

TITLE: A BROKEN RAIL DETECTION SYSTEM**FIELD OF THE INVENTION**

- 5 [001] The present invention relates to the field broken rail detection systems, and more particularly to detection systems that use voltage and/or current signals circulating in the railway track for detecting broken rails.

BACKGROUND OF THE INVENTION

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- [002] In order to ensure the safety of railway transportation, it is not only important to keep the locomotives in good working condition, it is also important to keep the railway tracks themselves in good working condition. Due to excessive use, and environmental conditions such as extreme temperatures, railway tracks can deteriorate and eventually break. It is therefore important to monitor the condition of the railway tracks in order to ensure that they do not include breaks that could cause them to be unsafe.

- [003] Systems for detecting broken rails are known in the art. As shown in Figure 1, such systems generally comprise wayside-based equipment 10 that is positioned in proximity to the railway tracks 12. The wayside-based equipment 10 is in communication with a transmitter 14 and a receiver 16. The railway track 12 that is being monitored is divided into sections by placing shunts 18 across the rails. By so doing, the railway track 12 and the shunts 18 create a closed conductive loop. The transmitter 14 then introduces either a current or a voltage signal into the closed loop, such that the signal is able to circulate through the railway track 12. Meanwhile, the receiver 16 monitors this signal circulating through the closed loop of the railway track 12. When a break occurs in the railway track 12, the break will interrupt the path of the signal, thus preventing the signal from reaching the receiver 16. When the wayside equipment 10 detects the absence of the signal at the receiver 16, the wayside-based equipment 10 determines that there is a break in the railway tracks 12.

[004] Unfortunately, such broken rail detection systems are plagued with numerous deficiencies. A first such deficiency is that a significant amount of wire is required in order to connect the transmitters 14 and the receivers 16 to the wayside equipment 10. 5 This is not only costly, but is also difficult to maintain.

[005] A further deficiency with existing systems lies in the fact that when trains are running on the track, the broken rail detection system cannot always be used. More specifically, when a train is travelling on the railway track between the transmitter 14 10 and the receiver 16, the train's axles act as shunts. As such, if a train is on the track, it will short out the section of track between itself and the shunt. Referring to figure 1, and assuming that a train's axles are positioned just in front of the break in the rails 12, the train's axles will complete the closed loop, such that the receiver 16 will continue to receive the signal that is circulating in the rails, regardless of the fact that 15 there is a break in the rails just beyond the train's axle. Therefore, depending on the placement of the transceiver 14 and the receiver 16, the portion of the rails positioned beyond the portion of the track that is shunted by the train cannot be monitored. As such, the wayside equipment will not be able to accurately perform broken rail detection on the rails when there are trains travelling thereon. The more trains that are 20 running on the track, the less the system can accurately perform broken rail detection, since the trains cause shunting of so much of the track.

[006] In light of the above, it can be seen that there is a need in the industry for an improved broken rail detection system that alleviates, at least in part, the deficiencies 25 of the prior art, and improves on the overall efficiency of the systems.

SUMMARY OF THE INVENTION

[007] In accordance with a first broad aspect, the present invention provides a 30 locomotive for travelling on a railway track. The locomotive comprises a receiver for receiving a track signal that is circulating in the railway track and a processing unit

that is in communication with the receiver. The processing unit is operative for detecting a characteristic of the track signal and for generating a signal indicative of a potential broken rail in response to the characteristic of the track signal circulating in the railway track.

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[008] In accordance with a non-limiting embodiment, the locomotive further comprises a transmitter for transmitting the track signal into the railway track. It should be appreciated that the track signal can also be introduced into the railway track by a different locomotive, or by track-side equipment.

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[009] In accordance with a second broad aspect, the present invention provides a system for performing broken rail detection on a railway track. The system comprises at least one locomotive and a monitoring entity. The locomotive comprises a receiver for receiving a track signal that is circulating in the railway track and a processing unit that is in communication with the receiver. The processing unit is operative for detecting the presence of the track signal and generating a signal indicative of a potential broken rail in response to the absence of the track signal circulating in the railway track. The locomotive further comprises a wireless transmitter for transmitting the signal indicative of a potential broken rail over a wireless communication link.

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20 The monitoring entity comprises a receiver for receiving the signal indicative of a potential broken rail and a processing unit for detecting a broken rail at least in part on the basis of the signal indicative of a potential broken rail from the locomotive.

[010] In accordance with another broad aspect, the present invention provides a monitoring entity for performing broken rail detection. The monitoring entity comprises a wireless receiver and a processing unit. The wireless receiver is operative for receiving a signal from at least one locomotive; the signal being indicative of a potential broken rail. The processing unit is operative for detecting a broken rail at least in part on the basis of the signal from the at least one locomotive.

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[011] In accordance with another broad aspect, the present invention provides a system for performing broken rail detection. The system comprises receiving means for mounting onboard a locomotive that is travelling on a railway track. The receiving means are operative for receiving a track signal that is circulating in the railway track.

5 The system further comprises processing means in communication with the receiving means. The processing means is operative for detecting the presence of the track signal and generating a signal indicative of a potential broken rail in response to the absence of the track signal circulating in the railway track.

10 [012] These and other aspects and features of the present invention will now become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

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[013] In the accompanying drawings:

[014] Figure 1 shows a schematic view of a broken rail detection system in accordance with the prior art;

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[015] Figure 2 shows a top schematic view of a locomotive-based broken rail detection system in accordance with a non-limiting example of implementation of the present invention;

25 [016] Figure 3 shows a schematic diagram of a locomotive in accordance with a non-limiting example of implementation of the present invention, travelling over a portion of railway track;

[017] Figure 4 shows a non-limiting schematic diagram of portions of a railway track surveyed by the locomotive-based broken rail detection system of Figure 2.

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[018] Figure 5 shows a block diagram of a locomotive in accordance with a non-limiting example of implementation of the present invention;

5 [019] Figure 6 shows a schematic diagram of the in accordance with the present invention;

[020] Figure 7 shows a non-limiting example of a flow diagram performed by a locomotive for generating a signal indicative of a potential broken rail in accordance with the present invention.

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[021] Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

DETAILED DESCRIPTION

[022] Shown in Figure 2 is a broken rail detection system 20 in accordance with a non-limiting example of implementation of the present invention. The broken rail detection system 20 comprises a monitoring entity 22 that is in communication with one or more locomotives 24. For the purposes of the following description, three locomotives 24a, 24b and 24c have been included in the schematic diagram of Figure 2. It should, however, be understood that any number of locomotives 24 can be included as part of the broken rail detection system 20, without departing from the spirit of the invention.

[023] The monitoring entity 22 is responsible for monitoring the condition of the railway track 24 in a predefined area or region in order to determine, among other things, whether the rails in that region include a break. The predefined area or region may be based on a certain length of railway track (i.e. 100 miles of track, for example) or based on a certain geographical area.

[024] The monitoring entity 22 can be a track-side device, such as wayside equipment, or can be a remotely located device, such as a computing unit that is located at a control station, for example. In use, monitoring entity 22 is operative for detecting a broken rail in the railway track 26 at least in part on the basis of signals received from the locomotives 24 travelling on the railway track 26. As the locomotives 24a, 24b and 24c travel along the railway track 26, they are operative for surveying a portion of the railway track 26 in order to detect a potential break in the rails. The surveying is performed by monitoring a track signal that is circulating in the railway track 26. As will be described in more detail below, the track signal can be introduced into the railway track 26 by the locomotive that is monitoring the signal, by a different locomotive or by track-side equipment.

[025] Upon detection of a potentially broken rail in the portion of railway track being surveyed, the locomotive transmits a signal indicative of a potential broken rail

to the monitoring entity 22. As such, the monitoring entity 22 includes a receiver 21 for receiving the signals from the locomotives 24a, 24b and 24c, and a processing unit 23 for determining, among other things, if there is a break in one of the rails. As will be described in more detail below, the monitoring entity 22 can perform the broken rail detection solely on the basis of the signals received from the locomotives 24, or in combination with conventional techniques (as described in the background) which involve introducing a signal into the rails via a track-side transmitter 25.

[026] In order to facilitate the ability of locomotives 24a, 24b and 24c to survey portions of the railway track 26, the railway track 26 is divided into sections via shunts 28. The railway track 26 shown in Figure 2 includes five shunts, which have been labelled 28a, 28b, 28c, 28d and 28e for clarity.

[027] In accordance with a non-limiting embodiment, at least some of the locomotives 24a, 24b and 24c are operative for introducing a signal into the track 26. Shown in Figure 3 is a non-limiting example of implementation of a locomotive 24 in accordance with the present invention. As shown, the locomotive 24 includes a transmitter 30 for issuing a signal into a rail of the railway track 26, and a receiver 32 for receiving the signal that has been introduced into the railway track 26. The transmitter 30 and the receiver 32 are positioned on the locomotive 24 such that they are set correctly with respect to the rails.

[028] The signal that is transmitted into the rails can either be a current signal or a voltage signal. In a preferred embodiment, the signal can be, but is not limited to, a low frequency audio signal having a frequency in the range of 4,000 Hz to 10,000 Hz. Such signals are inductively transmitted into the rails.

[029] Once the signal has been introduced into one of the rails by the transmitter 30, the signal travels through the rail to the nearest shunt 28 and then travels back towards the locomotive 24 through the other rail. The shunt 28 can be a conductive rod that is placed across the rails of the track 26, or alternatively, the shunt 28 can be an axle of

another locomotive travelling on the track 26. Once the signal has travelled through the shunt 28, it travels back towards the locomotive 24 that issued the signal. That locomotive's axle 34 then acts as a second shunt, such that a closed loop is created between the locomotive 24 and the shunt 28. The signal that has been introduced into the track 26 is then able to circulate through this closed loop continuously. In this manner, the receiver 32 is able to receive the signal as it circulates through the closed loop. As long as the rails are intact, the signal that has been introduced into the rails is also intact, and the receiver 32 receives the signal such that it can detect a characteristic of the signal. The characteristic of the signal can be the presence of the signal, the strength of the signal or a signature of signal, that can be detected by digital signal processing techniques, for example. On the basis of one or more of these characteristics, the locomotive 24 can survey the railway track 26 for possible breaks.

[030] In the case where the receiver 32 no longer receives the signal that is circulating through the railway track 26, it generally means that there is a break in one or both of the rails, thus causing a short in the closed circuit. Alternatively, in the case where the strength of the signal has deteriorated, or the signature of the signal is incorrect, it could also mean that there is a break, or a deterioration of the rails in the portion of the railway track 26 being surveyed. As such, when the receiver 32 fails to receive the track signal, or detects a deterioration in signal strength, or an incorrect signal signature, the locomotive 24 determines that there is a potential break or deterioration in one or both of the rails that it is surveying.

[031] Although Figure 3 shows only the front end of the locomotive 24, it should be understood that the locomotive 24 may have a similar transmitter 30 and receiver 32 positioned at the rear end of the locomotive 24. In such an embodiment, the locomotive 24 is able to survey both the portion of railway track 26 in front of it and the portion of railway track 26 behind it.

[032] As mentioned above, although the closed loop shown in Figure 3 is between the front axle 34 of the locomotive 24 and a shunt 28 in the form of a conductive rod,

the loop could also be formed between two locomotives 24. For example, in the case where there are no shunts positioned between two locomotives 24 (such as in the case of locomotives 24b and 24c shown in Figure 2) then the closed loop is formed between the rear axle of the front locomotive and the front axle of the rear locomotive.

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[033] Shown in Figure 4 is a representation of the portions of the railway track 26 surveyed by the locomotives 24a, 24b and 24c of Figure 2. In this non-limiting example, the locomotive 24a is operative to introduce a signal into the railway track 26 both ahead of it and behind it. As such, the locomotive 24a is surveying the portion of railway track between its rear axle and the shunt 28a, as well as the portion of the railway track 26 between its front axle and the shunt 28b. The locomotive 24b is also introducing a signal into the railway track 26 both ahead of it and behind it. As such, it is surveying the portion of railway track between its rear axle and the shunt 28b, and the portion of railway track between its front axle and the rear axle of locomotive 24c. In the embodiment shown, the locomotive 24c is only introducing a signal into the railway track ahead of it. As such, locomotive 24c is only surveying the portion of the railway track 26 between its front axle and the shunt 28c.

[034] Although in the embodiment shown in Figure 4, locomotive 24c is only introducing a signal into the railway track 26 ahead of it, it should be understood that it could also introduce a signal into the railway track behind it. In such a case, both the locomotive 24b and the locomotive 24c would be introducing a signal into the portion of railway track positioned between them, such that they are both surveying that portion of the railway track 26. In such a case, it may be beneficial for the two locomotives to introduce signals having two different frequencies into the rail in order to avoid frequency collisions.

[035] As will be described in more detail further on, the monitoring entity 22 is operative for receiving location information from each of the locomotives 24a, 24b and 24c such that the monitoring entity 22 has a complete picture of where each locomotive 24a, 24b and 24c is in relation to the track, and in relation to each other.

As such, when the monitoring entity 22 notices that there is a portion of track that is being monitored by two locomotives (such as the portion of track positioned between locomotive 24b and 24c) the monitoring entity 22 can issue signals to each of these two locomotives in order to assign to each of the locomotives a specific carrier
5 frequency for the signals that that locomotive transmits into, and receives from, the track 26. Alternatively, the monitoring entity 22 can issue signals to only one of the locomotives, such as locomotive 24c, for example, in order to instruct that locomotive to stop transmitting a signal into the track behind it. In such a case, the portions of the railway track 26 being surveyed would be as shown in Figure 4. In the case where the
10 monitoring entity 22 transmits signals to the locomotives 24, the monitoring entity 22 would also include a transmitter (not shown in the Figures).

[036] As such, it should be understood that the manner in which the locomotives 24 survey the railway track 26 can be dependent on the configuration of the tracks, or on
15 the basis of the number of locomotives 24 travelling on the track 26. The decision as to which locomotives perform the surveying operation, and which transmitters are used, can be predetermined, or can be dynamically controlled as the locomotives 24 travel across the railway track 26. For example, in the case where there are many locomotives 24 travelling across the track 26, it may be determined that each
20 locomotive 24 will only transmit and receive track signals from their front ends. Alternatively, it may be determined that only every second locomotive 24 will perform the railway track surveying. In accordance with a non-limiting embodiment, the co-ordination of the dynamically changing surveying operations will be controlled by the monitoring entity 22, which is in communication with each locomotive 24.

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[037] In yet another alternative embodiment, it is possible that one locomotive 24 transmits a signal into the rails, and that another locomotive 24 receives the signal. As such, only one locomotive transmits and only one locomotive receives.

30 [038] Shown in Figure 5 is a non-limiting block diagram of the components of a locomotive 24 that perform the functionality of the broken rail detection. As described

above, the locomotive 24 includes the rail transmitter 30 and the rail receiver 32. The locomotive 24 further includes a processing unit 40 and a transceiver 42. The processing unit 40 includes a signal generation unit 46 in communication with the transmitter 30, and a signal detection unit 44 in communication with the receiver 32.

- 5 In the case where the locomotive 24 includes a transmitter 30 and a receiver 32 at both the front and back of the locomotive, the locomotive may include two processing units 40, one for each of the transmitter/receiver pairs.

[039] The transceiver 42 is operative for communicating over a wireless communication link with the monitoring entity 22. It should be appreciated that the transceiver 42 of the locomotive 24 and the receiver 21 of the monitoring entity 22 are operative to communicate over a wireless communication link. In accordance with a non-limiting embodiment, this wireless communication link is an RF communication link, however, other suitable communication links could also be used without departing from the spirit of the invention. In addition, although Figure 5 shows the locomotive 24 as having a transceiver 42, the locomotive 24 could instead have included a separate receiver and transmitter for communicating with the monitoring entity 22.

20 [040] In operation, the signal generation unit 46 is operative for generating a current or voltage signal for being introduced into the rails by the transmitter 30. In the case where the signal being generated is a current (audio) signal, the signal generation unit 46 may include a programmable selectable oscillator, such that the frequency of the signal being introduced into the rails can be selected. It should be understood that the frequency of the signal generated by the signal generation unit 46 may be constant such that it is always the same, or may be selected based on a set of pre-programmed instructions stored in the memory unit 48. Alternatively, the frequency of the signal generated by the signal generation unit may be selected on the basis of a control signal from the monitoring entity 22. As described above, this may occur in the case where the frequency of the signals is selected in order to avoid frequency collisions with signals originating from other locomotives. Alternatively, in the case where the

locomotives travelling on the track 26 are able to communicate with one another, and they are surveying the same portion of track, the locomotives can communicate in order to establish different carrier frequencies for their respective signals. Alternatively, in the case where two different signals are travelling in the same portion
5 of railway track 26, the signal signatures can be used to differentiate between the two signals. For example, the locomotives may use a signal sorting techniques, such as signal signature analysis, in order to differentiate the two signals travelling in the track.

10 [041] As described above, once the transmitter 30 has introduced the signal into the closed loop of the railway tracks 26, the receiver 32 receives this signal (assuming there are no breaks in the rails). The signal detection unit 44, which is in communication with the receiver 32 is operative for detecting from the receiver 32 the presence of the signal circulating in the rails. The signal detection unit 44 is further
15 operative to measure the signal strength to help in determining the rail status. A weak signal may indicate a deterioration of the railway track 26. Likewise, the signal detection unit 44 may also detect the signal signature.

[042] The receiver 32 may be a programmable selectable receiver 32, such that it is
20 able to adjust the frequency of the signals it is receiving. The programmable selectable receiver 32 can select the frequency of signals to be received in the same manner as the frequency of the signals generated by the signal generation unit 46 selects the frequency of signals to be transmitted.

25 [043] In addition to detecting the presence of the track signal, the processing unit 40 is also operative for detecting the location of the locomotive 24 on the railway track 26 as it travels along. This may be done in a variety of manners, such as those described below.

30 [044] In a first non-limiting example, the locomotive 24 is operative for determining its location based on track-side positioning devices. For example, positioned along the

railway track 26 can be transponders, or some other type of wayside information storage device. The transponders (not shown in the Figures) are located at various positions along the railroad track 26 and include coded information that is stored by means of tuned resonators. In order to read the coded information from these
5 transponders, one or more antennas 50, which utilise a given frequency band and which emit an electromagnetic wave in that frequency band are positioned on the locomotive 24. As such, when the locomotive 24 transporting the one or more antennas 50 passes in the vicinity of a transponder, the antenna emits electromagnetic waves in a frequency band to which the transponder is tuned, such that the antenna's
10 electromagnetic waves power the transponder. This causes the resonator circuit in the transponder to resonate, which results in the transmission of the data stored therein. This data is received by the antenna 50 and is transmitted to the signal detection unit 44 that is coupled to the antenna 50.

15 [045] In accordance with this example, the locomotive 24 includes a map of the railway track 26 that includes an indication of where the transponders are located on the railway track, as well as their associated coded information. This map can be stored in the memory unit 48. As such, the processing unit 40 is operative to process the coded information received from the antenna 50 in combination with the map,
20 such that it can determine its location on the railroad track 26.

[046] In an alternative embodiment, the locomotive is operative to determine its location on the railroad track 26 based on GPS technology. In this specific example of implementation, the processing unit 40 would be equipped with a GPS receiver such
25 that it can receive GPS co-ordinates from a GPS satellite. These GPS co-ordinates can then be plotted on a corresponding map (which could be stored in the memory 48), such that the processing unit 40 could determine the locomotive's position on the railway track 26.

30 [047] As shown in Figure 6, and as described above, the locomotives 24a, 24b and 24c of the system 20 are in communication with the monitoring entity 22, such that

information can be transmitted between the locomotives 24a, 24b and 24c and the monitoring entity 22. During normal operation, the locomotives 24a, 24b and 24c, are operative for continually transmitting their location information to the monitoring entity 22 via transceiver 42. In this manner, the monitoring entity 22 is aware of the location of each locomotive 24a, 24b and 24c travelling in its region.

[048] Referring now to the flowchart of Figure 7, the process of surveying a portion of railway track that is performed by one or more of locomotive 24a, 24b and 24c will be described.

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[049] At step 60, the receiver 32 receives the signal circulating in the railway track 26 and the signal detection unit 44 monitors a characteristic of this track signal, whether it is the presence of the signal, the strength of the signal, or the signature of the signal. As described above, the track signal can be introduced into the rail by the locomotive 24 that is doing the signal monitoring, by another locomotive 24 or even by the monitoring entity 22.

[050] At step 62, the signal detection unit 44 continuously monitors the characteristic of the track signal. In the case where the characteristic of the track signal being monitored has not changed, the receiver 32 and the signal detection unit 44 continue to monitor the track signal.

[051] In the case where the signal detection unit 44 detects that the characteristic of the signal being received at receiver 32 has changed, whether that is the presence of the signal, the strength of the signal or the signature of the signal, the signal detection unit 44 proceeds to step 64 where it generates a signal indicative of a potentially broken rail. The generated signal can include an indication as to whether it the broken rail was detected in front of the locomotive or behind the locomotive. The signal detection unit 44 then passes this signal to the transceiver 42, such that at step 66, the transceiver 42 transmits the signal indicative of a potential broken rail to the monitoring entity 22.

[052] The signal indicative of a potentially broken rail can include a variety of information. In accordance with a first non-limiting example of implementation, the signal indicative of a potential broken rail advises the monitoring entity 22 of the portion of the railway track 26 it was surveying, and thus in which portion of track there could be a broken rail. For the sake of example, let us assume that locomotive 24b in Figure 2 has issued a signal to the monitoring entity 22 indicative of a potential broken rail.

[053] In accordance with this example, the locomotive 24b includes a map of the railway track 26 over which it is travelling. The map may include the location of the shunts 28a, 28b and 28c on the track, as well as the location of the switches and any other relevant rail information. This map may be stored in the memory unit 48, for example. The map may also be downloaded to the locomotive 24b prior to its journey, or the map can be transmitted to the locomotive 24b from the monitoring entity 22. In such a scenario, as the train passes into a region covered by a different monitoring entity 22, it is operative to receive a new map from the new monitoring entity 22.

[054] In accordance with this example, the monitoring entity 22 is operative to transmit to the locomotive 24b information associated with the railway track on which it is travelling. For example, the monitoring entity 22 may transmit information to the locomotive 24b indicative of the location of shunts, the location of other locomotives travelling on the track 26, or the location of other items, such as switches located on the track 26.

[055] Therefore, as the locomotive 24b travels over the railway track 26, it receives location information from the track-side transponders (or GPS), such that it is able to confirm/determine its position on the map, and also receives information indicative of the position of upcoming shunts and other locomotives 24 from the monitoring entity 22. This information is then stored in the memory unit 48 of the processing unit 40. Based on all this information the locomotive 24b has a complete picture of the things

shunting the track 26 both ahead of it and behind it. As such, the locomotive 24b can accurately determine the portion of the railroad track 26 that it is surveying, at any point in time.

5 **[056]** Keeping with the example of locomotive 24b, and assuming that the locomotive 24b is positioned in the location as shown in Figure 2, based on the information received from the track-side transponders, and the information received from the monitoring entity 22, the locomotive 24b would know that it is positioned between shunt 28b and shunt 28c, and that locomotive 24c is positioned between it
10 and the shunt 28c. On the basis of this information, the processing unit 40 would be able to determine that it is surveying the portion of railway track 26 between its rear axle and the shunt 28b, and the portion of railway track 26 between its front axle and the rear axle of locomotive 24c. As such, in the case where the locomotive 24b detects a change in the signal characteristic being monitored, the signal indicative of a
15 potential broken rail that it transmits to the monitoring entity 22 is indicative that there is a potential broken rail in the portion of railway track between its front axle and the rear axle of the locomotive 24c.

20 **[057]** In accordance with a second non-limiting example of implementation, the signal indicative of a potential broken rail that is sent from the locomotive 24b to the monitoring entity 22 may simply be indicative of a change in the characteristic of the track signal being monitored. As mentioned above, this change in characteristic may be the absence of the track signal, a decrease in signal strength or a change in signal signature, among other possibilities. In such a situation, the processing performed to
25 determine the portion of railway track being surveyed by the locomotive 24b is performed at the monitoring entity 22 instead of at the locomotive 24b.

30 **[058]** In such an embodiment, the transceiver 42 shown in Figure 5 may simply be a transmitter, since the locomotive 24b does not need to receive any railway track information from the monitoring entity 22. Instead, the locomotive 24b is only aware of its current location information, which is continually sent to the monitoring entity

22, and that it has detected a change in the track signal that is circulating in the railway track 26. The locomotive 24b is not aware of the positioning of other locomotives, or the positioning of the shunts on the railway track 26. Therefore, the locomotive 24b is not aware of the portion of the railway track that it is surveying.

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[059] In such an embodiment, upon receipt of the signal indicative of a potential broken rail from the locomotive 24b, the monitoring entity 22 is operative for processing the location information from locomotive 24b in combination with the location information of the other locomotives 24a and 24c, and the location
10 information associated with the shunts and switches located on the railway track 26. Based on this information, the monitoring entity 22 is operative to determine the portion of railway track 26 that was being surveyed by the locomotive 24b at the time the locomotive 24b sent the signal indicative of the potential broken rail.

15 [060] For the sake of example, let us assume that the locomotive 24b sends a signal indicative of a potential broken rail when it is in the position on the railway track shown in Figure 2. In such a case, the monitoring entity 22 knows the position of locomotive 24b, and knows that locomotive 24c is positioned between locomotive 24b and the shunt 28b. Based on this information, the monitoring entity 22 can
20 determine that the portion of railway track being surveyed by the locomotive 24b at the time it sent the signal indicative of the potential broken rail, is the portion of railway track 26 between the front axle of locomotive 24b, and the rear axle of locomotive 24c. As such, the monitoring entity 22 is operative for determining the portion of railway track 26 in which there is a broken rail.

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[061] Regardless of whether the determination of the portion of railroad track 26 being surveyed by the locomotive 24b is performed by the locomotive 24b, or the monitoring entity 22, upon receipt of a signal indicative of a potential break in the rail, the monitoring entity 22 is operative to determine that there is a broken rail in a
30 portion of railway track 26 in its region. More specifically, based on the signals received from all the locomotives 24a, 24b and 24c travelling along the railway track

26, the monitoring entity 22 is operative for determining a complete picture of the condition of the railway track 26. Upon detection of a broken rail within its region, the monitoring entity 22 may forward this information to a central control unit (not shown) that is in communication with multiple monitoring entities 22, such that the control unit can determine how to proceed. Alternatively, the monitoring entity 22 may issue a signal to advise railway maintenance workers that there is a potential broken rail in a certain portion of the railway track. In this manner, the maintenance workers can go to the specific section of railway track identified and can then find the location of the broken rail, and repair it.

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[062] As such, the monitoring entity 22 is operative for detecting broken rails in the region of railway track in large part on the basis of signals received from the locomotives 24a, 24b and 24c. However, as shown in Figure 6, the monitoring entity 22 may also use conventional detectors 64 for detecting broken rails, in combination with the methods described above. The conventional methods of detecting a broken rail may be used in portions of the railway track that include difficult physical layouts, such as switches, that may cause a locomotive to provide a false broken rail reading. For example, referring to Figure 2, the monitoring entity 22 may use the traditional broken rail detection techniques to detect broken rails in the portion of railway track 26 between shunt 28c and 28d. As described in the background of the invention, the traditional method of broken rail detection involve a transmitter and a receiver that are either connected directly to the monitoring entity 22, or that are connected to wayside equipment that is then in turn connected to the monitoring entity 22.

[063] In a first embodiment, as the locomotive 24c passes the shunt 28c, the monitoring entity 22 may issue a signal to the locomotive 24c advising the locomotive not to perform broken rail detection in this region. Alternatively, in the case where the locomotive 24c does continue to perform broken rail detection in this region, when the monitoring entity 22 receives a signal indicative of a broken rail from the locomotive 24c, the monitoring entity 22 knows that there is a railway switch within this section that may cause the locomotive 24c to detect a false broken rail. Once the locomotive

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24c has passed outside of this section, the monitoring entity 22 would use the conventional equipment 64 to determine whether there is in fact a broken rail within the section. In this manner, the processing unit 23 of the monitoring entity 22 may have to filter out false detection readings and combine information received from
5 multiple different sources, i.e. more than one locomotive, or a locomotive in combination with conventional techniques, in order to determine whether there is a broken rail in a portion of its railway track 26.

[064] In addition, while the method of performing broken rail detection using the
10 locomotives works well while there are many locomotives travelling on the railway track 26, in the case where there are no locomotives travelling along the railway track 26, the monitoring entity 22 may choose to perform broken rail detection using the traditional method, which can easily survey large sections of railway track 26 between shunts.

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[065] Those skilled in the art should appreciate that in some embodiments of the invention, all or part of the functionality previously described herein with respect to the locomotive 24, and the monitoring entity 22, may be implemented as pre-programmed hardware or firmware elements (e.g., application specific integrated
20 circuits (ASICs), electrically erasable programmable read-only memories (EEPROMs), etc.) or other related components.

[066] In other embodiments of the invention, all or part of the functionality of the locomotives 24, and the monitoring entity 22 may be implemented as software
25 consisting of a series of instructions for execution by a computing unit. The series of instructions could be stored on a medium which is fixed, tangible and readable directly by the computing unit (e.g., removable diskette, CD-ROM, ROM, PROM, EEPROM or fixed disk) or the instructions could be stored remotely but transmittable to the computing unit via a modem or other interface device (e.g., a communications
30 adapter) connected to a network over a transmission medium. The transmission medium may be either a tangible medium (e.g., optical or analog communications

lines) or a medium implemented using wireless techniques (e.g., microwave, infrared or other transmission schemes).

5 [067] As shown in Figure 5, the processing unit 40 of the locomotive 24 includes a memory 48 connected to both the signal generation unit 46 and the signal detection unit 44 by a communication bus. The memory 48 may include data and program instructions. The processing unit 40 is adapted to process the data and the program instructions in order to implement the method of performing broken rail detection described in the specification and depicted in the drawings.

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[068] Although the present invention has been described in considerable detail with reference to certain preferred embodiments thereof, variations and refinements are possible without departing from the spirit of the invention. Therefore, the scope of the invention should be limited only by the appended claims and their equivalents.

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CLAIMS:

1. A locomotive for travelling on a railway track, said locomotive comprising:
 - a receiver operative for receiving a track signal that is circulating in the railway track;
 - a processing unit in communication with said receiver, said processing unit being operative for:
 - i) detecting a characteristic of the track signal; and
 - ii) generating a signal indicative of a potential broken rail in response to a change in the characteristic of the track signal circulating in the railway track.
2. A locomotive as defined in claim 1, wherein the characteristic is the presence of the track signal circulating in the railway track.
3. A locomotive as defined in claim 1, wherein the characteristic is the strength of the track signal circulating in the railway track.
4. A locomotive as defined in claim 1, wherein the characteristic is the signature of the track signal circulating in the railway track.
5. A locomotive as defined in claim 1, further comprising a transmitter, said transmitter being operative for transmitting the track signal into the railway track.
6. A locomotive as defined in claim 5, wherein the track signal is a low frequency signal.
7. A locomotive as defined in claim 6, wherein the track signal is an audio signal.

8. A locomotive as defined in claim 5, wherein said processing unit includes a signal generating unit in communication with said transmitter, said signal generating unit being operative for selecting a frequency of the track signal.
- 5 9. A locomotive as defined in claim 8, wherein said receiver is operative for selecting a frequency of the track signals being detected.
10. A locomotive as defined in claim 1, further comprising a wireless transmitter, said wireless transmitter being operative for transmitting said signal indicative of a potential broken rail to a monitoring entity.
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11. A locomotive as defined in claim 10, wherein said wireless transmitter is operative for transmitting information indicative of a location of said locomotive to the monitoring entity.
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12. A locomotive as defined in claim 10, further comprising a wireless receiver for receiving signals from the monitoring entity.
13. A locomotive as defined in claim 12, wherein said wireless receiver is operative for receiving railway track information from the monitoring entity.
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14. A locomotive as defined in claim 13, wherein said railway track information includes information indicative of at least one of a location of a shunt on the railway track, a location of another locomotive on the railway track and a position of a switch on the railway track.
- 25
15. A locomotive as defined in claim 10, wherein said signal indicative of a potential broken rail includes information associated with a portion of track surveyed by said locomotive.
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16. A locomotive as defined in claim 12, wherein said wireless transmitter and said wireless receiver are operative for communication with the monitoring entity over an RF communication link.
- 5 17. A system for performing broken rail detection on a railway track, said system comprising:
- at least one locomotive comprising:
 - i) a receiver operative for receiving a track signal that is circulating in the railway track;
 - 10 ii) a processing unit in communication with said receiver, said processing unit being operative for:
 - i) detecting a characteristic of the track signal; and
 - ii) generating a signal indicative of a potential broken rail in response to a change in the characteristic of the track signal circulating in the railway track;
 - 15 iii) a wireless transmitter operative for transmitting said signal indicative of a potential broken rail over a wireless communication link;
 - a monitoring entity comprising:
 - 20 i) a receiver operative for receiving said signal indicative of a potential broken rail from said at least one locomotive;
 - ii) a processing unit operative for detecting a broken rail at least in part on the basis of said signal indicative of a potential broken rail from said at least one locomotive.
- 25 18. A system as defined in claim 17, wherein the characteristic is the presence of the track signal circulating in the railway track.
19. A system as defined in claim 17, wherein the characteristic is the strength of the track signal circulating in the railway track.
- 30

20. A system as defined in claim 17, wherein the characteristic is the signature of the track signal circulating in the railway track.
21. A system as defined in claim 17, wherein said at least one locomotive further
5 comprises a transmitter operative for transmitting the track signal into the railway track.
22. A system as defined in claim 17, wherein said wireless transmitter is further operative for transmitting a signal indicative of a location of said locomotive to
10 said monitoring entity.
23. A system as defined in claim 17, wherein said locomotive further comprises a wireless receiver for receiving signals from said monitoring entity.
- 15 24. A system as defined in claim 23, wherein said wireless receiver is operative for receiving railway track information from said monitoring entity.
25. A system as defined in claim 24, wherein said railway track information includes information indicative of at least one of a location of a shunt on the
20 railway track, a location of another locomotive on the railway track and a position of a switch on the railway track.
26. A system as defined in claim 17, wherein said signal indicative of a potential broken rail includes information associated with a portion of track surveyed by
25 said locomotive.
27. A system as defined in claim 17, wherein upon detection of a broken rail, said monitoring entity is operative for initiating an action.
- 30 28. A system as defined in claim 27, wherein said action is sending a repair team to repair the broken rail.

29. A monitoring entity suitable for performing broken rail detection, said monitoring entity comprising:
- a wireless receiver operative for receiving a signal from at least one locomotive, said signal being indicative of a potential broken rail;
 - a processing unit operative for detecting a broken rail at least in part on the basis of said signal from said at least one locomotive.
30. A monitoring entity as defined in claim 29, wherein said signal indicative of a potential broken rail includes information indicative of a portion of track surveyed by the at least one locomotive.
31. An monitoring entity as defined in claim 29, further comprising a wireless transmitter, said wireless transmitter being operative for transmitting railway track information to the at least one locomotive.
32. An monitoring entity as defined in claim 31, wherein said railway track information includes information indicative of at least one of a location of a shunt on the railway track, a location of a locomotive on the railway track and a position of a switch on the railway track.
33. A system for performing broken rail detection, said system comprising:
- receiving means for mounting onboard a locomotive that is travelling on a railway track, said receiving means being operative for receiving a track signal that is circulating in the railway track;
 - processing means in communication with said receiving means, said processing means being operative for:
 - i) detecting a characteristic of the track signal; and
 - ii) generating a signal indicative of a potential broken rail in response to a change in the characteristic of the track signal circulating in the railway track.