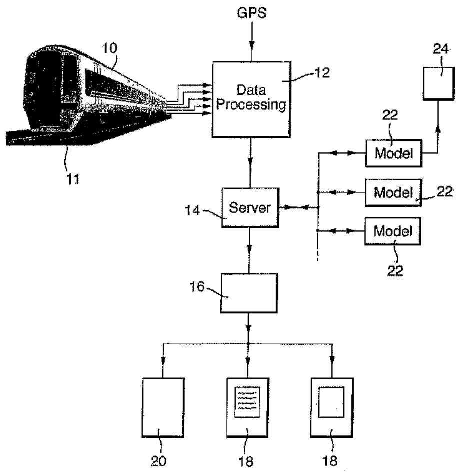
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP,*

[Continued on next page]

(54) Title: PROCESSING OF RAILWAY TRACK DATA



(57) Abstract: The quality of a railway track (11) may be assessed with transducers on a track recording vehicle (10). The received data are filtered in a way that introduces phase shifts, the filtration process having an associated transfer function (H). An inverting transfer function H<The is therefore selected which inverts at least the phasedifferences of the transfer function (H) of the filter. A multiplicity (N) of successive data samples are stored in a memory, each with an indication of the corresponding position or time, and an output data sample is calculated as the integral of the product of the stored data samples with an impulse function (F) centred on the middle stored sample. The impulse function F (T) is related to the inverting transfer function H<The . As each data sample is moved into the memory the oldest such sample is deleted, and on each occasion an output data sample is calculated. The resulting output data stream represents the original data, without the phase shifts that were caused by the filtration process.

WO 2005/118366 A1

KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

— *of inventorship (Rule 4.17(iv)) for US only*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Processing of Railway Track Data

This invention relates to an apparatus and a method for processing data, in particular data obtained by monitoring a railway track, such data for example being used for assessing the quality of the track.

Track recording vehicles are known, which are used in surveying a railway track to provide data representing the undulations of the rails in the vertical and horizontal planes, and their curvature. Software packages are also available, for example a software product under the trade mark VAMPIRE (from AEA Technology plc), for predicting how a particular vehicle will respond when travelling at a particular speed along a track; such software packages, which may be referred to as vehicle dynamics simulations, require input data providing an undistorted representation of the track. The raw data obtained by the sensors on a track recording vehicle provide information about train movement, and can be processed to determine track data, in particular being filtered to distinguish between short wavelength data and long wavelength data. This filtration process may introduce phase differences. Data from such a track recording vehicle can be subjected to a subsequent filtration process, referred to as "back filtering", to obtain accurate data about the track. However, this process requires all the data about an entire section of track (which might be say 200 km long), and this entire data stream is then processed in reverse; clearly this can't be done in real-time.

According to the present invention there is provided a method of obtaining data on the quality of a railway track, the method comprising:

a) receiving from a track recording vehicle data concerning variations of a parameter, the data comprising samples, obtained in either the spatial or the temporal domain, which have been subjected to a filtration process having an associated transfer function (H);

b) selecting a transfer function H_T which inverts at least the phase differences of the transfer function H of the filter;

c) temporarily storing a multiplicity (N) of sequentially-received samples in a memory, each said sample being stored with an indication of the corresponding position or time;

d) generating an output data sample by calculating the integral of the product of the stored data samples with an impulse function (F), wherein the impulse function is deduced from the selected transfer function H_T according to the equation:

$$H_T(j\omega) = \int_{-\infty}^{\infty} F(t) e^{j\omega t} dt$$

if time (t) is the appropriate variable, or, if expressed in terms of distance (s):

$$H_T(j\omega) = \int_{-\infty}^{\infty} F(s) e^{j\omega s} ds$$

e) storing the next successive sample of data in the memory and deleting the oldest sample stored in the memory, and repeating the step of generating an output data sample; and

f) repeatedly performing the preceding step.

Preferably the multiplicity (N) is an odd number; and preferably the impulse function is centred on the middle sample of those stored, that is $((N+1)/2)^{th}$ sample if N is odd. It should be appreciated that the impulse function need not be a symmetrical function; it is 'centred' in the sense that it is a function not of absolute time (or distance) but of the time (or distance) relative to that of a specific stored sample.

The method described above enables a series of output data samples to be generated substantially in real-time, the only delay being that taken for the receipt of ((N+1)/2) samples. By appropriately selecting the impulse function, F, the effect of the filtration process on phase, or indeed on both amplitude and phase of the data, can be eliminated.

This method may be performed within a track recording vehicle. For example it can enable amplitude and phase distortions of track geometry signals to be removed, so that the corrected signals can be used as input for a vehicle dynamics simulation. Another application is that, once amplitude and phase distortions of track geometry signals have been removed, the signals correctly represent the shape of track features such as dipped rail joints, and so can be used to guide track maintenance. The method of the invention can also remove distortions due to anti-aliasing filters.

The present invention also provides an apparatus for performing this method.

For example, the method of the invention may be used to provide input data to a vehicle dynamics simulator carried in a track recording vehicle, so that the simulator can deduce the risk of derailment of a particular type of vehicle in substantially real-time. The vehicle dynamics simulator could give a warning signal if the corresponding simulated vehicle would be derailed. Hence the track survey vehicle can, substantially in real-time, provide warnings of track sections that would give high derailment risk for a particular type of vehicle at a particular speed.

Warnings might also be given if the simulated vehicle would subject passengers to unacceptable jolts, or if the simulated vehicle would subject the portion of track to unacceptable track forces, and such information could also be reported as soon as the vehicle has passed over that section of the track. This enables track maintenance to be targeted at those sections of track most in need of improvement.

The invention will now be further and more particularly described, by way of example only, and with reference to the accompanying drawings which represents as a block diagram apparatus incorporating the present invention.

In this example, an apparatus incorporating the present invention is installed in a track recording vehicle 10, that is to say a rail vehicle incorporating transducers monitoring displacements and accelerations of the bogie and/or the body as the vehicle 10 moves along the track 11. For example it might incorporate an accelerometer monitoring vertical accelerations of the bogie, and a displacement transducer monitoring vertical displacement of the axle relative to the bogie; data from such transducers would enable undulations in the vertical plane of each rail of the track to be monitored. Similarly accelerometers measuring horizontal accelerations, along with a displacement transducer to monitor the wheel relative to the bogie, enable undulations of the track in the horizontal plane to be monitored. Track recording vehicles normally incorporate several different transducers, data from the transducers being sampled every 1/8 m and digitized, and the output data may involve calculations that combine data from several such transducers. In any event the data is subjected to signal processing (represented diagrammatically by box 12) that includes filtration so as to generate track data, which would typically be displayed to an operator, for example using a graphical interface, and stored for subsequent processing. The data may also be stored in conjunction with data from other sensors, for example positional data from a GPS sensor.

As regards the lateral plane, the data typically would represent alignment (a measure of the offset of the rails from the required smooth curve, measured in mm), and curvature (indicating the reciprocal of the radius of the curve followed by the track, measured in km^{-1}). Typically the cutoff wavelength is set at 70 m, horizontal displacements of shorter wavelength than this being treated as alignment, and horizontal displacements of longer wavelength being treated as curvature. As regards the vertical plane, the data typically would represent "top" (a measure of the displacement of the rails from the required smooth curve, measured in mm), and gradient (indicating the slope of the track, in mm/mm). The cutoff wavelength in this case is typically also set to 70 m.

In the apparatus shown, the track data streams from the processor 12 representing alignment, curvature, and top (and possibly also gradient), and possibly other data streams such as positional information, are transmitted to a data post-processing server 14, and thence to a reporting server 16, and so to various display interfaces 18 and to a data store 20.

Data streams representing alignment, curvature, and top (and possibly also gradient) are also supplied by the post-processing server 14 to several different vehicle dynamics modules 22 (three such modules are represented). Each such module 22 consists of a microprocessor arranged to model the dynamics of a particular vehicle travelling along the track 11 at a particular speed. The output of these vehicle dynamics modules 22 is fed back to the data post-processing server 14, and is supplied to the reporting server 16 along with the corresponding track data (processed as described below).

The data post-processing server 14 is programmed to subject the track data streams from the processor 12 to the filtration process of the invention.

As mentioned above, the processor 12 is used to separate high frequency (short wavelength) components from low frequency (long wavelength) components. Analogue filters or digital infinite impulse response (IIR) filters can perform these tasks efficiently, but they introduce distortion. Methods are known to eliminate this phase distortion, either avoiding it by using finite impulse response (FIR) filters instead of IIR filters, or by back filtering the already distorted data with an identical IIR filter to restore the original phase content. However, there are cases where a signal has already been distorted by an analogue or IIR filter, and an undistorted signal is required. This is taken to be the case here.

The server 14 performs signal shaping of the incoming data, and forwards it to the rest of the system for storage and/or further processing. The signal processing method can deal with both spatially and temporally sampled data streams. It can also perform 'cross-domain' operations, as well, that is to say to perform temporally defined operations in spatially sampled (taken at equal distances) data, and vice versa.

The server 14 consists of:

- Digital input and output interfaces
- A buffer memory to store N samples of the data stream, including the measured value and a time or distance stamp, indicating the time or distance the measurement was taken. The type of the stamp data depends on the actual operation: if temporal operation is needed, then time stamp, if spatial operation is needed the distance stamp has to be attached to each measured value. The actual sampling method (equal time or equal distances) does not affect the operation of the filter. For example, usually the measurements are taken at equal distances, so if the vehicle speed is increasing, then the differences between the consecutive time stamps will decrease, but the system operation will not change.
- Memory to store the parameters of the calculations.
- Arithmetic processing capability.

It will be appreciated that the details such as the data transfer protocols, memory type etc. must be adjusted to the system in which the server 14 is used. In certain cases it may be a separate instrument connected to the data bus of the measurement system, in other cases it may be fully integrated into the measurement system.

The operation of the server 14 is as follows:

1. The samples of the incoming data are stored in an N-element first-in-first-out (FIFO) buffer, which is initialized with zeros as measured values. Each new sample enters the first slot of the buffer, moving the previous measurements one slot forward. The data that had been in the N^{th} slot is deleted, since it is replaced by the one coming from the $(N-1)^{th}$ slot. N is preferably odd.

2. After the new data sample is inserted into the buffer, the following calculation is performed:

$$Y(T_0) = \int_{T_1}^{T_2} F(t - T_0) X(t) dt \qquad \text{Eq.1}$$

where:

$Y(T_0)$ is the output data, time stamped as taken at T_0.

T_0 is the actual time stamp of the $((N+1)/2)^{th}$ data in the buffer. In a certain sense, the calculation above is centred on T_0, and the output data stream is always delayed by $(N+1)/2$ samples.

T_1 is the time stamp of the oldest (N^{th}) data in the buffer.

T_2 is the time stamp of the latest (1^{st}) data in the buffer. It is also true, that $T_1 < T_0 < T_2$.

$X(t)$ is the data stream stored in the buffer.

$F(t)$ is the finite impulse function, derived from the desired restoration. $F(t)$ is integratable between any possible t values.

It will be appreciated that Equation 1, which is expressed above as an integral (implying continuous functions), must in practice be performed as a summation, by a suitable discrete calculation method. Since each sample is processed separately, and has an associated time stamp, if the time intervals or spatial distances between successive samples vary, or there are randomly missing samples, overall operation is not affected. This is a significant advantage.

Eq. 1 is shown in the temporal domain. The formula is still valid in the spatial domain, where the time values have to be replaced with distance values:

$$Y(S_0) = \int_{S_1}^{S_2} F(s - S_0) X(s) ds \qquad \text{Eq. 1b}$$

3. The calculated output is forwarded for further processing.

The operation clearly depends on correctly determining the impulse function, F(t) or F(s). The impulse function is defined from the desired system behaviour, described by a transfer function. Transfer functions are complex equations that describe the system behaviour as a function of the cyclic frequency, ω. If $H(j\omega)$ is the transfer function of a filter, then:

$|H(j\omega)|$ is the ratio of the output to the input amplitude,
$\phi(H(j\omega))$ is angle of the phase delay,
where j is the square root of -1.

The selected transfer function H_T is one that reverses at least the phase change, and may also be selected so as to return the amplitude to its original value. The relationship between the transfer function and F(t) is:

$$H_T(j\omega) = \int_{-\infty}^{\infty} F(t) e^{j\omega t} dt \qquad \text{Eq. 2}$$

The equation above has to be solved for F(t). Analytical and numerical solutions are both suitable to get a functional F(t), and some examples are discussed below.

The final step is to define the size of the buffer memory. First we calculate T_l and T_h, such that the following approximation will be true:

$$H_T(j\omega) = \int_{-\infty}^{\infty} F(t)e^{j\omega t}dt \approx \int_{T_l}^{T_h} F(t)e^{j\omega t}dt \qquad \text{Eq. 3}$$

Once T_l and T_h are found, the size of the buffer (N) can be calculated as follows:

1. The temporal window (time period) over which integration is performed is $T_w=T_h-T_l$.
2. The number of samples in this time period will change as the vehicle changes speed, but if the maximum speed of the vehicle is known, then the number of samples will not exceed
   N = Tw·(Top speed)·(Samples per metre)
3. If the vehicle is going slower than the top speed, some of the stored samples will fall outside this specified time period. However, Eq. 3 shows that we can take F(t)=0 for such samples.

This derivation assumes operation in the temporal domain. If spatial domain operation is needed, F(s) can be generated by replacing the temporal terms with spatial terms, as in Eq. 1b.

<u>Example 1</u>: <u>Restoring the original phase content of an anti-aliased signal</u>

This describes an operation in the temporal domain..

As mentioned earlier, a track recording vehicle 10 will include various transducers which measure aspects of the vehicle movement, such as an accelerometer, gyroscope etc. Typically the signal from such a transducer, which is an analogue signal, is first fed into an anti-aliasing filter, in order to avoid interference of high frequency signals with the digital sampling rate, called aliasing. Anti-aliasing filters are low frequency pass analogue filters, eliminating the undesired frequency content. The data processor 12 would then produce digital output signals by sampling the analogue signal at equal distances along the track. Anti-aliasing is essential, but it introduces a non-linear phase delay of the incoming signal. This phase delay will distort the shape of the signal. Until now back-filtering was only the way to restore the original phase content. However, back-filtering changes the amplitudes in the transition band and cannot be used if the results are needed in real time.

The transfer function H of the analogue anti-aliasing filter can be given by the amplitude and phase responses as a function of the cyclic frequency:

$$A(\omega) = |H(j\omega)| \text{ , and } \phi(\omega) = \phi(H(j\omega)), \qquad \text{Eq.4}$$

where ω is in radians per second. These two functions can be analytically derived, or measured. We must select or create a transfer function H_T which leaves the amplitude intact, but reverses the phase delay. Hence the amplitude and phase responses of the selected transfer function H_T should be as follows:

$$A_T(\omega) = 1,\ \phi_T(\omega) = -\phi(\omega). \qquad \text{Eqs. 5}$$

This is satisfied by the transfer function:

$$H_T(j\omega) = \cos(\phi_T(\omega)) + j\sin(\phi_T(\omega)) = \cos(-\phi(\omega)) + j\sin(-\phi(\omega)) \qquad \text{Eq.6}$$

Knowing the target transfer function, F(t) and N can be calculated as described above. Once these have been calculated, the server 14 can restore the original phase content of the incoming signal.

Example 2: Restoring broadband curvature signal from asymmetric versine input

This describes an operation in the spatial domain.

If we model the railway track as a planar curve, it may be described by its curvature. Curvature for any planar curve is defined as:

$$C(s) = \left| \frac{d^2\mathbf{p}(s)}{ds^2} \right| \qquad \text{Eq.7}$$

where p is the vector pointing to a location on the track, s is the path taken on the track. Usually, the track curvature is split into long and short wavelength parts: the long wavelength part describes the track design, all the bends and straight sections needed to lead the train from A to B, while the short wavelength part describes the local deviations from the design, affecting the ride quality along the track.

It is difficult to measure curvature directly, so different indirect methods are used. One of them is asymmetric versine; the asymmetric versine, v, is measured by considering a fixed length chord between two points on the rail. The chord is divided by a point Y into two unequal parts, L_1 and L_2, and v is the distance of the rail from the point Y measured along a line perpendicular to the chord. Asymmetric versine is easy to measure both manually and automatically. It gives a broadband description of the lateral track geometry, recording both short and long wavelengths components in the same output. Unfortunately, to determine curvature from asymmetric versine a complicated transfer function is required, which also introduces phase distortion. Previously-known methods were unable to give a proper reconstruction of curvature from versine in real time.

The server 14 can be configured to reproduce broadband curvature from digital asymmetric versine input in real time.

The transfer function from curvature to versine is:

$$H_{CV}(j\omega)=\frac{1}{\omega^2}\left(1-\frac{L_2}{L_1+L_2}e^{-jL_1\omega}-\frac{L_1}{L_1+L_2}e^{jL_2\omega}\right) \qquad \text{Eq.8}$$

where ω is in radians per metre, and L_1 and L_2 are in metres.

The inverse transfer function:

$$H_{VC}(j\omega)=\frac{1}{H_{CV}} \qquad \text{Eq. 9}$$

is the required transfer function (i.e. the selected transfer function H_T), and hence F(s) and N can be calculated as described above. Once these are calculated, the server 14 can restore the original curvature.

It will be appreciated that a track recording vehicle 10 might include several such vehicle dynamics modules 22 operating in parallel, for example twelve rather than the three modules 22 shown here. Operation of this one vehicle 10 is therefore equivalent to running a fleet of a dozen different vehicles that may use this particular route, each at their own speed, and each of the virtual vehicles is effectively instrumented for assessing the risk of derailment, and also other parameters such as passenger comfort, track forces, vehicle kinematic movements etc.. This information is obtained in real-time, and is reported as part of the data provided to the display interfaces 18 as soon as the track recording vehicle 10 has passed over a portion of the track 11. The information is embedded in the same stream of data as the information on track geometry. Hence it can be readily interfaced to track management software.

Although the method has been described as being performed within a track recording vehicle 10, and so giving information in real-time, it will also be appreciated that data previously obtained using a track recording vehicle 10 may be supplied later to such a phase and amplitude correction microprocessor (equivalent to the post processing server 14), and hence if desired to a plurality of vehicle dynamics modules 22.

Claims

1. A method of obtaining data on the quality of a railway track, the method comprising:

a) receiving from a track recording vehicle data concerning variations of a parameter, the data comprising samples, obtained in either the spatial or the temporal domain, which have been subjected to a filtration process having an associated transfer function (H);

b) selecting a transfer function H_T which inverts at least the phase differences of the transfer function H of the filter;

c) temporarily storing a multiplicity (N) of sequentially-received samples in a memory, each said sample being stored with an indication of the corresponding position or time;

d) generating an output data sample by calculating the integral of the product of the stored data samples with an impulse function (F), wherein the impulse function is deduced from the selected transfer function H_T according to the equation:

$$H_T(j\omega) = \int_{-\infty}^{\infty} F(t) e^{j\omega t} dt$$

if time (t) is the appropriate variable, or, if expressed in terms of distance (s):

$$H_T(j\omega) = \int_{-\infty}^{\infty} F(s) e^{j\omega s} ds$$

e) storing the next successive sample of data in the memory and deleting the oldest sample stored in the memory, and repeating the step of generating an output data sample; and

f) repeatedly performing the preceding step.

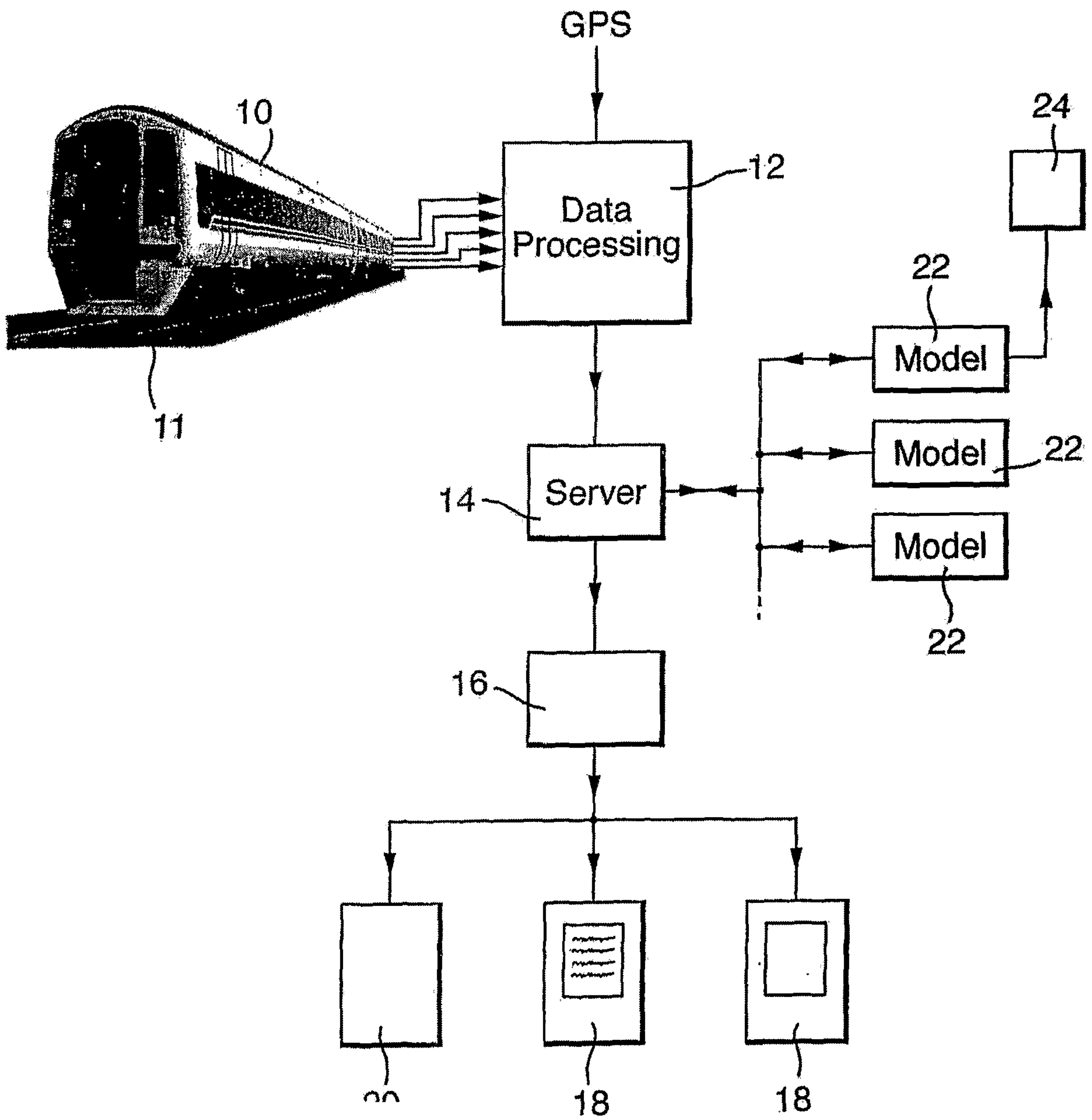
2. A method as claimed in claim 1 wherein the selected transfer function H_T is such as to reverse both the changes in phase and the changes in amplitude due to the filtration process.

3. A method is claimed in claim 1 or claim 2 wherein the impulse function is centred on the $((N+1)/2)^{th}$ stored sample.

4. A method as claimed in claim 3 wherein the multiplicity is an odd number.

5. A method as claimed in any one of the preceding claims wherein the method is performed within a track recording vehicle.

6. An apparatus for performing a method as claimed in any one of the preceding claims.


GPS
10
Data Processing
12
24
22
Model
Model
22
Model
22
11
Server
14
16
18
18

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2005/001600

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B61K9/08 B61L23/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B61K B61L E01B G06F G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2004/009422 A (AEA TECHNOLOGY PLC; GILBERT, DAVID) 29 January 2004 (2004-01-29) page 4, line 8 - page 6, line 11; figure 1	6
A		1,5
A	EP 0 697 672 A (MAN TECHNOLOGIE AKTIENGESELLSCHAFT) 21 February 1996 (1996-02-21) page 17, line 17 - page 18, line 46 page 20, line 51 - page 21, line 6; figures 1-5,7,8	1,6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 July 2005	03/08/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Chlosta, P

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2005/001600

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 2004009422	A	29-01-2004	AU	2003281520	A1	09-02-2004
			WO	2004009422	A1	29-01-2004
			GB	2405722	A	09-03-2005
EP 0697672	A	21-02-1996	DE	4429517	A1	22-02-1996
			AT	187827	T	15-01-2000
			DE	59507421	D1	20-01-2000
			EP	0697672	A2	21-02-1996