

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HUM INDUSTRIAL TECHNOLOGY, INC.
Petitioner

v.

AMSTED RAIL COMPANY, INC.
Patent Owner

Case IPR2023-00540
US Patent No. 10,137,915

Before JAMES P. CALVE, KEVIN W. CHERRY, and MICHAEL L. WOODS,
Administrative Patent Judges.

PETITIONER'S DEMONSTRATIVES FOR ORAL ARGUMENT

Case No. IPR2023-00540
US Patent No. 10,137,915

Pursuant to the May 17, 2024 Order Setting Oral Argument (Paper 33) and 37 C.F.R. § 42.70, Petitioner Hum Industrial Technology, Inc. hereby files its Demonstratives for use at Oral Argument, attached hereto.

Respectfully submitted,

Dated: June 7, 2024

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CERTIFICATE OF SERVICE

I hereby certify that on this 7th day of June, 2024, the foregoing was served via electronic mail to the attorneys of record for the '915 patent at the following address:

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Hum Industrial Technology, Inc.,
Petitioner

v.

Amsted Rail Company, Inc.,
Patent Owner.

Case No. IPR2023-00540

U.S. Patent No. 10,137,915

The '915 Patent

System and Method for Detecting Operational
Anomalies in Train Consists and Railcars

The '915 Patent

US010137915B2

(12) **United States Patent**
LeFebvre et al.

(10) **Patent No.:** US 10,137,915 B2
(45) **Date of Patent:** Nov. 27, 2018

(54) **SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS**

(71) Applicant: Amsted Rail Company, Inc., Chicago, IL (US)

(72) Inventors: William LeFebvre, West Chester, PA (US); Andrew Martin, West Chester, PA (US); Francis James Cooper, Downingtown, PA (US); Rachel W. Adamec, Norristown, PA (US)

(73) Assignee: AMSTED RAIL COMPANY, INC., Chicago, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 156(b) by 0 days.

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(22) PCT Filed: Dec. 24, 2014
(86) PCT No.: PCT/US2014/072380
§ 371 (c)(1),
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PCT Pub. Date: Jul. 2, 2015

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Related U.S. Application Data
(60) Provisional application No. 61/920,700, filed on Dec. 24, 2013.

(51) **Int. Cl.**
B61L 2700 (2006.01)
B61L 1500 (2006.01)
(Continued)

(52) **U.S. CL.**
CPC **B61L 270094** (2013.01); **B61K 900** (2013.01); **B61K 904** (2013.01); **B61L 150027** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC B60T 17/22; B61L 1500; B61L 150018; B61L 150027; B61L 150054;
(Continued)

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Primary Examiner — Jason C. Smith
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(57) **ABSTRACT**
A system for monitoring railcar and tram consist operational parameters and detecting anomalies in the operation and condition thereof using sensors to feed data to a distributive complex event processing engine.

37 Claims, 14 Drawing Sheets

(57)

ABSTRACT

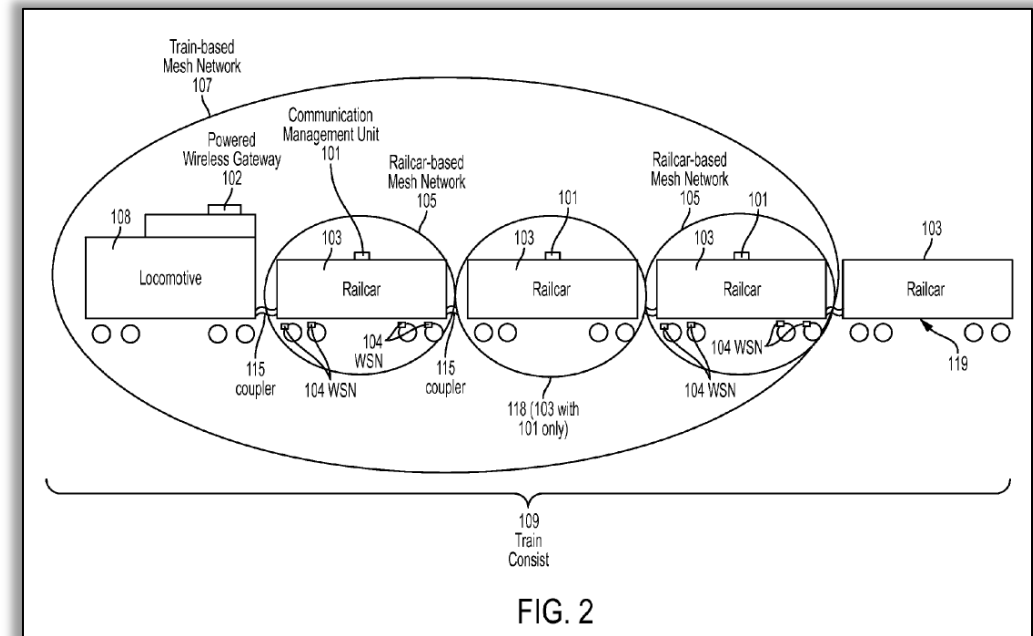
A system for monitoring railcar and tram consist operational parameters and detecting anomalies in the operation and condition thereof using sensors to feed data to a distributive complex event processing engine.

The '915 Patent

- The '915 Patent provides an alleged solution to problems with prior art wayside detectors

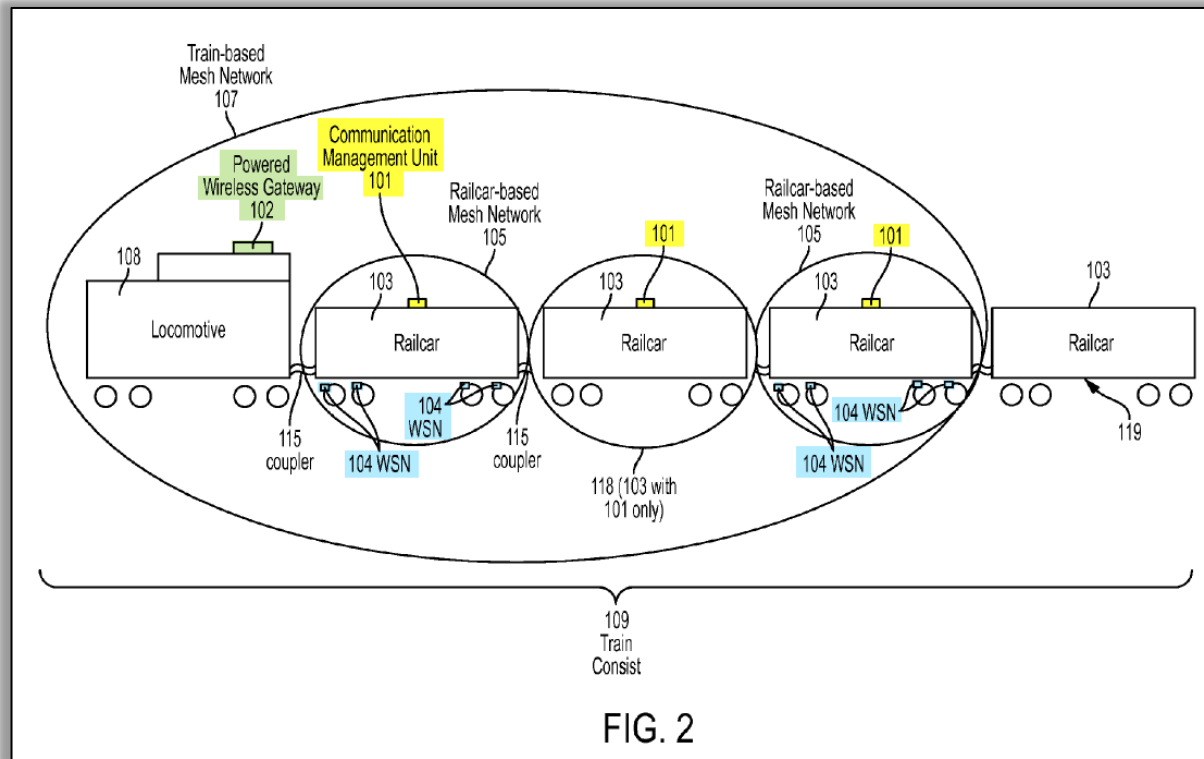
SUMMARY OF THE INVENTION

The system presented herein addresses the deficiencies in prior art monitoring systems for railcars and train consists. The system consists of a hierarchical arrangement of components which provide a distributed data analysis capability that is capable of detecting operational anomalies at various levels of the hierarchy, and which provides for the flow of data, events and alerts to a central point.



Petition, pp. 7-8; EX1001 at 1:21-28, 1:59-65, 1:13-17, 1:66-2:4, 1:22-36, 2:4-25, 17:48-22:37, 2:32-41, Figs. 1-2

Specification of the '915 Patent



- Wireless Sensor Nodes (WSN)
- Communication Management Units (CMU)
- Powered Wireless Gateway (PWG)
- Remote Railroad Operations Center/Remote Servers

EX1001, Fig. 2; Petition, pp. 7-8

Specification of the '915 Patent

- The '915 Patent teaches standard mechanical and digital/software filters to filter data:

Additionally, a mechanical filter **410** consisting of upper sections **410a** and lower sections **410b** further serve to mechanically filter high and low frequency types of accelerations that are considered noise and which are preferably removed from the signal of interest. Preferably, these components are composed respectively of silicone of durometer 70 Shore A (the upper filter sections **410a**) and 30 Shore A (the lower filter sections **410b**) in view of the differences of the surface areas of each section and this affect on the filtering characteristics.

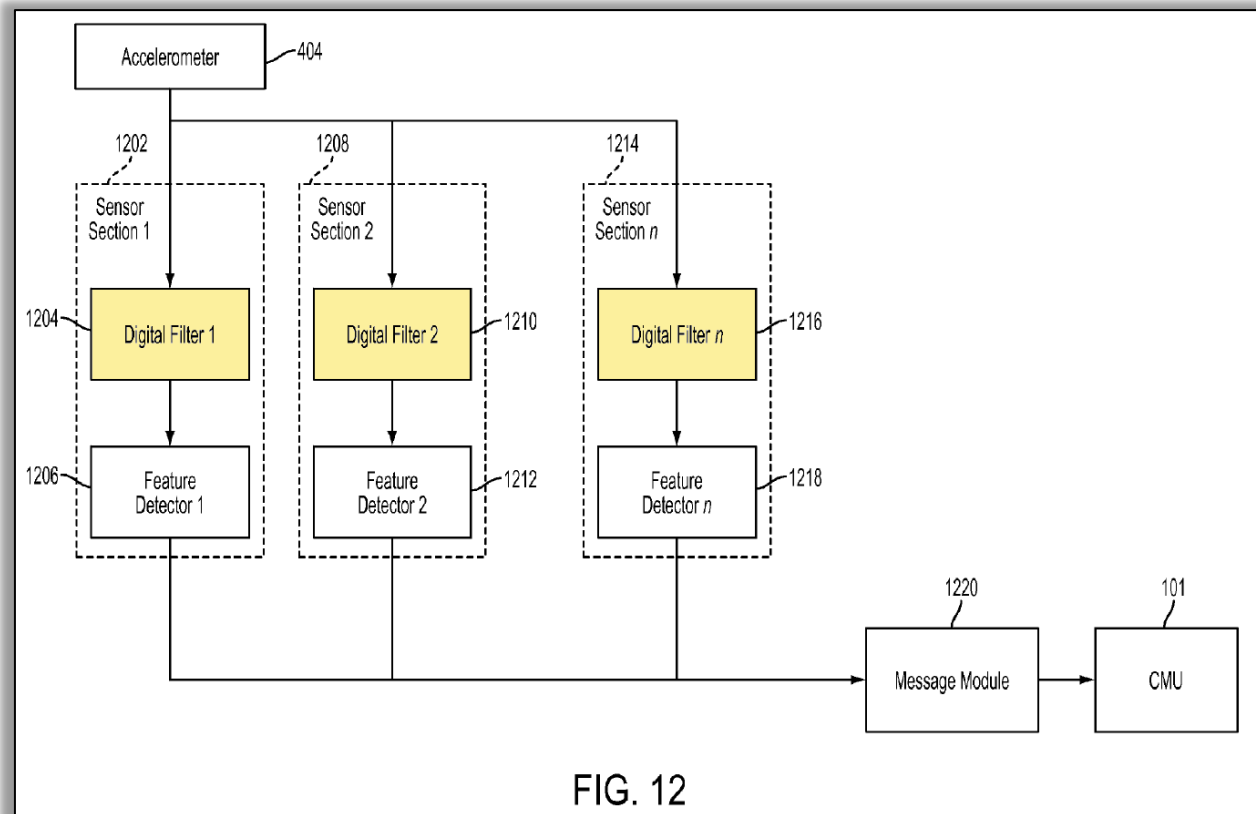
In a preferred embodiment, each WSN **104** may have one or more accelerometers **404** and one or more temperature sensors **406**. The tuning of WSN **104** is accomplished by a combination of the selection of the potting material, the durometer of upper and lower silicone mechanical filtering elements **410a** and **410b**, and software filtering performed by software executing on a processor on main PC board **402a**. The software filter used is a digital filter to decrease noise from unwanted acceleration frequencies and increase signals from acceleration frequencies of interest.

EX1001 at 5:23-32, 5:33-42; Institution Decision, p. 27;
Reply, p. 15, n.5; EX1025, ¶¶ 4-6

Specification of the '915 Patent

- Digital data filters “select” the data to be analyzed:

With reference to FIGS. 4 and 12, a general implementation model of the analysis system of a WSN 104 is now described. As depicted in the preferred embodiment, the analyzed signal (what is not filtered out by the mechanical filter 410 or potting material), originates with accelerometer hardware 404 and is passed to one or more sensor sections 1202, 1208 or 1214. These sensor sections select the data to be analyzed using a digital data filter 1204, 1210 or 1216, and passes this data on to a feature detector 1206, 1212 or 1218. Data selection can be based on, for example, direction (e.g. vertical or longitudinal components), frequency (e.g. high-frequency clangs or low frequency rocking), overall magnitude (combination of 2 or 3 directional components), or other variations of the collected data.



EX1001, 13:11-24, Fig. 12; Reply, pp. 1, 4-9, 22; EX1025, ¶¶ 5-6

Specification of the '915 Patent

One possible implementation of the analysis system of FIG. 12 is shown in FIG. 13. Here, accelerometer 404 passes data on to three sensor sections. The first section 1302 selects data from the longitudinal direction down the length of the railcar 103 and uses Longitudinal Section 1304 to extract longitudinal impact data. Longitudinal impacts are detected in Impact Detector 1306 when the peak value of the longitudinal data exceeds a longitudinal impact threshold. The second section 1308 selects data from the lateral direction across the railcar 103 and uses Lateral Section 1310 to extract lateral oscillation data. Lateral oscillations are detected in Vehicle Dynamics Detector 1312 when the RMS value of the oscillations exceeds a lateral oscillation threshold. The third section 1314 selects data from the vertical direction and uses Vertical Section 1316 to extract vertical oscillation data. Vertical oscillations are detected in Vehicle Dynamics Detector 1318 when the RMS value of the oscillations exceeds a vertical oscillation threshold. Each of these sensor sections sends its messages on to message module 1220 which, in turn, passes these messages on to the CMU 101.

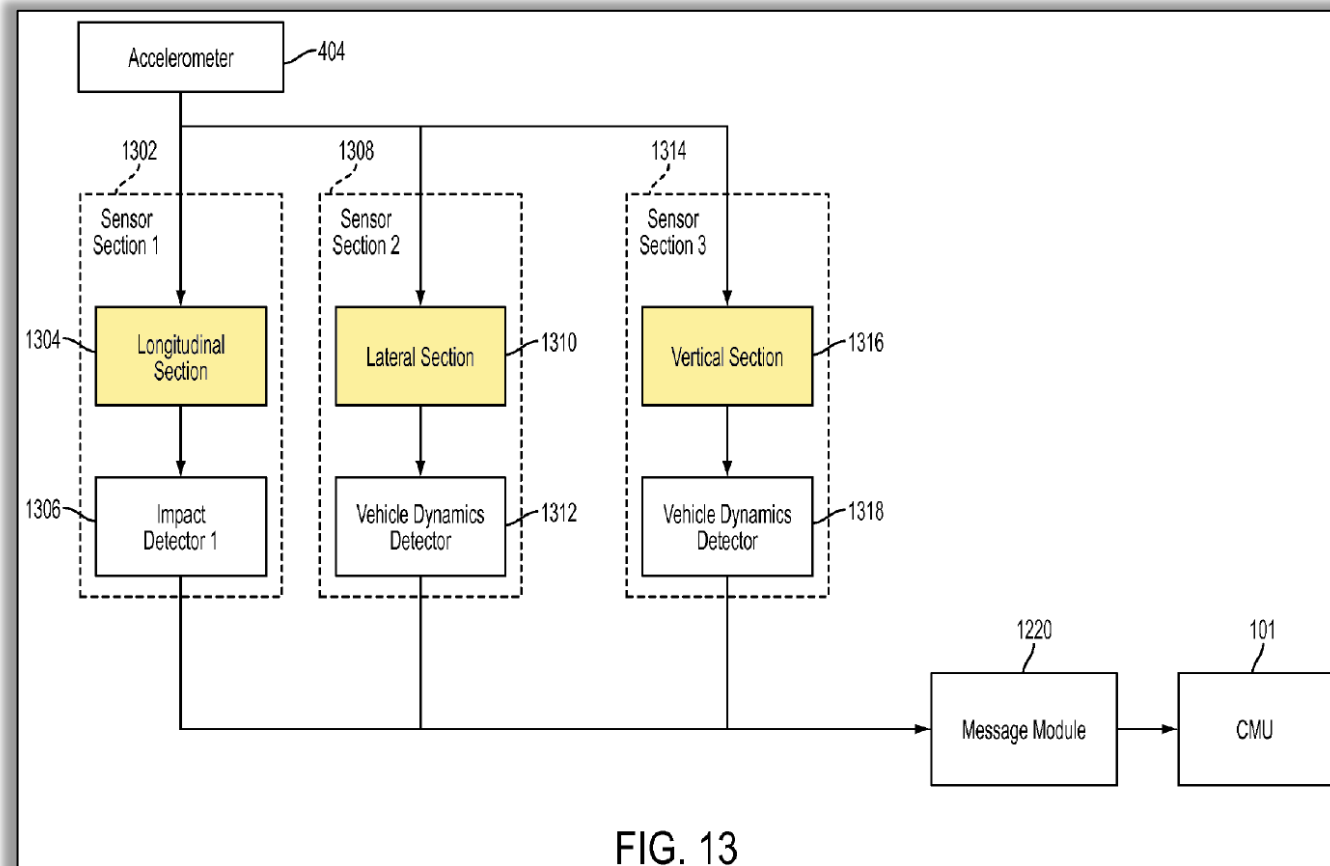


FIG. 13

EX1001 at 13:36-56, Fig. 13; Reply, pp. 5-6; EX1025, ¶¶ 5-6

Specification of the '915 Patent

Another possible implementation of the analysis system is shown in FIG. 14. Here, accelerometer 404 passes data on to three sensor sections. The first section 1402 looks at data from the vertical direction and uses Vertical Derailment Filter 1404 to extract the characteristic frequencies of a derailment. Derailment events are detected in Derailment RMS Detector 1406 when the RMS value of the filtered data exceeds a derailment threshold. The second section 1408 also selects data from the vertical direction, but uses Vertical Wheel Damage Filter 1410 to extract the characteristic frequencies of wheel damage. Wheel damage is detected in

Wheel Damage RMS Detector 1412 when the RMS value of the filtered data exceeds a wheel damage threshold. The third section 1414 also selects data from the vertical direction and uses Vertical Impact Filter 1416 to extract vertical impact data. Vertical impacts are detected in Vertical Impact Peak Detector 1418 when the peak value of the filtered data exceeds a vertical impact threshold. Each of these sensor sections sends its messages on to message module 1220 which, in turn, passes these messages on to the CMU 101.

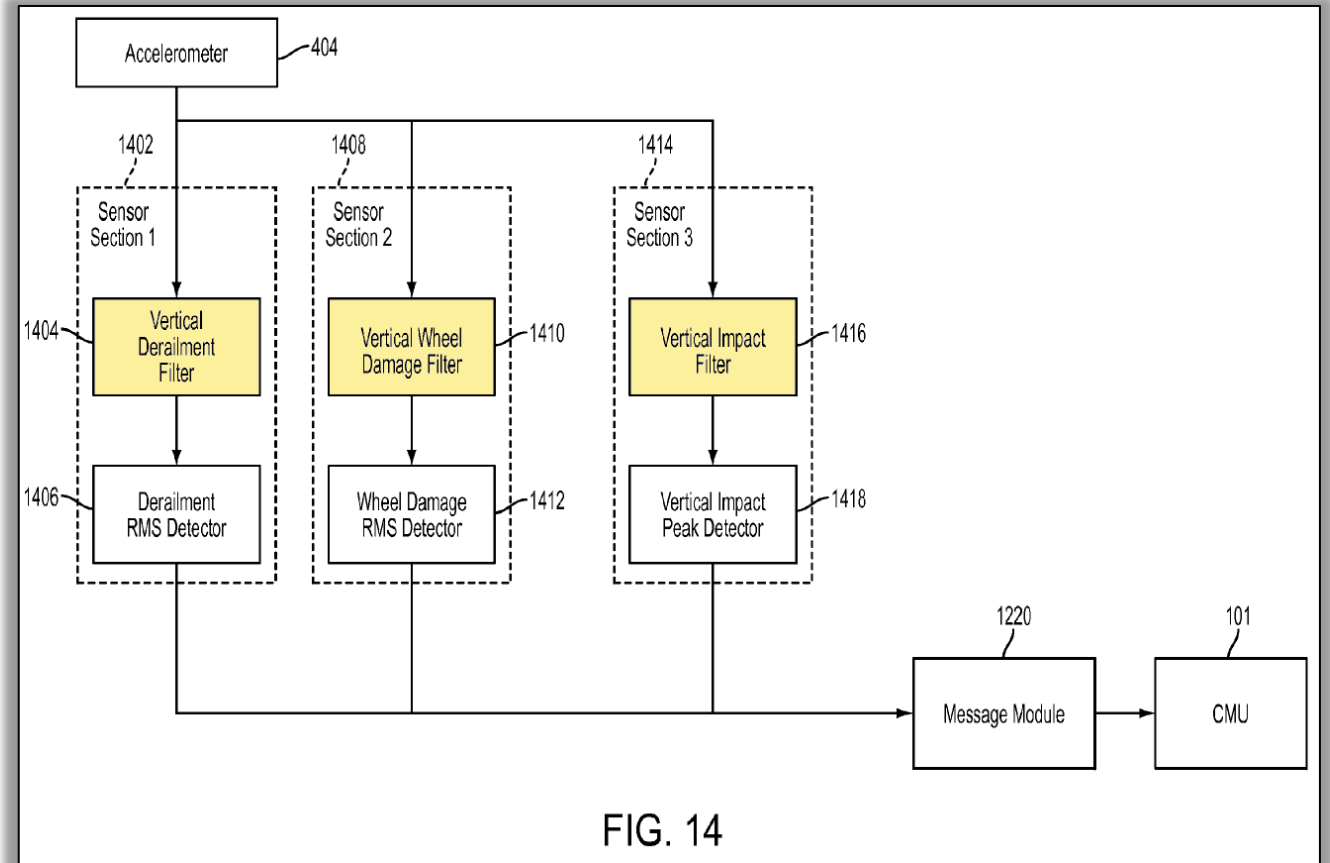


FIG. 14

EX1001 at 13:57-14:9, Fig. 14; Reply, pp. 6-7, 22; EX1025, ¶¶ 5-6

Independent Claim 1

1. A system for detecting operational anomalies on a train consist or railcar comprising:

- (a) one or more communication management units mounted on one or more railcars;
- (b) one or more sensors located on said one or more railcars configured to sense an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and
- (c) one or more filters configured to filter at least a portion of the accelerations,

wherein said communication management units perform the functions of:

- (i) collecting data regarding said one or more railcar operational parameters;
 - (ii) analyzing said collected data for trends or events indicative of an anomalous operational condition;
- and

Independent Claims 30 and 36

30. A method for detecting operational anomalies on a train consist or railcar comprising the steps of:
sensing, by one or more sensors located on one or more railcars, one or more operational parameters of the one or more railcars, wherein the one or more operational parameters comprise one or more accelerations of the one or more railcars;
filtering, by one or more filters, at least a portion of the accelerations; and
by one or more communication management units associated with the one or more railcars:
collecting data regarding said one or more railcar operational parameters;
analyzing said collected data for trends or events indicative of an anomalous operational condition; and
communicating a message to a remote receiver when said trend or event is detected.

36. A system for detecting operational anomalies on a railcar that is part of a train consist comprising:

(a) at least one communication management unit (CMU) mounted on the a railcar in said train consist;

(b) at least two sensors located on the said railcar for configured to sense operational parameters of the railcar, said sensors being in communication with said communication management unit, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

(c) one or more filters configured to filter at least a portion of the accelerations,

wherein said communication management unit performs the following functions:

- (i) receiving data from said sensors;
- (ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and
- (iii) communicating a message to a remote receiver when an anomaly is detected.

EX1001, Claims 30, 36

Prosecution History

- Claims allowed when “filter” limitations added to independent claims.

1 (Currently Amended). A system for detecting operational anomalies on a train consist or railcar comprising:

(a) one or more communication management units mounted on one or more railcars; ~~and~~

(b) one or more sensors located on said one or more railcars ~~for sensing~~ configured to sense an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

(c) one or more filters configured to filter at least a portion of the accelerations, wherein said communication management units perform the functions of:

(i) collecting data regarding said one or more railcar operational parameters;

(ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and

(iii) communicating a message to a remote receiver when said trend or event is detected.

EX1002, p. 531; Petition, pp. 9-10

Limitations in Dispute

Independent Claim 1, 30, and 36:

- **Limitation 1(d):** “(c) one or more filters configured to filter at least a portion of the accelerations”
- **Limitation 30(c):** “filtering, by one or more filters, at least a portion of the accelerations”
- **Limitation 36(d):** “(c) one or more filters configured to filter at least a portion of the accelerations”

EX1001 at Claims 1, 30, 36

Limitations in Dispute

- **Claim 25:** The system of claim 1, further comprising one or more wireless sensor nodes in communication with at least one of the communication management units, wherein one or more of the wireless sensor nodes comprises a microprocessor configured to execute firmware to control operation of the one or more of the wireless sensor nodes, wherein the firmware comprises **one or more software filters** configured to isolate one or more types of accelerations.
- **Claim 28:** The system of claim 1, wherein the one or more filters comprise one or more **digital filters**.

EX1001 at Claims 25, 28

Asserted Prior Art

Prior Art References

- U.S. Patent Publication No. 2011/0282540 (“Armitage”)
- U.S. Patent Publication No. 2007/029884 (“Barone”)
- U.S. Patent Publication No. 2007/0152107 (“LeFebvre”)
- U.S. Patent No. 7,706,213 (“Winfree”)

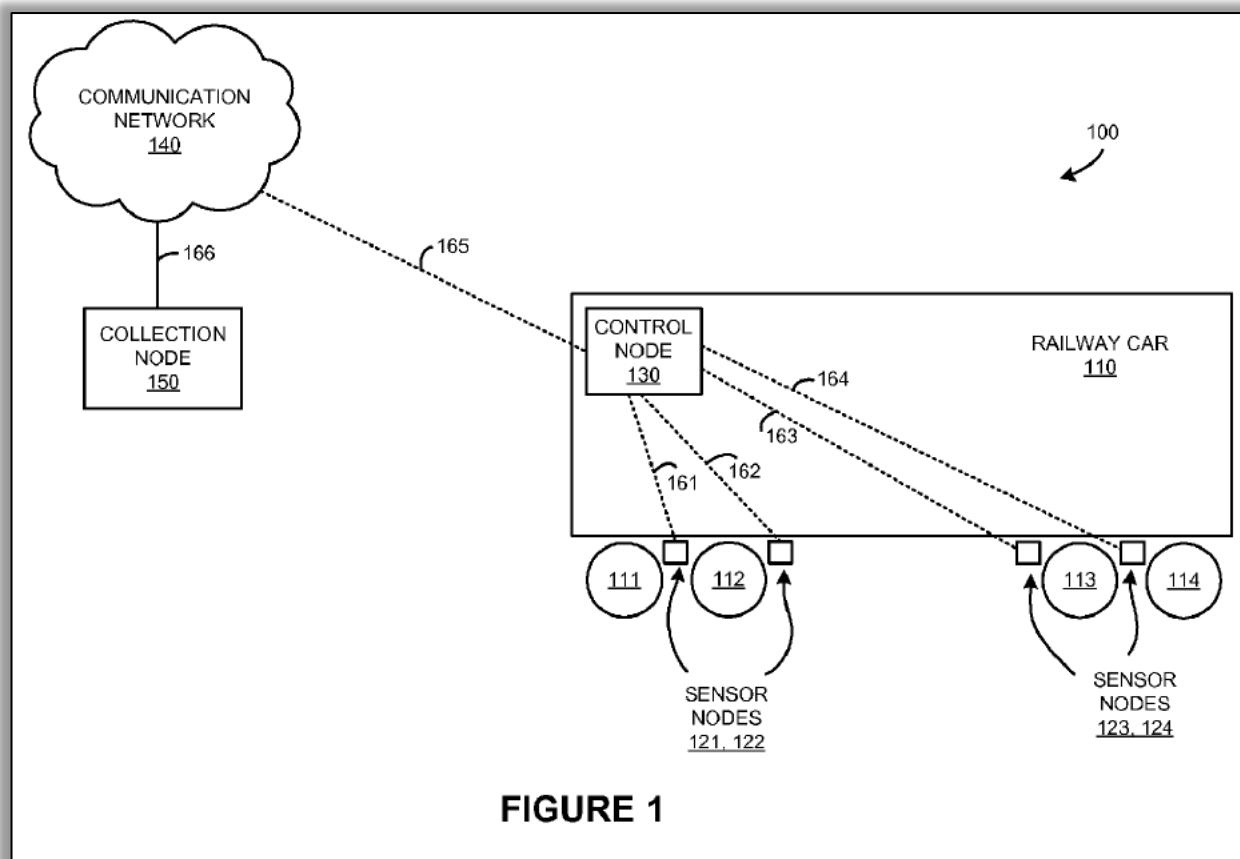
EX1005; EX1006; EX1007; EX1008

Armitage - U.S. Patent Pub. No. 2011/0282540

(57)

ABSTRACT

What is disclosed is a mobile railway car monitoring system. The mobile railway car monitoring system includes a plurality of sensor nodes coupled to an undercarriage portion of a railway car, and a control node coupled to the railway car. Each of the plurality of sensor nodes is configured to monitor the undercarriage portion of the railway car when in motion and transmit information about the undercarriage portion to the control node. The control node is configured to receive the information about the undercarriage portion, process the information to determine a fault condition for the undercarriage portion, and wirelessly report the fault condition to a collection system.



EX1006, Abstract, Fig. 1;
Petition, pp. 10-11; EX1003, ¶ 49

Barone - U.S. Patent Pub. No. 2007/029884

(57)

ABSTRACT

A low power self-organizing network is made up of a plurality of wireless communication nodes communicating wirelessly with each other. The nodes each have a sensor providing a respective sensor data value indicative of a physical parameter in the environment of that node. The wireless network discontinues communication with any nodes in which the sensor data value is outside a range of network sensor data values. The network is preferably a group of vehicles moving together, especially a train in which each node is associated with a respective wheel of a railroad car. The nodes are low-power devices that communicate using wireless communications according to a Zigbee protocol. The nodes each have an additional sensor sensing a physical parameter the respective wheel thereof and determines from said electrical signal a degree of degradation of a bearing of the wheel, and transmits data of the degree of degradation to the main node. The main node communicates with another computer system using a higher power communication system and transmits thereto data indicative of degradation of said bearings.

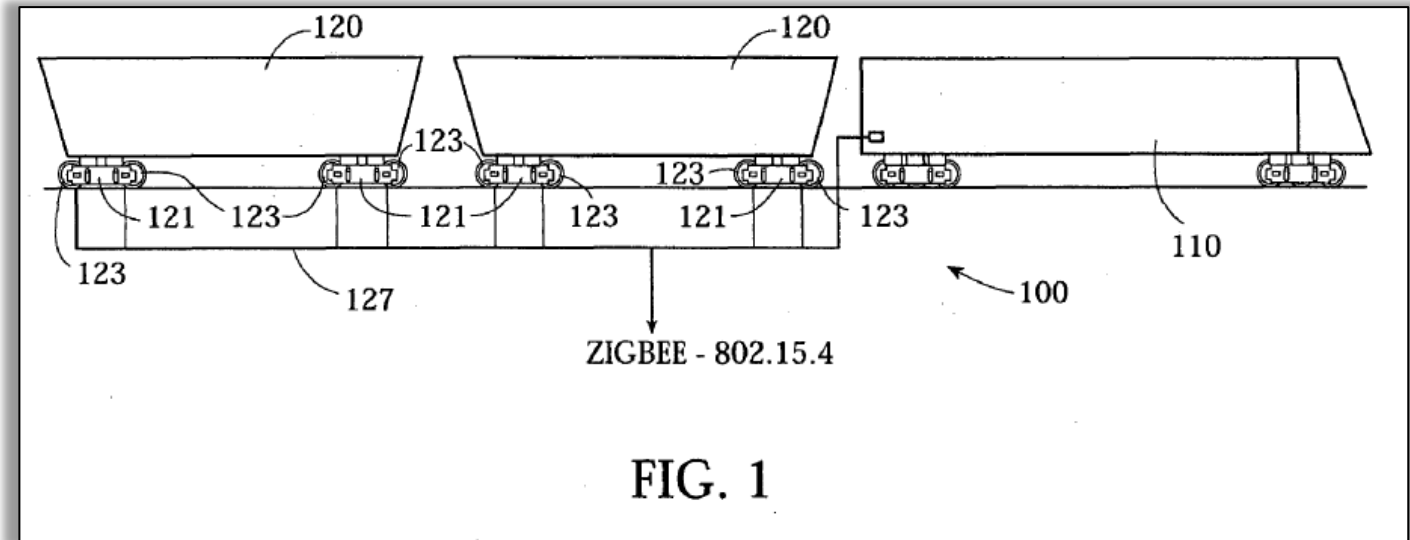


FIG. 1

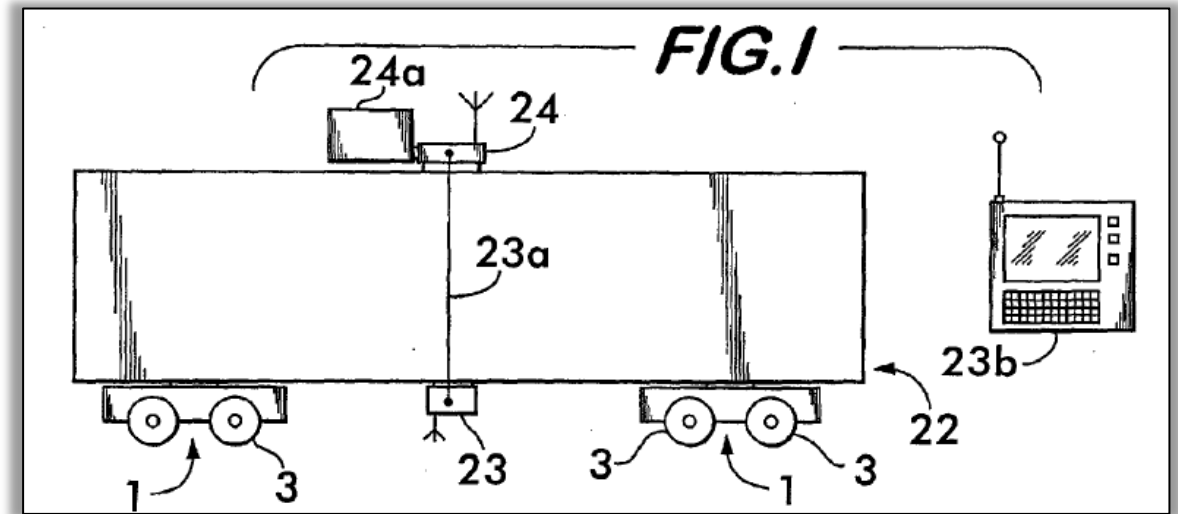
EX1007, Abstract, Fig. 1;
Petition, pp. 11-12; EX1003, ¶¶ 50-51

LeFebvre - U.S. Patent Pub. No. 2007/0152107

(57)

ABSTRACT

Railcar monitoring utilizes instrumented, flexible pads supported within the truck pedestal jaws on the bearing adapters. The pads contain sensors for monitoring temperature pressure, shifting loads, truck hunting and the like and have circuitry for processing information received from the sensors and for processing and reporting departures of performance variables to a remote source. The system cyclically activates polling each pad on a car and communicates signals of critical departures and car identity to a remote source.



EX1005, Abstract, Fig. 1;
Petition, p. 13; EX1003, ¶¶ 52-53

Winfree - U.S. Patent No. 7,706,213

(57)

ABSTRACT

An arrangement of material layers designed and utilized as a filter to mechanical waves entering a sensor. To isolate the sensor, the filter can be designed to attenuate specified frequencies that could propagate from the environment and into the sensor. Provided there is a difference in the mechanical impedance between the environment and the sensor case, then a filter can be designed to amplify a specified range of frequencies, enhancing the coupling of the sensor to its environment. The filters work by altering the transmission and reflection of incident waves. Dissipative mechanisms are not required. Test data is included that demonstrates the effectiveness of layered isolation mounts developed to block inputs that would excite the resonance frequency an accelerometer's seismic mass.

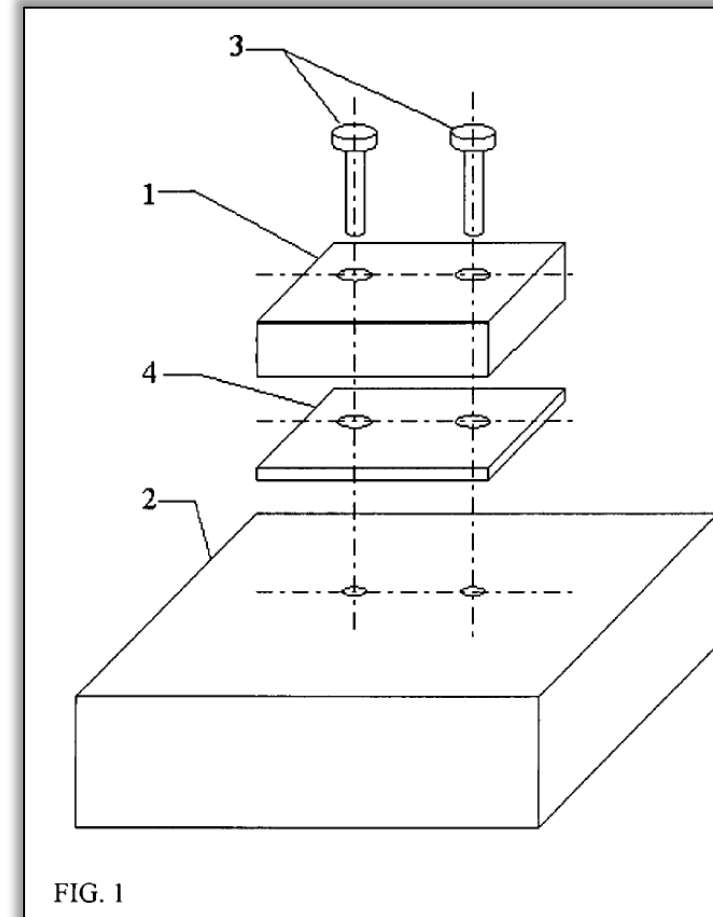


FIG. 1

EX1008, Abstract, Fig. 1;
Petition, p. 14; EX1003, ¶ 54

Grounds of Unpatentability

Grounds of Unpatentability

- **Ground 1:** **Claims 1, 22, 24-25, 27-30, 36, and 37** are unpatentable under 35 U.S.C. § 103(a) in view of Armitage and Barone
- **Ground 2:** **Claim 21** is unpatentable under 35 U.S.C. § 103(a) in view of Armitage, Barone, and LeFebvre
- **Ground 3:** **Claims 23 and 26** unpatentable under 35 U.S.C. § 103(a) in view of Armitage, Barone, and Winfree
- **Ground 4:** **Claims 1, 21-22, 25, 27-30, 36, and 37** are unpatentable under 35 U.S.C. § 103(a) in view of LeFebvre and Barone
- **Ground 5:** **Claims 24 and 37** are unpatentable under 35 U.S.C. § 103(a) over LeFebvre in view of Barone and Armitage
- **Ground 6:** **Claims 23 and 26** are unpatentable under 35 U.S.C. § 103(a) over LeFebvre in view of Barone and Winfree

Petition, pp. 5-6

Grounds and Claims in Dispute

- **Ground 1 (Armitage + Barone):**
 - Independent claims 1, 30, and 36 (filter)
 - Dependent claim 25 (software filter)
 - Dependent claim 28 (digital filter)
- **Ground 4 (LeFebvre + Barone):**
 - Independent claims 1, 30, and 36 (filter)
 - Dependent claim 25 (software filter)
 - Dependent claim 28 (digital filter)

Ground 1: Obviousness in view of Armitage and Barone

Independent Claim 1

Claim Designation	Claim Language
Claim 1 Preamble (Limitation 1(a))	A system for detecting operational anomalies on a train consist or railcar comprising:
Limitation 1(b)	(a) one or more communication management units mounted on one or more railcars;
Limitation 1(c)	(b) one or more sensors located on said one or more railcars configured to sense an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and
Limitation 1(d)	(c) one or more filters configured to filter at least a portion of the accelerations,
Limitation 1(e)	wherein said communication management units perform the functions of: (i) collecting data regarding said one or more railcar operational parameters;
Limitation 1(f)	(ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and
Limitation 1(g)	(iii) communicating a message to a remote receiver when said trend or event is detected.

EX1001 at Claim 1

Independent Claims 30 and 36

Claim Designation	Claim Language
Claim 30 Preamble (Limitation 30(a))	A method for detecting operational anomalies on a train consist or railcar comprising the steps of:
Limitation 30(b)	sensing, by one or more sensors located on one or more railcars, one or more operational parameters of the one or more railcars, wherein the one or more operational parameters comprise one or more accelerations of the one or more railcars;
Limitation 30(c)	filtering, by one or more filters, at least a portion of the accelerations; and
Limitation 30(d)	by one or more communication management units associated with the one or more railcars: collecting data regarding said one or more railcar operational parameters;
Limitation 30(e)	analyzing said collected data for trends or events indicative of an anomalous operational condition; and
Limitation 30(f)	communicating a message to a remote receiver when said trend or event is detected.

Claim Designation	Claim Language
Claim 36 Preamble (Limitation 36(a))	A system for detecting operational anomalies on a railcar that is part of a train consist comprising:
Limitation 36(b)	(a) at least one communication management unit (CMU) mounted on the a railcar in said train consist;
Limitation 36(c)	(b) at least two sensors located on the said railcar for configured to sense operational parameters of the railcar, said sensors being in communication with said communication management unit, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and
Limitation 36(d)	(c) one or more filters configured to filter at least a portion of the accelerations,
Limitation 36(e)	wherein said communication management unit performs the following functions: (i) receiving data from said sensors;
Limitation 36(f)	(ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and
Limitation 36(g)	(iii) communicating a message to a remote receiver when an anomaly is detected.

Independent Claims 1, 30 and 36

- Patent Owner does not dispute Armitage teaches every limitation of the independent claims except for the “filter” limitation.
- Armitage and Barone both teach ways to filter acceleration data from an accelerometer.

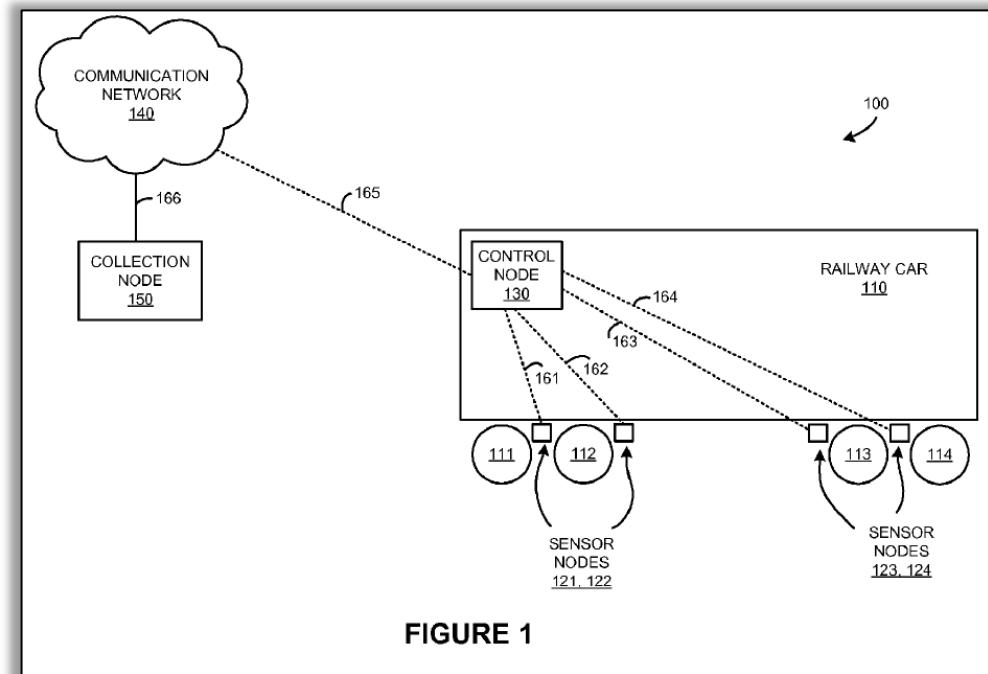
EX1001 at Claims 1, 30, 36; Petition, pp. 25-29;
Response, pp. 5-16; Reply, pp. 3-20;
EX1003, ¶¶ 66-67, 76-82; EX1025, ¶¶ 7-9, 13-16

Armitage

Claim 1 Preamble (Limitation 1(a))

A system for detecting operational anomalies on a train consist or railcar comprising:

- Armitage teaches a “railway car monitoring system 100,” which includes a “railway car 110” and “sensor nodes 121-124” with a wireless transceiver for communication with “control node 130.”

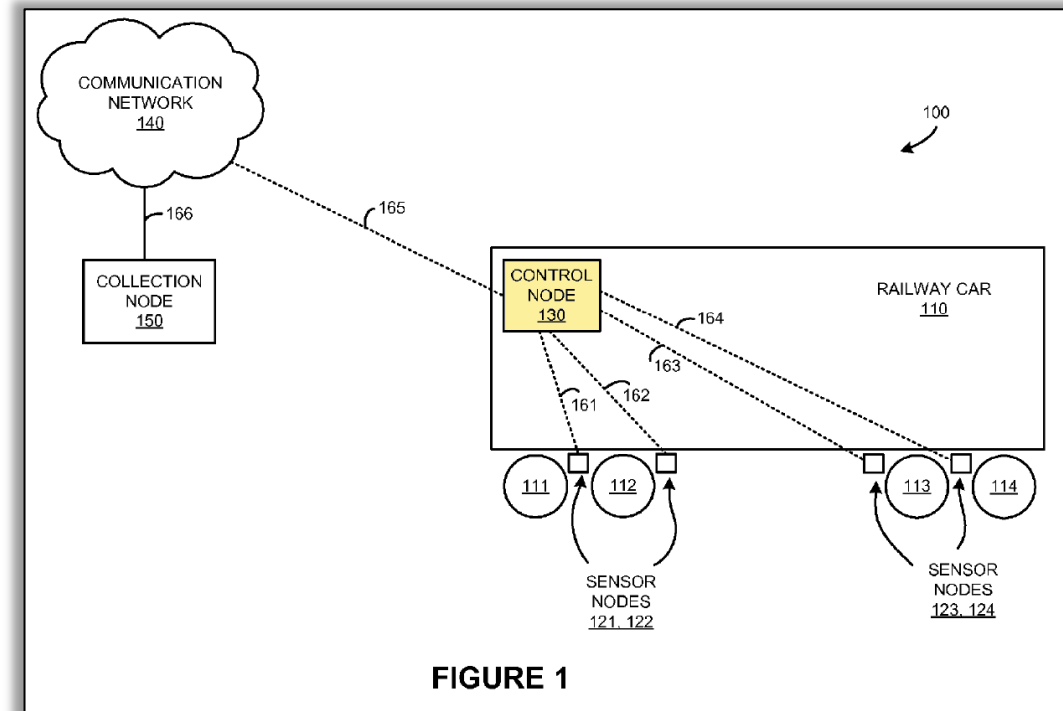


Petition, p. 22; EX1003, ¶¶ 69-71; EX1006, Figs. 1, 3, 5, ¶¶ [0012], [0014], [0020]

Armitage

Limitation 1(b) (a) one or more communication management units mounted on one or more railcars;

- Armitage teaches one or more “control nodes 130” (i.e., a communication management unit) coupled to one or more railway cars.
- Armitage’s “control nodes” communicate with the “sensor nodes” and “collection network” over wireless network.



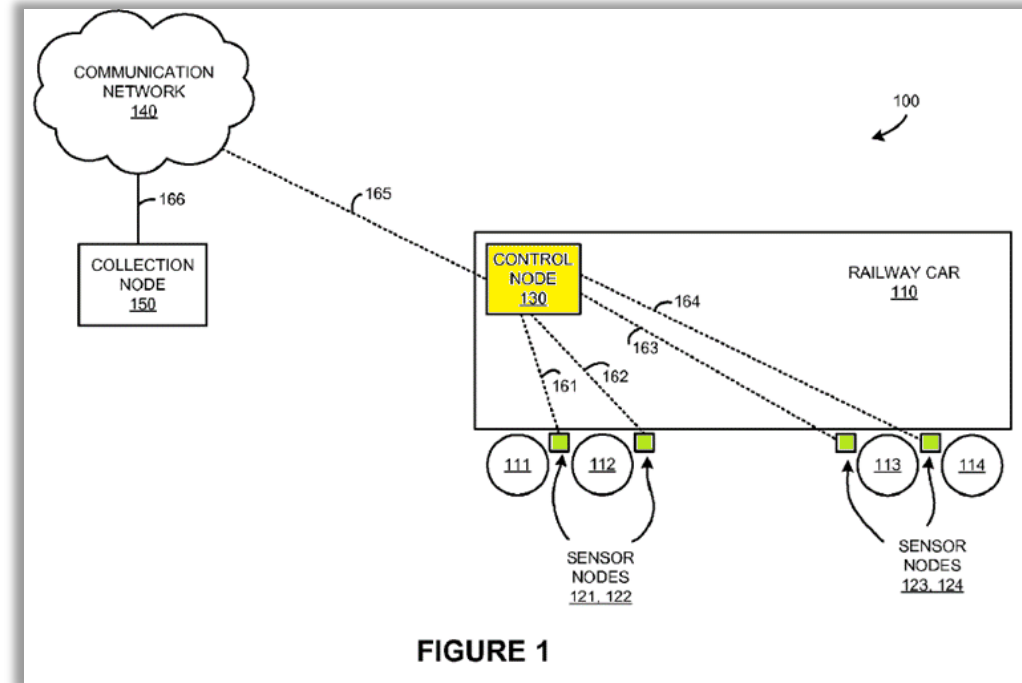
Petition, p. 23; EX1003, ¶ 72; EX1006, Figs. 1, 3, 5, [0004], [0012], [0014], [0017], [0020], [0026], [0036], [0038]

Armitage

Limitation 1(c)

(b) one or more sensors located on said one or more railcars configured to sense an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

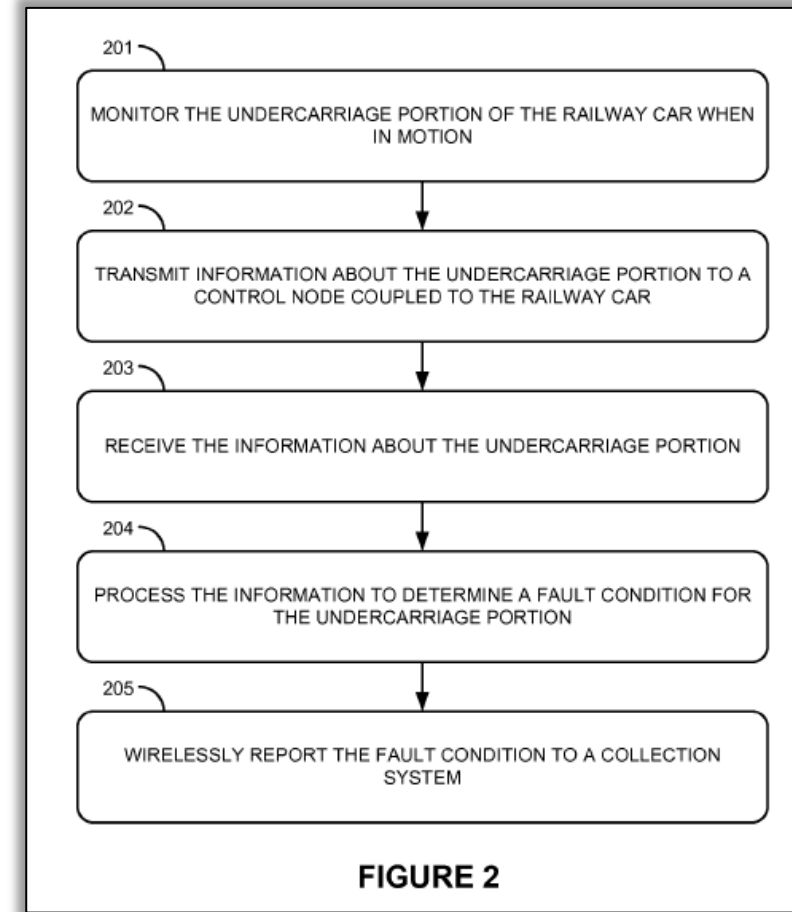
- Armitage teaches a plurality of “sensors nodes 121-124” mounted on railway cars, which contain a “sensor portion” that may comprise a “three-dimensional accelerometer,” that communicate with the control node (i.e., communication management unit”).



Petition, pp. 23-25; EX1003, ¶¶ 73-75; EX1006, Figs. 1, 3, 5, [0004], [0012], [0014], [0021], [0027], [0033], [0045], [0046], [0054], [0056]

Armitage

Limitation 1(e)	wherein said communication management units perform the functions of: (i) collecting data regarding said one or more railcar operational parameters;
Limitation 1(f)	(ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and
Limitation 1(g)	(iii) communicating a message to a remote receiver when said trend or event is detected.



Petition, pp. 30-34; EX1006, Fig. 1, [0004], [0012], [0016], [0019], [0020], [0028]-[0030], [0028]-[0040], [0042], [0045], [0090]; EX1003, ¶¶ 84-90

Armitage teaches the claimed “filter”

Limitation 1(d)

(c) one or more filters configured to filter at least a portion of the accelerations;

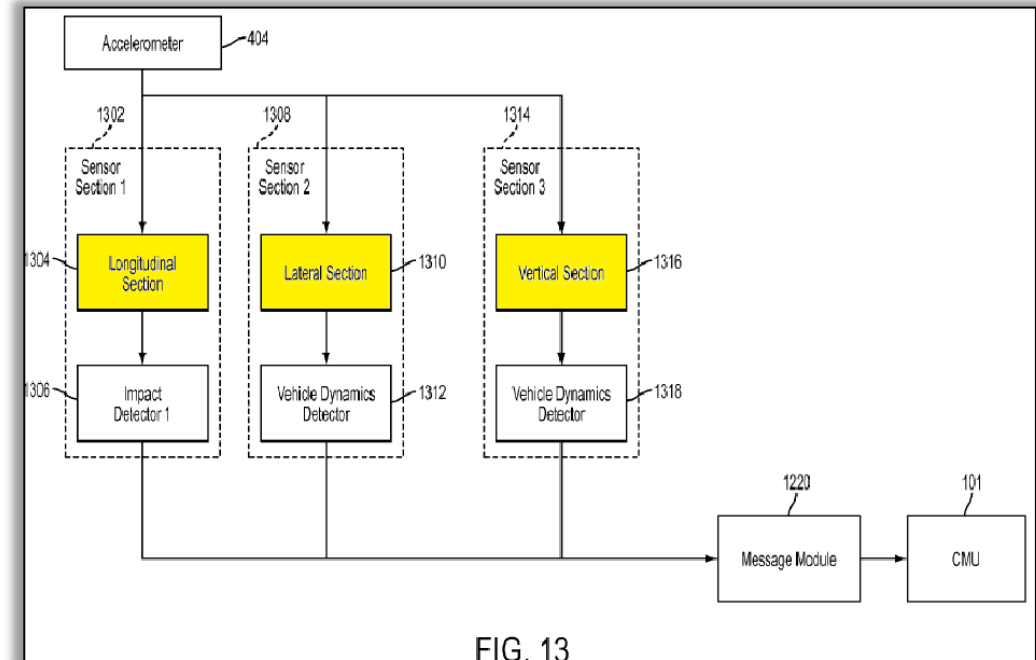
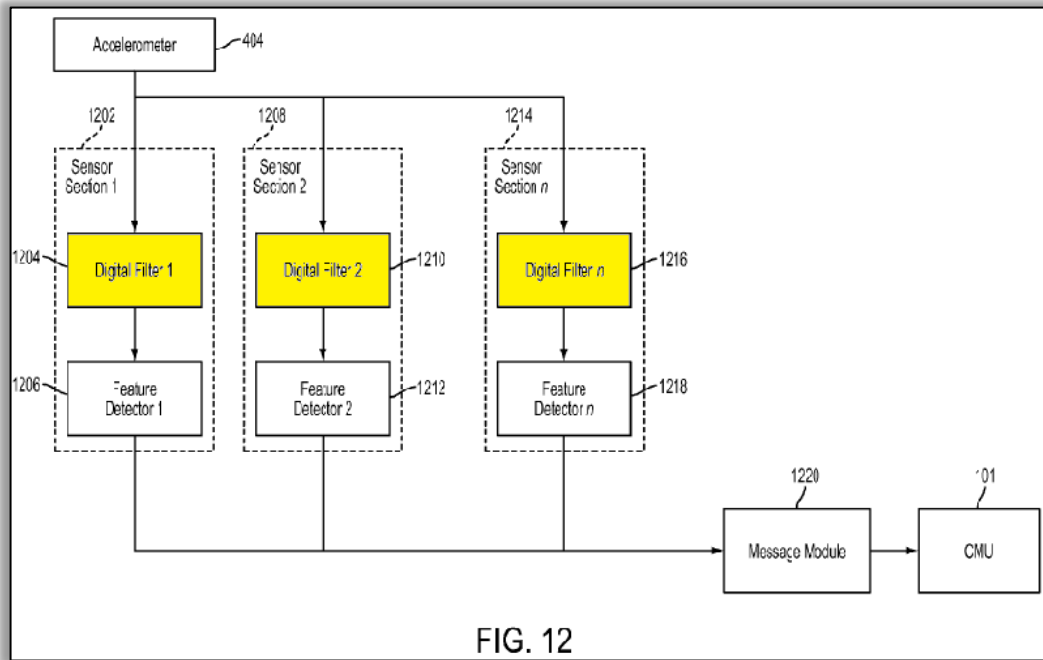
- The '915 Patent's “digital data filter” filters data by selecting certain data to be analyzed and ignoring other data collected by the sensors of the WSN.

With reference to FIGS. 4 and 12, a general implementation model of the analysis system of a WSN 104 is now described. As depicted in the preferred embodiment, the analyzed signal (what is not filtered out by the mechanical filter 410 or potting material), originates with accelerometer hardware 404 and is passed to one or more sensor sections 1202, 1208 or 1214. These sensor sections select the data to be analyzed using a digital data filter 1204, 1210 or 1216, and passes this data on to a feature detector 1206, 1212 or 1218. Data selection can be based on, for example, direction (e.g. vertical or longitudinal components), frequency (e.g. high-frequency clangs or low frequency rocking), overall magnitude (combination of 2 or 3 directional components), or other variations of the collected data.

Petition, pp. 25-27; Reply, pp. 3-4; EX1001 at 13:11-24;
EX1003, ¶¶ 78-79; EX1025, ¶¶ 4-6

Armitage teaches the claimed “filter”

- Figure 13 is “[o]ne possible implementation” of Figure 12:



EX1006, Figs. 12-13; Reply, p. 5; EX1025, ¶ 5

Armitage teaches the claimed “filter”

One possible implementation of the analysis system of FIG. 12 is shown in FIG. 13. Here, accelerometer 404 passes data on to three sensor sections. The first section 1302 selects data from the longitudinal direction down the length of the railcar 103 and uses Longitudinal Section 1304 to extract longitudinal impact data. Longitudinal impacts are detected in Impact Detector 1306 when the peak value of the longitudinal data exceeds a longitudinal impact threshold. The second section 1308 selects data from the lateral direction across the railcar 103 and uses Lateral Section 1310 to extract lateral oscillation data. Lateral oscillations are detected in Vehicle Dynamics Detector 1312 when the RMS value of the oscillations exceeds a lateral oscillation threshold. The third section 1314 selects data from the vertical direction and uses Vertical Section 1316 to extract vertical oscillation data. Vertical oscillations are detected in Vehicle Dynamics Detector 1318 when the RMS value of the oscillations exceeds a vertical oscillation threshold. Each of these sensor sections sends its messages on to message module 1220 which, in turn, passes these messages on to the CMU 101.

- The first section 1302 “***selects*** data from the longitudinal direction” (i.e., the x-axis) **using** “Longitudinal Section 1304 to ***extract*** longitudinal impact data” = **Filter to select accelerations along the x-axis and ignore accelerations along the y- and z-axes.**
- The second section 1308 “***selects*** data from the lateral direction” (i.e., the z-axis) **using** “Lateral Section 1310 to ***extract*** lateral oscillation data” = **Filter to select accelerations along the z-axis and ignore accelerations along the x- and y-axes.**
- The third section 1314 “***selects*** data from the vertical direction” (i.e., the y-axis) **using** “Vertical Section 1316 to ***extract*** vertical oscillation data” = **Filter to select accelerations along the y-axis and ignore accelerations along the x- and z-axes.**

EX1006 at 13:36-56; Petition, pp. 25-27;
Reply, pp. 3-6; EX1025, ¶¶ 4-6

Armitage teaches the claimed “filter”

[0045] In another embodiment, vibration is monitored as graph 400. The vibration could be monitored with a three-dimensional accelerometer, such as a solid state accelerometer device. The accelerations monitored by the 3-D accelerometer are interpreted as vibrations. In some examples, axial vibration is monitored along a single axis, such as a z-axis aligned with the axle of a particular wheel or wheel assembly, and vibrations in other axes are ignored, such as radial axes including an x-axis aligned with the horizontal and a y-axis aligned with the vertical with respect to the railway car or wheel. At high sampling rates of the accelerometer, the sampling only occurs for a portion of a wheel rotation, and radial acceleration or vibration (x-axis or y-axis) data could be ignored. Ignoring radial acceleration can allow for gravity and wheel balance effects to be minimized in the processing of vibration data for the wheel assemblies or wheels. Axial vibration data could still indicate wheel flat conditions, which are typically high impact, ‘loud’ events, vibrationally. By only sampling a portion of the wheel rotation a determination could be made on how much of the circumference of a wheel is damaged or flat based on the vibration characteristics. In an example wheel rotation, 60 milliseconds of vibration are sampled every two seconds and the vibrations are averaged (along with determining minimums and maximums) every sixty seconds and stored. Time series analysis could then be performed on the readings to determine the failure conditions.

- Paragraph 45 of Armitage describes the same filtering of acceleration data along the x-, y-, and z-axes
- Three-dimensional accelerometer
- “In some examples, **axial vibration is monitored** along a single axis, such as a z-axis aligned with the axle of a particular wheel or wheel assembly, and **vibrations in other axes are ignored**, such as radial axes including an x-axis aligned with the horizontal and a y-axis aligned with the vertical ...”
- Selecting axial vibration data (z-axis) and ignoring radial vibration data (x- and y-axis) can indicate wheel flat conditions

EX1006, ¶ [0045]; Petition, pp. 25-29; Reply, pp. 6-7;
EX1003, ¶¶ 66-67, 76-82; EX1025, ¶¶ 7-9

Armitage teaches the claimed “filter”

78. Filtering data was well-known in the art and a PHOSITA would have understood the Armitage system filters sensor data. A PHOSITA would have understood the meaning of filtering is excluding some portion of a data set, and it is desirable to include a filter in any data collection and processing system to get rid of unwanted data, and/or to identify and amplify particularly relevant data. In this field, filtering can be accomplished by choice of the sensor that has a specific range or resolution, through physical methods (i.e., mechanical filtering), electronic filtering, or digital filtering. Electronic filtering is a type of filtering

which utilizes electrical circuits to process signals (i.e., analog signals), and includes a number of different types of filters. Mechanical filtering is another type of signal processing filtering, that relies on physical parameters in order to remove unwanted high and low frequencies from a signal of interest. Digital filtering uses software to manipulate and filter data in order to decrease unwanted signals and increase signals from a particular area of interest.

79. All three types of filters (electronic, mechanical, digital) have been commonplace in the art for decades and would have been well-understood by a PHOSITA. See, e.g., EX1009 (“There are times when you should build the filter with analog hardware and times when it is appropriate to implement it with a controller or processor in firmware.”). In summary, in any data collection analysis, data is almost always filtered in some manner, and the system can utilize the various types of filters alone or in combination to achieve the most effective filtering of data to achieve more accurate and/or targeted data analysis for detection of fault conditions. A PHOSITA would understand that Armitage’s teachings of sampling and ignoring certain data points equates to filtering data in the ’915 Patent.

Filtering? Before or after?

EDN edn.com/filtering-before-or-after/

Bonnie Baker

February 20, 2003

There are times when you should build the filter with analog hardware and times when it is appropriate to implement it with a controller or processor in firmware. Generally, every circuit in which an analog signal converts to the digital domain should have an analog lowpass filter. This situation is true whether the ADC is a successive-approximation-register (SAR), delta-sigma, pipeline, dual-slope, or any other type of converter you may contrive. The placement of this type of filter in the circuit must always be on the analog side, in front of the converter.

Armitage teaches the claimed “filter”

- A PHOSITA would understand the “examples” of monitoring z-axis accelerations are merely “examples” for detecting wheel damage.
- A PHOSITA would understand Armitage’s system would also monitor accelerations on the x- and y-axes to detect other railcar conditions.

9. In addition to these examples, there are a number of reasons why a PHOSITA would want to monitor accelerations along each axis to determine certain problem conditions of a railcar. As one example, a PHOSITA would have understood that accelerations along the transverse axis extending along the width of the railcar can be used to monitor conditions including truck hunting, which is a repetitive movement truck back and forth across the line of the rails (*see, e.g.*, EX1005, ¶ [0054]), wheel flat conditions (EX1006, ¶ [0045]), and bearing defects, among others. As another example, a PHOSITA would have understood that accelerations along the vertical axis can be used to monitor conditions including track defects, which generate large and sudden forces in the wheels and bearings (*see, e.g.*, EX1005, ¶¶ [0054], [0066]), wheel derailments (*see, e.g.*, EX1005, ¶ [0061]), and bearing defects, among others. And a PHOSITA would have understood that accelerations along the longitudinal axis extending along the length of the railcar can be used to monitor conditions including truck hunting movements involving yaw displacements (*see, e.g.*, EX1005, ¶ [0062]), changes in velocity (including collisions), and bearing defects, among others.

EX1025, ¶ 9; Petition, pp. 25-27; Reply, pp. 6-7;
EX1003, ¶ 76; EX1025, ¶¶ 7-8

The claims are not limited to filtering accelerations only after they are sensed by an accelerometer

- Claim 1 requires:
 - “one or more sensors *configured to* measure accelerations of the railcar”
- AND
- “one or more filters configured to filter at least a portion of the accelerations”
- Nothing requires filtering accelerations before or after they are measured
 - “the accelerations” refers to “accelerations of the railcar”
 - claim language does not require filtering of “measuredd” accelerations

Reply, pp. 8-10; EX1025, ¶¶ 11-12;
EX1001 at claims 1, 26, 30, 36, 13:13-18

The claims are not limited to filtering accelerations only after they are sensed by an accelerometer

- Patent Owner's claim construction argument would exclude a preferred embodiment.
- Specification contemplates filtering both before and after data collection.
- There is no reasonable argument claim 26 is a draftsman's error.

26. The system of claim 1, wherein the one or more filters comprise one or more mechanical filters.

described. As depicted in the preferred embodiment, the analyzed signal (what is not filtered out by the mechanical filter 410 or potting material), originates with accelerometer hardware 404 and is passed to one or more sensor sections 1202, 1208 or 1214. These sensor sections select the data to

Patent Owner wants to rewrite the entire claim:
26. The system of claim 1, further comprising one or more mechanical filters.

Reply, pp. 8-10; EX1025, ¶¶ 11-12;
EX1001 at claims 1, 26, 30, 36, 13:13-18

Barone also teaches the claimed “filter”

- *Alternatively*, a PHOSITA would have been motivated to use the data filtering of Barone in Armitage’s system.
- Barone was introduced in Ground 1 to the extent Armitage does not explicitly teach “a filter” or “a filter” located in the “sensor node” (in contrast to the CMU/“control node”).
 - “A PHOSITA would understand it is general knowledge **filtering means excluding or amplifying certain ranges of data (or signals) within a data set**—and would require an actual filter to achieve said filtering. EX1003, ¶ 66. **To the extent Armitage does not explicitly disclose a filter, Barone shows filtering accelerations** with an electronic or digital filter was well-known in the art and conventionally used in the field at the time of the invention. EX1003, ¶ 66; EX1007, Fig. 8, ¶¶ [0114]-[0115], [0150], [0172]- [0185].” Petition, pp. 20-21; *see also id* at 27.
 - “**The filtering in Barone occurs in the sensor.** EX1003, ¶ 80; EX1006, ¶¶ [0114]-[0115], Fig. 8. A PHOSITA would have understood **filtering of data can take place anywhere in the system**—including in either the CMU or sensor. EX1003, ¶ 80. Further, a PHOSITA would understand various considerations impact where the filtering takes place in a data processing system. *Id.*” Petition, pp. 27-28.

Barone also teaches the claimed “filter”

- No dispute Barone teaches filtering data generally or electronically.

[0114] As seen in FIG. 8, the output of the accelerometer 171, the microphone 175, and the temperature sensor 175 (as well as the output of any other analog sensors, such as geophones, accelerometers, acoustic sensors, ultrasonic sensors, electric field sensors, magnetic field sensors, light intensity sensors, light selective frequency sensors, humidity, angular rate sensors, Global Positioning System (GPS), mechanical shock, pressure, or fluid or gas flow rate sensors) are transmitted to signal conditioning 178, where the analog signals are amplified and/or filtered as appropriate, and then routed to fast analog to digital (A/D) converters 183.

[0176] The signal in the preferred embodiment is split into two signals, each of which is sent through signal conditioning 178. One of these signals is conditioned as set out above for the microphone output except that it is sent through a high-pass filter that permits only frequencies of 200 or 300 Hz or above to pass, which transmits the accelerations of the axle that preferably have the resonance frequencies of the truck, which are usually above about 300 Hz to about 900 Hz. A band pass filter may also be used instead of the high-pass filter, but preferably the upper limit of passed frequencies in the band-pass filter is 2 kHz or higher, the upper limit of the accelerometer detection being at 2.5 kHz max, and the filter should pass at least one resonant frequency of the truck. This filtered output signal is then transmitted to an amplifier and amplified with a gain of about 11. The amplified signal is sent to a half wave rectifier and load with a time constant of about 0.68 ms, yielding a rectified waveform signal. The rectified signal is sent through a low pass filter or band pass filter that filters out frequencies substantially above the highest frequencies of interest in the bearing degradation analysis, preferably, e.g., 290 or 300 Hz, yielding a signal that is composed of any periodic peaks in the accelerometer data that repeat below that frequency.

Barone also teaches the claimed “filter”

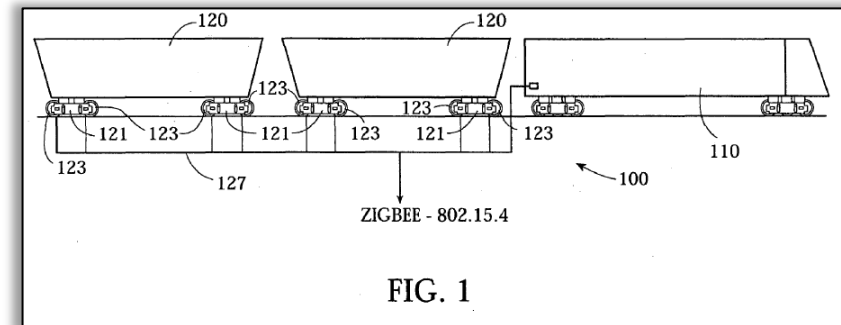
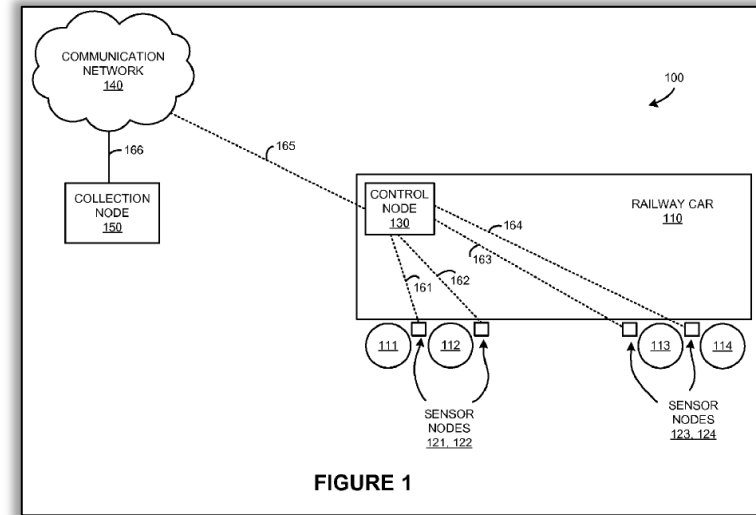
- [The '915 Patent](#) teaches filtering can be based on direction and frequency.
- [Armitage](#) teaches data filtering based on direction.
- [Barone](#) teaches data filtering based on frequency.

With reference to FIGS. 4 and 12, a general implementation model of the analysis system of a WSN 104 is now described. As depicted in the preferred embodiment, the analyzed signal (what is not filtered out by the mechanical filter 410 or potting material), originates with accelerometer hardware 404 and is passed to one or more sensor sections 1202, 1208 or 1214. These sensor sections select the data to be analyzed using a digital data filter 1204, 1210 or 1216, and passes this data on to a feature detector 1206, 1212 or 1218. Data selection can be based on, for example, direction (e.g. vertical or longitudinal components), frequency (e.g. high-frequency clangs or low frequency rocking), overall magnitude (combination of 2 or 3 directional components), or other variations of the collected data.

Reply, pp. 19-20; Petition, pp. 25-29; EX1006, ¶ [0045]; EX1007, ¶¶ [0172]-[0185], [0221]-[0222]; EX1003, ¶¶ 76, 80-81; EX1025, ¶¶ 26-27; EX1001 at 13:11-24

A PHOSITA would have been motivated to use Barone's filtering in Armitage's System

- Both Armitage and Barone teach systems utilizing sensors, CMUs, and wireless networks to determine and wireless report anomalous conditions on a railcar(s) in real-time and avoid false or inaccurate data processing.
- Armitage and Barone both filter acceleration data to accurately detect railcar conditions and defects, i.e., to remove unwanted data and/or amplify particularly relevant data.



EX1006, Fig. 1; EX1007, Fig. 1; Petition, pp. 27-29;
Reply, pp. 10-14; EX1003, ¶ 82; EX1025, ¶¶ 6-9

A PHOSITA would have been motivated to use Barone's filtering in Armitage's System

- The combination would predictably result in filtering of acceleration data in two ways: (1) by selecting accelerations along a particular axis or axes for analysis and ignoring the other(s) (**Armitage**); *and* (2) removing unwanted outlier data and noise and amplifying relevant data based on vibration frequency (**Barone**).
 - **Armitage** recognizes noise affects sensor signals. EX1006, ¶¶ [0029].
 - **Barone** notes the advantage filtering and processing data is to “enhance the quality of data” EX1007, ¶ [0175].
 - **Winfree** explains “[t]he structure is designed and used as a filter to selectively transmit, attenuate, or amplify various frequencies of incident elastic waves that would otherwise propagate from the environment and into the sensor.” EX1008 at 2:25-29.
 - **The '915 Patent** also recognizes the advantage of filtering based on frequency to “decrease noise from unwanted acceleration frequencies and increase signals from acceleration frequencies of interest.” EX1001 at 5:40-42.

Petition, pp. 20-21; Reply, pp. 10-11;
EX1003, ¶¶ 66-67; EX1025, ¶ 13

A PHOSITA would have been motivated to use Barone's filtering in Armitage's System

- Adding the frequency filtering of Barone to Armitage's system would not frustrate Armitage's purpose.
- A PHOSITA would have understood:
 - a single data outlier from an enormous population of data would not indicate a failure condition and would rather result in repeated false failure conditions and skewed data analysis.
 - collection, transmission, analysis, and storage of every single data point collected by sensors would not be practical.
 - collecting, transmitting, analyzing, and storing that much data would require higher speed communication links, a higher processing power control node, and a more powerful energy source, thereby increasing costs.

[0030] In some examples of analyzing the sensor information, a moving average and trend analysis is employed on the entire population of the undercarriage elements, such as those monitored by sensor nodes 121-124. Statistically significant deviations are derived from a series of sensor data captured over time for one or several members of the population of sensors. Each of sensor nodes 121-124 typically measure similar conditions for the undercarriage elements even though the conditions themselves may change or trend together. Deviations from these similar conditions are monitored. When one or more of the sensor nodes begin to deviate from the others in the population, then a failure condition could be determined. In this example, the deviations are not deviations of data of a single data reading or a single undercarriage element, but instead deviations from a time series of data readings for all undercarriage elements of railway car 110.

Reply, pp. 12-13; EX1025, ¶¶ 14-15; EX1006, ¶ [0030]

Independent Claims 30 and 36

Patent Owner presents no additional arguments in rebuttal to Petitioner's prima facie case of obviousness of independent claims 30 and 36 over Armitage in view of Barone.

30. A method for detecting operational anomalies on a train consist or railcar comprising the steps of:
sensing, by one or more sensors located on one or more railcars, one or more operational parameters of the one or more railcars, wherein the one or more operational parameters comprise one or more accelerations of the one or more railcars;
filtering, by one or more filters, at least a portion of the accelerations; and
by one or more communication management units associated with the one or more railcars:
collecting data regarding said one or more railcar operational parameters;
analyzing said collected data for trends or events indicative of an anomalous operational condition; and
communicating a message to a remote receiver when said trend or event is detected.

36. A system for detecting operational anomalies on a railcar that is part of a train consist comprising:

(a) at least one communication management unit (CMU) mounted on the a railcar in said train consist;

(b) at least two sensors located on the said railcar for configured to sense operational parameters of the railcar, said sensors being in communication with said communication management unit, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

(c) one or more filters configured to filter at least a portion of the accelerations,

wherein said communication management unit performs the following functions:

- (i) receiving data from said sensors;
- (ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and
- (iii) communicating a message to a remote receiver when an anomaly is detected.

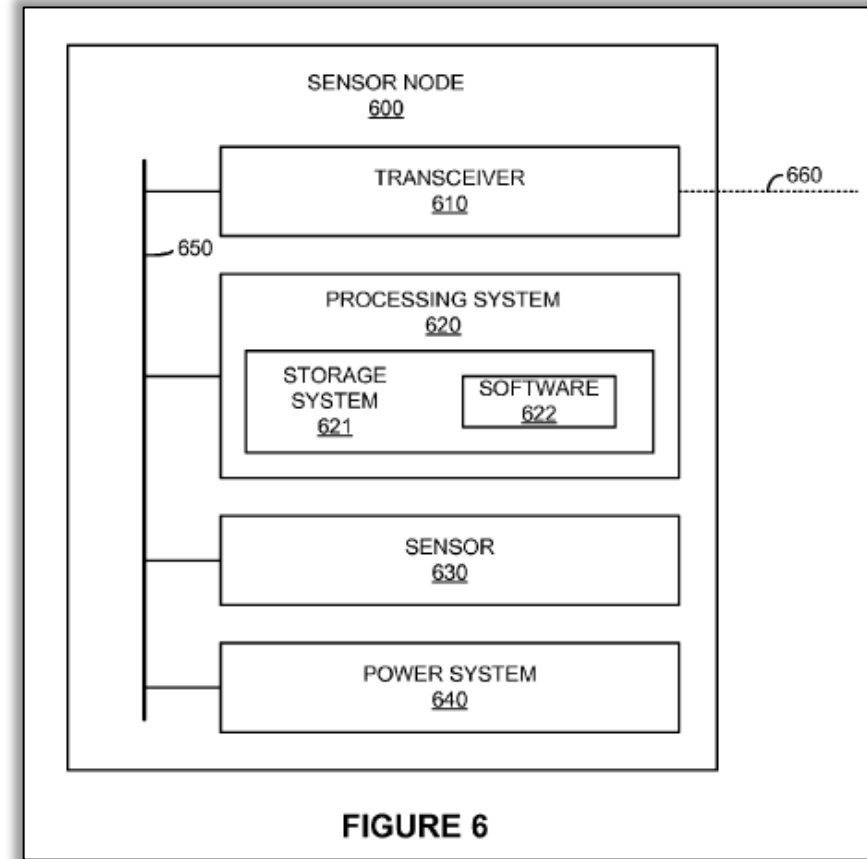
EX1001 at Claims 30, 36; Reply, pp. 28-29

Dependent Claims 25 and 28

- **Claim 25:** The system of claim 1, further comprising one or more wireless sensor nodes in communication with at least one of the communication management units, wherein one or more of the wireless sensor nodes comprises a microprocessor configured to execute firmware to control operation of the one or more of the wireless sensor nodes, wherein the firmware comprises **one or more software filters** configured to isolate one or more types of accelerations.
- **Claim 28:** The system of claim 1, wherein the one or more filters comprise one or more **digital filters**.
- The '915 Patent explains, and the parties agree, the software filter is a type of digital filter. Response, p. 25; Reply, p. 14.

Dependent Claims 25 and 28

- “Software 622 may include an operating system, logs, utilities, drivers, networking software, and other software typically loaded onto a computer system. **Software 622 could contain** an application program, **firmware**, or some other form of computer-readable processing instructions. When executed by processing system 620, **software 622 directs processing system 620 to operate as described herein**, such as monitor sensor 630, process the sensor information, and transfer sensor information or data.” EX1006, ¶ 55.
- A PHOSITA would understand data filtering in Armitage can occur in the sensor node.



EX1006, Fig. 6

Petition, pp. 26-28, 36-37; EX1003, ¶¶ 77-81

Dependent Claims 25 and 28

78. Filtering data was well-known in the art and a PHOSITA would have understood the Armitage system filters sensor data. A PHOSITA would have understood the meaning of filtering is excluding some portion of a data set, and it is desirable to include a filter in any data collection and processing system to get rid of unwanted data, and/or to identify and amplify particularly relevant data. In this field, filtering can be accomplished by choice of the sensor that has a specific range or resolution, through physical methods (i.e., mechanical filtering), electronic filtering, or digital filtering. Electronic filtering is a type of filtering which utilizes electrical circuits to process signals (i.e., analog signals), and includes a number of different types of filters. Mechanical filtering is another type of signal processing filtering, that relies on physical parameters in order to remove unwanted high and low frequencies from a signal of interest. Digital filtering uses software to manipulate and filter data in order to decrease unwanted signals and increase signals from a particular area of interest.

108. It is my opinion that a PHOSITA would understand firmware is often considered to be more closely related to the hardware (or physical components) of a system (i.e., making a measurement or detecting a switch position), while software is the layer of programming evaluating rules and making complex decisions. One type of filtering firmware can execute is identifying and isolating certain types of data—in this case, accelerations data. In contrast, software is described as programing that acts on the data; in other words, software performs post data collection algorithms—which is different from the functions of firmware. Therefore, a PHOSITA would understand that firmware and software have different functions, and that a software filter would be required in combination with the firmware in order to execute the filtering of the accelerations data. Even further, a PHOSITA would understand a function of filtering data by a software filter can be isolating or excluding certain types of accelerations data - based on programming that would be present in the software filter.

EX1003, ¶¶ 78, 108; Petition, pp. 26-27, 37-38

Dependent Claims 25 and 28

- Barone not limited to analog accelerometers.

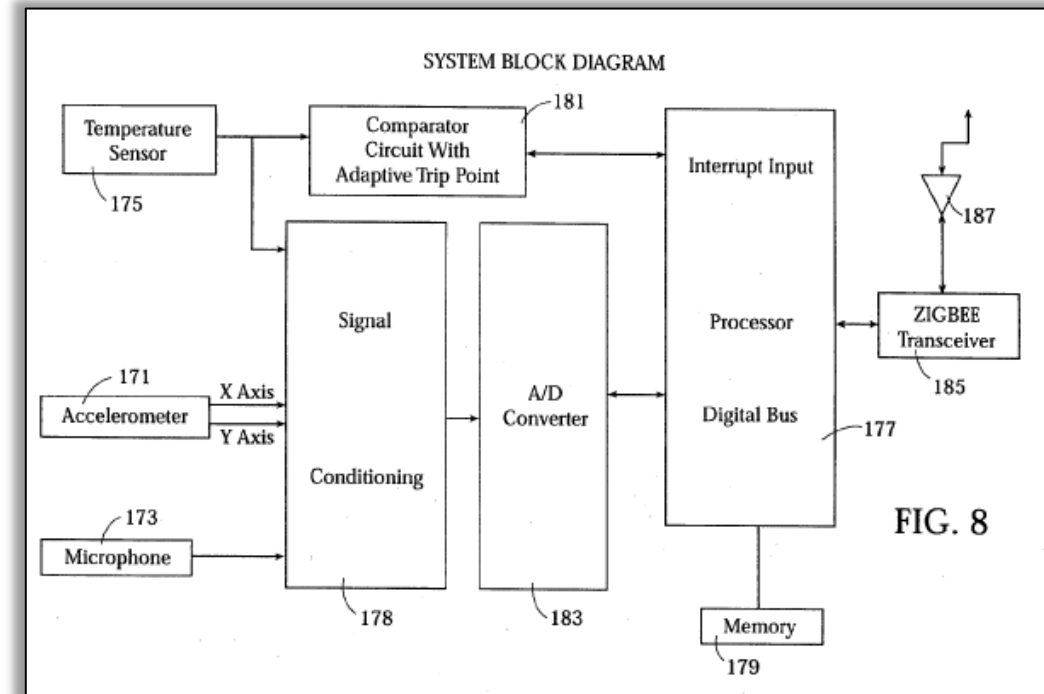
[0175] The output of the accelerometers is preferably analog signals, and these are processed to enhance the quality of data derived. To take advantage of the resonance frequencies of the truck as being particularly meaningful in terms of output of the accelerometers, the outputs of the accelerometers (both x (or axial) and y (or radial) axes) are passed through a preprocessing circuit, i.e., signal conditioner 178 of FIG. 8, before the accelerometer outputs are analyzed by the microprocessor of the node.

- A PHOSITA would understand high, low, and band pass filters can filter digital data and use software to execute pass filtering on digital data.

[0176] The signal in the preferred embodiment is split into two signals, each of which is sent through signal conditioning 178. One of these signals is conditioned as set out above for the microphone output except that it is sent through a high-pass filter that permits only frequencies of 200 or 300 Hz or above to pass, which transmits the accelerations of the axle that preferably have the resonance frequencies of the truck, which are usually above about 300 Hz to about 900 Hz. A band pass filter may also be used instead of the high-pass filter, but preferably the upper limit of passed frequencies in the band-pass filter is 2 kHz or higher, the upper limit of the accelerometer detection being at 2.5 kHz max, and the filter should pass at least one resonant frequency of the truck. This filtered output signal is then transmitted to an amplifier and amplified with a gain of about 11. The amplified signal is sent to a half wave rectifier and load with a time constant of about 0.68 ms, yielding a rectified waveform signal. The rectified signal is sent through a low pass filter or band pass filter that filters out frequencies substantially above the highest frequencies of interest in the bearing degradation analysis, preferably, e.g., 290 or 300 Hz, yielding a signal that is composed of any periodic peaks in the accelerometer data that repeat below that frequency.

Dependent Claims 25 and 28

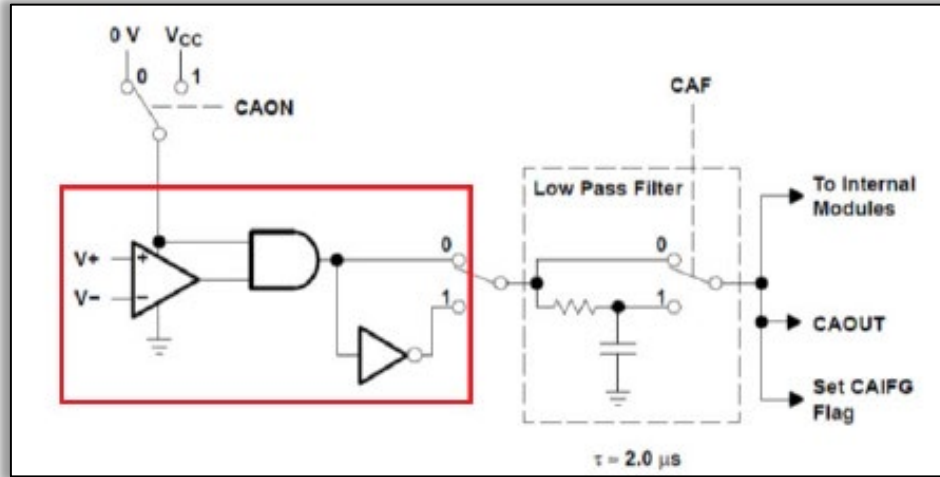
- “The circuit of the node 125 also includes a low-power microcontroller 177 such as the MSP430F1611 or MSP430FG4618 sold by Texas Instruments, programmed with algorithms to determine the health of bearings through vibration and acoustic trending and temperature monitoring received from the sensor array via operational amplifiers and/or signal conditioners 178, and comparator 181 and/or analog/digital converter 183.”
EX1007, ¶ 116.



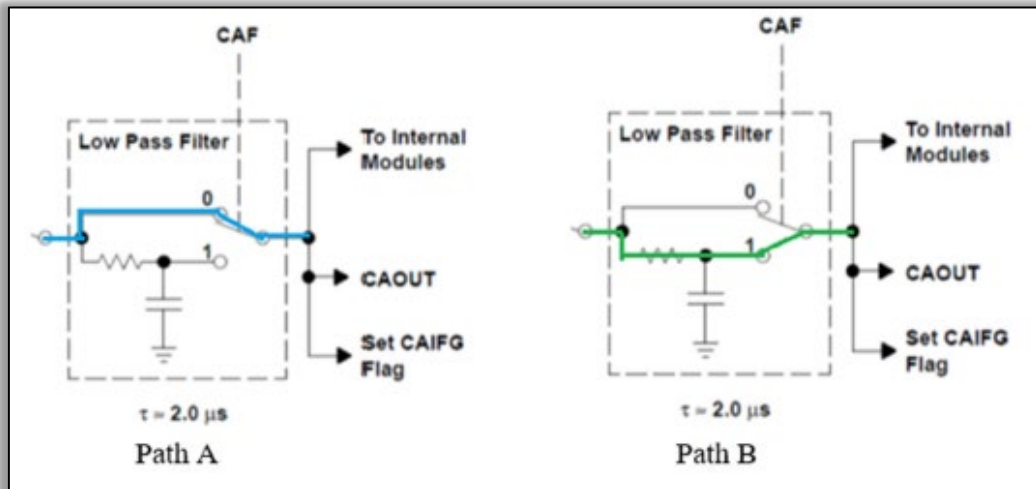
EX1007, Fig. 8

Reply, pp. 15-19; EX1025, ¶¶ 19-25, 33-34

Dependent Claims 25 and 28



1. The incoming signal is passed through a series of digital logic gates and is presented to the Low-Pass Filter as a stream of digital data. EX1025, ¶ 22.
2. The digital data stream can take two potential paths through the Low-Pass Filter—Path A (marked in blue) and Path B (marked in green).
3. Software running on the microcontroller determines which path to take (“0” = Path A; “1” = Path B).
4. On Path A, the digital data is not filtered; On Path B, the digital data is filtered.



Reply, pp. 15-18; EX1026, Fig. 8 (annotated); EX1025, ¶¶ 19-25

Dependent Claims 25 and 28

[0221] Detecting these 16 frequency data values requires 32 bytes of data, i.e., two bytes each. The microprocessor of the preferred embodiment, the Texas Instruments

MSP430FG4618 has 8 kilobytes of RAM and 116 K of flash memory, which can accommodate more frequencies around the calculated defect frequencies screened for, to allow for any slight variation in the accuracy of the detection of the rate of rotation of the wheel. Accordingly, the discrete Fourier transform is further used to derive data values corresponding to the presence in the data samples of twenty (20) lines of frequencies in steps of 0.5 to 1 Hz above and below the above-defined defect frequencies and their harmonic overtones, i.e., ± 0.5 or 1 Hz to 10 to 20 Hz of the identified exemplary frequencies. It may be noted that the range of frequencies is preferably enough to allow analysis of the defect frequency plus and minus the wheel rotation frequency. The size of the incremental difference of frequency varies with the rate of rotation of the wheel because it is expressed as a ratio of wheel rpm, as are all other frequencies of interest. At some rate of wheel rotation, however, the increments are desirably in the 0.5 to 1 Hz range. If the wheel turns faster, the increment will become larger in real terms, although its ratio to the wheel rpm will remain constant.

- A PHOSITA would understand this to be a type of bandpass filter based on a range of frequencies determined by 16 defined defect frequencies plus a certain range of frequencies *above and below* the defined defect frequencies.

[0222] The discrete Fourier transform is performed according to any numerical computing method therefor known in the art. In the preferred embodiment, the microcontroller performs a software implemented algorithm for each of the above 16 defect frequencies, and for each of the ten frequencies above and below each of the defect frequencies. For each frequency kk , representing a number that is 10 times the ratio to wheel rpm, being detected, the following iteration is performed:

EX1007, ¶¶ [0221]-[0222];
Reply, pp. 19-20; EX1025, ¶ 26

Dependent Claims 22, 24, 27, 29, 30 and 37

Patent Owner presents no additional arguments in rebuttal to Petitioner's prima facie case of obviousness of dependent claims 22, 24, 27, 29 and 37 over Armitage in view of Barone.

Ground 2: Obviousness in view of Armitage, Barone, and LeFebvre

Ground 2: Obviousness of Claim 21 in view of Armitage, Barone, and LeFebvre

Patent Owner presents no additional arguments in rebuttal to Petitioner's prima facie case of obviousness of claim 21 (CMU includes at least one sensor) over Armitage in view of Barone and LeFebvre.

Response, p. 29

Ground 3: Obviousness in view of Armitage, Barone, and Winfree

Ground 3: Obviousness in view of Armitage, Barone, and Winfree

Patent Owner presents no additional arguments in rebuttal to Petitioner's prima facie case of obviousness of claims 23 and 26 over Armitage in view of Barone and Winfree.

23. The system of claim 1, wherein the one or more filters comprise one or more **mechanical filters** that include a resilient material configured to filter out undesirable accelerations from the accelerations, wherein the one or more **mechanical filters** are disposed to remove the undesirable accelerations before the undesirable accelerations reach the one or more sensors that are configured to measure accelerations.

26. The system of claim 1, wherein the one or more filters comprise one or more **mechanical filters**.

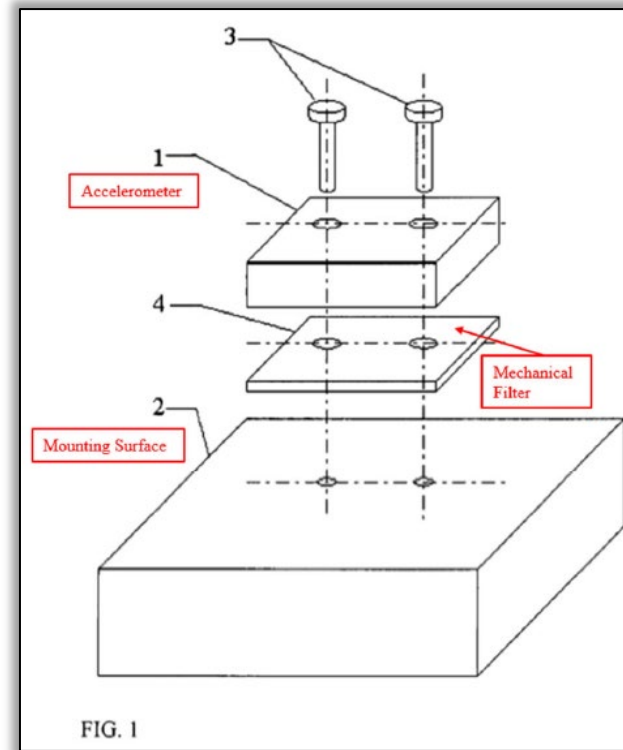


FIG. 1

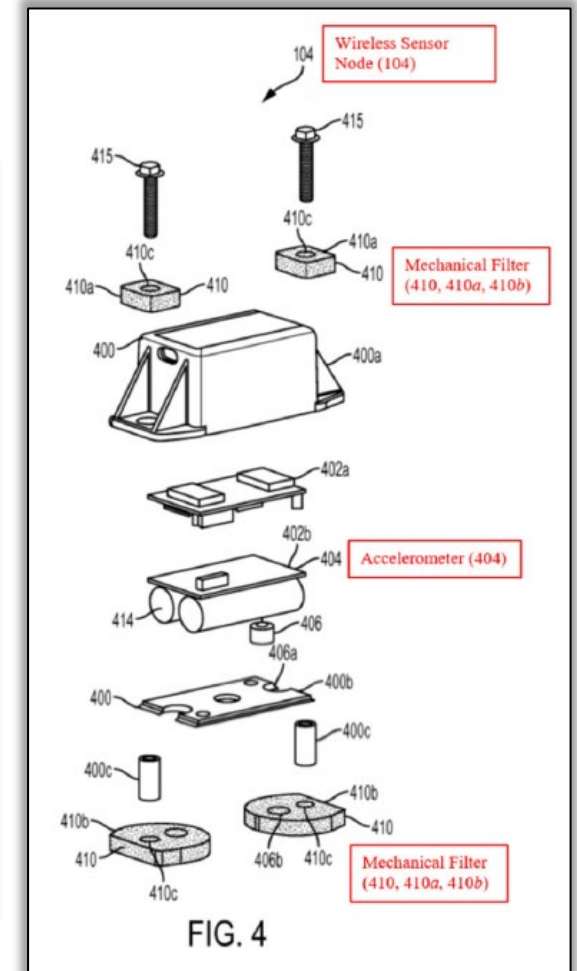


FIG. 4

Petition, pp. 46-49; EX1003, ¶¶ 139-144; EX1008, Fig. 1; EX1001, Fig. 4; Response, p. 30

Ground 4: Obviousness in view of LeFebvre and Barone

Independent Claims 1, 30 and 36

- Patent Owner does not dispute LeFebvre teaches every limitation of the independent claims except for the “filter” limitation.
- LeFebvre and Barone both teach ways to filter acceleration data from an accelerometer.

Petition, pp. 54-57; Response, pp. 30-35;
Reply, pp. 21-23; EX1003, ¶¶ 156-162; EX1025, ¶¶ 30-32

1. A system for detecting operational anomalies on a train consist or railcar comprising:
(a) one or more communication management units mounted on one or more railcars;
(b) one or more sensors located on said one or more railcars configured to sense an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and
(c) one or more filters configured to filter at least a portion of the accelerations,
wherein said communication management units perform the functions of:
(i) collecting data regarding said one or more railcar operational parameters;
(ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and
(iii) communicating a message to a remote receiver when said trend or event is detected.

30. A method for detecting operational anomalies on a train consist or railcar comprising the steps of:
sensing, by one or more sensors located on one or more railcars, one or more operational parameters of the one or more railcars, wherein the one or more operational parameters comprise one or more accelerations of the one or more railcars;
filtering, by one or more filters, at least a portion of the accelerations; and
by one or more communication management units associated with the one or more railcars: collecting data regarding said one or more railcar operational parameters;
analyzing said collected data for trends or events indicative of an anomalous operational condition; and
communicating a message to a remote receiver when said trend or event is detected.

36. A system for detecting operational anomalies on a railcar that is part of a train consist comprising:
(a) at least one communication management unit (CMU) mounted on the a railcar in said train consist;
(b) at least two sensors located on the said railcar for configured to sense operational parameters of the railcar, said sensors being in communication with said communication management unit, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and
(c) one or more filters configured to filter at least a portion of the accelerations,
wherein said communication management unit performs the following functions:
(i) receiving data from said sensors;
(ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and
(iii) communicating a message to a remote receiver when an anomaly is detected.

LeFebvre

Claim 1 Preamble (Limitation 1(a))

A system for detecting operational anomalies on a train consist or railcar comprising:

(19) **United States**

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LeFebvre et al. (43) Pub. Date: **Jul. 5, 2007**

(54) **RAILROAD TRAIN MONITORING SYSTEM**

Publication Classification

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(52) U.S. Cl. **246/169 R**

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(57) **ABSTRACT**

(73) Assignee: **AFS-Keystone, Inc.**, Granite City, IL (US)

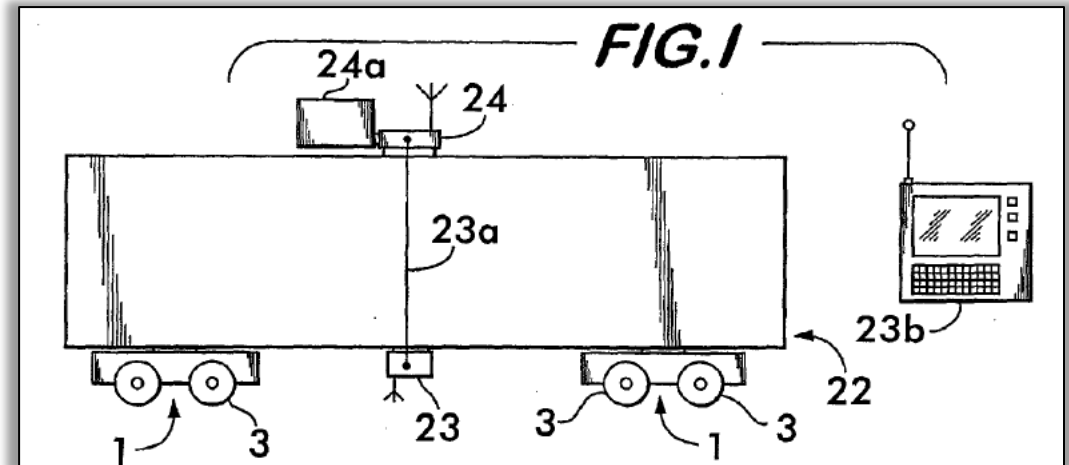
(21) Appl. No.: **11/615,309**

(22) Filed: **Dec. 22, 2006**

Related U.S. Application Data

(60) Provisional application No. 60/753,593, filed on Dec. 23, 2005.

Railcar monitoring utilizes instrumented, flexible pads supported within the truck pedestal jaws on the bearing adapters. The pads contain sensors for monitoring temperature, pressure, shifting loads, truck hunting and the like and have circuitry for processing information received from the sensors and for processing and reporting departures of performance variables to a remote source. The system cyclically activates polling each pad on a car and communicates signals of critical departures and car identity to a remote source.

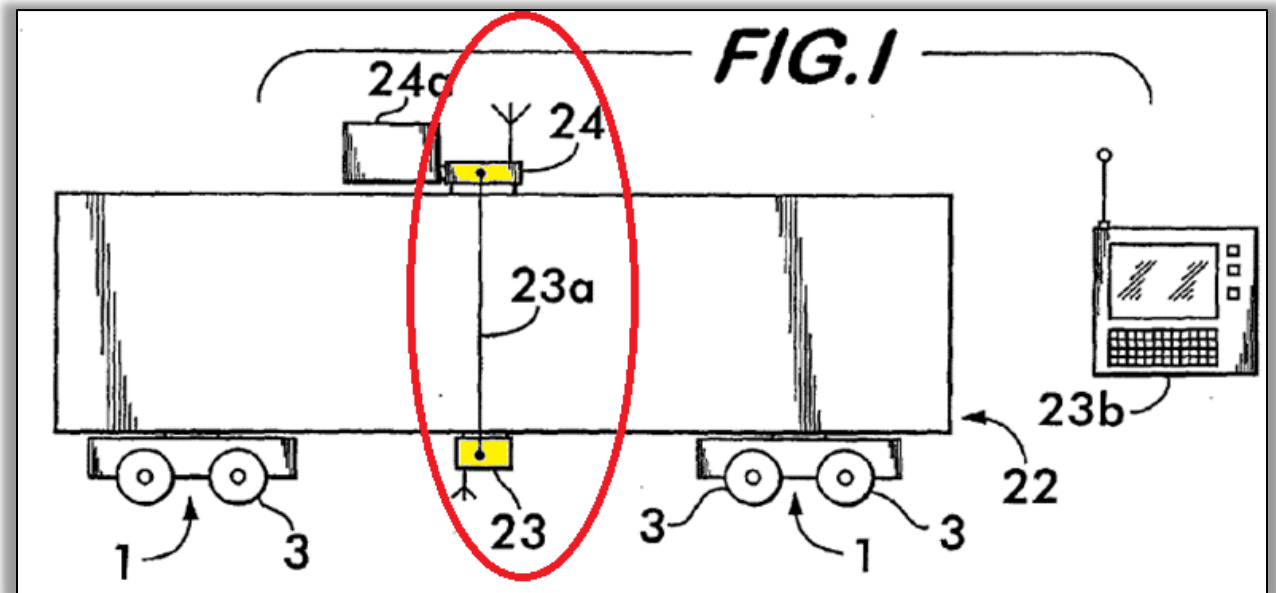


Petition, p. 51; EX1003, ¶¶ 147-149; EX1005, Abstract, Fig. 1, ¶¶ [0003], [0006]

LeFebvre

Limitation 1(b) (a) one or more communication management units mounted on one or more railcars;

- “Communications device 24” and “data control unit 23” and mounted on the railcar and may be combined into one device.



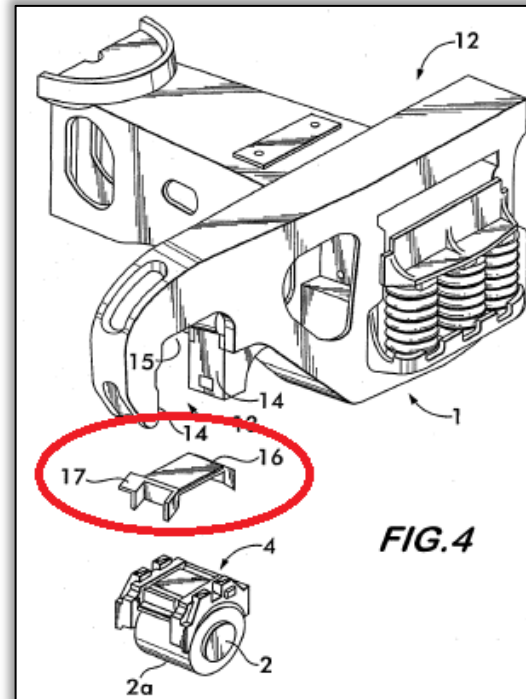
Petition, p. 52; EX1003, ¶¶ 150-151; EX1005, ¶¶ [0008], [0024]-[0026], [0068], Fig. 1

LeFebvre

Limitation 1(c)

(b) one or more sensors located on said one or more railcars configured to sense an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

- A plurality of “instrumented pads 16” are mounted on a railcar and comprise one or more sensors, including accelerometers
- The “instrumented pads 16” communicates wirelessly with the “communications device 24” and “date control unit 23”



28. A method of monitoring performance of wheeled, interconnected mobile units having bodies supported by wheels, wherein one of said mobile units is a controllable prime mover and the remainder of said units are interconnected to the said one of said units, said method comprising:

providing interfacing flexible, elastomeric pads between the wheels and the bodies of the wheeled mobile units, said pads having embedded sensors for measuring a parameter selected from the group consisting of temperature, displacement, velocity, **acceleration**, stress, strain pressure, force and combinations thereof; and

generating signals by said sensors representative of said parameters, separately processing and evaluating the signals received for each parameter, and identifying performance behavior derived from said signals considered to be sufficient to cause alarm and communicating to the prime mover messages identifying only the performance behavior sufficient to cause alarm.

LeFebvre

Limitation 1(e)	wherein said communication management units perform the functions of: (i) collecting data regarding said one or more railcar operational parameters;
Limitation 1(f)	(ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and
Limitation 1(g)	(iii) communicating a message to a remote receiver when said trend or event is detected.

- “Data control unit 23”, “[a]s an aggregator of information ... is programmed to compare information from al of the trucks on the railcar and draws inferences from them as to the status of the car, for example, the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment.” EX1005, ¶ 36; Petition, pp. 58-60.
- “The data control unit then performs the assessments described above for the inference engine to check if the freight car, its trucks or wheels or axles are behaving sufficiently poorly that a report to the central data handling location or owner or operator or locomotive is needed. If so, then the report can be sent. EX1005, ¶ 95; Petition, pp. 60-61.

Petition, pp. 30-34; EX1005, ¶¶ 24, 25, 36, 38, 52, 53, 56, 58-66, 95; EX1003, ¶¶ 173-177

LeFebvre teaches the claimed filtering

Limitation 1(d)

(c) one or more filters configured to filter at least a portion of the accelerations;

LeFebvre

[0053] However, the burden of transmitting all the data that might be sampled in performing such monitoring is extremely large and, for the most part, detailed data is not significant. Preferably, only the observations which imply some fault or misbehavior are recognized. To reduce the radio traffic to manageable proportions, the system is designed to process the raw sensor data, looking for signs of trouble and then send only essential indicative information. To this end, a distributed inference engine is used, sharing the essential functions between the microprocessors at the instrumented pads and at the data control unit 23. It is a purpose of this invention to reduce the radio traffic between pads and data control unit so part of the data analysis is done at the pads and only relevant information is transmitted to the data control unit from the pads for further analysis and recognition of faults.

EX1005, ¶ [0053]

'915 Patent

Another possible implementation of the analysis system is shown in FIG. 14. Here, accelerometer 404 passes data on to three sensor sections. The first section 1402 looks at data from the vertical direction and uses Vertical Derailment Filter 1404 to extract the characteristic frequencies of a derailment. Derailment events are detected in Derailment RMS Detector 1406 when the RMS value of the filtered data exceeds a derailment threshold. The second section 1408 also selects data from the vertical direction, but uses Vertical Wheel Damage Filter 1410 to extract the characteristic frequencies of wheel damage. Wheel damage is detected in

Wheel Damage RMS Detector 1412 when the RMS value of the filtered data exceeds a wheel damage threshold. The third section 1414 also selects data from the vertical direction and uses Vertical Impact Filter 1416 to extract vertical impact data. Vertical impacts are detected in Vertical Impact Peak Detector 1418 when the peak value of the filtered data exceeds a vertical impact threshold. Each of these sensor sections sends its messages on to message module 1220 which, in turn, passes these messages on to the CMU 101.

EX1001 at 13:57-14:9

A PHOSITA would have been motivated to use Barone's filtering in LeFebvre's System

- To the extent LeFebvre does not explicitly describe “*a* filter,” it would have been obvious to modify LeFebvre to include Barone's filters for the same reasons as explained for Ground 1/Armitage.
- Adding the filtering of Barone to LeFebvre's system would not frustrate LeFebvre's purpose for the same reasons as explained for Ground 1/Armitage. In fact, LeFebvre explains:

[0096] The rules for assessing freight car performance are designed to be tolerant of missing data, since it will be apparent from the above description of the system that either due to communications difficulties or to the rigors of the environment, components may fail to provide all the requested data.

EX1005, ¶ [0096]

Petition, pp. 54-55; Reply, pp. 21-23;
EX1003, ¶¶ 160-162; EX1025, ¶ 131

Independent Claims 30 and 36

Patent Owner presents no additional arguments in rebuttal to Petitioner's prima facie case of obviousness of independent claims 30 and 36 over LeFebvre in view of Barone.

30. A method for detecting operational anomalies on a train consist or railcar comprising the steps of:
sensing, by one or more sensors located on one or more railcars, one or more operational parameters of the one or more railcars, wherein the one or more operational parameters comprise one or more accelerations of the one or more railcars;
filtering, by one or more filters, at least a portion of the accelerations; and
by one or more communication management units associated with the one or more railcars:
collecting data regarding said one or more railcar operational parameters;
analyzing said collected data for trends or events indicative of an anomalous operational condition; and
communicating a message to a remote receiver when said trend or event is detected.

36. A system for detecting operational anomalies on a railcar that is part of a train consist comprising:

(a) at least one communication management unit (CMU) mounted on the a railcar in said train consist;

(b) at least two sensors located on the said railcar for configured to sense operational parameters of the railcar, said sensors being in communication with said communication management unit, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

(c) one or more filters configured to filter at least a portion of the accelerations,

wherein said communication management unit performs the following functions:

- (i) receiving data from said sensors;
- (ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and
- (iii) communicating a message to a remote receiver when an anomaly is detected.

Dependent Claims 25 and 28

78. Filtering data was well-known in the art and a PHOSITA would have understood the Armitage system filters sensor data. A PHOSITA would have understood the meaning of filtering is excluding some portion of a data set, and it is desirable to include a filter in any data collection and processing system to get rid of unwanted data, and/or to identify and amplify particularly relevant data. In this field, filtering can be accomplished by choice of the sensor that has a specific range or resolution, through physical methods (i.e., mechanical filtering), electronic filtering, or digital filtering. Electronic filtering is a type of filtering which utilizes electrical circuits to process signals (i.e., analog signals), and includes a number of different types of filters. Mechanical filtering is another type of signal processing filtering, that relies on physical parameters in order to remove unwanted high and low frequencies from a signal of interest. Digital filtering uses software to manipulate and filter data in order to decrease unwanted signals and increase signals from a particular area of interest.

179. In my opinion, a PHOSITA would understand firmware and software have different purposes and functions, but that both can execute the filtering of accelerations data. As discussed in Limitation 1(d), LeFebvre discloses filtering in the instrumented pad, which a PHOSITA would understand requires a microprocessor and firmware in order to execute. A PHOSITA would understand firmware is often considered to be more closely related to the hardware (or physical components) of a system (i.e., making a measurement or detecting a switch position), while software is the layer of programming evaluating rules and making complex decisions. One type of filtering firmware can execute is identifying and isolating certain types of data—in this case, accelerations data. In contrast, software is described as programing that acts on the data; in other words, software performs post data collection algorithms—which is different from the functions of firmware. A PHOSITA would understand a function of filtering data by a software filter can be isolating or excluding certain types of accelerations data (i.e., “essential indicative information”) - based on programming that would be present in the software filter. Therefore, a PHOSITA would understand that LeFebvre in combination with Barone discloses this limitation.

Dependent Claims 25 and 28

- Barone not limited to analog accelerometers.

[0175] The output of the accelerometers is preferably analog signals, and these are processed to enhance the quality of data derived. To take advantage of the resonance frequencies of the truck as being particularly meaningful in terms of output of the accelerometers, the outputs of the accelerometers (both x (or axial) and y (or radial) axes) are passed through a preprocessing circuit, i.e., signal conditioner 178 of FIG. 8, before the accelerometer outputs are analyzed by the microprocessor of the node.

- A PHOSITA would understand high, low, and band pass filters can filter digital data and use software to execute pass filtering on digital data.

[0176] The signal in the preferred embodiment is split into two signals, each of which is sent through signal conditioning 178. One of these signals is conditioned as set out above for the microphone output except that it is sent through a high-pass filter that permits only frequencies of 200 or 300 Hz or above to pass, which transmits the accelerations of the axle that preferably have the resonance frequencies of the truck, which are usually above about 300 Hz to about 900 Hz. A band pass filter may also be used instead of the high-pass filter, but preferably the upper limit of passed frequencies in the band-pass filter is 2 kHz or higher, the upper limit of the accelerometer detection being at 2.5 kHz max, and the filter should pass at least one resonant frequency of the truck. This filtered output signal is then transmitted to an amplifier and amplified with a gain of about 11. The amplified signal is sent to a half wave rectifier and load with a time constant of about 0.68 ms, yielding a rectified waveform signal. The rectified signal is sent through a low pass filter or band pass filter that filters out frequencies substantially above the highest frequencies of interest in the bearing degradation analysis, preferably, e.g., 290 or 300 Hz, yielding a signal that is composed of any periodic peaks in the accelerometer data that repeat below that frequency.

Dependent Claims 25 and 28

[0221] Detecting these 16 frequency data values requires 32 bytes of data, i.e., two bytes each. The microprocessor of the preferred embodiment, the Texas Instruments

MSP430FG4618 has 8 kilobytes of RAM and 116 K of flash memory, which can accommodate more frequencies around the calculated defect frequencies screened for, to allow for any slight variation in the accuracy of the detection of the rate of rotation of the wheel. Accordingly, the discrete Fourier transform is further used to derive data values corresponding to the presence in the data samples of twenty (20) lines of frequencies in steps of 0.5 to 1 Hz above and below the above-defined defect frequencies and their harmonic overtones, i.e., ± 0.5 or 1 Hz to 10 to 20 Hz of the identified exemplary frequencies. It may be noted that the range of frequencies is preferably enough to allow analysis of the defect frequency plus and minus the wheel rotation frequency. The size of the incremental difference of frequency varies with the rate of rotation of the wheel because it is expressed as a ratio of wheel rpm, as are all other frequencies of interest. At some rate of wheel rotation, however, the increments are desirably in the 0.5 to 1 Hz range. If the wheel turns faster, the increment will become larger in real terms, although its ratio to the wheel rpm will remain constant.

- A PHOSITA would understand this to be a type of bandpass filter based on a range of frequencies determined by 16 defined defect frequencies plus a certain range of frequencies ***above and below*** the defined defect frequencies.

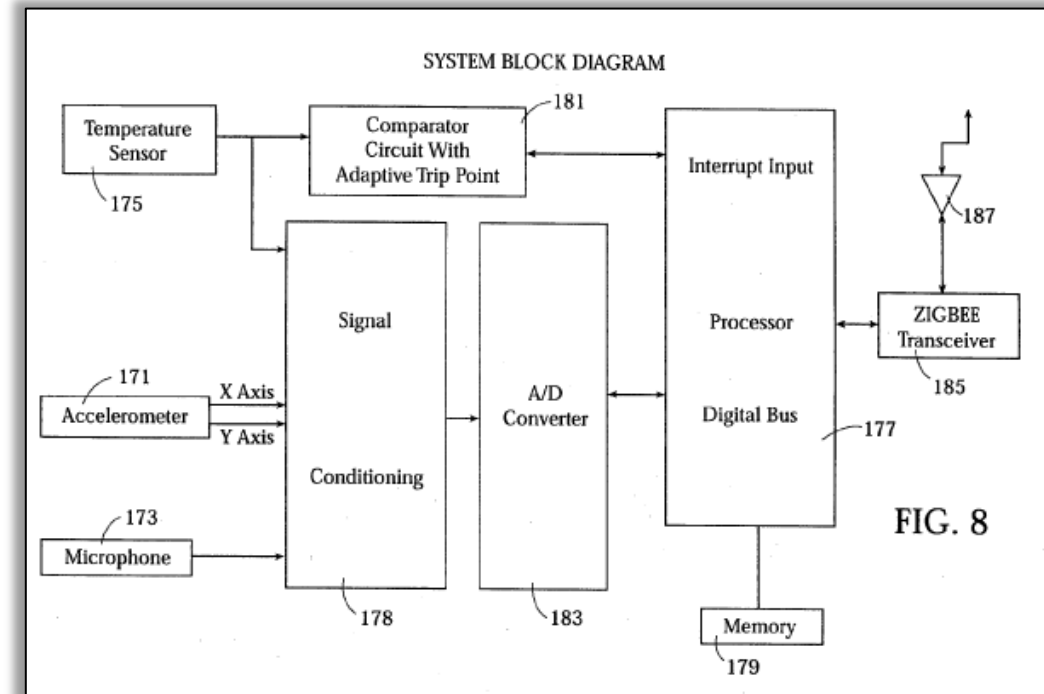
[0222] The discrete Fourier transform is performed according to any numerical computing method therefor known in the art. In the preferred embodiment, the microcontroller performs a software implemented algorithm for each of the above 16 defect frequencies, and for each of the ten frequencies above and below each of the defect frequencies. For each frequency kk , representing a number that is 10 times the ratio to wheel rpm, being detected, the following iteration is performed:

EX1007, ¶¶ [0221]-[0222]
Reply, pp. 19-20; EX1025, ¶ 26

Dependent Claims 25 and 28

- “The circuit of the node 125 also includes a low-power microcontroller 177 such as the MSP430F1611 or MSP430FG4618 sold by Texas Instruments, programmed with algorithms to determine the health of bearings through vibration and acoustic trending and temperature monitoring received from the sensor array via operational amplifiers and/or signal conditioners 178, and comparator 181 and/or analog/digital converter 183.”

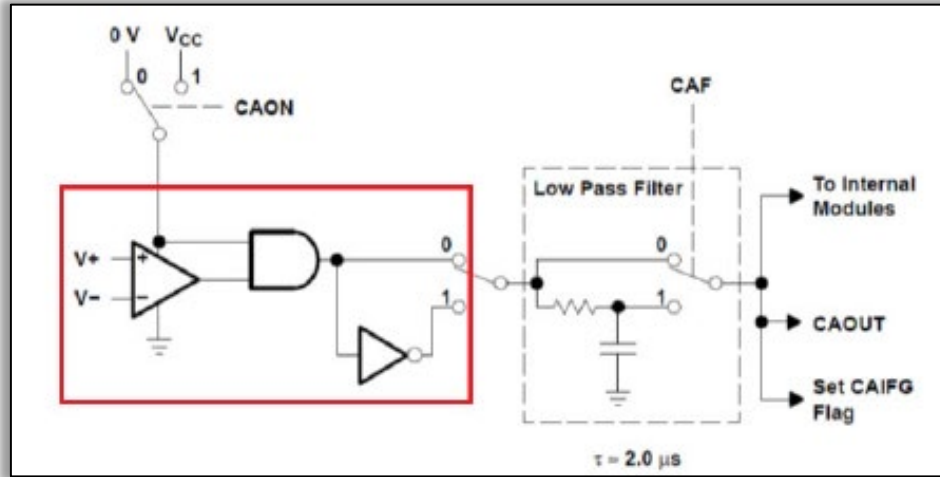
EX1007, ¶ 116.



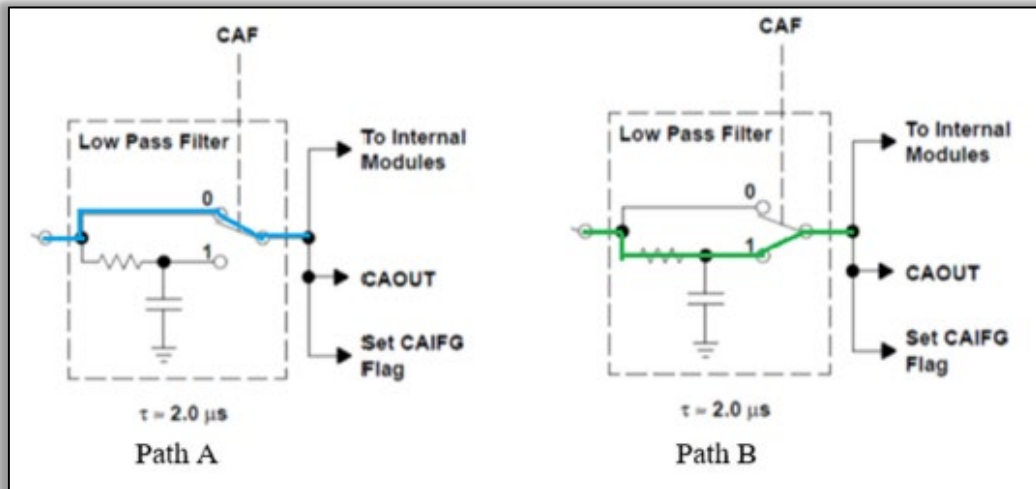
EX1007, Fig. 8

Reply, pp. 15-19; EX1025, ¶¶ 19-25, 33-34

Dependent Claims 25 and 28



1. The incoming signal is passed through a series of digital logic gates and is presented to the Low-Pass Filter as a stream of digital data. EX1025, ¶ 22.
2. The digital data stream can take two potential paths through the Low-Pass Filter—Path A (marked in blue) and Path B (marked in green).
3. Software running on the microcontroller determines which path to take (“0” = Path A; “1” = Path B).
4. On Path A, the digital data is not filtered; On Path B, the digital data is filtered.



Reply, pp. 15-18; EX1026, Fig. 8 (annotated); EX1025, ¶¶ 19-25

Ground 5: Obviousness over LeFebvre in view of Barone and Armitage

Ground 5: Obviousness over LeFebvre in view of Barone and Armitage

Patent Owner presents no additional arguments in rebuttal to Petitioner's prima facie case of obviousness of claims 24 and 37 over LeFebvre in view of Barone and Armitage.

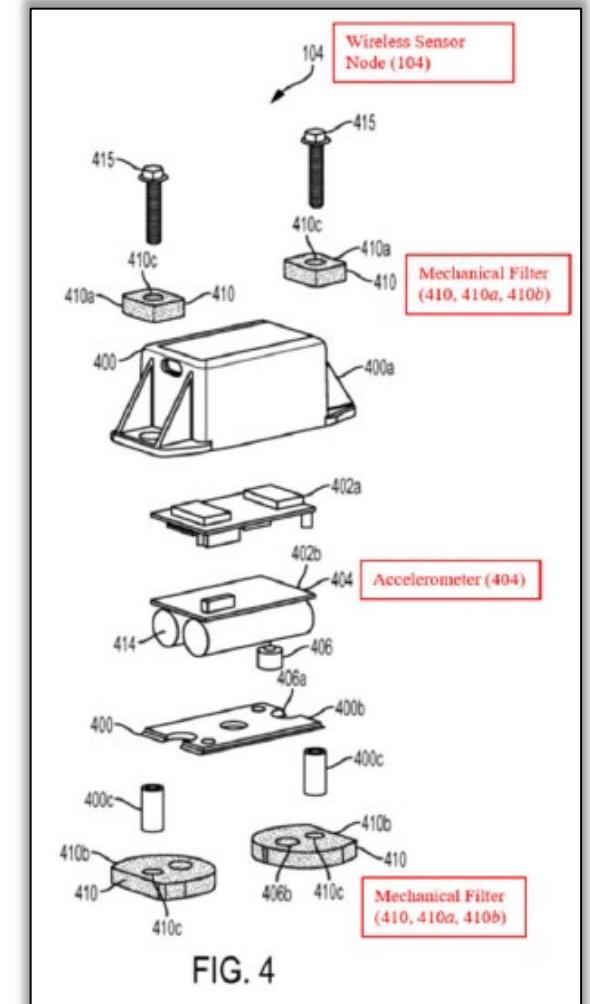
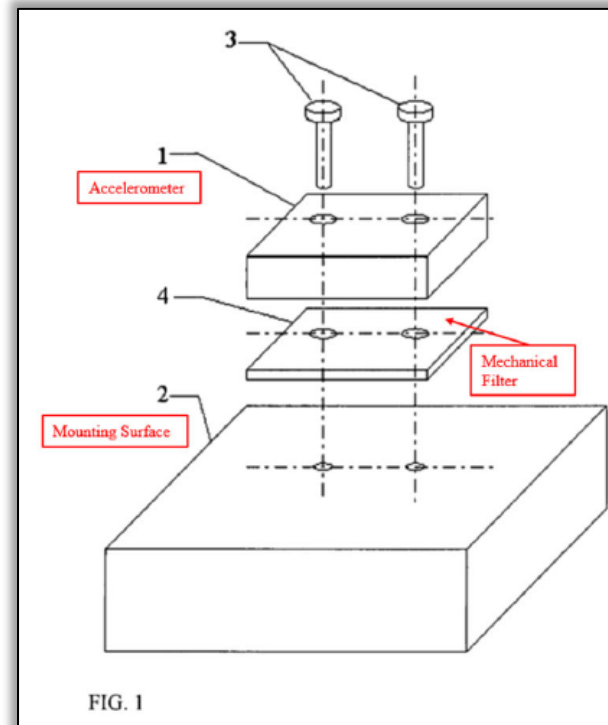
Ground 6: Obviousness over LeFebvre in view of Barone and Winfree

Ground 6: Obviousness over LeFebvre in view of Barone and Winfree

Patent Owner presents no additional arguments in rebuttal to Petitioner's prima facie case of obviousness of claims 23 and 26 over LeFebvre in view of Barone and Winfree.

23. The system of claim 1, wherein the one or more filters comprise one or more **mechanical filters** that include a resilient material configured to filter out undesirable accelerations from the accelerations, wherein the one or more **mechanical filters** are disposed to remove the undesirable accelerations before the undesirable accelerations reach the one or more sensors that are configured to measure accelerations.

26. The system of claim 1, wherein the one or more filters comprise one or more **mechanical filters**.



Amsted's Revised Motion to Amend

Substitute Claim 38

Claim 38 (Substitute for claim 1, if found unpatentable)

[[1]]38. A system for detecting operational anomalies on a train consist or railcar, comprising:

(a) one or more communication management units mounted on one or more railcars;

(b) one or more wireless sensor[[s]] nodes located on said one or more railcars and configured to sense an operational parameter of said one or more railcars, said one or more wireless sensor[[s]] nodes being in communication with said one or more communication management units, wherein the one or more wireless sensor[[s]] nodes comprise a tri-axis one or more sensor[[s]] configured to measure accelerations of the railcar along a plurality of axes comprising a first axis extending along a length of the railcar, a second axis extending across a width of the railcar, and a third axis extending along a height of the railcar; and

(c) a plurality of one or more sensor sections that are provided with the one or more wireless sensor nodes and that comprise

(i) a plurality of filters that are each configured to filter at least a portion of the accelerations by receiving an output signal directly from the tri-axis sensor and selecting ones of the accelerations in the output signal that were

measured in a dimension represented by a respective axis of the plurality of axes, and

(ii) a plurality of detectors respectively coupled to the plurality of filters, each one of the detectors being configured to detect a respective one of a plurality of different railcar conditions based on ones of the accelerations that are associated with only the respective axis of the plurality of axes;

wherein said communication management units perform the functions of:

(i) collecting, from the one or more wireless sensor nodes, data regarding said ~~one or more railcar~~ operational parameter[[s]] of said one or more railcars;

(ii) analyzing said collected data to detect a[[for]] trend[[s]] or event[[s]] indicative of an anomalous operational condition of said one or more railcars; and

(iii) communicating a message to a remote receiver when said trend or event is detected.

Patent Owner's RMTA (Paper 31) at iv-v

Substitute Claim 46

Claim 46 (Substitute for claim 30, if found unpatentable)

[[30]]46. A method for detecting operational anomalies on a train consist or railcar comprising the steps of:

sensing, by ~~a one or more~~ tri-axis sensor[[s]] of one or more wireless sensor nodes located on one or more railcars, one or more operational parameters of the one or more railcars, wherein the one or more operational parameters comprise one or more accelerations and the tri-axis sensor is configured to measure accelerations of the ~~one or more~~ railcar[[s]] along a plurality of axes comprising a first axis extending along a length of the railcar, a second axis extending across a width of the railcar, and a third axis extending along a height of the railcar;

filtering, by each of a plurality of ~~one or more~~ filters of a plurality of sensor sections that are provided with the one or more wireless sensor nodes, at least a portion of the accelerations by receiving an output signal directly from the tri-axis

sensor and selecting ones of the accelerations in the output signal that were measured in a dimension represented by a respective axis of the plurality of axes;

detecting, by each of a plurality of detectors of the plurality of sensor sections, a respective one of a plurality of different railcar conditions based on ones of the accelerations that are associated with only the respective axis of the plurality of axes;
and

by one or more communication management units associated with the one or more railcars:

collecting, from the one or more wireless sensor nodes, data regarding said ~~one or more railcar~~ operational parameters of said one or more railcars;

analyzing said collected data to detect a[[for]] trend[[s]] or event[[s]] indicative of an anomalous operational condition of said one or more railcars; and

communicating a message to a remote receiver when said trend or event is detected.

Patent Owner's RTMA at vii-viii

Substitute Claim 47

Claim 47 (Substitute for claim 36, if found unpatentable)

[[36]]47. A system for detecting operational anomalies on a railcar that is part of a train consist comprising:

(a) at least one communication management unit (CMU) mounted on the [[a]]railcar in said train consist;

(b) at least two wireless sensor[[s]] nodes located on the [[said]]railcar and[[for]] configured to sense operational parameters of the railcar, said wireless sensor[[s]] nodes being in communication with said communication management unit, wherein the at least two ~~one or more~~ wireless sensor[[s]] nodes comprise a tri-axis ~~one or more~~ sensor[[s]] configured to measure accelerations of the railcar along a plurality of axes comprising a first axis extending along a length of the railcar, a

second axis extending across a width of the railcar, and a third axis extending along a height of the railcar; and

(c) a plurality of ~~one or more~~ sensor sections that are provided with the one or more wireless sensor nodes and that comprise

a plurality of filters that are each configured to filter at least a portion of the accelerations by receiving an output signal directly from the tri-axis sensor and selecting ones of the accelerations in the output signal that were measured in a dimension represented by a respective axis of the plurality of axes, and

a plurality of detectors respectively coupled to the plurality of filters, each one of the detectors being configured to detect a respective one of a plurality of different railcar conditions based on ones of the accelerations that are associated with only the respective axis of the plurality of axes;

wherein said communication management unit performs the following functions:

- (i) receiving data from said at least two wireless sensor[[s]] nodes;
- (ii) drawing inferences from the data received from at least two wireless ~~of the~~ sensor[[s]] nodes regarding the performance of the railcar; and
- (iii) communicating a message to a remote receiver when an anomaly is detected.

Patent Owner's RTMA at viii-ix

The Substitute Claims Do Not Satisfy the Requirements of §§ 112(a) and (b)

Substitute Independent Claims 38, 46, and 47 are Indefinite

- Limitation 38(c)(i): “a plurality of filters that are each configured to filter at least a portion of the accelerations by receiving an output signal directly from the tri-axis sensor and selecting **ones of the accelerations** in the output signal that were measured in a dimension represented by a respective axis of the plurality of axes”
- Limitation 38(c)(ii): “a plurality of detectors respectively coupled to the plurality of filters, each one of the detectors being configured to detect a respective one of a plurality of different railcar conditions based on ones of the accelerations that are associated with only the respective axis of the plurality of axes”
- *See also* limitations 46(b), 46(c), 47(c)(i), 47(c)(ii)

Substitute Dependent Claim 43 Lacks Written Description

Claim 43: The system of claim 38[[1]], ~~further comprising one or more wireless sensor nodes in communication with at least one of the communication management units, wherein the one or more sensors form part of the one or more wireless sensor nodes, wherein one or more of the wireless sensor nodes comprises a microprocessor configured to execute firmware to control operation of the one or more of the wireless sensor nodes, wherein the firmware comprises one or more software filters configured to isolate one or more types of accelerations, and wherein a first one of the plurality of detectors is always enabled when the railcar is moving, and a second one of the plurality of detections is enabled when the railcar is traveling faster than a specific speed and is disabled when the railyard is traveling slower than the specific speed.~~

The Substitute Claims are Obvious under § 103

Prior Art

- U.S. Patent Publication No. 2011/0282540 (“Armitage”)
- U.S. Patent Publication No. 2007/029884 (“Barone”)
- U.S. Patent Publication No. 2007/0152107 (“LeFebvre”)
- U.S. Patent No. 7,706,213 (“Winfree”)
- U.S. Patent Publication No. 2011/0231039 (“Leitel”)

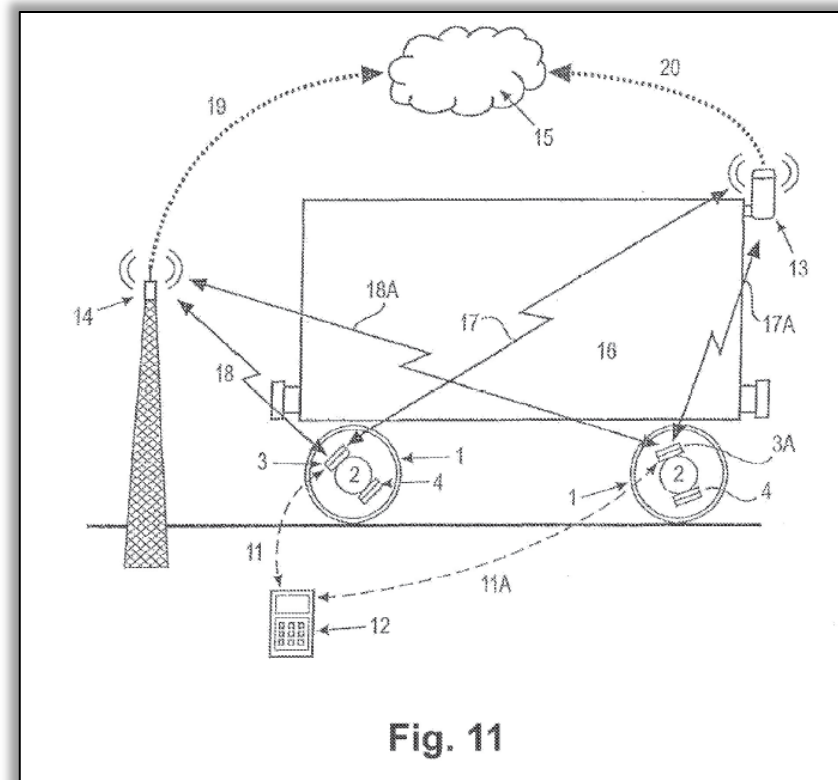
EX1005; EX1006; EX1007; EX1008; EX1029

Leitel – U.S. Patent Publication No. 2011/0231039

(57)

ABSTRACT

The invention relates to devices and methods, which relate to the arrangement of a sensor on the shaft of a rail vehicle.



EX1029, Abstract, Fig. 11

Winfree is Analogous Prior Art

'915 Patent

Additionally, a mechanical filter **410** consisting of upper sections **410a** and lower sections **410b** further serve to mechanically filter high and low frequency types of accelerations that are considered noise and which are preferably removed from the signal of interest. Preferably, these components are composed respectively of silicone of durometer 70 Shore A (the upper filter sections **410a**) and 30 Shore A (the lower filter sections **410b**) in view of the differences of the surface areas of each section and this affect on the filtering characteristics.

Additionally, the lower sections **410b** of the mechanical filter are of a suitable thickness to create an air gap between the enclosure base **400b** and the surface to which the WSN **104** is mounted. The lower sections **410b** of the mechanical filter and the air gap create good thermal protection and low heat transfer from the surface to which the WSN **104** is mounted. This thermal protection keeps the electronics (all except for the temperature sensor **406**) and the power source from being exposed to excess and potentially damaging heat. WSN **104** may also be equipped with additional temperature sensors (not shown) for sensing the ambient temperature.

Winfree

The invention is a structure of one or multiple layers of material placed between a sensor and its environment. The structure is designed and used as a filter to selectively transmit, attenuate, or amplify various frequencies of incident elastic waves that would otherwise propagate from the environment and into the sensor.

It is an object of the present invention to enable the isolation of a sensor from incident frequencies that may excite its resonance, damage it, or for some other reason be undesirable.

EX1001 at 5:23-32, 5:55-67; Sur-Reply
to RMTA, p. 5; EX1008 at 2:24-33;
EX1003, ¶¶20-23

Grounds of Unpatentability

- **Ground 1:** **Claims 1, 22, 24-25, 27-30, 36, and 37** are unpatentable under 35 U.S.C. § 103(a) in view of Armitage and Barone
- **Ground 2:** **Claim 21** is unpatentable under 35 U.S.C. § 103(a) in view of Armitage, Barone, and LeFebvre
- **Ground 3:** **Claims 23 and 26** unpatentable under 35 U.S.C. § 103(a) in view of Armitage, Barone, and Winfree
- **Ground 4:** **Claims 1, 21-22, 25, 27-30, 36, and 37** are unpatentable under 35 U.S.C. § 103(a) in view of LeFebvre and Barone
- **Ground 5:** **Claims 24 and 37** are unpatentable under 35 U.S.C. § 103(a) over LeFebvre in view of Barone and Armitage
- **Ground 6:** **Claims 23 and 26** are unpatentable under 35 U.S.C. § 103(a) over LeFebvre in view of Barone and Winfree

Substitute Claim 38(b)

[[1]]38. A system for detecting operational anomalies on a train consist or railcar, comprising:

(a) one or more communication management units mounted on one or more railcars;

(b) one or more wireless sensor[[s]] nodes located on said one or more railcars and configured to sense an operational parameter of said one or more railcars, said one or more wireless sensor[[s]] nodes being in communication with said one or more communication management units, wherein the one or more wireless sensor[[s]] nodes comprise a tri-axis one or more sensor[[s]] configured to measure accelerations of the railcar along a plurality of axes comprising a first axis extending along a length of the railcar, a second axis extending across a width of the railcar, and a third axis extending along a height of the railcar; and

(c) a plurality of one or more sensor sections that are provided with the one or more wireless sensor nodes and that comprise

(i) a plurality of filters that are each configured to filter at least a portion of the accelerations by receiving an output signal directly from the tri-axis sensor and selecting ones of the accelerations in the output signal that were

measured in a dimension represented by a respective axis of the plurality of axes, and

(ii) a plurality of detectors respectively coupled to the plurality of filters, each one of the detectors being configured to detect a respective one of a plurality of different railcar conditions based on ones of the accelerations that are associated with only the respective axis of the plurality of axes;

wherein said communication management units perform the functions of:

(i) collecting, from the one or more wireless sensor nodes, data regarding said one or more railcar operational parameter[[s]] of said one or more railcars;

(ii) analyzing said collected data to detect a[[for]] trend[[s]] or event[[s]] indicative of an anomalous operational condition of said one or more railcars; and

(iii) communicating a message to a remote receiver when said trend or event is detected.

Substitute Claim 38(b) – Grounds 1 and 2

- Armitage teaches:
 - Plurality of sensor nodes that communicate wirelessly with a control node (i.e., CMU) on same railcar

Opposition to RMTA, pp. 5-6; EX1003, ¶¶ 70, 74; EX1030, ¶¶ 27, 29; EX1006, Figs. 1, 3, 5, ¶¶ [0004], [0012], [0014]-[0016], [0020], [0025]-[0027], [0029]-[0031], [0033]-[0035], [0045]-[0046], [0050], [0053], [0056]; Petition, pp. 23-35

- The sensor nodes may include “three-dimensional accelerometers”

Opposition to RMTA, p. 6; EX1006, ¶ [0045]; EX1030, ¶ 29

[0045] In another embodiment, vibration is monitored as graph 400. The vibration could be monitored with a three-dimensional accelerometer, such as a solid state accelerometer device. The accelerations monitored by the 3-D accelerometer are interpreted as vibrations. In some examples, axial vibration is monitored along a single axis, such as a z-axis aligned with the axle of a particular wheel or wheel assembly, and vibrations in other axes are ignored, such as radial axes including an x-axis aligned with the horizontal and a y-axis aligned with the vertical with respect to the railway car or wheel. At high sampling rates of the accelerometer, the sam-

EX1006, ¶ [0045]

Substitute Claim 38(b) – Grounds 5 and 6

- LeFebvre teaches:
 - Sensor nodes comprising accelerometers;
 - A triaxial accelerometer located in the data control unit 23 (i.e., CMU);
 - A PHOSITA would be motivated to use a triaxial accelerometer in the sensor nodes
 - Known benefits of a triaxial accelerometer
 - Also obvious in view of Armitage

Opposition to RMTA, pp. 6-7; EX1005, ¶¶ [0006], [0021], [0024]-[0026], [0031]-[0032], Fig. 1, Claims 28, 30; EX1003, ¶¶ 152, 155, 206; EX1030, ¶¶ 30-34

Substitute Claim 38(c)(i)

[[1]]38. A system for detecting operational anomalies on a train consist or railcar, comprising:

(a) one or more communication management units mounted on one or more railcars;

(b) one or more wireless sensor[[s]] nodes located on said one or more railcars and configured to sense an operational parameter of said one or more railcars, said one or more wireless sensor[[s]] nodes being in communication with said one or more communication management units, wherein the one or more wireless sensor[[s]] nodes comprise a tri-axis ~~one or more~~ sensor[[s]] configured to measure accelerations of the railcar along a plurality of axes comprising a first axis extending along a length of the railcar, a second axis extending across a width of the railcar, and a third axis extending along a height of the railcar; and

(c) a plurality of ~~one or more~~ sensor sections that are provided with the one or more wireless sensor nodes and that comprise

(i) a plurality of filters that are each configured to filter at least a portion of the accelerations by receiving an output signal directly from the tri-axis sensor and selecting ones of the accelerations in the output signal that were

measured in a dimension represented by a respective axis of the plurality of axes, and

(ii) a plurality of detectors respectively coupled to the plurality of filters, each one of the detectors being configured to detect a respective one of a plurality of different railcar conditions based on ones of the accelerations that are associated with only the respective axis of the plurality of axes;

wherein said communication management units perform the functions of:

(i) collecting, from the one or more wireless sensor nodes, data regarding said ~~one or more railcar~~ operational parameter[[s]] of said one or more railcars;

(ii) analyzing said collected data to detect a[[for]] trend[[s]] or event[[s]] indicative of an anomalous operational condition of said one or more railcars; and

(iii) communicating a message to a remote receiver when said trend or event is detected.

Substitute Claim 38(c)(i) – Ground 1

- A PHOSITA would understand Armitage collects and analyzes data from all three axes measured by a triaxial accelerometer.
- Use of multiple filters to isolate each axes is the mere duplication of parts with no new or unexpected results.

40, In my experience, there are several examples of why a PHOSITA would want to monitor accelerations along each axis to determine certain problem conditions of a railcar. As one example, a PHOSITA would have understood that accelerations along the transverse axis extending along the width of the railcar can be used to monitor conditions including truck hunting, which is a repetitive movement truck back and forth across the line of the rails (see, e.g., EX1005, ¶ [0054]), wheel flat conditions (EX1006, ¶ [0045]), and bearing defects, among others. As another example, a PHOSITA would have understood that accelerations along the vertical axis can be used to monitor conditions including track defects, which generate large and sudden forces in the wheels and bearings (see, e.g., EX1005, ¶ [0054], [0066]), wheel derailments (see, e.g., EX1005, ¶ [0061]; EX1029 (Leitel), ¶ [0066]), and bearing defects, among others. And a PHOSITA would have understood that accelerations along the longitudinal axis extending along the length of the railcar can be used to monitor conditions including track switching impacts (see, e.g., EX1029 (Leitel), ¶ [0064]), truck hunting movements involving yaw displacements (see, e.g., EX1005, ¶ [0062]), changes in velocity (including collisions), and bearing defects, among others.

Opposition to RMTA, pp. 8-12;
EX1030, ¶¶ 35-44; EX1006, ¶¶ [0014], [0045]

Substitute Claim 38(c)(i) – Ground 2

- Alternatively, a PHOSITA would have been motivated to filter the output of Armitage's triaxial accelerometer into three distinct outputs corresponding to each measured axis as taught in Leitel.
- Leitel demonstrates three distinct signals corresponding to each axis are useful to detect a variety of conditions based on a single axis or multiple axes.
- Leitel notes the advantages of filtering in the sensor node.

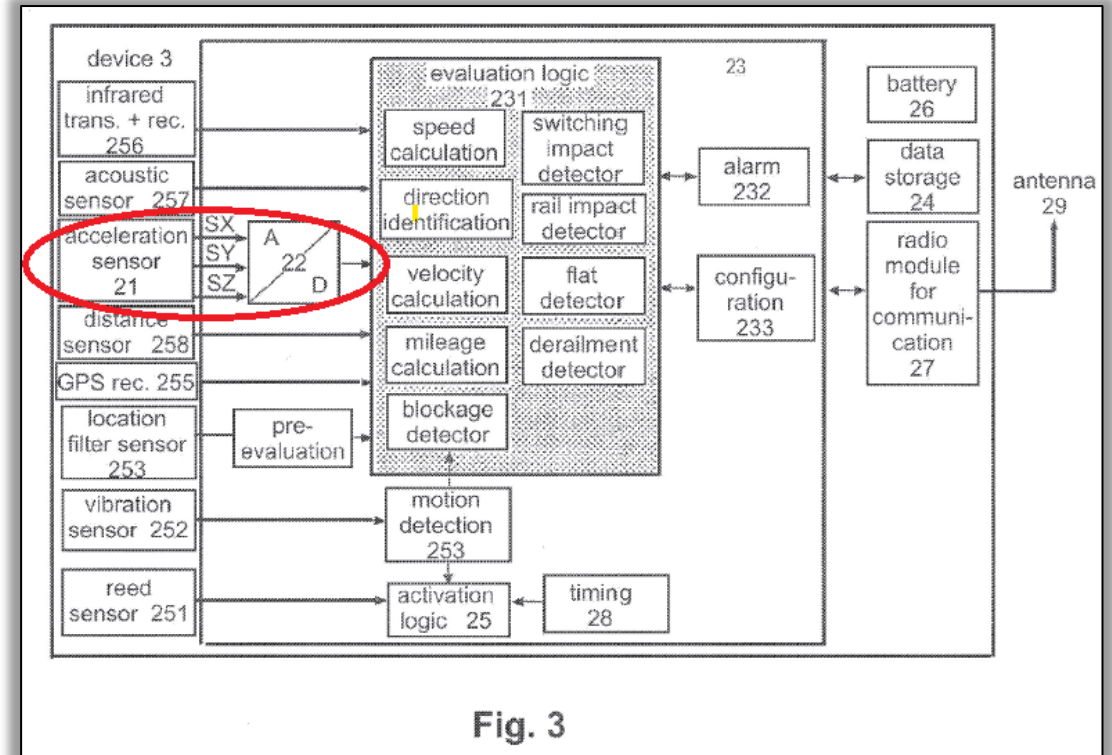
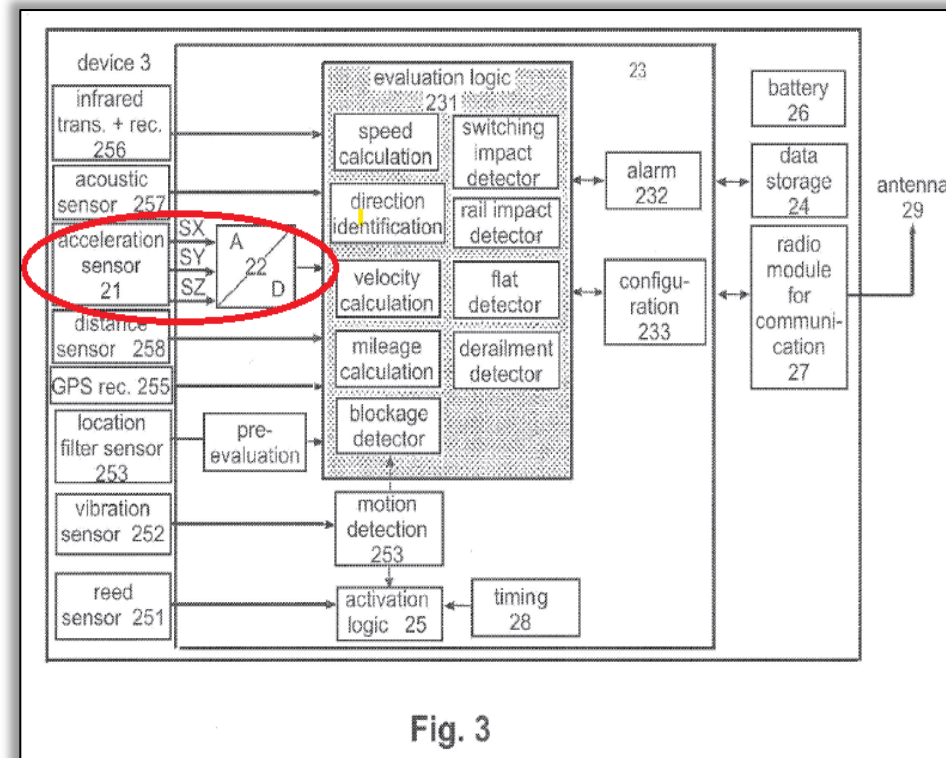


Fig. 3

Opp. to RMTA, 12-15; EX1029, Fig. 3,
¶¶ [0037], [0047], [0049], [0054], [0056],
[0060], [0065], [0068], [0071], [0073],
[0122], [0125], [0128], [0151]-[0164],
EX1030, ¶¶ 48-55;
Sur-Reply to RMTA, pp. 6-8

Substitute Claim 38(c)(i) – Grounds 5 and 6

- A PHOSITA would have been motivated to filter, at the sensor, the output of LeFebvre's triaxial accelerometer into three distinct sets of data, corresponding to each measured axis to determine the “variety of car body motions” described by LeFebvre.
- Alternatively, a PHOSITA would have been motivated to filter the output of Armitage's triaxial accelerometer into three distinct outputs corresponding to each measured axis as taught in Leitell for the same reasons as Ground 2.



Substitute Claim 38(c)(ii)

[[1]]38. A system for detecting operational anomalies on a train consist or railcar, comprising:

(a) one or more communication management units mounted on one or more railcars;

(b) one or more wireless sensor[[s]] nodes located on said one or more railcars and configured to sense an operational parameter of said one or more railcars, said one or more wireless sensor[[s]] nodes being in communication with said one or more communication management units, wherein the one or more wireless sensor[[s]] nodes comprise a tri-axis ~~one or more~~ sensor[[s]] configured to measure accelerations of the railcar along a plurality of axes comprising a first axis extending along a length of the railcar, a second axis extending across a width of the railcar, and a third axis extending along a height of the railcar; and

(c) a plurality of ~~one or more~~ sensor sections that are provided with the one or more wireless sensor nodes and that comprise

(i) a plurality of filters that are each configured to filter at least a portion of the accelerations by receiving an output signal directly from the tri-axis sensor and selecting ones of the accelerations in the output signal that were

measured in a dimension represented by a respective axis of the plurality of axes, and

(ii) a plurality of detectors respectively coupled to the plurality of filters, each one of the detectors being configured to detect a respective one of a plurality of different railcar conditions based on ones of the accelerations that are associated with only the respective axis of the plurality of axes;

wherein said communication management units perform the functions of:

(i) collecting, from the one or more wireless sensor nodes, data regarding said ~~one or more railcar~~ operational parameter[[s]] of said one or more railcars;

(ii) analyzing said collected data to detect a[[for]] trend[[s]] or event[[s]] indicative of an anomalous operational condition of said one or more railcars; and

(iii) communicating a message to a remote receiver when said trend or event is detected.

Substitute Claim 38(c)(ii) – Grounds 1 and 2

- A PHOSITA would understand that the “processing portion” of Armitage’s sensor nodes would include detectors to detect the conditions specifically identified in Armitage.
- Leitel discloses “detectors” that detect various railcar conditions based on signals SX, SY, and SZ from the accelerometer.

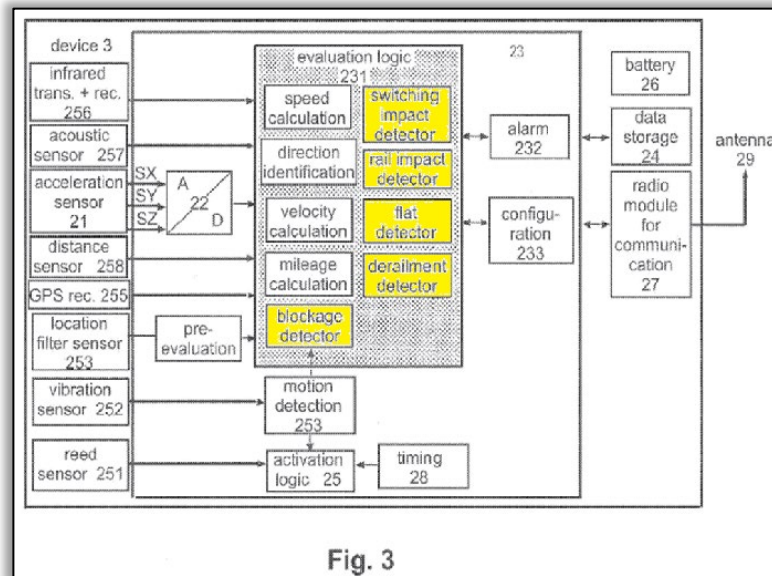


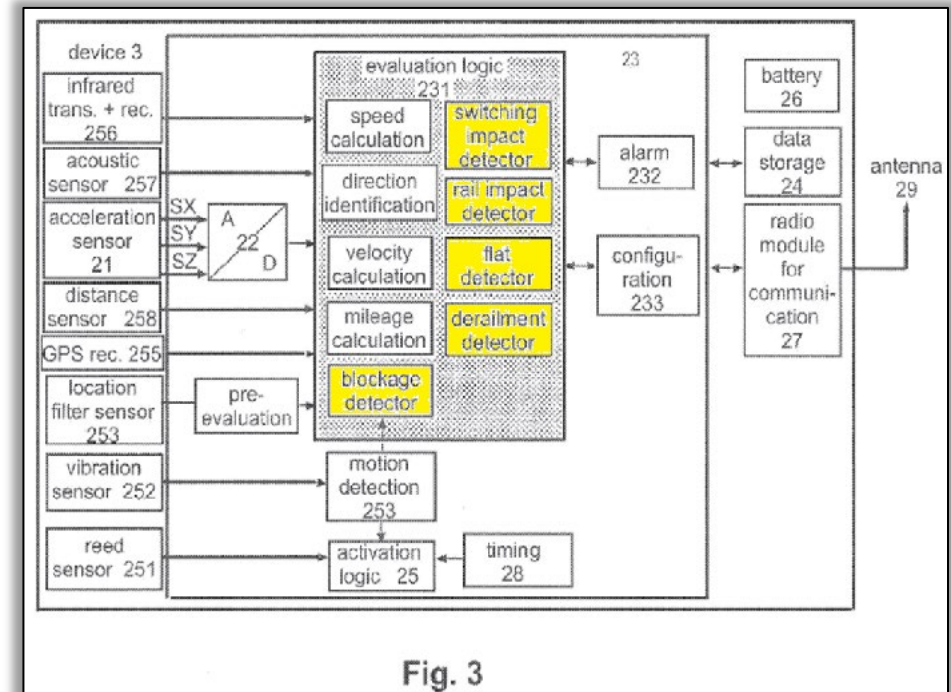
Fig. 3

[0125] The evaluation in the unit 23 can extend beyond intermediate storage and/or transmission of the sensor data SX, SY and/or SZ. It can be provided to perform certain evaluation steps already within the device 3 to reduce the amount of data for storage/transmission or to make subsequent evaluation dispensable. Thus, for example, the number of the revolutions of the wheels or the traveled distance could be immediately provided based on the sensor signals SX, SY and SZ. In addition, certain error signals (blockage of the wheels) could be calculated and/or transmitted with time designations such as point of time and/or duration of the error. However, such an evaluation of the data can also be effected in a separate evaluation unit attached to the rail vehicle or stationarily provided outside of the rail vehicle. An evaluation logic 231 thus can in particular provide: speed calculation, direction identification, velocity calculation, mileage calculation in combination with one or more errors such as switching impact detector (for example with limit value >2.4 g), rail impact detector, flat detector, derailment detector and/or blockage detector.

Opp. to RMTA, pp. 17-20; EX1006, ¶ [0014];
EX1029, ¶¶ [0122], [0125], [0128]-[0129]; Fig. 3;
EX1030, ¶¶ 63-66; Sur-Reply to RMTA, p. 10

Substitute Claim 38(c)(ii) – Grounds 5 and 6

- LeFebvre also discloses processing sensor information to detect different railcar conditions.
- A PHOSITA would be motivated to use the detectors of Leitel in LeFebvre's sensor nodes to detect various railcar conditions based on signals SX, SY, and SZ from the accelerometer for the same reasons as Ground 1/Armitage.



Opposition to RMTA, p. 20;
EX1029, Fig. 3; EX1030, ¶¶ 67-68

Substitute Dependent Claim 43

- Ground 1: Armitage and Barone teach monitoring “enabled” when railcar is in motion. EX1006, ¶¶ 4, 25; EX1007, ¶ 44.
- Ground 5: LeFebvre discloses detectors that are turned on only periodically to save power. EX1005, ¶¶ 21, 36.
- Grounds 2 and 6: Leitel teaches an activation log 25 and motion detection 253, which determine whether to turn on the detectors based on whether the railcar is moving. EX1029, ¶¶122.
 - A PHOSITA would have been motivated to only enable sensors/detectors when a railcar is moving to save power when it is not needed.
- A PHOSITA would have been motivated to include a second detector designed to only turn on at high speeds.

72. In my opinion, it would have also been obvious to a PHOSITA to include a second detector designed to turn on when the railcar is traveling faster than a specific speed because, for example, high speeds can cause different types of railcar conditions that lower speeds do not and some conditions require immediate action only when they occur at higher speeds. A PHOSITA would understand that there are certain measurements that are meaningless except at higher speeds, so sensors should only be enabled at those speeds. One example is using an accelerometer to measure wheel balance – at low speeds the acceleration is undetectable or so low it would be in the noise margin but at higher speeds the signal stands out so enabling the sensor and taking the measurement makes sense. A PHOSITA would understand that the second, high-speed detector would not need to be enabled at lower speeds, as it is advantageous to save power and not overload the system with unnecessary data collection and processing.

Remaining Claims

- Substitute Independent Claims 46 and 47
 - Patent Owner states that claims 46 and 47 are “limited in a manner similar to independent substitute claim 38. Therefore, claim 46 is not taught by LeFebvre, Armitage, Barone, Winfree and/or Leitell for the reasons set forth above in relation to claim 38.” RMTA, p. 23.
 - None of the minor differences between the new or original claim language of claims 47(d)-(f) requires a different analysis of the prior art for the corresponding limitations 38(d)9i)-(iii).
- Each remaining substitute dependent claim was addressed with respect to Substitute Independent Claim 38.

Opposition to RMTA, pp. 22-25;
Sur-Reply to RMTA, p. 12