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(54) **A BALISE FOR A RAILWAY TRACK**

(57) A balise such as a Eurobalise for a railway track having planar dielectric circuit substrate design with a rectangular receiver loop antenna and a rectangular transmitter loop antenna formed on said circuit substrate, wherein an input flux to the receiver loop antenna is conform with a predetermined input flux in a balise active reference area and an output field from the transmitter loop antenna is conform with a field from a predetermined current encircling said balise active reference area, and wherein the receiver loop antenna and the transmitter loop antenna having a separation of at least two times a thickness of the dielectric substrate.

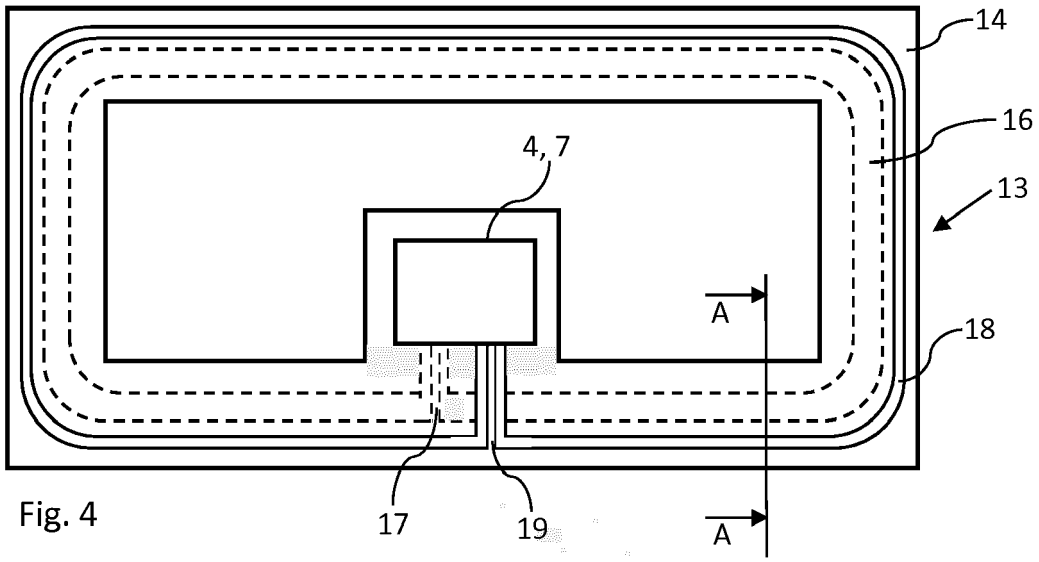

Fig. 4

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Description

TECHNICAL FILED

[0001] The present invention relates to a balise, which is a type of electronic transponder located between the rails of a railway track typically as a part of an automatic train protection system. In particular, the invention relates to a balise in the European Rail Traffic Management System, ERTMS, a so-called Eurobalise. This balise forms an integral part of the European Train Control System and is specified with respect to function and design in a European standard called "FFFIS for Eurobalise". A Eurobalise should comply with the standardization document "SUBSET-036: Specification for Eurobalises".

BACKGROUND AND RELATED ART

[0002] Balises are distributed along railway tracks to send information from the track side to passing trains enabling safe control of the traffic on the railway tracks through use of this information by automatic supervising systems on board the trains (railway vehicles) moving on the railway tracks. Such an automatic supervising system is defined as an ATP (Automatic Train Protection) system, and it may for instance operate according to the European standard ERTMS. The link between the balise and an ATP antenna on the train is based on magnetic coupling, which means that the balise and the ATP antenna constitute an air transformer whenever the antenna is located above or in a vicinity of the balise. This link is bi-directional, and the down link from the transmitter on the railway vehicle transmits power to the balise by magnetic induction of the receiver loop antenna of the balise, whereas the uplink transmits data to the ATP system on board the railway vehicle by the use of the transmitter loop antenna of the balise through the balise transmitter, which is powered by the electric energy received by the receiver loop.

[0003] The FFFIS for Eurobalise specifies the strength and character of the electromagnetic fields generated by the Eurobalise and onboard antennas in the train by first defining two reference loops of predetermined size. Accordingly, the Eurobalise is required to have an active reference area of 358 mm x 488 mm for a standard size Eurobalise and an active reference area of 200 mm x 390 mm for a reduced size Eurobalise. The standard states that the fields generated by the Eurobalise and onboard antenna shall conform to the fields generated by either one of the reference loops. This implies that the physical size of the Eurobalise must be largely the same as the reference loops defined by the standard. In a known Eurobalise, a receiver loop antenna and a transmitter loop antenna, respectively, were arranged essentially coaxially on the bottom and top, respectively, of a printed circuit board. The respective loops have been arranged essentially overlapping in order for both loop antennas to fulfil the size requirements.

[0004] It is in the nature of the transmission link that the two balise loop antennas should be close to each other since they are both interacting with the same antenna function on the train. However, the closer to each other they are positioned, the more capacitive and inductive coupling is created between them. This has the effect of re-tuning the transmitter circuitry and receiver circuitry away from the intended resonant frequencies and the links become inefficient. Consequently, Eurobalises have used thicker than standard circuit boards. To alleviate the problem of coupling and re-tuning, the above-mentioned known Eurobalise used a circuit board of about 3.2 mm thickness, that is, about twice that of today's standard-thickness circuit boards. A large loop separation is achieved in the known design, which means less coupling between the receiver loop antenna and the transmitter loop antenna. However, this thickness makes the circuit board heavy and expensive.

SUMMARY OF THE INVENTION

[0005] In general the present invention provides a balise in which a receiver loop antenna and a transmitter loop antenna performances conform with respect to a balise active reference area of a predetermined nominal size. Further, the balise should allow for its integration in an ATP system and thus comply with requirements typically defined in a related standardization document. The standard Eurobalise Transmission System, SUBSET-036, Issue 3.1.0, is incorporated in this disclosure through this reference.

[0006] In particular, the balise of the present invention is to be arranged stationary between rails of a railway track to wirelessly transmit data to at least one vehicle antenna of a railway vehicle on the railway track, wherein the balise comprises: an essentially planar dielectric circuit substrate having a first side to be facing upwards and a second side to be facing downwards when the balise is arranged stationary between the two rails, wherein the circuit substrate has an essentially even substrate thickness; an essentially rectangular receiver loop antenna formed on said circuit substrate and having a receiver loop central trace along which is defined a receiver loop physical length, wherein an input flux to the receiver loop antenna is conform with a predetermined input flux in a balise active reference area, and wherein the receiver loop antenna is configured to receive operational energy wirelessly from a vehicle transmitter in the railway vehicle when in a vicinity of the balise; receiver circuitry connected by a receiver feed connection to said receiver loop antenna and configured to receive the operational energy from the receiver loop antenna; an essentially rectangular transmitter loop antenna formed on said circuit substrate and having a transmitter loop central trace along which is defined a transmitter loop physical length, wherein an output field from the transmitter loop antenna is conform with a field from a predetermined current encircling said balise active reference area and

wherein the transmitter loop antenna is configured to transmit data wirelessly to a vehicle receiver in the railway vehicle when in a vicinity of the balise; transmitter circuitry connected by a transmitter feed connection to the transmitter loop antenna and configured to feed to the transmitter loop antenna a transmit signal including said data; the receiver loop central trace and the transmitter loop central trace having a mean separation of at least two times the substrate thickness.

[0007] Loop separation thus achieved allows for an improved material-efficiency and weight reduction by use of a relatively thin circuit substrate (circuit board) material. One tenth of an inch (2.5 mm) or, preferably, one sixteenth of an inch (1.6 mm) would be sufficient. Recent simulations have shown, contrary to what one would expect, that arranging the receiver loop antenna inside the transmitter loop antenna in a co-planar fashion will have a tolerably sized influence on the conformity of the antenna performance of the balise, such that it still meets the standardization requirements. Specifically, the simulations indicated that the field strength conformity requirement according to the Eurobalise specifications was attainable with separate receiver and transmitter loops in the same plane on one side of the circuit substrate. It should be noted that, in case of a co-planar layout, the physical dimensions, such as along a central trace, of at least one of the receiver loop and the transmitter loop will have to deviate clearly from the Eurobalise active reference area sizes stated in the standardization document.

[0008] The concept of a central trace, an imagined path essentially in the middle of an antenna loop, for the purpose of definition in this disclosure, is a reasonable approximation of the path of currents in a loop antenna, although the real transverse distribution of the currents may deviate somewhat from the middle, typically towards an inner edge of the loop.

[0009] Due to uneven current distribution phenomena in the receiver loop antenna, particular care is necessary in order to attain conformity of a balise when the receiver loop physical length is essentially a tenth or more of a wavelength, as defined in free space propagation, at operating frequencies of the receiver loop antenna. This is the case for a Eurobalise of standard size or reduced size. A tenth or more of a wavelength should be understood as defining a starting point, with a +/- 10% precision, of a range relating to every operating frequency in question (in a very narrow band at about 27 MHz for a Eurobalise).

[0010] An advantageous way of overcoming the adverse current distribution phenomena is to provide the receiver loop antenna with two, three, four or more loop segments separated by respective gaps away from the receiver feed connection, i.e. in addition to a gap that is necessary at the feed connection of a loop antenna. Each of the at least one gap being bridged by a respective capacitance so as to render an even current distribution in the receiver loop antenna. At least in the case of a Eurobalise, the capacitance may be a discrete capacitor component soldered to adjacent ends of loop segments formed as printed (etched) conductor patterns on a circuit board. This arrangement of segments and gaps will become particularly efficient in case the at least one gap is located essentially on a symmetry line of the receiver loop antenna and/or essentially equidistantly along the receiver loop antenna.

[0011] Several different arrangements of the receiver loop antenna and the transmitter loop antenna, respectively, may be realized on a printed circuit substrate of the balise, each having a set of advantages and, possibly, trade-offs. The receiver loop antenna and the transmitter loop antenna may both be formed one inside the other on the circuit substrate. This means that an inner edge of the one loop is wide enough to encircle an outer edge of the other loop, even if the loops are on opposite sides of the circuit substrate. It has been found to be advantageous to form the receiver loop antenna inside the transmitter loop antenna.

[0012] For good performance, at least one of the receiver loop antenna and the transmitter loop antenna can be provided, preferably overlapping itself, on both sides of the circuit substrate. An alternative would be to provide the receiver loop antenna on only one of the sides of the circuit substrate and if so, preferably on the second side as this tends to give performance gains. Particularly in the latter arrangement, the transmitter loop antenna is advantageously provided on only one of the sides of the circuit substrate, preferably on the first side. The transmitter loop antenna and the receiver loop antenna being only provided on opposite sides of the circuit substrate may give a particularly advantageous geometry, wherein the thickness of the dielectric substrate and loop separation in the plane of the dielectric substrate may both contribute to a relatively large total loop separation. To attain the good properties, the substrate thickness is less than or equal to one tenth of an inch.

[0013] For the balise disclosed herein a predetermined loop size range may be defined as a difference between the receiver loop physical length and the transmitter loop physical length being at least 20 mm, preferably 40 mm.

[0014] As indicated herein, the balise active reference area being a rectangle of either 358 mm by 488 mm, or 200 mm by 390 mm, essentially in concentric and co-planar relation to the receiver loop antenna and the transmitter loop antenna. Essentially in concentric and co-planar relation should be understood as typically including an approximation for cases wherein the receiver loop antenna and the transmitter loop antenna are not located on the same side only of the circuit substrate. A condition of conformity for the receiver loop antenna and the transmitter loop antenna, respectively, is +/- 1.5 dB as regards the balise active reference areas.

[0015] The balise of this disclosure is typically a balise with its receiver loop antenna and its transmitter loop antenna being configured to be in accordance with Eurobalise Transmission System, SUBSET-036, Issue

3.1.0, although other systematic approaches are conceivable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 shows how balises may conventionally be arranged on sleepers of a railway track.

Fig. 2 shows a functional block diagram of a balise according to the present invention.

Fig. 3 shows in a bottom-view a simplified circuit layout of a balise according to an embodiment of the present invention.

Fig. 4 shows in a top-view a simplified circuit layout of a balise according to an embodiment of the present invention.

Figs. 5a-5h show in a sectional view alternative printed circuits layout patterns of the loop antennas according to the invention.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0017] The drawings are focused on the circuitry of a balise, which is conventionally provided with a weatherproof housing (not shown) having fastening means for stationary arrangement on a railway. The drawings are not drawn to scale.

[0018] Fig. 1 shows a balise 1, in this case a Eurobalise, arranged in a stationary location between rails 2a of a railway track. The balise is typically attached to sleepers 2b of the railway track and may form groups of balises 1. A function of the balise 1 is to wirelessly transmit data to at least one conventional vehicle antenna (not shown) of a railway vehicle (not shown) travelling on the railway track.

[0019] Fig 2 shows in a simplified manner a functional block diagram of a balise 1 of a type to which the present invention relates. The balise 1 has a conducting receiver loop antenna 3 configured to receive electric power by magnetic induction from a vehicle transmitter antenna (not shown) the vehicle when passing the balise 1. The magnetic field generated by the transmitter antenna causes a current to flow in the receiver loop antenna 3. The current is rectified in a receiver 4 and the associated energy is stored in an energy storage 5. The energy is used to power consumer circuits of the balise, for instance, a resonant circuit 6 in a transmitter 7 of the balise. The balise further comprises a conducting transmitter loop antenna 8 configured to be fed by the resonant circuit 6 to transmit data from a controller 9 to the railway vehicle via its vehicle antenna, as the vehicle passes the balise. The controller 9 (not part of the present invention) has a serial link input 10 and an input from a default telegram unit 11 provided with a programming interface 12.

[0020] Fig. 3 and 4 show an essentially planar dielectric circuit substrate 13, also referred to as a circuit board, of conventional type. It has a first side 14 to be facing upwards and a second side 15 to be facing downwards when the balise 1 is arranged in its stationary position between the two rails 2b. The circuit substrate 13 has an essentially even substrate thickness of about 1.6 or 2.5 mm, and is typically too thin to provide enough separation of loop antennas overlapping each other on opposite sides of the substrate, in order to meet the stringent requirements for standardized balises such as the Eurobalise. Since balises form part of a railway safety system, the designing thereof tends to be conservative. However, as indicated, a more recent design thereof utilized overlapping conductive patterns on opposite sides of an extra thick circuit board to provide appropriately separated receiver and transmitter loops, one on each circuit board side and having the same predetermined size.

[0021] Fig. 3 and 4 further show essentially rectangular receiver loop antenna 16 formed on said circuit substrate 13 and having a receiver loop central trace along which is defined a receiver loop physical length, wherein an input flux to the receiver loop antenna is conform with a predetermined input flux in a balise active reference area, and wherein the receiver loop antenna 16 is configured receive operational energy wirelessly from a vehicle transmitter in the railway vehicle when in a vicinity of the balise, and receiver circuitry 4 connected by a receiver feed connection 17 to said receiver loop antenna 16 and configured to receive the operational energy from the receiver loop antenna 16. There is an essentially rectangular transmitter loop antenna 18 formed on said circuit substrate 13 and having a transmitter loop central trace along which is defined a transmitter loop physical length, wherein an output field from the transmitter loop antenna 18 is conform with a field from a predetermined current encircling said balise active reference area and wherein the transmitter loop antenna 18 is configured to transmit data wirelessly to a vehicle receiver in the railway vehicle when in a vicinity of the balise, transmitter circuitry 7 connected by a transmitter feed connection 19 to the transmitter loop antenna and configured to feed to the transmitter loop antenna 18 a transmit signal including said data. The receiver loop antenna and the transmitter loop antenna are separated to limit the coupling between them, such that the receiver loop central trace and the transmitter loop central trace have a mean separation of at least two times the thickness of the dielectric substrate. In figs. 3 and 4, an inter-loop separation is substantially larger than double the dielectric substrate thickness, since the receiver loop antenna is arranged inside, but on an opposing side to, the transmitter loop antenna. As shown, there is also a separating gap between the two loops in the plane of circuit substrate.

[0022] The Eurobalise of figs. 3 and 4 is standard size or reduced size. This means that the receiver loop phys-

ical length is essentially a tenth or more of a wavelength, as defined in free space propagation, at the 27.095 MHz operating frequency of the receiver loop antenna. At such a relation between physical length and wavelength, the inventive balise provides means for an even current distribution in the form of capacitors 20 included in the receiver loop antenna 16. This is an advantageous way of overcoming adverse current distribution phenomena. In the shown example the loop antenna is provided with four loop segments 21, 22, 23, 24 separated by respective gaps away from the receiver feed connection 17. Each gap is bridged by a capacitance 25, 26, 27 so as to render an even current distribution in the receiver loop antenna. For this Eurobalise, the capacitances 25, 26, 27 are discrete capacitor component soldered to adjacent ends of loop segments 21, 22, 23, 24. This arrangement of segment and gaps will become particularly efficient in case at least one gap is located essentially on a symmetry line of the receiver loop antenna and/or essentially equidistantly along the receiver loop antenna. It should be noted that the feed connections 17 and 19 may or may not overlap.

[0023] Figs. 5a - 5h show several different arrangements of the receiver loop antenna 16 and the transmitter loop antenna 18, respectively, on a printed circuit substrate 13 of the balise. This is illustrated by a section marked A-A in fig. 4. The views of figs. 5b-5h correspond to that of fig. 5a, but show different designs of the conductive traces of the loops. It should be noted that there is an aperture in the circuit substrate inside the loop antennas in fig. 4, which provides for the rather narrow substrate section of figs 5a - 5h depicting the different loop geometries, each having a set of advantages and, possibly, trade-offs. The receiver loop antenna and the transmitter loop antenna may both be formed one inside the other on the circuit substrate. This means that an inner edge of the one loop is wide enough to encircle an outer edge of the other loop, even if the loops are on opposite sides of the circuit substrate. It has been found to be advantageous to form the receiver loop antenna inside the transmitter loop antenna. Receiver and transmitter loop central traces are indicated by 28 and 29, respectively.

[0024] If a loop antenna is formed by conductive patterns on both sides of the dielectric circuit substrate, conductive vias (not shown) through the substrate would typically be used in various locations to connect the conductive patterns of the loop antenna on the opposing sides of the substrate. Preferably, this would be the case in figs. 5c, 5d, and 5g.

[0025] For the Eurobalise disclosed in figs. 3 and 4, a predetermined loop size range is defined as a difference between the receiver loop physical length and the transmitter loop physical length. In this example, this range is larger than 40 mm and the total length of the respective loop is about 1692 mm for a Eurobalise of Standard Size or 1180 mm for a Eurobalise of Reduced Size.

[0026] An active reference area of the Eurobalise is a rectangle of either 358 mm by 488 mm, or 200 mm by 390 mm, essentially in concentric and co-planar relation to the receiver loop antenna and the transmitter loop antenna. Essentially in concentric and co-planar relation should be understood as typically including an approximation for cases wherein the receiver loop antenna and the transmitter loop antenna are not located on the same side only of the circuit substrate. A condition of conformity for the receiver loop antenna and the transmitter loop antenna, respectively, is +/- 1.5 dB as regards the balise active reference areas. The Eurobalise of this embodiment has its receiver loop antenna and its transmitter loop antenna configured to be in accordance with Eurobalise Transmission System, SUBSET-036, Issue 3.1.0.

[0027] Although described mainly in relation to a Eurobalise, the inventor foresees the applicability of the inventive balise in accordance with ERTMS/ETCS, Interface 'G' Specification, SUBSET-100, Issue 2.0.0 of February 24, 2012.

Claims

1. A balise to be arranged stationary between rails of a railway track to wirelessly transmit data to at least one vehicle antenna of a railway vehicle on the railway track, said balise comprising:

an essentially planar dielectric circuit substrate having a first side to be facing upwards and a second side to be facing downwards when the balise is arranged stationary between the two rails, wherein the circuit substrate has an essentially even substrate thickness,

an essentially rectangular receiver loop antenna formed on said circuit substrate and having a receiver loop central trace along which is defined a receiver loop physical length, wherein an input flux to the receiver loop antenna is conform with a predetermined input flux in a balise active reference area, and wherein the receiver loop antenna is configured receive operational energy wirelessly from a vehicle transmitter in the railway vehicle when in a vicinity of the balise,

receiver circuitry connected by a receiver feed connection to said receiver loop antenna and configured to receive the operational energy from the receiver loop antenna,

an essentially rectangular transmitter loop antenna formed on said circuit substrate and having a transmitter loop central trace along which is defined a transmitter loop physical length, wherein an output field from the transmitter loop antenna is conform with a field from a predetermined current encircling said balise active reference area and wherein the transmitter loop antenna is configured to transmit data wirelessly to a vehicle receiver in the railway vehicle when

in a vicinity of the balise,
transmitter circuitry connected by a transmitter feed connection to the transmitter loop antenna and configured to feed to the transmitter loop antenna a transmit signal including said data,
characterized by,
the receiver loop central trace and the transmitter loop central trace having a mean separation of at least two times the dielectric substrate thickness.

2. The balise of claim 1, further comprising:
the receiver loop physical length being essentially a tenth or more of a wavelength, as defined in free space propagation, at operating frequencies of the receiver loop antenna.

3. The balise of any preceding claim, further comprising:

the receiver loop antenna having two, three, four or more loop segments separated by respective gaps away from the receiver feed connection,
each of the at least one gap being bridged by a respective capacitance so as to render an even current distribution in the receiver loop antenna.

4. The balise of any preceding claim, further comprising:
the at least one gap being located essentially on a symmetry line of the receiver loop antenna and/or essentially equidistantly along the receiver loop antenna.

5. The balise of any preceding claim, further comprising:
the receiver loop antenna and the transmitter loop antenna both being formed one inside the other on the circuit substrate.

6. The balise of claim 5, further comprising:
the receiver loop antenna being formed inside the transmitter loop antenna.

7. The balise of any preceding claim, further comprising:
the receiver loop antenna being formed, preferably overlapping itself, on both sides of the circuit substrate.

8. The balise of any preceding claim, further comprising:
the transmitter loop antenna being formed, preferably overlapping itself, on both sides of the circuit substrate.

9. The balise of any of claims 1-6, further comprising:
the receiver loop antenna being provided on only one of the sides of the circuit substrate, preferably on the second side.

10. The balise of any of claims 1-6, further comprising:
the transmitter loop antenna being provided on only one of the sides of the circuit substrate, preferably on the first side.

11. The balise of claims 1-6 or 9-10, further comprising:
the transmitter loop antenna and the receiver loop antenna being only provided on opposite sides of the circuit substrate.

12. The balise of any preceding claim, further comprising:
the substrate thickness is less than or equal to one tenth of an inch.

13. The balise of any preceding claim, further comprising:
the predetermined loop size range being defined as a difference between the receiver loop physical length and the transmitter loop physical length being at least 20 mm, preferably 40 mm.

14. The balise of any preceding claim, further comprising:
the balise active reference area being a rectangle of either 358 mm by 488 mm, or 200 mm by 390 mm, essentially in concentric and co-planar relation to the receiver loop antenna and the transmitter loop antenna.

15. The balise of any preceding claim, further comprising:
a condition of conformity for the receiver loop antenna and the transmitter loop antenna, respectively, is +/- 1.5 dB.

16. The balise of any preceding claim, further comprising:
the balise with its receiver loop antenna and its transmitter loop antenna, being configured to be in accordance with Eurobalise Transmission System, SUBSET-036, Issue 3.1.0.

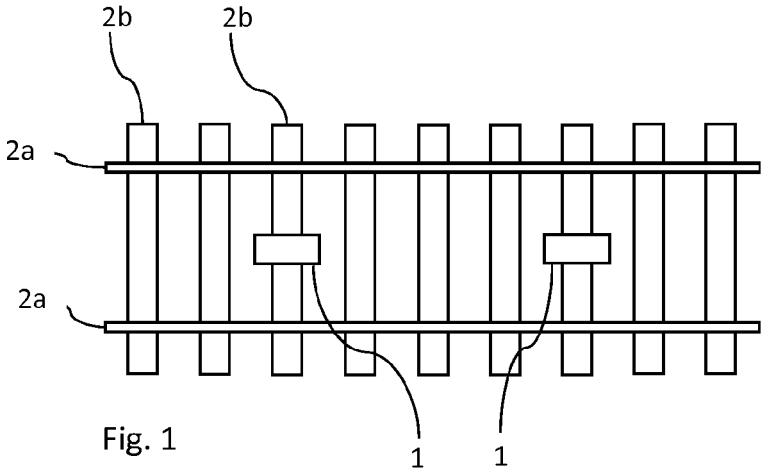

Fig. 1

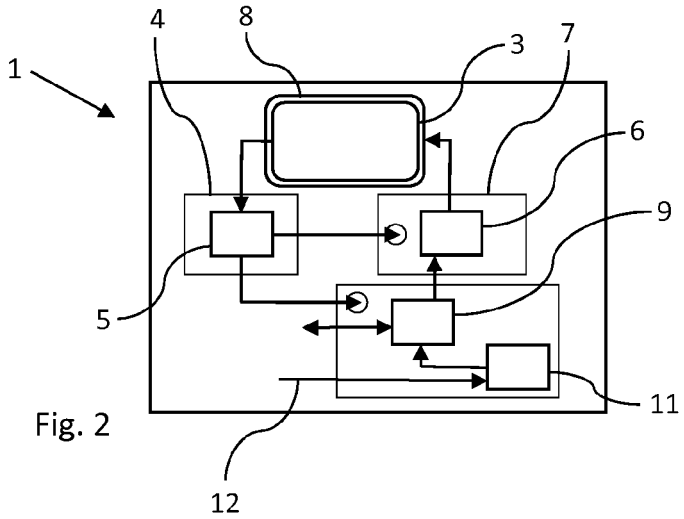

Fig. 2

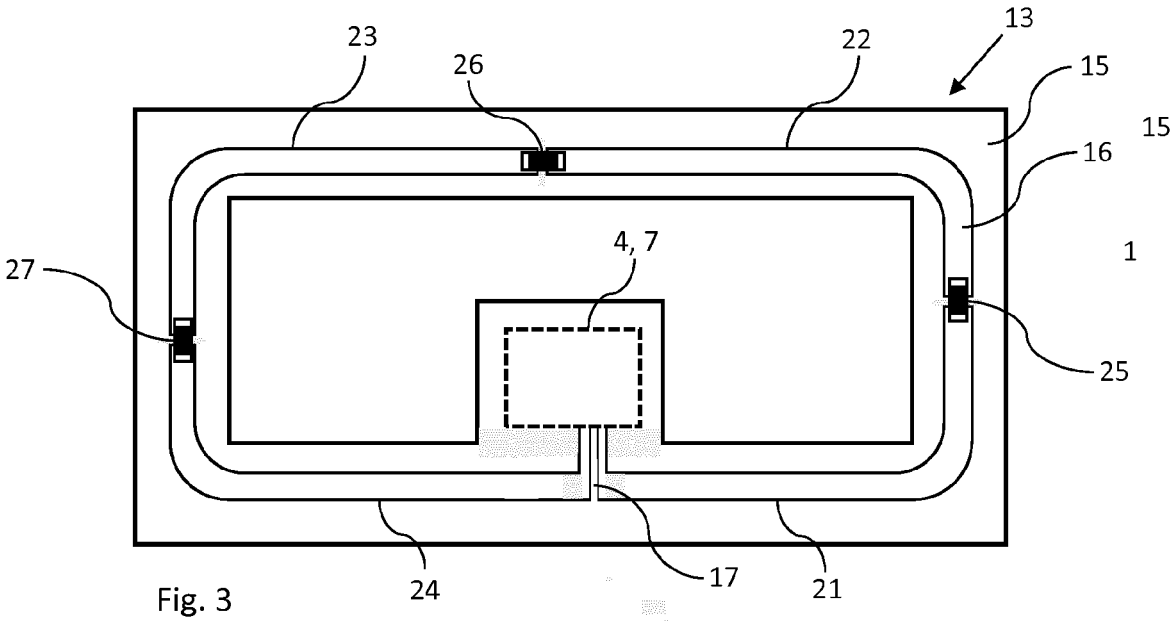

Fig. 3

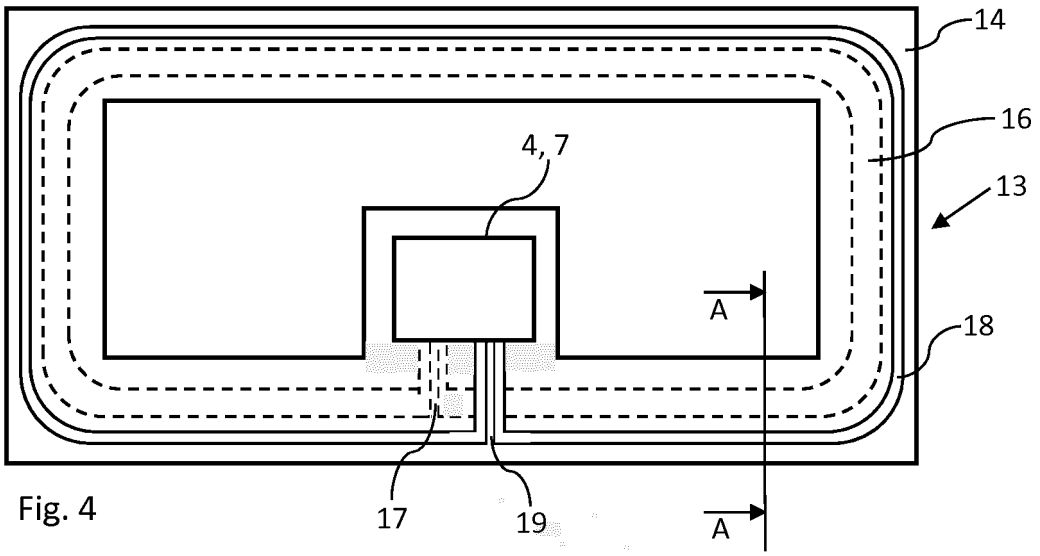

Fig. 4

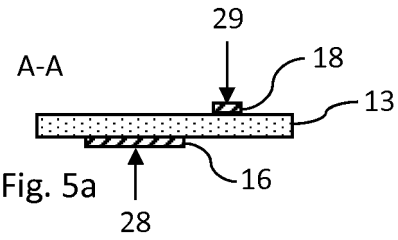

Fig. 5a

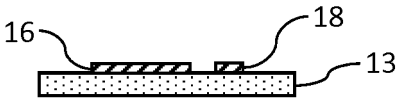

Fig. 5e

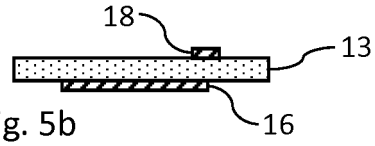

Fig. 5b

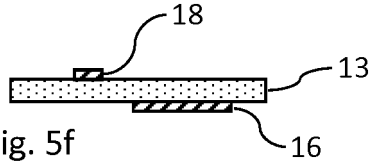

Fig. 5f

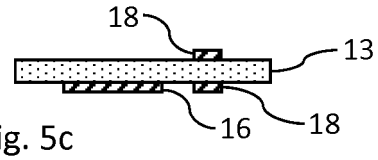

Fig. 5c

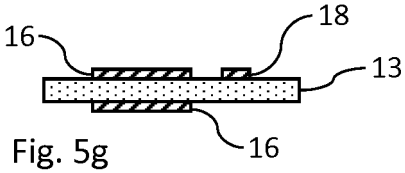

Fig. 5g

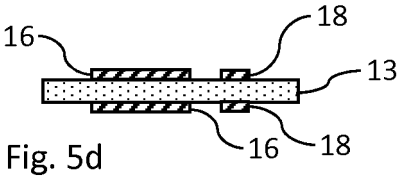

Fig. 5d

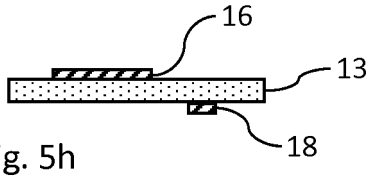

Fig. 5h

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European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 19 18 6298

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	EP 3 406 502 A1 (BOMBARDIER TRANSP GMBH [DE]) 28 November 2018 (2018-11-28) * paragraph [0001]; figures 1-5 * * paragraph [0007] - paragraph [0009] * * paragraph [0022] * * paragraph [0023] * * paragraph [0027] *	1,2,5-16 3,4	INV. B61L3/12 H01Q1/32
Y	KR 101 789 226 B1 (INDUSTRY-ACADEMIC COOP FOUND GYEONGSANG NAT UNIV [KR]) 23 October 2017 (2017-10-23) * paragraph [0039]; figure 3 *	3,4	
A	Alstom Ansaldo ET AL: "ERTMS/ETCS FFFIS for Eurobalise REF : Company Technical Approval Management approval", , 17 December 2015 (2015-12-17), XP055647946, Retrieved from the Internet: URL:https://www.era.europa.eu/sites/default/files/filesystem/ertms/ccs_tsi_annex_a_-_mandatory_specifications/set_of_specifications_3_etcs_b3_r2_gsm-r_b1/index009_-_subset-036_v310.pdf [retrieved on 2019-11-28] * 5.2.2.4 Balise Reference Areas * * 6.2.1.2.1 CW Tele-powering signal *	1,2,14,16	

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TECHNICAL FIELDS SEARCHED (IPC)
B61L
H01Q
H04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	5 December 2019	Pita Priegue, Miguel

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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EUROPEAN SEARCH REPORT

Application Number
EP 19 18 6298

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