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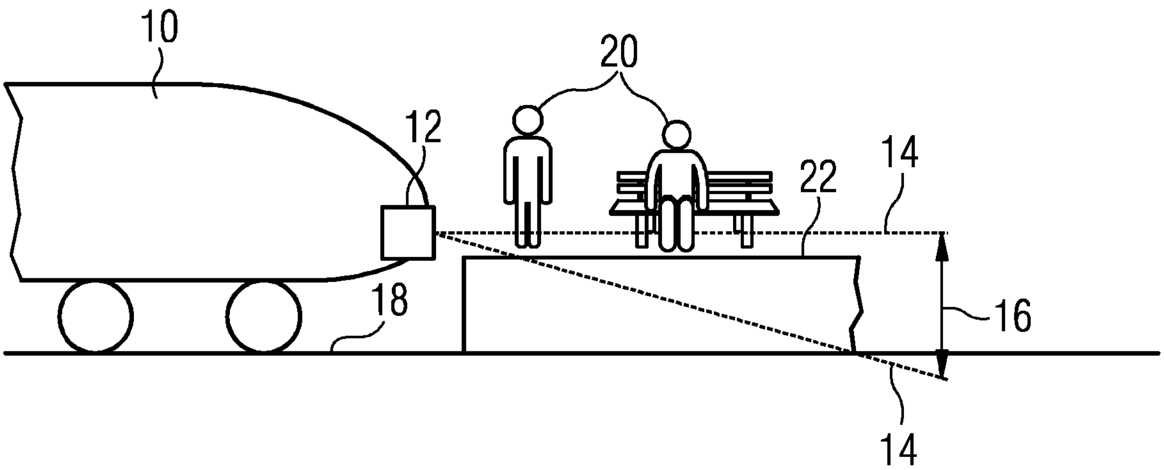
(54) MOVING VEHICLE WARNING SYSTEM

(57) A moving vehicle alarm system arranged to be mounted to a vehicle, with reduced levels of sound perceptible outside of an area of protection.

FIG 1



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Description

[0001] Low friction between train wheels and the tracks over which they run is beneficial for the transport efficiency of trains when up to speed. However, low friction also means that trains can take considerable distances to stop. Furthermore, a train cannot take evasive action to avoid incidents as its course is fixed and determined by the tracks and a train driver can typically only see as far ahead as the view from their cab will allow. Therefore wherever possible, persons are normally prevented from being on tracks where trains are running. If things do go wrong and a train is approaching a person on the track, the driver has little they can do except apply the emergency brakes and use the horn on the train. Both of these measures rely on the train driver's reaction times. The train continues on until the end of its, potentially large, braking distance, meanwhile persons on the track have hopefully taken up positions of safety.

[0002] However, any persons on the track may not be paying attention or may not be able to see or hear a train approaching and then may not be able to take appropriate action to move out of the way of the train in time to avoid a collision. Workers in particular, may be surprised by an unexpected train or may be pre-occupied and not notice it approaching.

[0003] Advances in train technology have made them quieter, and so an approaching train may not be heard as readily as in the past by persons on or near the track. Improvements in rail technology, such as continuously welded rail, also contribute to this by minimising vibrations and noise that might otherwise be felt or heard by persons near, or in contact with the rails.

[0004] Such difficulties are most prevalent when workers are using machinery or are in the presence of suddenly-moving or slow-moving vehicles, such as during engineering works or during shunting manoeuvres. In all cases, it is imperative to alert and provide any persons in danger with as much warning as possible so that they may take up a position of safety. The proposed invention thus provides for a solution to mitigate the dangers faced by persons who are trackside.

[0005] Due to quieter-running trains, it may be insufficient to rely on the inherent noise made by an approaching train, and reliance on a driver's reaction time reduces reliability of a warning, and reduces the useful warning time to a person in danger on or near the tracks.

[0006] Several conventional "safe systems of work" exist to enable work to be carried out on the railway, and to ensure that moving rolling stock is kept away from track workers, or at least to ensure that track workers are given a useful degree of warning of approaching rolling stock.

[0007] In the UK, such "safe systems of work" include:

1. Safeguarded - all lines are blocked
2. Fenced - a fence is put up between the site of work and nearest open line
3. Equipment warning:
    a. Automatic Track Warning System (ATWS): using lights and sirens and/or a personal warning device
    b. Train Operated Warning System (TOWS): using sirens
    c. Lookout Operated Warning System (LOWS): using lights and sirens and/or a personal warning device
4. Lookout warning - a nominated person warns of oncoming rail vehicles using a horn, whistle or touch.
5. Site Warden warning - a space is provided between the site of work and nearest open line and a 'Site Warden' watches everyone working to ensure they remain within the safe area

[0008] Safeguarded ("1") and fenced ("2") arrangements rely on the signaller, and interlocking arrangements for preventing trains from entering certain lines.

[0009] Fenced ("2") and equipment warning ("3") require the correct setup of equipment and all require the workers to work on the correct area of track and that said works have been planned with sufficient access and working limits to the work site. Such methods rely on human interaction to be correctly enforced.

[0010] Furthermore, all such conventional track warning systems rely on being correctly set up and are even then only protective of specific sections of track.

[0011] None of the "safe systems of work" described above will provide any protection to trespassers on the railway track, or persons legitimately using level crossings.

[0012] Conventional train horns, operated by a driver, can warn persons in danger, but have limitations, in particular that they need to be operated by a driver, and are typically activated either at fixed locations, or in response to the driver visually identifying a hazard on the track. Furthermore, conventional train horns may not be rated to output sound at a high enough volume for workers to be able to distinguish the sound above the noise levels of running machinery (https://www.gov.uk/raib-reports/report-1-2020-track-workers-struck-by-a-train-at-margam).

[0013] The present invention accordingly seeks to alleviate some of the limitations of conventional warning systems.

[0014] The present invention accordingly seeks to provide an arrangement that would be mounted to a vehicle, such as a rail vehicle, and may therefore provide a moving area of protection ahead of the vehicle. In the following description, this area of protection will be referred to as an Extended Protection Region (EPR).

[0015] Such arrangement would allow protection of the tracks ahead of a moving rail vehicle, wherever the rail vehicle can travel. Protection may thereby be accorded to trespassers, workers in places where they should not be, workers where a rail vehicle has entered section of track incorrectly and workers wherever engineering vehicles are in use.

[0016] The present invention therefore provides methods and apparatus as defined in the appended claims.

[0017] The above, and further, objects, characteristics and advantages of the present invention will become more apparent from the following description of certain embodiments, by way of examples only, in conjunction with the accompanying drawings, wherein:

Figs. 1 and 2 illustrate highly directional speakers generating an alarm signal, according to operation of an embodiment of the present invention;
Fig. 3 illustrates potential alarm signal focus directions, defined using railway parameters and UK average heights for persons;
Fig. 4 is a schematic diagram of a train-mounted alarm system in accordance with an embodiment of the present invention The present invention provides methods and apparatus for providing warning to persons in the path of a moving vehicle;
Fig. 5 is a chart illustrating the requirements of the sound pressure used in embodiments in accordance with the present invention in more detail; and
Fig. 6 is a schematic diagram illustrating the collimated beam generated by embodiments of the present invention in more detail.

[0018] The present description may use a number of acronyms or terms as follows:

Rail vehicle - any vehicle which may use railway networks including, but not limited to, passenger trains, freight trains and road-rail vehicles;
EPR - Extended Protection Region - the region protected by a system of the present invention within which any persons would be alerted to a vehicle's presence and outside of which the alarm will be minimised;
NOM - Normal Operation Mode - When a rail vehicle is moving, or able to move, according to the particular embodiment, the alarm system of the present invention is active and focussed on the EPR with minimal effect outside the EPR;
EOM - Emergency Operation Mode - Enhanced operation (increased intensity and EPR area size at the cost of alarming rail users not in danger), as may be triggered in an emergency situation;
AOM - Active Operation Mode - NOM plus added adjustment of alarm parameters depending on the situation;
Alarm signature - an underlying pattern or feature that is part of the alarm, for example a pattern of flashing lights or a recognisable sound such as fire alarms or sirens;
Phased array - an arrangement comprising an array of transducers which may be triggered in sequence such that the resulting combined focus of the array as a whole is shifted;
x-y plane - defined as a plane through which the cab of a rail vehicle would travel, perpendicular to the ground and to the rails;
Persons not in danger - anyone that would not be involved in an accident or near miss if the rail vehicle being considered continues normally. This includes people outside of the railway boundaries;
Position of safety - a position where a person is not in danger.

[0019] The methods and apparatus of the present invention provide a moving vehicle warning which is not reliant on human reaction times to be operated.

[0020] The warning is continuously active after being automatically triggered, whenever the vehicle is in motion; or is capable of being in motion, according to the particular embodiment.

[0021] The warning should be sufficiently perceptible to effectively warn those with ear defenders, such as track workers, and should be effective even in the presence of large amounts of ambient noise.

[0022] The warning should be effective over a long distance, yet should provide minimal disruption to persons outside of an area of danger, in that only a much reduced level of sound or other alarm characteristic is perceptible outside of the area of danger.

[0023] Preferably, an easily recognisable alarm signature is employed, that should only be audible to persons in danger. Rail workers, and the wider general public, may be trained to recognise the alarm signature, allowing workers and the general public to be trained to have a clear procedure to follow upon hearing the alarm.

[0024] Alarm sounds should be directional, such that persons in danger hearing the alarm sounds may be made aware of the direction and severity of a situation more immediately than compared to omnidirectional alarms. This may allow increased chances for the person in danger to reach a position of safety.

[0025] According to the present invention, a warning device is introduced, which is, or may be, attached to a vehicle, and is directional and continuously active while the vehicle is in motion. Optionally, the warning device may also be continuously active whenever the vehicle is capable of motion. Such arrangements provide a protection region extending in front of a moving vehicle, defining an area of protection, which may be known herein as an Extended Protection Region (EPR).

[0026] An EPR is defined as the region around a rail vehicle which is protected by the system of the present invention. Inside the EPR, persons would be alerted to the train's presence and approach, while outside of the EPR the sound of the alarm is minimised.

[0027] By providing a continuously-active, directional alarm, the arrangements of the present invention serve to both maximise the warning provided to persons in danger and to minimise the unnecessary alarming of persons not in danger, such as passengers at a station; persons waiting at a level crossing (rail/road crossing); persons inside a rail vehicle running on another line; or residents living near to the railway.

[0028] A first embodiment of the invention comprises highly directional speakers retrofitted to the front of a train and arranged to focus emitted sound on an area ahead of the train, the area covering the tracks on which the train may run, and a protection region either side of such tracks. Those areas cover the locations where persons would be in danger from the approach of the train.

[0029] A further embodiment of the invention includes the relevant hardware designed and built into vehicles at manufacture.

[0030] Another embodiment provides a removable version that could be retrofitted temporarily to a vehicle. For example, a temporary version could be affixed to road-rail vehicles not otherwise provided with protection systems, which would then increase protection of persons working around them.

[0031] Figs. 1-3 illustrate the desired effects of the alarm according to the present invention. Preferably, the present invention provides an alarm sound to persons within the EPR, but generates a minimal level of sound outside of the EPR.

[0032] As illustrated in Fig. 1, an approaching train 10 carries an alarm system 12 according to an embodiment of the present invention. Highly directional speakers may be employed as the sound source. The alarm system is shown generating an alarm signal in directions 14, defined as a radiating beam, into an EPR 16 at the level of the tracks 18, for perception by any persons on the tracks 18, but minimally perceptible by people 20 waiting on an adjacent platform 22 at a station.

[0033] As illustrated in Fig. 2, the alarm system 12 is shown generating an alarm signal into the EPR 16 at the level of the tracks 18, for perception by any persons on the tracks 18, but minimally perceptible by people 23 on a passing train 24.

[0034] Fig. 3 illustrates an example of alarm signal focus directions, defined using railway parameters and UK average heights for persons. In the illustrated example, the alarm sound is transmitted as a beam in directions 14 of rectangular cross-section, as may be expected if produced by a rectangular phased array of emitters. As illustrated in Fig. 3, the dimensions of the beam directions 14 are preferably determined to cover core directions 26, which would include the position of the head of the vast majority of the relevant population, in sitting or standing positions. The upper extent of the core directions 26 corresponds to the standing height of males at 95th percentile, while the lower extent of the core directions 26 corresponds to the seated height of females at 5th percentile. Width-wise, the width of the core directions 26 corresponds to the separation of the rails. Thus, the core directions 26 include the likely position of the head of a person in danger. The core directions 26 are expanded to radiating beam directions 14 to include a safety factor. Persons whose heads are slightly outside the core directions 26 may still be in danger from the approaching vehicle, and must be alerted to the approach of the vehicle by perception of the alarm signal generated by the alarm system 12. Therefore, the radiating beam directions 14 are extended beyond the core directions 26 to provide alarm signals to the EPR 16, while minimising the amplitude of alarm signal which enters regions outside of the radiating beam directions 14, for example, onto the platform at the likely head height of waiting passengers, as illustrated in Fig. 1; or at the likely head height of passengers on a passing train, as illustrated in Fig. 2.

[0035] In Fig. 3 are listed various heights which may be used to determine the radiating beam directions 14.

[0036] A more complex embodiment of the invention may have different modes of operation. A Normal Operation Mode (NOM) may be defined as a mode of operation in which the alarm is focused on the EPR 16 and such that the alarm sounds extend minimally outside of the EPR 16. This represents a normal default mode of operation which would be continuously active whenever a rail vehicle was moving, or capable of moving. This NOM mode would minimise annoyance to other users of the railway, such as passengers at stations etc. and crucially would allow for the system to be continuously active, without the need for driver input. Such an embodiment would ensure that persons entering the EPR would always be warned instantly. Human reaction time in triggering a warning signal is therefore not a factor as the EPR is always active.

[0037] Although an advantage of the present invention is that it does not rely on human interaction, it may be advantageous in some embodiments to provide for a manual override by a driver: for example, where a driver may observe people in locations outside of the EPR, but where the driver considers that those persons may enter a dangerous location. A manual override may be applied to shift the alarm focus or activate EOM in some cases to expand the protection region such that the people observed by the driver can perceive an alarm sound generated by the system of the present invention.

[0038] Alternatively, or additionally, an Emergency Operation Mode (EOM) may be available, which would be automatically activated or manually by human intervention, either locally, such as by the driver, or remotely, such as by the signaller, in cases of emergency such as where persons are detected just outside of the EPR 16 but are in danger of entering it; or where persons are observed to be unresponsive to a normal mode alarm configuration.

[0039] Automatic operation may be activated in response to a detected object on the line, for example by computer vision, such as may be captured by an infrared camera. Suitable arrangements for such embodiments may be found described in a co-pending UK patent application GB 2103661.1, filed of even date herewith.

[0040] In an example embodiment, when triggered, EOM would increase the size of the EPR 16 and the intensity of the alarm. EOM would improve the chance of persons on or near the line being warned, at the cost of potentially disrupting people in safe positions such as those outside the railway boundaries or passengers on platforms. For that reason, EOM is not intended to be used continuously.

[0041] Furthermore, or alternatively, an Active Operation Mode (AOM) may be provided, the AOM could allow for certain alarm parameters to be adjusted in real time. Such alarm parameters may include sound intensity, EPR size, alarm focus.

[0042] In a particular embodiment, operation of AOM adjusts the power or range of the alarm depending on the vehicle's speed. In this case the size of the EPR 16 could be reduced at low speeds and increased at high speeds, by adjusting the directions 14 and/or adjusting the intensity of the generated sound. This may be beneficial when slowing down to take a corner, as reducing the range of the alarm sound would mean that the alarm sound extends less onto other lines or away from the railway. It may also be beneficial when shunting at low speeds. Similarly, reduction in alarm range commensurate with reduction in speed of the train may also be beneficial when using engineering vehicles during a possession of the railway as it would allow workers to work safely on the line when a vehicle is static or slowly moving but would warn workers with sufficient warning if the vehicle started to approach where they are working. By reducing the range of the alarm by reducing the EPR, alarms are not generated over an excessive distance with regard to the danger posed by a slowly-moving train.

[0043] In some embodiments, the shape of the track ahead of the train may be taken into account. In cases where the track ahead includes one or more sets of points, the setting of the points, or the intended path of the train, may be used to calculate the appropriate shape of track to be considered. Suitable arrangements for deriving the shape of the track ahead of the train are discussed in co-pending UK patent application GB 2103661.1, filed of even date herewith.

[0044] A highly directional speaker, used to deliver alarm sounds according to an embodiment of the invention, may be adjusted so that alarm sounds are projected in the direction of the track ahead of the train, or the intended path of the train, even if that does not extend in a "straight ahead" orientation in front of the train.

[0045] An embodiment of the invention would alter the distance and/or focus of the alarm sound generated by the highly directional speaker to follow the curvature of the track, or the intended path of the train and be directed at a certain defined position on the track ahead of the train.

[0046] For example, methods listed below could be used in combination or alone to estimate track layout ahead of a vehicle in order to optimally focus the alarm beam to protect persons that might be in positions of danger ahead of the vehicle.

[0047] Methods may include: Computer vision of image feed ahead of the vehicle, as described in co-pending UK patent application GB 2103661.1, filed of even date herewith; Route network map data may be stored aboard the vehicle and used with information enabling the vehicle to determine its location within the route network, and, knowing the vehicle's current position, a track layout ahead of the vehicle may be determined from the route network map data, providing direction on where to focus the alarm beam of the present invention at any given location along route.

[0048] A current position of the vehicle on the route network may be obtained, for example, from one or more of the following methods: from GPS data; from identifiers read or received from trackside balises or nodes; commands transmitted from trackside nodes for focussing the alarm beam of the present invention through an upcoming section of track; a predicted itinerary of the vehicle will provide information on the vehicle's intended route such as passing through points in either normal or reverse states, for example; data received from or updated by communication from passing vehicles, or from a wireless network or other data sources; sensors carried aboard the vehicle may detect route features such as cornering radius, gradient, which may be matched to corresponding features in the route network map data to determine a current location of the vehicle; or manual human override and control, which may be useful in case situations arise in which a driver or other user determines that the alarm beam of the present invention should be directed in a certain direction, which is not the direction determined by any of the other arrangements provided.

[0049] In the case of using stored route network map data, the map data could be updated by vehicles that have previously passed through area part of the route network; or may be updated by commands sent from a control centre. This could include changes based on new temporary speed restrictions imposed or based on expert input. For example, in the case of preparing a new route for focussing of the alarm beam of the present invention, a person with the relevant expertise could pass through the area in a vehicle during a calibration exercise to manually aim the focus of the alarm beam of the present invention the vehicle passes along a route. This data could then be saved to the route map data and communicated to a central data store, and could be copied into any other vehicles with maps. In subsequent journeys made by this or other vehicles, the vehicles could then look up the beam storing information initially determined by the expert user and use it to direct the beam.

[0050] As described above, certain embodiments of the present invention provides a moving vehicle alarm system which is connected to receive data from other systems, such data indicating features of the track ahead of the railway vehicle. The system operates to evaluate a condition of the track ahead, from the received data. One of the other systems may include a network map. Another of the systems may provide an indication of a current position of the rail vehicle.

[0051] The positions to focus may be calculated by computer simulation of the network and this information may then be provided to the route network map data or live to the system of the present invention.

[0052] Temporary Speed Restrictions or other alterations to the expected track layout, information on these could be received at the train using radio communications for example by using GSMR cab radio, and stored in the memory.

[0053] While the alarm signal of the present invention is largely described herein as an audible signal, embodiments of the present invention could employ a number of different alarm signal generator elements, for example elements providing highly directional alarm signals by sound, vibration or light emission.

[0054] Recognisable signatures may be incorporated into the alarm signals, whether they be audible, vibration or light signals. For example, a signature of timing and intensity similar to that of a fire alarm or an emergency services siren could be used. This may evidently be applied to audible signals, but equivalent patterns of timing and intensity may be used for vibration or light signals or other aspects of the alarm. The signature, that is, the pattern of timing and intensity, could aid in warning persons in danger of the type of danger they are in and hence this would help to trigger an appropriate response reducing the time that a person in danger needs to recognise and understand the meaning of the alarm signal received.

[0055] This response could be learned, for example, workers would be trained to recognise specific alarm signatures and then taught the appropriate procedures to follow in order to maximise their chances of survival. With practice, this response could become automatic, similar to people's reaction in response to fire alarm sounds.

[0056] In more specific embodiments, arrangements may be made to convey direction and urgency of danger to a person in danger. For example, a person in danger may have their back to an approaching rail vehicle. If the rail vehicle is fitted with an alarm device according to the present invention, emitting an appropriate alarm signature, the person in danger may be able to rapidly ascertain that the alarm indicates the approach of a rail vehicle; and the person in danger may be able to ascertain the direction that the rail vehicle is approaching from, reducing the time to assess danger and allowing the person in danger to move to a position of safety earlier. As the vehicle approaches, the alarm signature as perceived by the person in danger may also change, for example increasing in intensity, assisting the person in danger in evaluating the type and urgency of the danger.

[0057] In certain embodiments, signatures could be overlaid, for example, there could be a high pitch component to the alarm sound and a low pitch component. The different components could serve different purposes, for example the high pitch could be designed to be most effective at transmitting a sound similar to a fire alarm through the air as discussed. However, the low pitch component could be designed to maximise distance travelled and could travel best through the rails, potentially being registered as vibrations and through touch. For a person on the track some distance away, they may first notice a vibration in the rails, which may attract their attention and may be sufficient warning that a rail vehicle is approaching. If the person in danger fails to react to the vibration in the rails, for any reason, the rail vehicle will approach closer to the person in danger. The person in danger may then hear the low pitch component audibly. That component, like the rail vibrations, may carry an alarm signature such as variations in timing or intensity. The person in danger may recognise the alarm signature and may respond by moving out of danger. On the other hand, if the person in danger fails to react to the low pitch audible alarm, for any reason, the rail vehicle will approach closer to the person in danger. The person in danger may then hear the high pitch component audibly. The high pitch component will preferably carry an alarm signature, for example as variations in timing and intensity. The high pitch component is preferably an intense sound, and will be accompanied by the low pitch sound and the rail vibrations, respectively described above, meaning that the person in danger should be able to perceive the alarm and remove themselves from their position of danger before the arrival of the rail vehicle.

[0058] Some embodiments of the present invention may provide a vibratory aspect directly through the ground or rails. Such vibratory aspect may be particularly useful to alert those that cannot hear an audible alarm, for example those working with ear defenders or in an area of excessive ambient noise. This vibratory alarm component would be identifiable through touch or through vibrations passing through solid infrastructure. Furthermore, the vibratory alarm component could be used to warn workers in areas further ahead due to lower attenuation and higher speed of vibration in the rails than sound in the air. Providing a vibratory warning through the rails could also allow for warnings to extend beyond corners, which is difficult for sound alarms, and impossible for visual alarms, so providing early warning for areas separated from an approaching vehicle with blind bends. A worker working on the tracks and touching them, or in a rail vehicle touching the tracks, would be particularly protected by this embodiment.

[0059] In order to prevent damage to rails, as discussed previously, a vibratory signature could be chosen that is identifiable so that the intensity can be reduced while maintaining an acceptable chance of detection by a person in danger. This would keep vibrations small, to minimise the risk of damage to the rail tracks. It may also be possible to emit a sound directly through the rails, such as the low pitch component discussed above, as an alternative to larger-amplitude mechanical vibrations and hence mitigating the railway damage risk. However, in the case of emergency EOM operation, larger vibrations through the rails could also be applied, to improve the chance that a person in danger will perceive the alarm and react in good time to move from the position of danger into a position of safety.

[0060] A component of the alarm could be visible, based on appropriate lighting, for example a flashing light to illuminate far ahead. Any light source used in such a role preferably has a highly directional light output, to avoid unnecessarily illuminating nearby areas and alerting persons who are not in danger. The light source could, for example, be activated only in Emergency EOM running and would not be active normally. The signature of the alarm output components could also match - for example the light source may be arranged to flash in accordance with an alarm signature of an audible alarm, if desired.

[0061] The present invention preferably utilises a highly directional speaker system, which enables a specific area to be targeted where persons in danger would most likely be located. Use of a highly directional speaker system would minimise noise generated by the alarm of the present invention outside the EPR. Highly directional speakers would also allow for greater sound intensity in the specific area, for a given power input, than would be provided with an omnidirectional speaker provided with the same amount of input power. Accordingly, the highly directional aspect to the alarm would allow for an area far ahead of a train to be protected and included within the EPR, as well as limiting disruption to the surrounding areas. This would allow the previously discussed NOM to be achieved, where the alarm is continuously active when the train is moving, and workers far ahead can be automatically warned without relying on the reaction time of the driver. This is beneficial to persons in danger, as it would allow them the greatest amount of warning and would increase their chance of reaching a position of safety. Highly directional speakers would allow for further range, no dependency on driver reaction time and minimal disruption to persons not in danger, and hence are improvements over traditional rail vehicle mounted horns, at least in these respects.

[0062] In a simple embodiment, a highly directional speaker is directed by passive focusing. For example, a highly directional speaker system may simply be fixed to the front of the rail vehicle. This would mean the focus of the highly directional speaker would line up with the "straight ahead" direction of the rail vehicle, but there would be inaccuracies when cornering. In an improved version of such an embodiment, focussing of the alarm beam of the present invention may be adjusted manually by the driver or other user. Such embodiments are simpler, and so may be expected to be relatively low-cost. Such embodiments may be of particular use for low-speed applications. Such low-speed applications may include possessions, where works are being carried out on the track, and depots, where rail vehicles typically move slowly over limited distances. Such embodiments may also be found appropriate in areas with "permeable" rail boundaries, such as in some developing countries, where animals and trespassers are commonly found on the track.

[0063] In more advanced embodiments provided with a type of automatic focussing, as described elsewhere herein, the option to have manual override of the system and manual focus of the alarm beam could be added, and may allow savings to be made in other components, thereby to maintain lower costs.

[0064] In a preferred embodiment, active x-y focus of the highly directional speaker could be achieved. Arrangements providing for this are known in themselves. For example, a phased array of transducers may be pulsed in the correct time intervals to provide the required beam steering, or mechanical means may be used to physically rotate the highly directional speaker about appropriate axes, relative to the front of the rail vehicle.

[0065] Optionally, the braking distance of the vehicle may be taken into account when calculating the dimensions of the EPR. A factor of safety should be added to the braking distance. The dimensions of the EPR may be adaptive, increasing in size with increasing speed of the approaching vehicle. The apparent intensity of the vehicle's alarm could be arranged to increase if the vehicle approaches a person in danger. If the vehicle were to brake and the EPR, reducing in size due to the reduced speed of the vehicle, and so the reduced braking distance, no longer reached the position where a person was standing, then the pedestrian would hear the intensity of the alarm decrease, indicating that the vehicle is slowing and might come to a stop before reaching them.

[0066] The present invention therefore provides a safety system whereby vehicles are fitted with warning systems to protect the area ahead of the vehicle in its direction of travel. The system provides alarm signals into an Extended Protection Region (EPR) to minimise disruption to persons not in danger from the approach of the vehicle. By using a highly directional speaker, specific regions may be targeted with the alarm.

[0067] The present invention may be found useful in providing a protection region in the path ahead of vehicles which may move unexpectedly, for example when shunting or conducting engineering works at low speeds, where the alarm of the present invention may be active whenever the vehicle is capable of moving. On the other hand, the alarm as proposed by the present invention is very useful in situations where vehicles may move at high speed. In such cases, the time available to alert a person in danger, for example a worker with their back to an oncoming train, is very limited and such person's chance of escaping from the danger of the approaching vehicle is significantly increased through use of an alarm which is continuously active whenever the vehicle is moving, or is capable of moving. Directionality of the alarm signals, particularly in the case of use of a highly directional speaker, allows for higher power signals within a protection region which can potentially travel further, hence providing earlier warning to a person in danger. Vibrational and "fire alarm" signature aspects of the alarm of embodiments of the invention can improve the chance of alerting persons in danger and getting them to follow the correct procedure, potentially improving their chances of survival.

[0068] In certain preferred embodiments, alarm parameters such as intensity can be modified in real time to convey urgency, alter alarm range, so as to best protect regions ahead of the vehicle, while minimising disruption to persons not in danger.

[0069] While the present invention has been particularly described with reference to the use of a highly directional speaker (for example, "Long Range Acoustic Devices" as described at https://www.genasys.com/ahd-products/), the present invention may be implemented with any suitable directional sound generator.

[0070] Although the embodiments of the present invention have been described generally above, the operation of the train-mounted alarm system and the system itself will now be described in further detail. A main advantage of the embodiments of the present invention are their applicability to situations such as track worker safety. Furthermore, the system may be adapted to aid in preventing trespass on to a rail track, and also persons at level crossings.

[0071] Fig. 4 is a schematic diagram of a train-mounted alarm system in accordance with an embodiment of the present invention. A train 40 is shown on a railway track 41 comprising a first rail 42a and a second rail 42b fixed to a plurality of sleepers 43a...n laid on ballast 44. The train-mounted alarm system 45 comprises a highly directional sound generator 46 mounted at the end of the train 40 corresponding to the front of the train 40 based on the direction of travel. The highly directional sound generator 46 is adapted to produce a collimated beam 47 of sound parallel to the direction of travel of the train 40, and extends from the train 40 to form the extended protection region, EPR,. The highly directional sound generator 46 is further adapted to deliver a minimum sound pressure corresponding to a pre-determined threshold within the collimated beam 47 only. This results in the sound pressure being detectable within the extended protection region EPR only. The highly directional sound generator 46 is mounted on a moveable support 48 that enables the highly directional sound generator 46 to be rotated about an axis perpendicular to the train 40 in use. The highly directional sound generator 46 is mounted on the train 40 at a height corresponding to the head height of an average-sized person standing on the railway track 41, ensuring that the collimated beam 47 is directed firstly to a region where the sound pressure will have most impact, and secondly at a level below the head height of passengers standing on a platform at a railway station. In practice, the maximum height of the collimated beam 47 from the railway track is in the range 1.25m to 2.0m.

[0072] The highly directional sound generator 46 comprises a phased array 49 of acoustic emitters 50a...n. This may be in the form of the long range acoustic device described above, or a combination of a phased array of ultrasonic acoustic emitters having an audio-frequency within the range of human hearing modulated on top of the acoustic signal. This forms a collimated beam of sound parallel to the direction of travel of the train 40. In this latter case, an audio-frequency generator 51 is provided, along with the circuitry 52 required to generate the modulated signal. The overall result is a collimated beam of sound pressure that is audible by humans. Such a beam comprises a central lobe with lobes at harmonics minimised. The width *W* and height *H* of the extended protection region EPR is determined by the dimensions of the phased array 49 and the signals used to drive the individual ultrasonic acoustic emitters 50a...*n*. For example, the width *W* may be adjusted by varying which of the individual ultrasonic acoustic emitters 50a...*n* are turned on across a single row in the phased array 49 at any one time.

[0073] Fig. 5 is a chart illustrating the requirements of the sound pressure used in embodiments in accordance with the present invention in more detail. The *x*-axis represents distance from a trackside worker in metres and the *y*-axis is the sound pressure level at that distance in dB. As stated in the RAIB report referenced above, at a level crossing where work is being carried out, the background or ambient noise will be around 50dB to 55dB, and at a distance of 25m from the worker, the horn on a train will sound approximately 88 dB to persons at the crossing. However, if any of the trackside workers is using heavy machinery, such as an impact wrench, the sound pressure level increases to around 105dB to 113dB, which also requires persons to wear hearing protection. It is clear therefore that a train horn sounding at 88dB will not warn persons of the approach of the train. Preferably, the pre-determined threshold for sound pressure in this situation is at least 20dB above any ambient noise. Therefore, a minimum sound pressure threshold for persons working with heavy machinery would be at least 120dB. For persons who are not using heavy machinery, whilst they are likely to hear the train horn above the ambient noise depending on the layout of the track this may not always be enough to alert such persons to the imminent danger of the train approach, for example, if the track curves away from the location of such persons. This may give a false impression of how far away the train actually is. However, by having the sound pressure within the collimated beam 47 of the train mounted alarm system 45 set to a pre-determined threshold that corresponds to the threshold at which the human ear detects pain, and that this occurs only within the collimated beam, persons are alerted to move out of the range of the sound pressure, and thence to safety. This is at around 112dB to 120dB.

[0074] Fig. 6 is a schematic diagram illustrating the collimated beam generated by embodiments of the present invention in more detail. The train 40 travels at a speed 5 along the railway track 41. The train mounted alarm system 45 generates an extended protection region EPR that has a length *L* that is a function of the speed 5 of the train. This is the case whether the train mounted alarm system 45 is adapted to be used continuously whilst the train 40 is travelling at a speed 5 or intermittently whilst the train 40 is travelling at a speed S. The length of the extended protection region EPR is preferably a linear function of the speed 5 of the train. For situations where this would lead to an impractical length of collimated beam 47, the length of the extended protection region EPR may be a function of the logarithm of the speed 5 of the train (such as base 10 or a natural logarithm). It may be desirable to have the length of the extended protection region EPR as a linear function of the speed 5 of the train at lower speeds and as a logarithm function of the speed *5* of the train at higher speeds, with the switch between the two occurring at speeds that are typical outside of built up areas. In addition, it may be preferable for the train mounted alarm system to be turned on when the train 40 begins to move from a stationary position. At very low speeds it may be desirable for the length of the extended protection region to be a quadratic function of the speed 5 of the train to ensure that the alarm function is successful.

[0075] As described above the highly directional sound generator 46 is mounted on a movable support 48. This is to enable the collimated beam 47 to be moved whilst the train is in motion, for example, to sweep across the width of the railway track 41 or to anticipate rail track curvature. This allows the collimated beam 47 to effectively push persons or animals across a railway track and out of danger to avoid the sound pressure within the collimated beam. The sound pressure within the collimated beam 47 may vary over time, for example, having a lower dB level in regions where there are no crossings or ingress onto the railway track is unlikely or there is no night-time working planned, and a dB level above the pre-determined threshold only where required. In addition, data from acoustic signals picked up from optical fibres laid alongside the railway track 41 for signalling purposes may be used to indicate regions where the train mounted alarm system should be turned on. The highly directional sound generator 46 may comprise more than one audio frequency generator 51 such that sound pressure within the collimated beam 47 is provided with different frequencies. Such frequencies may be tailed to individual issues, such as those most likely to affect humans and those most likely to affect wildlife. It is also possible to adjust the sound pressure output of the collimated beam 47 to create an alarm signature, for example, by using either longer and shorter bursts of sound pressure or bursts of sound pressure at different frequencies. The highly directional sound generator may also further comprise a low-frequency signal generator 53 that is used to generate vibrations along the railway track 41 as an additional alarm mechanism. These vibrations may be felt by persons on the track before the collimated beam 47 is audible.

[0076] As mentioned above, it is possible to combine the embodiments of the present invention with a train mounted railway track 41 detection system. Such a system comprises a sensor unit, mounted on the train 40, and image processing equipment, preferably within the train in this example. Housing the image processing equipment within the train 40 provides increased security and reduced likelihood of damage from everyday train operation. However, both the sensor unit and the image processing equipment may be fitted to the train 40 together in a single housing, if desired. The sensor unit comprises a housing, within which is mounted a LiDAR system. The LiDAR system comprises a laser having a wavelength in the infra-red region of the electromagnetic spectrum, a phased array of optical antennas adapted to illuminate at least one region of interest on the railway track 41, a moveable mount adapted to direct the laser in the direction of the railway track 41 ahead of the rail vehicle, and a photodetector connected to the image processing equipment. A power source may be provided, or the sensor unit may be linked to a power source on the train. Initially, the LiDAR system is activated to detect image data received from the railway track 41 when the train 40 is in motion. Image data is received from at least one region of interest on the railway track 41 in order to be able to determine the direction of the railway track 41 ahead, such as the set-direction of a set of points. During motion of the train 40, the direction of the LiDAR system may be altered to match that of the upcoming railway track 41 by tilting the moveable base. Alternatively, the LiDAR system may have a wide enough field of view to omit the moveable base as all reasonable railway track 41 configurations will sit within that field of view. Whilst data is received continuously from the LiDAR system, regions of interest are analysed specifically to reduce the on-board computing cost required to implement the overall system. The image data is processed to identify the set direction of a set of points in the railway track 41 ahead of the train 40. This set direction may then be used by the train mounted alarm system 45 to alter the direction of the collimated beam 47, in order to ensure the effective generation of the extended protection region EPR.

Claims

1. A train-mounted alarm system adapted to warn of the presence of an oncoming train along a railway track, the system comprising:
   a highly directional sound generator adapted to be mounted on an end of a train and to produce a collimated beam of sound parallel to a direction of travel of the train and extending from the train to form an extended protection region (EPR), the sound generator being further adapted to deliver a minimum sound pressure corresponding to a pre-determined threshold within the collimated beam only, such that said sound pressure is detectable within the extended protection region only.

2. A train-mounted alarm system according to claim 1, wherein the sound pressure is not detectable outside

of the extended protection region.

3. A train-mounted alarm system according to claim 1 or 2, wherein the pre-determined threshold for the sound pressure is equal to the threshold at which the human ear detects pain.

4. A train-mounted alarm system according to claim 1 or 2, wherein the pre-determined threshold is equal to a sound pressure of at least twenty dB above any ambient noise.

5. A train-mounted alarm system according to any preceding claim, adapted to be used continuously when the train is travelling at a speed 5, and wherein the length of the extended protection region is a function of the speed 5 of the train.

6. A train-mounted alarm system according to any of claims 1 to 4, adapted to be used intermittently when the train is travelling at a speed 5, and wherein the length of the extended protection region is a function of the speed 5 of the train.

7. A train-mounted alarm system according to any of claims 1 to 4, adapted to be turned on when the train begins to move from a stationary position, and wherein the length of the extended protection region is a function of the length of the train.

8. A train-mounted alarm system according to claim 5, 6 or 7, further comprising means to adjust the direction of the collimated beam to project the extended protection region in the direction of the railway track on which the train is travelling.

9. A train mounted alarm system according to claim 8, wherein the direction of the collimated beam is adapted to sweep across the width of the railway track.

10. A train-mounted alarm system according to any preceding claim, wherein the highly directional sound generator is mounted on the train such that the maximum height of the collimated beam from the ground is in the range 1.25m to 2.0m.

11. A train-mounted alarm system according to any preceding claim, wherein the sound pressure within the collimated beam varies over time.

12. A train-mounted alarm system according to any preceding claim, wherein the sound pressure within the collimated beam is composed of components having different frequencies.

13. A train-mounted alarm system according to any preceding claim, wherein the sound pressure within the collimated beam is pulsed to create an alarm signature.

14. A train-mounted alarm system according to any preceding claim, further comprising a low-frequency sound generator adapted to create vibrations along the railway track.

15. A train-mounted alarm system according to any preceding claim, wherein the highly direction sound generator comprises a phased array of acoustic emitters.

16. A railway track worker safety system comprising the train-mounted alarm system according to any of claims 1 to 15.

17. A train comprising the train-mounted alarm system according to any of claims 1 to 15.

FIG 1

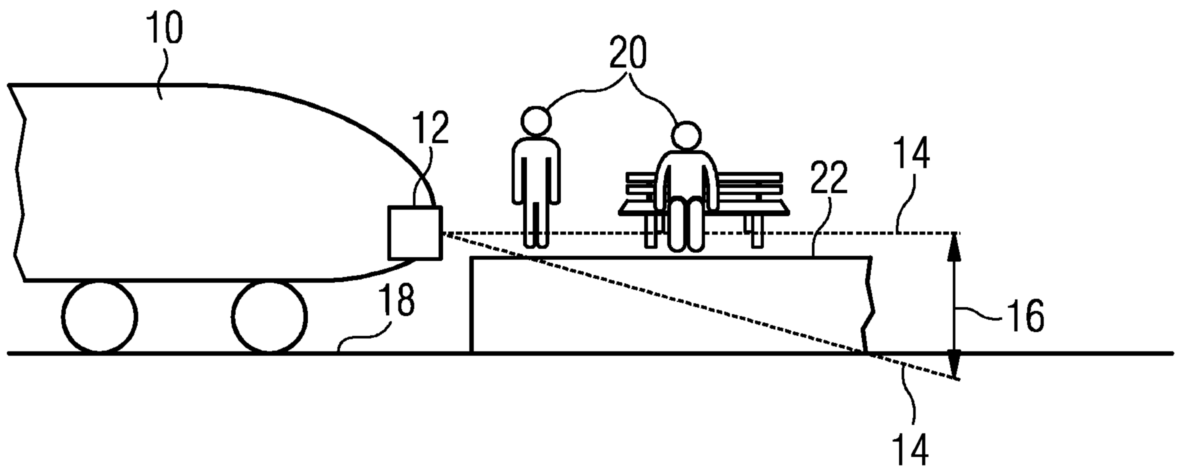


FIG 2

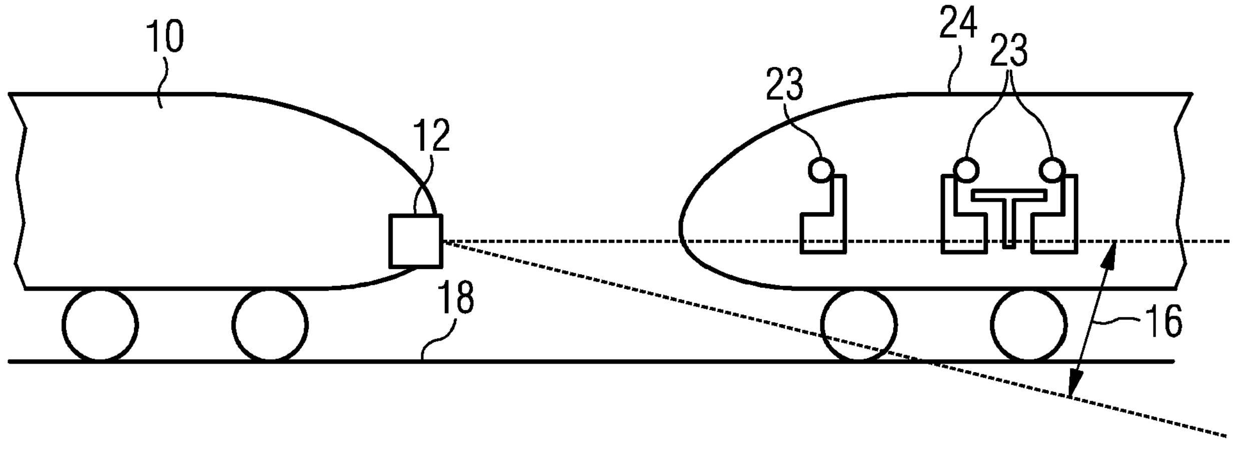
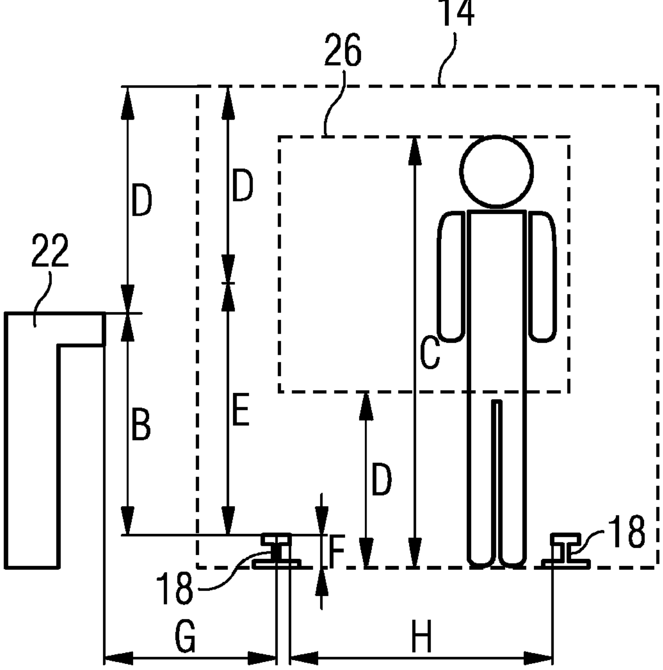
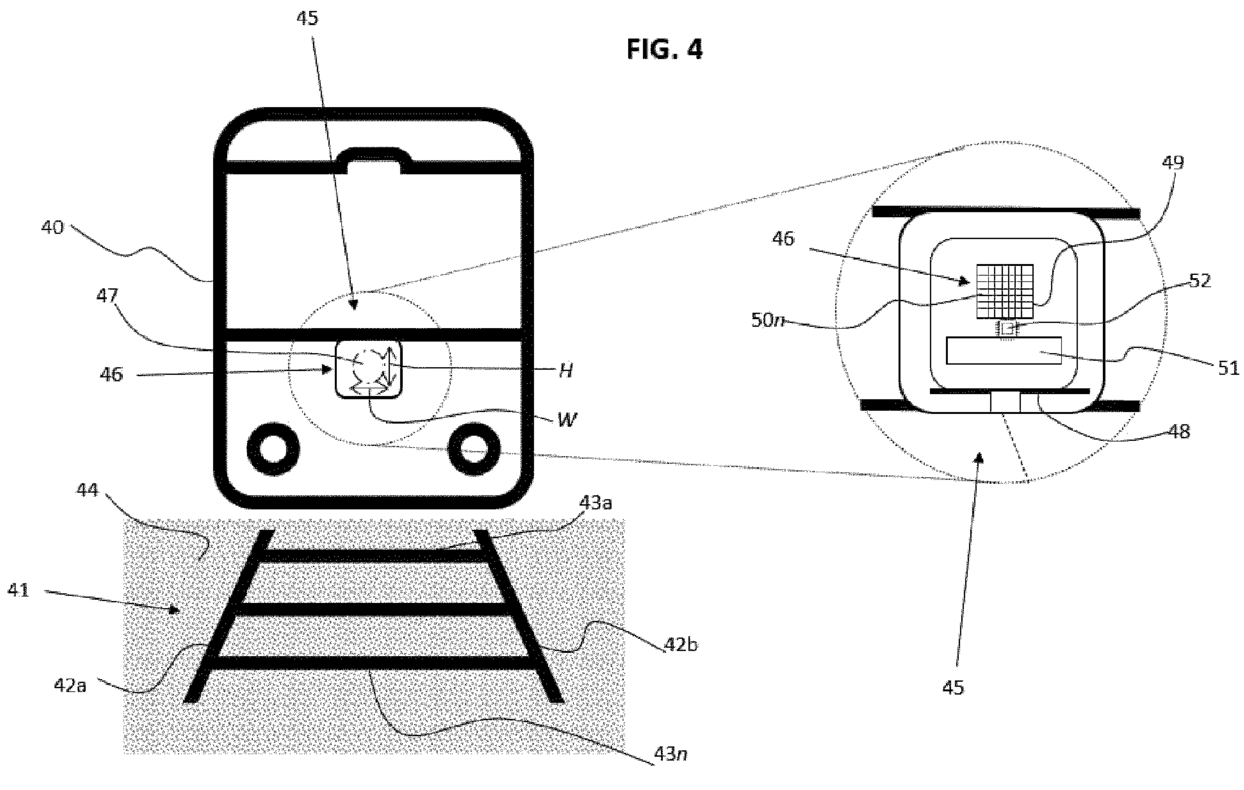


FIG 3



Ref.	Desc.	Value
B	UK platform height	915 mm
C	UK Male Standing Height 95th percentile	1869.2 mm
D	UK Female Sitting Height 5th percentile	803.4 mm
E	Hitachi DEP floor height	1185 mm
F	EN13674-1 Flat bottom rails >46Kg/m height range	145-172 mm
G	Platform rail offset range	730-745 mm
H	Standard track gauge	1435 mm

FIG. 4



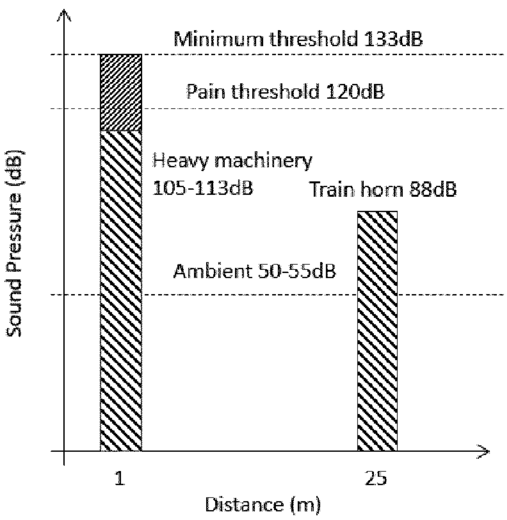

Minimum threshold 133dB
Pain threshold 120dB
Heavy machinery
105-113dB
Train horn 88dB
Ambient 50-55dB
Sound Pressure (dB)
1
25
Distance (m)

FIG. 5

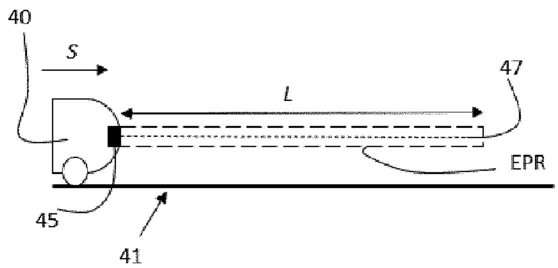

40
S
47
L
EPR
45
41

FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 2103661 A **[0039] [0043] [0047]**