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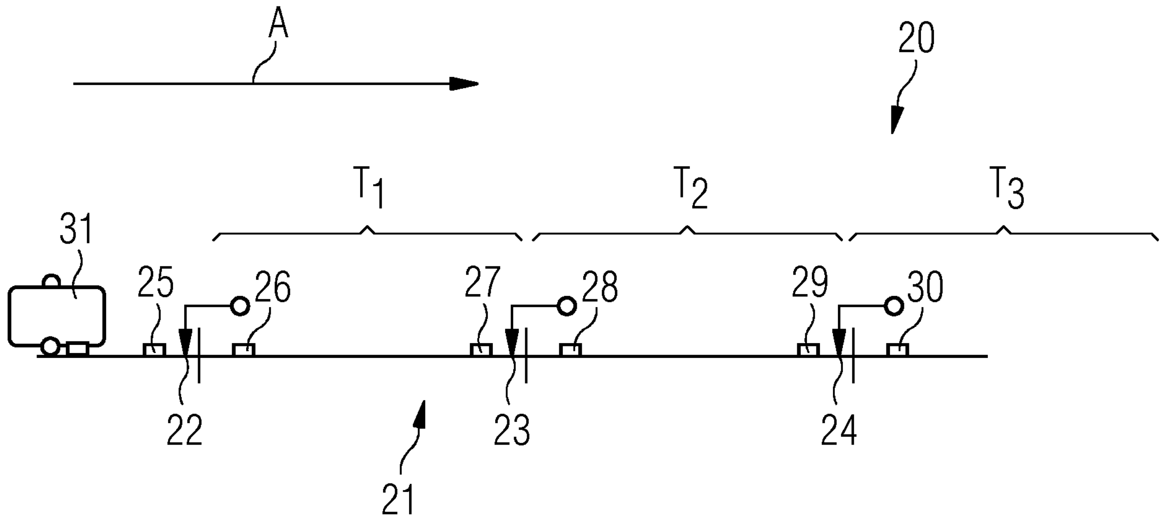
(54) **METHOD OF VERIFYING AN ETCS (EUROPEAN TRAIN CONTROL SYSTEM) DESIGN**

(57) Verifying an ETCS design overlaid on an existing signalling system is described. This involves logging timestamped data on a train and at a trackside train detection system to determine the distance between balises and their location relative to known track section boundaries. If the distances determined using the data logged by both a train and the trackside train detection device match that of the ETCS design, the correctness of the design is considered to be verified. The train may be an ETCS-compliant or a non-ETCS-compliant train.

FIG 2



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Description

[0001] The present invention relates to a method of verifying an ETCS (European Train Control System) design, in particular, a method of verifying an ETCS design installed on a railway having an existing signalling system.

[0002] The European Train Control System (ETCS) is the signalling and control component of the European Rail Traffic Management System (ERTMS). It is designed to replace the various legacy signalling systems in place across Europe, ensuring a common standard. In addition, it has been adopted as an option globally, and offers Positive Train Control (PTC) in various locations across the world. There are currently four numbered levels of ETCS, based upon the extent of cab-based signalling versus trackside equipment in the train control process. The levels are as follows:

Table 1: ETCS levels

Level	Description
0	ETCS compliant rolling stock does not interact with trackside equipment
NTC	ETCS-compliant train rolling stock is provided with additional Specific Transmission Modules (STM) to interact with legacy signalling systems under National Train Control (NTC)
1	ETCS trackside equipment is installed and spot transmission of data between trackside equipment and rolling stock via balises takes place
2	As level 1 but signalling information is provided by continuous transmission with a Radio Block Centre (RBC) via GSM-R (Global System for Mobile Communication - Railway), with balises used to detect train position
3	As level 2 but trackside equipment such as axle counters or track circuits is no longer relied upon

[0003] Level 1 is a cab-signalling system that is often superimposed on existing signalling systems. The balises are electronic beacons or transponders placed between the rails of the railway track that provide data as a train passes over via an uplink. A fixed balise is programmed to provide the same information to every train, and a programmable balise is used to transmit data to a train from a Lineside Electronic Unit (LEU) as part of ETCS Level 1 signalling control. Balises are installed in pairs so that the direction of travel can be indicated by the order in which the balises are detected.

[0004] An ETCS design specifies the locations in which the balises as installed. In a Level 1 system, the balise installation points are determined by the position of the existing signalling system, as indicated in Figure 1. Figure 1 is a schematic diagram of the interaction between an ETCS design and an existing signalling system. A railway track 1 comprises two rails 2 (of which one is shown) mounted on sleepers 3 resting on ballast 4. A signal 5 is provided at the start of a track section, along with an interlocking 6. A first 7 and a second 8 balise are provided either side of the signal 5. An approaching train 9 is provided with an ETCS receiver 10 and a GSM-R antenna 11. As the train 9 approaches the signal 5, the first balise 7 provides details of its location and the state of the signal 5 based on interaction with the interlocking 6. As the train 9 passes though the signal 5 and over the train detection section boundary 12, the interlocking 6 detects the train movement and the aspect of the signal 5 is changed.

[0005] Since ETCS carries out safety calculations, such as maximum speed and braking curve, it is vital that the information received by the system is correct. The calculations are made on the basis of the lengths of the railway tracks, the locations of the balises along the railway tracks and the location of train detection sections based on the locations of track circuits and axle counter heads. Any errors therefore in this data would affect the safety of ETCS operations, which need to be carried out with a high degree of confidence. During commissioning of new ETCS installations either as new build or overlaying existing signalling designs a number of manual surveying activities are carried out to ensure that the track and balise distances recorded in the ETCS configuration data from the ETCS design match the railway track and trackside equipment. This is also relevant for installing ETCS level 2 designs, as well as the ETCS level 1 configuration outlined above. Once commissioned, the parameters of the ETCS design may be altered during routine maintenance, upgrades or renewals, since the locations of the balises may be shifted, resulting in changes to the distances between them. Several mechanisms may cause a change in the railway geometry:

- Realignment of a crossover between railway tracks with a new crossover of a different type or length (for example, to facilitate higher-speed running);
- Realignment of the railway track;
- Incorrect re-installation of balises following track work;
- Incorrect re-installation or replacement of trackside equipment.

Depending on the extent or nature of the geometry change the ETCS may detect the error, continue to operate normally or operate with an altered safety margin.

[0006] It is common practice in the United Kingdom, for example, when commissioning an ETCS design to check the required locations of the balises and other track information using multiple measuring methods, such as manual surveying. This methodology ensures that the failure of a single measuring method cannot cause a system failure. However, these existing measurement techniques are typically manual and therefore time consuming and resource intensive. Post-commissioning changes are prevented or recorded using a manual process, which again is time consuming and resource intensive. Since the only automated monitoring of the ETCS is that which is built into the system itself in terms of its error detection capabilities, the checking aspect of the commissioning process or post-commissioning works represents a significant outlay in time and resource each time it is required.

[0007] The embodiments of the present invention aim to address these issues by providing, in a first instance a method of verifying an ETCS (European train Control System) design installed on a railway to overlay an existing signalling system, the method comprising: logging timestamped data on a train travelling on the railway indicating the time of detection, the identity and the location of two or more balises; analysing the data logged by the train to determine the distance between the balises and comparing this to an ETCS design for the railway; logging timestamped data at a trackside train detection system indicating the time at which the front of the train passed through the boundaries of a track section on the railway; correlating the data logged by the train and the data logged by the trackside train detection system based on the timestamps; on the basis of the timestamped data correlation, determining the location of each balise relative to a boundary of the track section and comparing this with the ETCS design; and wherein if the distance between the balises is within an expected tolerance of the ETCS design and the location of the balises is within an expected tolerance of the ECTS design, the ETCS design is verified.

[0008] By using a combination of data sources and analysing the collected data the invention offers the advantage that the correctness of ETCS configuration data and design can be verified without requiring invasive, costly, time-consuming or labour-intensive surveying techniques. In particular, it is possible to use a non-ETCS-compliant train in the design verification method.

[0009] Correlating the data may comprise: logging the time at which the front of the ETCS-compliant train passed through a boundary of a track section on the train; comparing the time at which the front wheel of the train passed through a boundary of a track section logged by the train with the time at which the front of the train passed through the same boundary of a track section logged by the trackside train detection system to determine a correction factor; and applying the correction factor either to the timestamped data logged by the train or to the timestamped data logged by the trackside train detection system.

[0010] Alternatively, the clock used for the timestamped data logged by the train and the clock used timestamped data logged by the trackside train detection system may be synchronised.

[0011] Preferably, the distance between balises is determined by either: calculating the distance travelled between the balises at a constant speed based on the timestamped identity and location data logged by the train; or accessing the absolute position of the train at the time the identity and location data are recorded from a Global Navigation Satellite System (GNSS) device.

[0012] At least two trains may travel on the railway and log timestamped data indicating the time of detection, the identity and the location of the two or more balises, and wherein the method further comprises: determining a range of distances between two balises that lies within the expected tolerance; and determining a range of locations of at least one of the two balises relative to the same boundary of a track section. Preferably, in this situation, when a train travels along the railway and logs timestamped data indicating the time of detection, the identity and the location of the two or more balises and the distance between the two balises and/or the location of at least one of the balises relative to the same boundary of a track section lie outside the determined ranges, an alarm is raised.

[0013] Preferably, if the distance between the balises is outside the expected tolerance of the ETCS design and/or the location of the balises is outside the expected tolerance of the ECTS design, an alarm is raised. Preferably, if an alarm is raised, the balise locations are surveyed using a method independent of a train and/or the balises are relocated.

[0014] The verification of the ETCS design may be carried out on installation of the ETCS design in a region having an existing signalling system. Alternatively, the verification of the ETCS design may be carried out following engineering work in any of the track sections of the railway where the ETCS design is already installed.

[0015] The method may further comprise: logging timestamped train-based accelerometer data and railway track elevation data on the train; retrieving railway track gradient and geometry data from a balise or an RBC; comparing the retrieved railway track gradient and geometry data with railway track gradient and geometry data calculated from the train-based accelerometer data and track elevation data; and if the data correlates, indicating that the information accessed from the balise or RBC is verified.

[0016] Preferably, the trackside train detection system is a track circuit, an axle counter or an interlocking.

[0017] The trackside train detection system may be a video of the track. The logging of timestamped data by the train may be carried out using a video of the track. In this situation, the location of at least two balises may be determined using image recognition software.

[0018] Preferably, the train is an ETCS-compliant train.

[0019] The present invention will now be described by way of example only, and with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of the interaction between an ETCS level 1 design and an existing signalling system;
Figure 2 is a schematic diagram of an overlay of an ETCS design installed on an existing signalling system;
Figure 3 is a flow chart of the steps in a method in accordance with embodiments of the present invention; and
Figure 4 is a flow chart of the steps in a method in accordance with a further embodiment of the present invention.

[0020] The embodiments of the present invention take the approach that the verification of an ETCS design installed over an existing signalling system may be automated by using data collected by a train. This is done by taking a combination of data sources and analysing logged data to verify the correctness of the ETCS configuration data. To begin with, timestamped data is logged by a train travelling on the railway. This data indicates the time of detection, the identity and the location of two or more balises. This data is analysed to determine the distance between the balises, which is then compared to an ETCS design. Timestamped data is also logged at a trackside train detection system, which indicates the time at which the front wheel of the train passed through the boundaries of a track section on the railway. The data logged by the train and the data logged by the trackside train detection system are correlated based on the timestamps, and on the basis of this, the location of each balise relative to a boundary of the track section is determined and also compared with the ETCS design. If the distance between the balises is within an expected tolerance of the ETCS design and the location of the balises is within an expected tolerance of the ECTS design, the ETCS design is then considered verified. If not, a number of options are available, as described in more detail below.

[0021] Figure 2 is a schematic diagram of an overlay of an ETCS level 1 design installed on an existing signalling system. The direction of travel and therefore the ordering of trackside equipment is indicated to be left to right by arrow A. The layout of a railway track 20 is shown to comprise a first route 21 having first 22, second 23 and third 24 signals, where each signal indicates the boundary of a track section: a first track section T_1 being between the first 22 and second 23 signals; a second track T_2 section between the second 23 and third 34 signals. The signals 22, 23, 24 each have an interlocking (not shown). A pair of balises is provided per signal as detailed below:

Signal	Balises
first signal 22	first balise 25 prior to the signal
	second balise 26 past the signal
second signal 23	first balise 27 prior to the signal
	second balise 28 past the signal
third signal 24	first balise 29 prior to the signal
	second balise 30 past the signal

The balises 25 - 30 are placed at a known distance on each side of the respective signal 22, 23, 24. These enable an ETCS compliant train to determine the direction in which it has entered a track section. In contrast, for an ETCS level 2 design, the second, even-numbered balise 26, 28, 30 following each signal 22, 23, 24 is absent, as there is periodic communication between the train and an RBC (Radio Block Centre).

[0022] Figure 3 is a flow chart of the steps in a method in accordance with embodiments of the present invention. The method 300 takes place on a railway that has an existing signalling system on which an ETCS design is overlaid. For ease of reference this is described in relation to the ETCS level 1 configuration of Figure 2, but is applicable to ETCS level 2 and any railway line configuration. Initially, at step 302, timestamped data is logged on an ETCS-compliant train 31 travelling on the railway 20. The ETCS-compliant train 31 is provided with train-borne equipment including an ETCS receiver, computer and driver's console, as well as a GSM-R antenna to enable the integration of GSM-R and the computer. The ETCS-compliant train 31 begins by travelling into the first track section T_1. The data is logged to indicate the time of detection, the identity and the location of two or more balises 25 - 30, which in the first track section T_1, is initially the first 25 and second 26 balises adjacent the first signal 22.

[0023] At step 304, the data logged by the ETCS-compliant train 31 is analysed to determine the distance between the balises 25, 26. This is done in one of two ways, depending upon the speed of the ETCS-compliant train 31. If the ETCS-compliant train 31 is travelling at a constant speed 5, the distance travelled between the balises is calculated based on the timestamped identity and location data logged by the train 31. If the train 31 is travelling at a variable speed *V*, then the absolute position of the train at the time the identity and location data are recorded from a Global Navigation Satellite

System (GNSS) device. This GNSS device may be a separate Global Positioning System (GPS) or integrated within the GSM-R. Alternatively, a dedicated data logger connected to a tachometer or accelerometer on the train may, or image analysis of trackside objects viewed from the train as it passes by may be used to determine train speed and therefore distance from known locations. Once the distance has been calculated, they can then be compared to the ETCS design for the railway 20.

[0024] At step 306, timestamped data is logged at a trackside train detection system. The trackside train detection system may be a track circuit, an axle counter or an interlocking. This data indicates the time at which the front of the ETCS-compliant train 31 passed through the boundary of the first track section T_1 on the railway 20. At step 308, the data logged by the ETCS-compliant train 31 and the data logged by the trackside train detection system is correlated based on the timestamps. This may be done by applying a correction factor to either the timestamped data logged by the ETCS-compliant train 31 or the timestamped data logged by the trackside train detection system. Alternatively, the clock used for the timestamped data logged by the ETCS-compliant train and the clock used timestamped data logged by the trackside train detection system may be synchronised. At step 308, on the basis of the timestamped data correlation, the location of each balise 25, 26 relative to a boundary of the track section T_1 is determined and compared to the ETCS design. If the distance between the balises 25, 26 is within an expected tolerance of the ETCS design and the location of the balises 25, 26 is within an expected tolerance of the ECTS design, the ETCS design is verified. This means that the newly-commissioned ETCS can be used with confidence as the correct data will be available for any and all safety calculations. However, if the distance between the balises is outside the expected tolerance of the ETCS design and the location of the balises is outside the expected tolerance of the ECTS design, an alarm is raised. These steps are repeated for each track section T_2, T_3 where the location of the balises 25 -30 needs to be determined. As a result, corrective action can be taken, such as re-surveying with more traditional methods or remedial engineering work to reposition the balises. The method 300 may also be applied following engineering works to ensure that all equipment has been replaced in the correct location.

[0025] It may also be desirable to collect data from more than one train, for example, to ensure that there are no changes to the locations of the balises following engineering work or during day-to-day running. At least two trains may travel on the railway and log timestamped data indicating the time of detection, the identity and the location of the two or more balises. The method 300 can then be enhanced by determining ranges of distances between balises that lie within the expected tolerance as well as determining a range of locations of a balise relative to the same boundary of a track section within the tolerance. Hence when a train travels along the railway and logs the relevant timestamped data along with the trackside train detection system, should there be any locations that lie out of range and/or tolerance an alarm can be raised. Once it has been discovered that a location lies out of range and/tolerance, it implies that equipment has been moved or track altered and the infrastructure manager should take action to ensure that the signalling system is still able to operate safely. It is therefore possible for the infrastructure manager to set pass/fail criteria for the level of correspondence between the designed location and the measured location of an item could be set depending on the type of the balise, system accuracy needs, or other operational requirements.

[0026] In addition to logging balise positions, the method 300 may also include a verification step for the data transmitted by the balise regarding the railway track geometry. Figure 4 is a flow chart of a method in accordance with a further embodiment of the present invention. The steps of the method 300 outlined above are shown in broken lines, since these remain the same. The additional steps are indicated in solid lines. As well as logging the timestamped data indicating the time of detection, the identity and the location of two or more balises, at step 402 timestamped train-based accelerometer data and railway track elevation data are logged on the train 31. The train-based accelerometer is able to detect changes in railway track 20 gradient and railway track 20 geometry, such as curves and cross-overs, and the railway track elevation data is available from the GNSS system. At step 404, the railway track gradient and geometry data is retrieved from a balise 25 -30 by reading the balise 25 - 30 using the receiver provided on the train 31. At step 406, the retrieved railway track gradient and geometry data with railway track gradient and geometry data calculated from the train-based accelerometer data and railway track elevation data are compared, and if the data correlates, this indicates that the information accessed from the balise 25 - 30 is verified.

[0027] In the examples outlined above, the train 31 is preferably an ETCS-compliant train, and logs the locations of the balises 25 -30 using data obtained from the receiver reading the balises 25 - 30 as the train 31 passes over them. However, it may also be desirable to equip the train 31 with the ability to record a video of the railway track 20. This creates a trackside detection system where the data used in the verification method is based upon optical recognition of trackside equipment, such that as in the example above, the trackside equipment is used to determine the position of the train 31. The location of each item of trackside equipment is known, and by recognising individual items, such as balises, the optical recognition data may be combined with map and GNSS data to determine the position of the train 31. This may be done using either a front-facing camera or a camera mounted underneath the train 31 a processor equipped with object recognition capabilities present on the train 31, or using post-processing facilities offline or remote from the train. This removes the need to use a specific ETCS-compliant train for the verification of the ETCS design, and enables any train to be used. Alternatively, a trackside camera may be used to record an image of the train 31 as it passes a known location, such as a balise. The object recognition in a video may be carried out using machine learning techniques alongside object recognition mechanisms such as edge detection set up to recognise a balise 25 - 30 or other trackside objects, such as axle counter heads and track circuits ends with known locations. Alternatively line scanning data may be used to identify the balises 25 - 30. Suitable cameras and software to carry out such object recognition are available from One Big Circle, https://onebigcircle.co.uk/ and utilise AIVR technology for employing AI in video recognition on railways. Image recognition data, along with GNSS location data may then be used to calculate the distances between the at least two balises 25 - 30.

[0028] In an alternative embodiment, the logging of timestamped data by the train 31 may also be done using a video taken of the track. In this embodiment, a front-facing or undermount camera mounted on the train 31 may be used to video the track as the train 31 progresses along its route. Each image frame of the video is timestamped, and in conjunction with the image recognition software may be used to generate the required timestamped data for use in the method 300. Again, a processor equipped with object recognition capabilities present on the train 31, or using post-processing facilities offline or remote from the train may be used to carry out object recognition of the video.

[0029] The method 300 outlined above may be carried out using any train 31, for example, such as a train in service on a route along the railway track 20, or a specific monitoring train used to monitor the overall condition of the railway track 20.

[0030] These and other advantages of the embodiments of the invention will be apparent to the person skilled in the art from the scope of the appended claims.

Claims

1. Method of verifying an ETCS (European train Control System) design installed on a railway to overlay an existing signalling system, the method comprising:

logging timestamped data on a train travelling on the railway indicating the time of detection, the identity and the location of two or more balises;
analysing the data logged by the train to determine the distance between the balises and comparing this to an ETCS design for the railway;
logging timestamped data at a trackside train detection system indicating the time at which the front of the train passed through the boundaries of a track section on the railway;
correlating the data logged by the train and the data logged by the trackside train detection system based on the timestamps;
on the basis of the timestamped data correlation, determining the location of each balise relative to a boundary of the track section and comparing this with the ETCS design; and
wherein if the distance between the balises is within an expected tolerance of the ETCS design and the location of the balises is within an expected tolerance of the ECTS design, the ETCS design is verified.

2. Method as claimed in claim 1, wherein correlating the data comprises:

logging the time at which the front of the train passed through a boundary of a track section on the train;
comparing the time at which the front of the train passed through a boundary of a track section logged by the train with the time at which the front of the train passed through the same boundary of a track section logged by the trackside train detection system to determine a correction factor; and
applying the correction factor either to the timestamped data logged by the train or to the timestamped data logged by the trackside train detection system.

3. Method as claimed in claim 1, wherein the clock used for the timestamped data logged by the train and the clock used timestamped data logged by the trackside train detection system are synchronised.

4. Method as claimed in any of claims 1 to 3, wherein the distance between balises is determined by either:

calculating the distance travelled between the balises at a constant speed based on the timestamped identity and location data logged by the train; or
accessing the absolute position of the train at the time the identity and location data are recorded from a Global Navigation Satellite System (GNSS) device.

5. Method as claimed in any of claims 1 to 4, wherein at least two trains travel on the railway and log timestamped data indicating the time of detection, the identity and the location of the two or more balises, and wherein the method further comprises:

determining a range of distances between two balises that lies within the expected tolerance; and
determining a range of locations of at least one of the two balises relative to the same boundary of a track section.

6. Method as claimed in claim 5, wherein when a train travels along the railway and logs timestamped data indicating the time of detection, the identity and the location of the two or more balises and the distance between the two balises and/or the location of at least one of the balises relative to the same boundary of a track section lie outside the determined ranges, an alarm is raised.

7. Method as claimed in any of claims 1 to 5, wherein if the distance between the balises is outside the expected tolerance of the ETCS design and/or the location of the balises is outside the expected tolerance of the ECTS design, an alarm is raised.

8. Method as claimed in claim 6 or 7, wherein if an alarm is raised, the balise locations are surveyed using a method independent of an ETCS-compliant train and/or the balises are relocated.

9. Method as claimed in any preceding claim, wherein verification of the ETCS design is carried out on installation of the ETCS design in a region having an existing signalling system.

10. Method as claimed in any of claims 1 to 8, wherein verification of the ETCS design is carried out following engineering work in any of the track sections of the railway where the ETCS design is already installed.

11. Method as claimed in any preceding claim, further comprising:

logging timestamped train-based accelerometer data and railway track elevation data on the train;
retrieving railway track gradient and geometry data from a balise;
comparing the retrieved railway track gradient and geometry data with railway track gradient and geometry data calculated from the train-based accelerometer data and track elevation data; and
if the data correlates, indicating that the information accessed from the balise is verified.

12. Method as claimed in any preceding claim, wherein the trackside train detection system is a track circuit, an axle counter or an interlocking.

13. Method as claimed in any of claims 1 to 11, wherein the trackside train detection system is a video of the track.

14. Method as claimed in any preceding claim, wherein the logging of timestamped data by the train is carried out using a video of the track.

15. Method as claimed in claim 13 or 14, wherein the location of the at least two balises is determined using image recognition software.

16. Method as claimed in any preceding claim, wherein the train is an ETCS-compliant train.

FIG 1

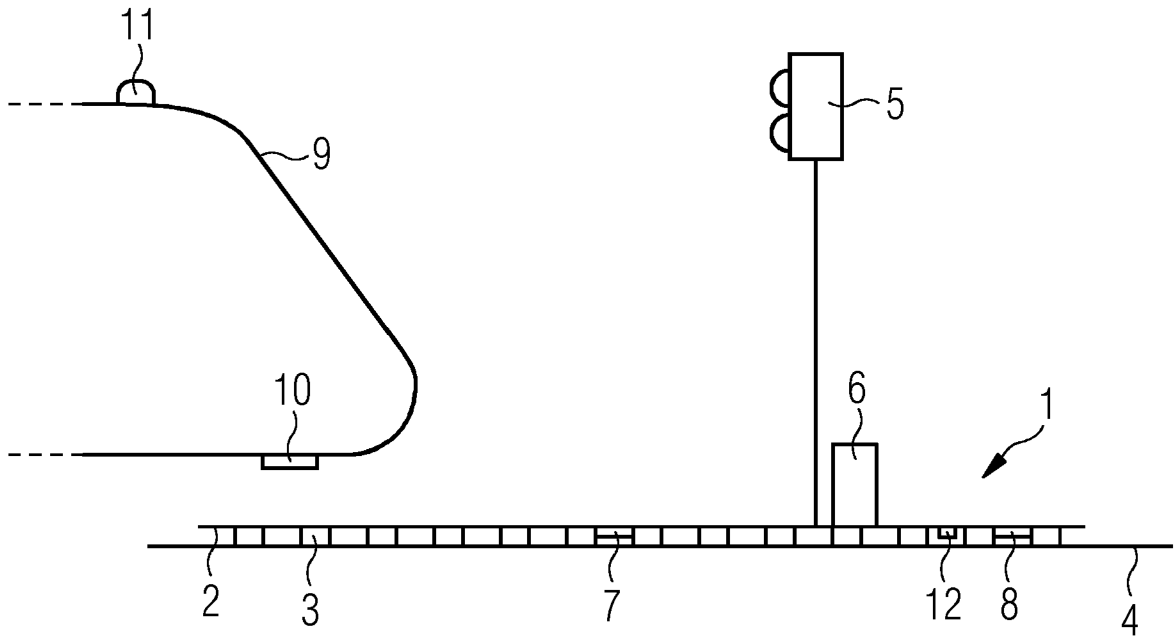


FIG 2

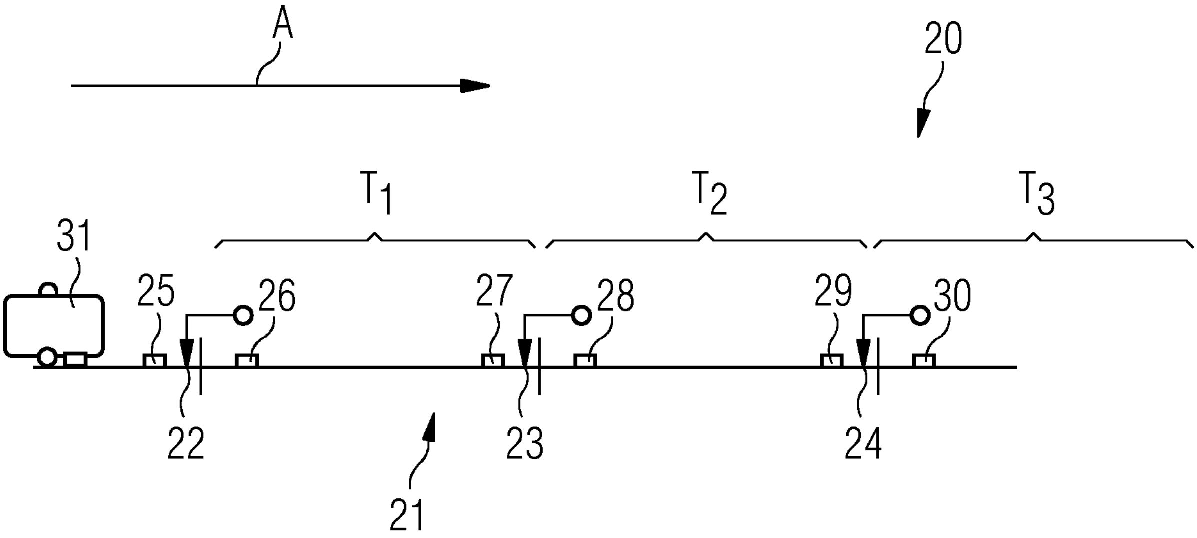


FIG 3

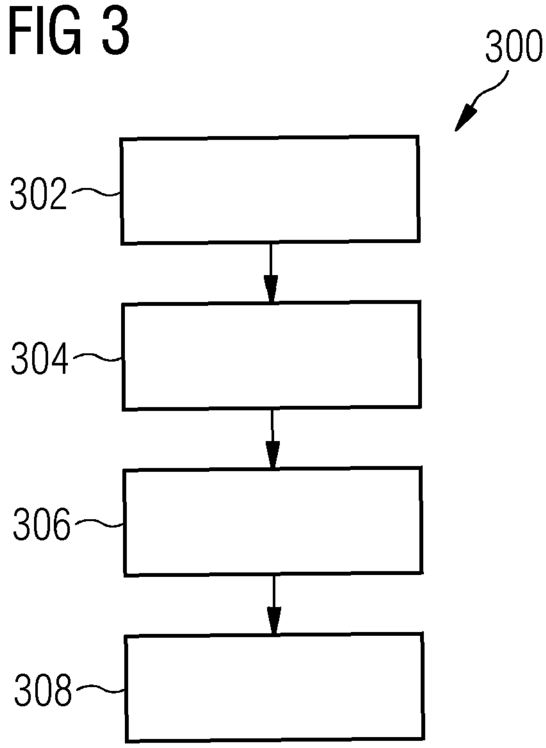
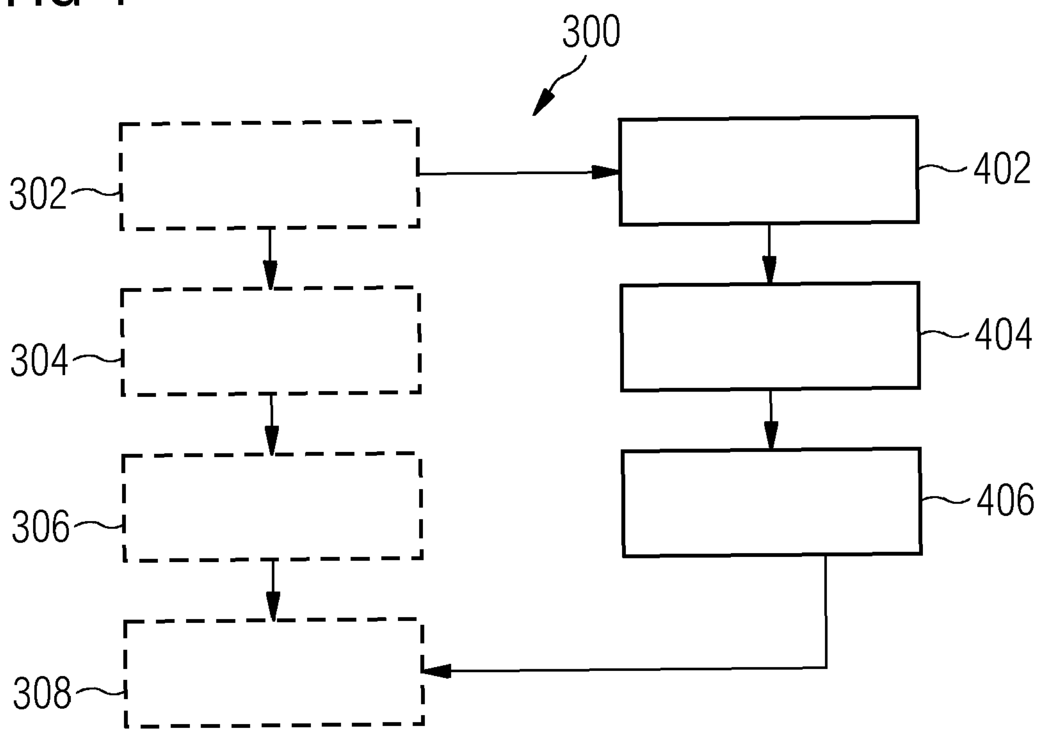


FIG 4



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EUROPEAN SEARCH REPORT

Application Number
EP 24 19 9770

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	KOCH ET AL: "Sat.valid: Tool-supported verification and validation of ETCS implementations", SIGNAL UND DRAHT: SIGNALLING & DATACOMMUNICATION, EURAILPRESS, DE, vol. 106, no. 3, 1 March 2014 (2014-03-01), pages 46-50, XP001587475, ISSN: 0037-4997	1,3-16	INV. B61L23/04 B61L27/37 B61L27/60 ADD. B61L27/20
A	* abstract * * 3 Infrastructure recording with SAt.engine; figure 2 * * 4 Validation with SAT.valid *	2	
Y	EP 2 873 585 A1 (BOMBARDIER TRANSP GMBH [DE]) 20 May 2015 (2015-05-20) * paragraph [0001] * * paragraph [0022] - paragraph [0053] * * paragraph [0057] - paragraph [0060]; figure 1 *	1,3-16	
Y	DE 10 2011 106345 A1 (DEUTSCH ZENTR LUFT & RAUMFAHRT [DE]) 13 December 2012 (2012-12-13) * paragraph [0002] - paragraph [0005] * * paragraph [0010] - paragraph [0026] * * paragraph [0033] - paragraph [0046]; figures 1,2 *	1,3-16	TECHNICAL FIELDS SEARCHED (IPC): B61L

1 The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	13 February 2025	Pita Priegue, Miguel

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82