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(54) **TRACK CIRCUIT**

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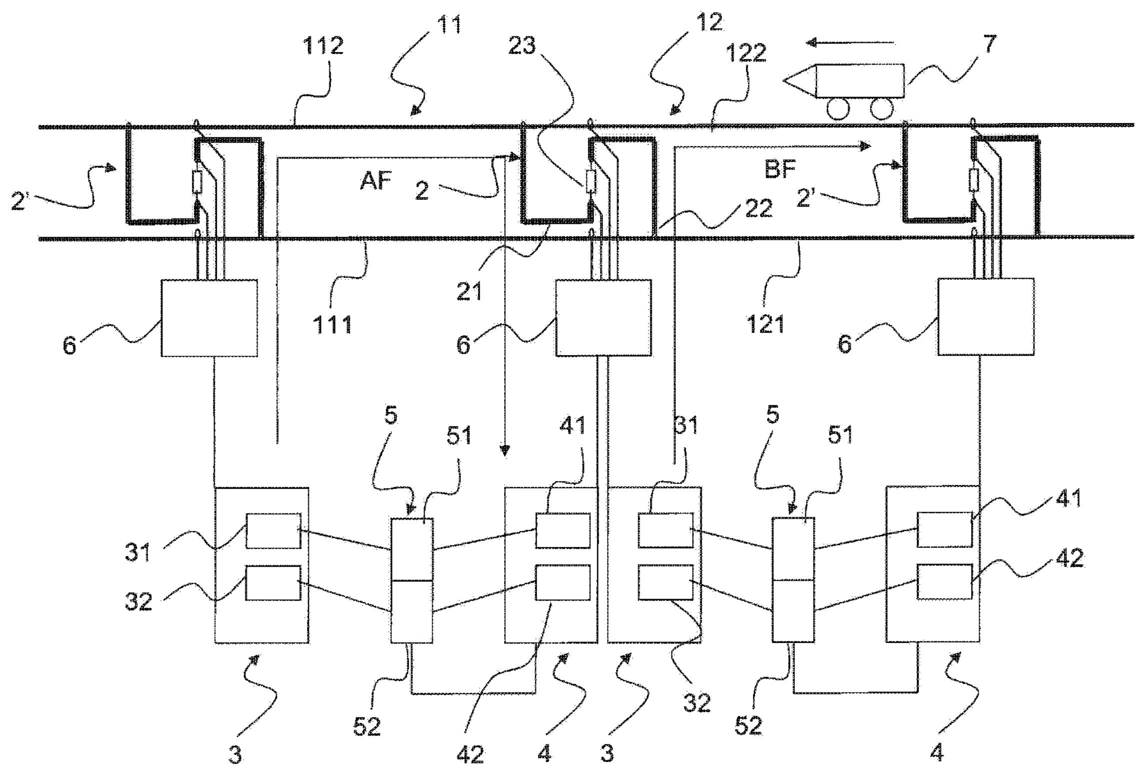
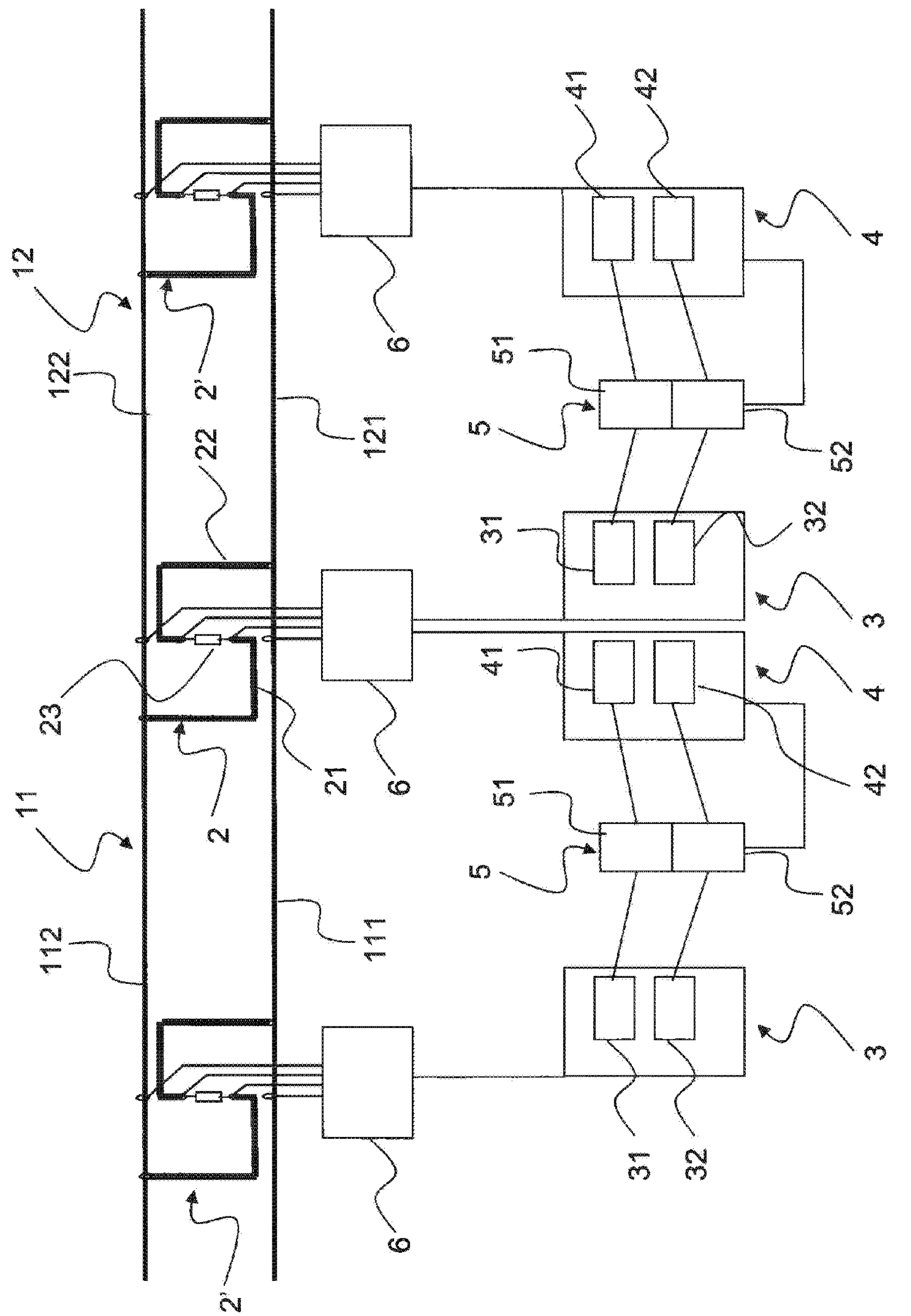
(57) **ABSTRACT**

A track circuit for railway systems or the like includes a track segment of predetermined length electrically insulated from an adjacent track segment by an electric joint, which includes a conductor and forms two loops arranged in a longitudinal S-shape within the space between the rails. Units are provided that transmit and receive electric signals and that are operatively coupled with the electric joints. The transmitting/receiving units include a unit transmitting and receiving a high-frequency signal to detect a train on the a track segment, and a unit transmitting and receiving a low-frequency signal which provides the carrier encoded with information to be transmitted to a train-based receiving unit. Units are further provided that enable/disable the high-frequency signal transmitting/receiving units, and units that enable/disable the low-frequency signal transmitting/receiving units, which are alternately actuated. The electric joint includes an internal impedance disposed between the two loops.





12
122
2'
22
121
6
41
42
4
51
5
52
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32
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11
112
111
41
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52
31
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2'

Fig. 1

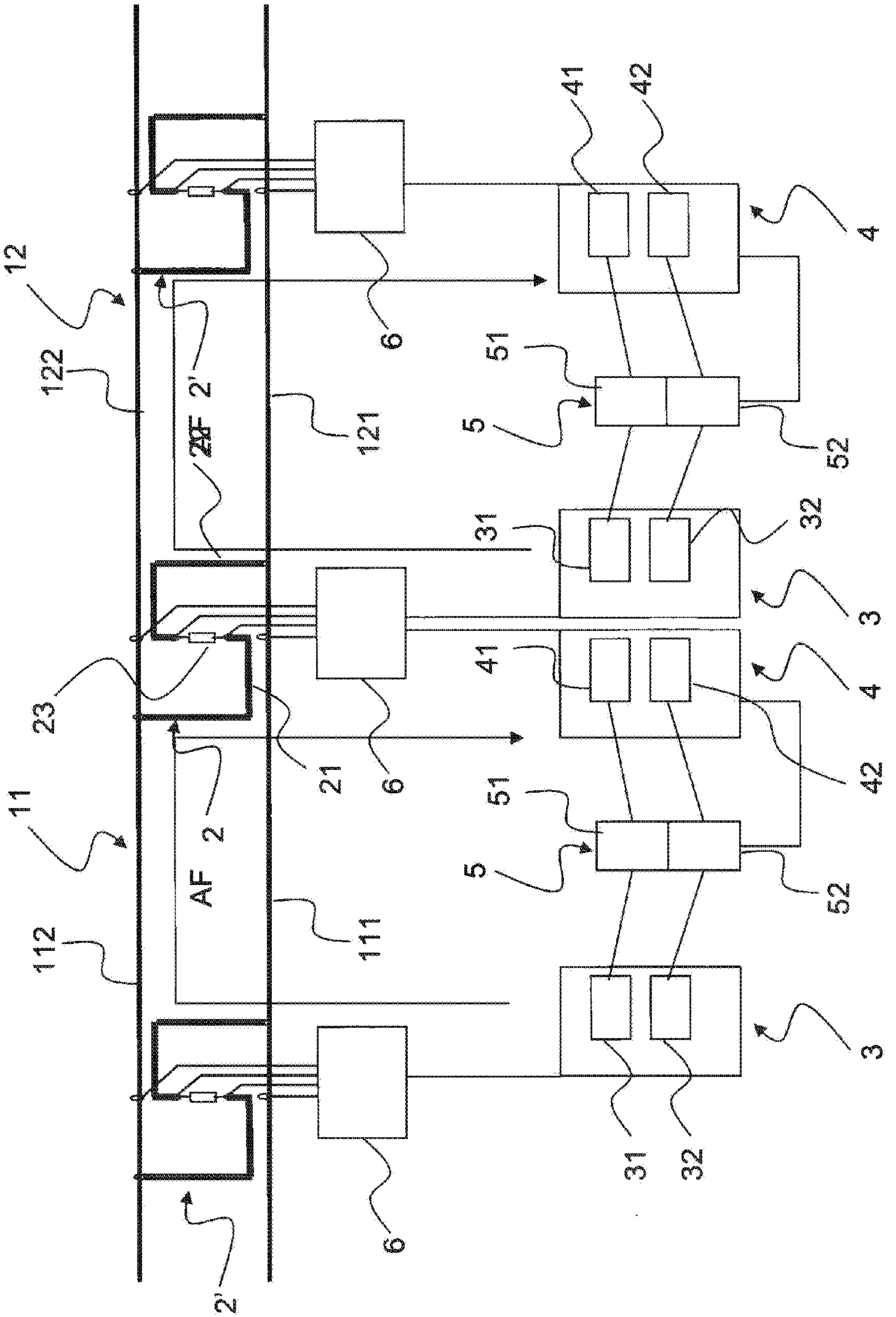

Fig. 2a

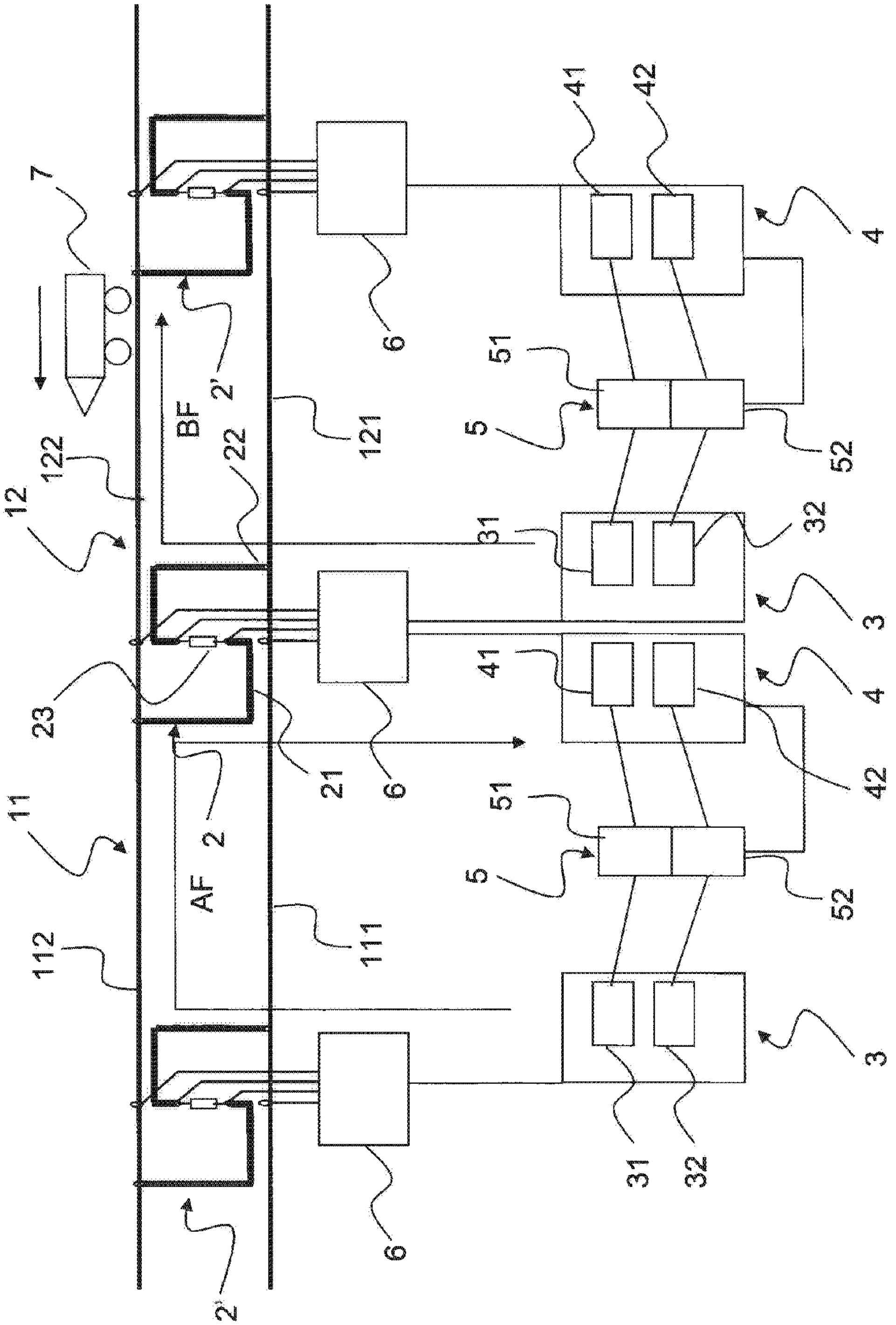

Fig. 2b

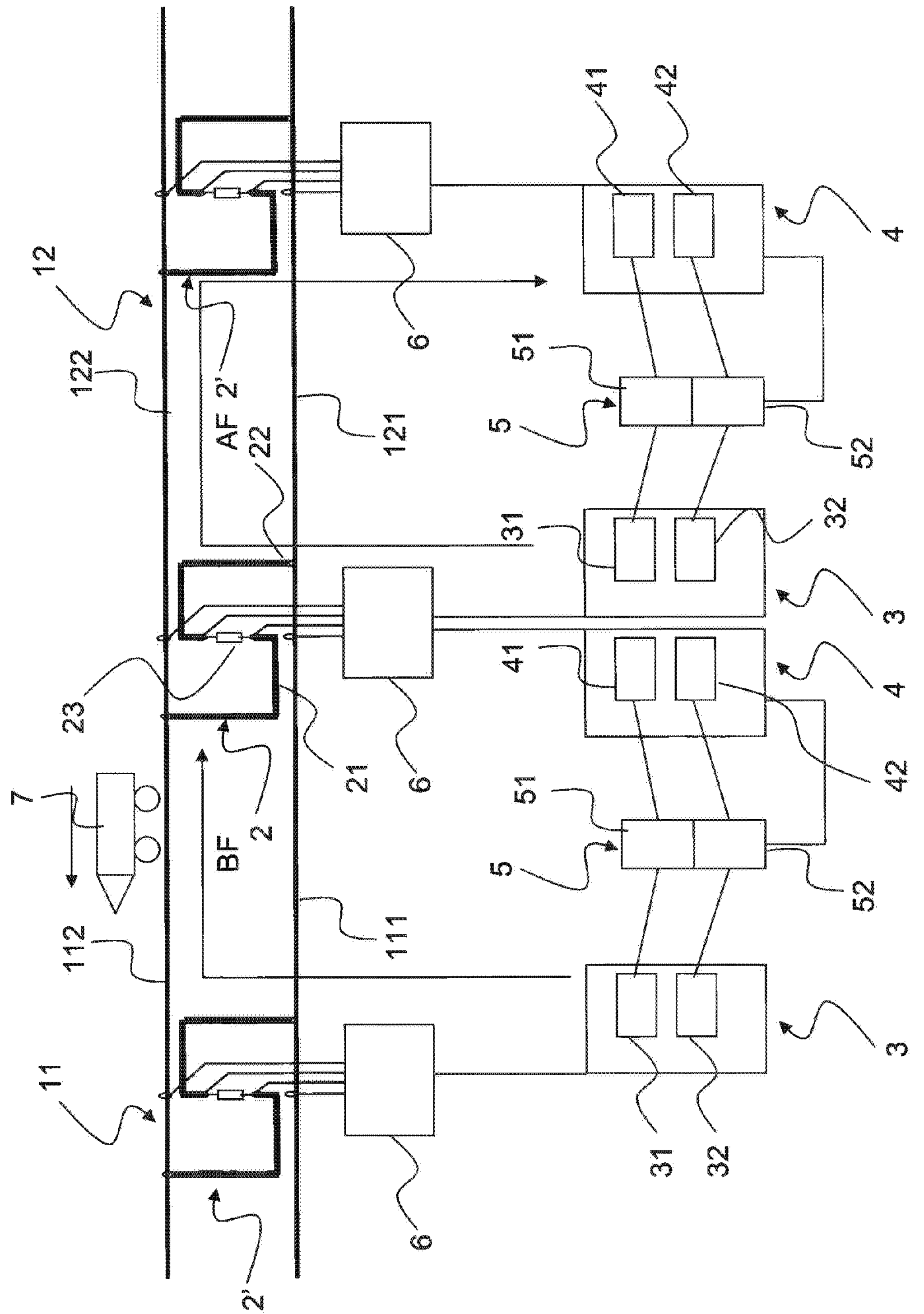

Fig. 2c

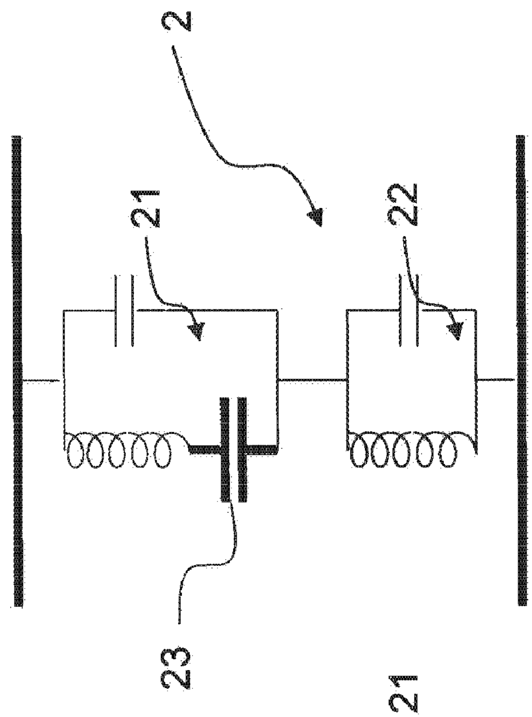

Fig. 3b

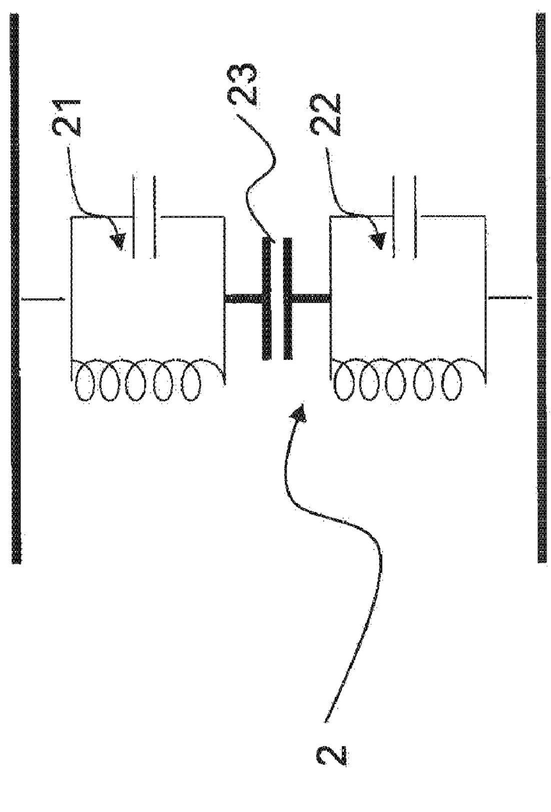

Fig. 3a

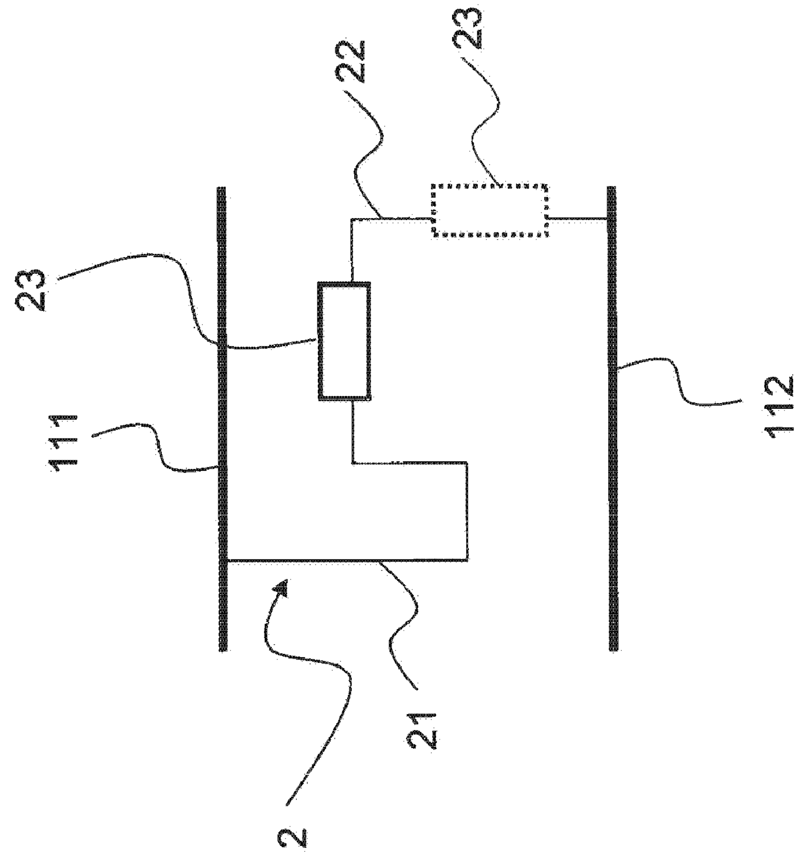

Fig. 4b

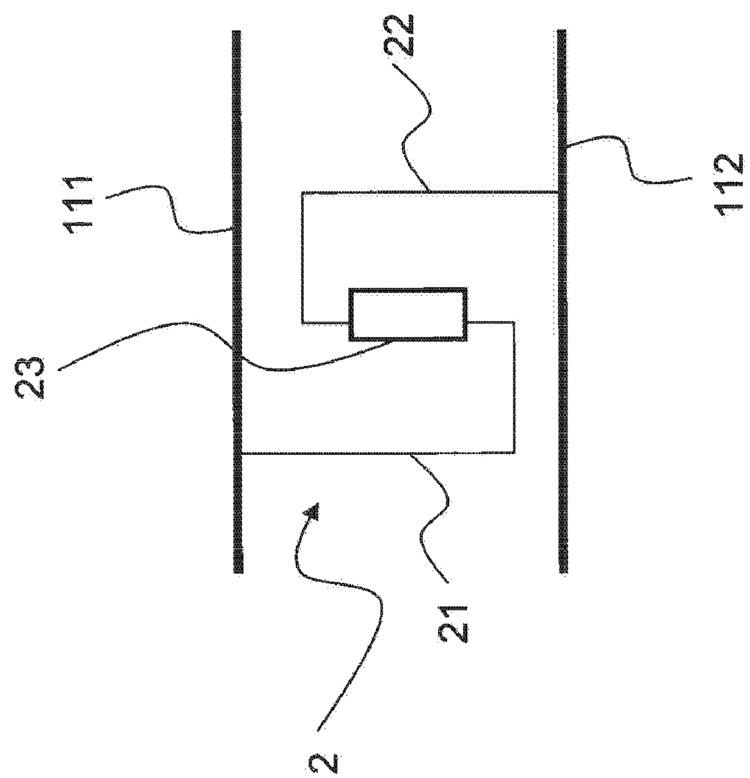

Fig. 4a

TRACK CIRCUIT

FIELD OF THE INVENTION

[0001] The present invention relates to a track circuit for railway systems or the like, which includes a track segment of predetermined length, electrically insulated from adjoining segments by electric joints, each comprising a conductor. The electric joints connect together the rails at the ends of the track segments and form two curves arranged in an S-shape, in the space between the rails, with the S lying in the direction of the track axis and having arms extending in the direction of the track, arranged along the inner sides of the rails.

[0002] Means that transmit and receive electric signals are also provided, which are associated with the electric joints, so that one joint is alternately connected with the transmitting or receiving means of its track segment and the transmitting or receiving means of the adjacent track segment, and each electric joint forms the start of its track segment and the end of the previous track segment.

[0003] The transmitting and receiving means also include ground-based fixed means for transmitting and receiving a high-frequency signal for detection of a train within the track segment, and ground-based fixed means for transmitting and receiving a low-frequency signal which constitutes the carrier encoded with the information to be transmitted to train-based receiving units. These signals are transmitted from the ground-based means to the train-based means through the rails of the track segment when the train runs on it.

BACKGROUND OF THE INVENTION

[0004] Track circuit design must account for several needs, which may be in contrast with one another. While on the one hand mechanical discontinuities within the rails are undesired, on the other hand electric separation between track circuits is required for detecting train position and for associating each segment with a given information set which generally changes according to the track circuit with to it is related. This balance is achieved with the help of electric joints, which confine the information transmitted through the track to the corresponding particular track segment. Proper consideration should be also given to providing track segments of a given length, while maintaining a low transmission power, and to ensuring that the transmitted signal will not be attenuated due to the low transmission power to such an extent as to be unreadable when received.

[0005] The track circuit should operate at such frequencies to be unaffected by traction currents, but the usable frequency bands should also be wide enough to allow transmission of a large amount of information.

[0006] Patent EP 771711 B1 discloses a track circuit adapted to transmit information from ground-based units to train-based units through the rails of each isolated track segment, as the train runs on it. The track segments are electrically insulated using S-shaped electric joints, with a compensation network composed of capacitors associated with each track circuit. The addition of such a network of capacitors improves the reliability of the electric joint in transmitting the signal used for train detection through the rails of each track segment while increasing the length of each track segment, and ensures effective confinement of the power associated with each track segment and the transmission of a very large amount of data while still maintaining a high safety level.

[0007] Nevertheless, the track circuit disclosed in EP 771711 B1 only operates at high frequencies, i.e. in the audio-frequency range from 2 to 20 kHz, and is not suitable for low frequencies, which are generally used in railway applications to transmit codes from the rails to train-based receiving means. Two frequency modulations are usually applied to alternate currents, at 50 Hz and 178 Hz, in order to enable transmission of a larger number of codes, thereby improving safety by providing more complete information to the trains in a shorter time.

[0008] Therefore, there exists a yet unfulfilled need for a track circuit that, by means of simple and inexpensive arrangements, can use electric joints, associated to track segments, which can transmit and receive both high and low-frequency signals, thereby allowing both train detection in a track segment by the use of high frequencies, and transmission of codes from the track segments rails to the train and/or vice versa by using low frequencies.

SUMMARY OF THE INVENTION

[0009] The invention fulfils the above purposes by providing a track circuit, in which there are means configured to enable/disable the transmission and reception of high-frequency signals, and means configured to enable/disable the transmission and reception of low-frequency signals, these means being actuated alternately.

[0010] In a variant embodiment, only a single type of means configured to enable/disable is used for both high and low-frequency signals, but the enabling/disabling state is still alternated, which means that when low-frequency communication is enabled, the high-frequency communication is disabled and vice versa.

[0011] Moreover, each electric joint uses internal impedance between the two loops.

[0012] The addition of impedance in the electric joint, and particularly of capacitive type impedance, enables the track circuit to operate both at high frequency to detect a train in a track segment, and at low frequency to transmit codes from the track segment rails to the train.

[0013] This is made possible by the added impedance, which prevents short circuits between the rails of the electric joint when low-frequency signals are transmitted into the track circuit and which maintains at a negligible level the signal loss introduced when high-frequency signals are transmitted into the track circuit.

[0014] In one embodiment, the track circuit of the present invention uses high-frequency signals in the audio-frequency range, from 2 to 20 kHz, and low-frequency signals from 50 to 178 Hz The low-frequency signals may be introduced into the track circuit using the cable that is used for transmission of audio-frequencies, by direct injection into the rails.

[0015] There is no directivity in the transmission of low-frequency signals in the range of 50 to 178 Hz, i.e. the power introduced into the rails is symmetrically distributed when the train is far away and as the train approaches the injection point, power increases in the direction of the train.

[0016] Moreover, the use of analog-to-digital converters and digital-to-analog converters at the output of the transmitting means and at the input of the receiving means respectively, allows the transmitted and received signals to be encoded as digital signals, adding robustness to the transmitted signals.

[0017] For a proper operation of each electric joint and hence of a track circuit constructed according to the principles of the present invention, the enabling/disabling means are configured to enable the high-frequency signal transmitting and receiving means and the low-frequency signal transmitting and receiving means alternately. Thus, when a train is detected within the track circuit, the enabling/disabling means enable the low-frequency signal transmitting and receiving means and disable the high-frequency signal transmitting and receiving means such to allow transmission of track codes to the train.

[0018] Conversely, when no train is detected within said track circuit, the enabling/disabling means disable the low-frequency signal transmitting and receiving means and enable the high-frequency signal transmitting and receiving means to allow train detection within the track segment, when a train comes into the corresponding track segment.

[0019] In one embodiment, operation of the enabling/disabling means is optimized by including a control unit in the transmitting and receiving means that controls the enabling/disabling means and that sets the enabling/disabling state of the transmitting and receiving means in response to a train detection signal for the track segment of interest.

[0020] As described above, the electric joint in a track circuit according to the present invention has an S shape formed of two loops. An impedance, preferably of capacitive type, is connected between such two loops. In two exemplary embodiments, such impedance may have different positions.

[0021] The two loops of the joint form two oscillatory circuits and, in a first embodiment, the impedance may be inserted between the two oscillatory circuits, i.e. outside the resonant loop of the electric joint. Therefore the impedance is unaffected by the resonance current of the electric joint and provides minimum signal attenuation for the high-frequency signal range, although any capacitance drop due to a failure would cause an increase of the current circulating within the electric joint, which would be undesired when considering the safety requirements that are applicable to railway applications and impose a maximum limit to the current circulating in an electric joint.

[0022] Therefore, the impedance is located in the middle of the conductor that forms the joint and particularly in the middle of the central section of said conductor, oriented perpendicularly to the tracks.

[0023] Alternatively, the impedance may be inserted asymmetrically with respect to the two loops of the electric joint. In this embodiment, the impedance is placed within one of the two oscillatory circuits. This solves the problem associated with safety requirements, because it helps in reducing the current circulating in the joint in case of capacitance degradation, although a higher attenuation is introduced for the range of high-frequency signals, but only in the loop with the impedance.

[0024] In this case, the impedance is placed in the conductor sections that form the S-shaped joint and are connected to one end of said central section perpendicular to the tracks.

[0025] Regardless of the selected configuration, additional advantages may be obtained by accurately tuning the capacitance value associated with the added impedance. The purpose is to obtain an input current for the receiving means which asymptotically tends to constant values, as a function of track segment length.

[0026] As described above, attenuation of high frequency signals should be as low as possible, but care should be taken to avoid dangerous increases in the current circulating in the joint, which requires the impedance to be tuned according to the selected configuration of the electric joint.

[0027] Studies and simulations show that if the capacitive impedance is inserted between the two loops of the joint, then a capacitance value of about 75 microfarads will provide an input current to the receiving means that asymptotically tends to constant value.

[0028] Conversely, if the capacitive impedance is inserted asymmetrically with respect to the two loops of the electric joint, the capacitance values of the impedance, required to obtain an input current for the receiving means that asymptomatically tends to constant value, are about 1000 microfarads.

[0029] Different embodiments of the invention include a variety of features that further improve a track circuit according to the invention, as recited in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] These and other features and advantages of the invention will be more apparent from the following description of a few embodiments shown in the accompanying drawings, in which:

[0031] FIG. **1** shows an embodiment of a track circuit according to the present invention;

[0032] FIGS. **2***a* to **2***c* show the operation of the track circuit of FIG. **1**;

[0033] FIGS. **3***a* and **3***b* show equivalent circuits of two possible configurations of electric joints for a track circuit according to the present invention, which are illustrated in FIGS. **4***a* and **4***b;*

[0034] FIGS. **4***a* and **4***b* show the electric joints of two possible configurations of the equivalent circuits of FIGS. **3***a* and **3***b*.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0035] Detailed descriptions of embodiments of the invention are provided herein. It is to be understood, however, that the present invention may be embodied in various forms. Therefore, the specific details disclosed herein are not to be interpreted as limiting, but rather as a representative basis for teaching one skilled in the art how to employ the present invention in virtually any detailed system, structure, or manner.

[0036] FIG. **1** shows a track circuit for railway systems or the like, which comprises two adjacent track segments **11** and **12** of predetermined length, each track segment **11** and **12** being electrically insulated from the track segment adjacent thereto by using electric joints **2** and **2'**.

[0037] Each electric joint **2** and **2'** consists of a conductor, which connects together rails **111**, **112**, **121** and **122** at the ends of track segments **11** and **12** and forms two loops **21** and **22** arranged in an S-shape in the space between said rails **111**, **112**, **121** and **122**. The S lies in the direction of the track axis and has arms extending in the direction of the track, arranged along the inner sides of rails **111**, **112**, **121** and **122**. Therefore, each joint defines the boundaries of the track circuits for adjacent track segments, and referring to FIG. **1** the joint **2** forms the end of the track segment **11** and the start of track segment **12**.

[0038] Still referring to FIG. **1**, each joint **2** and **2'** has an impedance **23** connecting the two loops **21** and **22**, which is preferably but without limitation a capacitive impedance.

[0039] Each joint has connected thereto a receiving unit (or means) for the track segment, of which the joint is the end, and a transmitting unit (or means) for the track segment, of which the joint is the start. FIG. **1** also shows transmitting unit (or means) **3** and receiving unit (or means) **4**, which are connected upstream and downstream of impedance **23**, so that receiving means **4** for track segment **11** and transmitting means **3** for track segment **12** are connected to the ends of impedance **23**.

[0040] In the embodiment shown in FIG. **1**, a tuning box, designated by numeral **6**, may be used.

[0041] Transmitting means **3** and receiving means **4** include a ground-based fixed transmitting unit (or means) **31** and a receiving unit (or means) **41** for transmitting and receiving a high-frequency signal for detection of a train within track segments **11** and **12**, and a ground-based fixed transmitting unit (or means) **32** and a receiving unit (or means) **42** for transmitting and receiving a low-frequency signal, which constitutes the carrier encoded with the information to be transmitted to train-based receiving units (not shown). Those signals are transmitted from the ground-based means to the train-based means through the rails of track segments **11** and **12**, when the train runs on them.

[0042] High-frequency signal transmitting means **31** and receiving means **41** transmit and receive a signal in the audio-frequency band, preferably at a range of frequencies from 2 to 20 kHz, while low-frequency transmitting means **32** and receiving means **42** transmit and receive a signal in the frequency range from 50 to 178 Hz.

[0043] In one embodiment, the signals transmitted and received by transmitting means **3** and receiving means **4** are digital signals, in which case analog-to-digital converter means and digital-to-analog reconverter means are provided at the output of said transmitting means **3** and at the input of receiving means **4**.

[0044] Still referring to FIG. **1**, in a preferred embodiment of a track circuit according to the present invention, high-frequency signal transmitting means **31** and receiving means **41** are combined with enabling/disabling means **51**, which enable or disable transmission and reception of the transmitting means **31** and receiving means **41** for the same track segment **11** and **12**.

[0045] Likewise, low-frequency signal transmitting means **32** and receiving means **42** are combined with enabling/disabling means **52**, which enable or disable transmission and reception of transmitting means **32** and receiving means **42** for the same track segment **11** and **12**.

[0046] Enabling/disabling means **51** and **52** are provided alternately to each other, such that if enabling/disabling means **51** enable reception and transmission by high-frequency signal transmitting means **31** and receiving means **41**, low-frequency signal transmitting means **32** and receiving means **42** are disabled by enabling/disabling means **52** and vice versa.

[0047] As described in greater detail in the next figures, the presence of a train in the track circuit will cause low-frequency signal transmitting means **32** and receiving means **32** to be enabled, and as a result, high-frequency signal transmitting means **31** and receiving means **41** to be disabled. In this case, in an embodiment of the track circuit of the present invention, a control unit **5** for controlling the enabling/disabling means will set the enabling/disabling state of high-frequency transmitting means **31** and receiving means **41**, and of low-frequency transmitting means **32** and receiving means **42**, as a function of the train detection signal for the track segment.

[0048] FIGS. **2***a* to **2***c* show the operation of a track circuit according to the present invention.

[0049] In particular, FIGS. **2***a* to **2***c* show the track circuit as described above, which consists of two adjacent track segments **11** and **12** of predetermined length, electrically insulated by electric joints **2** and **2'**.

[0050] Electric joints **2** and **2'** consist of a conductor, use an impedance **23** and are connected to transmitting means **3** and the receiving means **4**. Transmitting means **3** and receiving means **4** include high-frequency signal transmitting means **31** and receiving means **41**, and low-frequency transmitting means **42** and receiving means **32**, whose actuation is controlled by enabling/disabling means **51** and **52**.

[0051] More particularly, FIG. **2***a* shows a condition, in which there is no train in track segments **11** and **12**, and in which transmitting and receiving means **3** and **4** for the track segment **11** detect no train, and control unit **5** sets the state of the enabling/disabling means **51** and **52** for high-frequency signal transmitting means **31** and receiving means **41** to be enabled, and low-frequency signal transmitting means **31** and receiving means **42** to be disabled.

[0052] The same state is found in track segment **12**, i.e. communication both in track segment **11** and in track segment **12** occurs via high-frequency signals, designated as AF, and electric joints **2** and **2'** can both electrically insulate track segments **11** and **12** and allow such high-frequency communication without any significant signal loss.

[0053] In FIG. **2***b*, a train **7** comes into the circuit formed by track segment **12**. In this event, transmitting and receiving means **3** and **4** for track segment **11** detect no train and control unit **5** sets the state of enabling/disabling means **51** and **52** for high-frequency signal transmitting means **31** and receiving means **41** to be enabled, and low-frequency signal transmitting means **32** and receiving means **42** to be disabled. Such system will still transmit high-frequency signals, designated as AF.

[0054] However, in track segment **12**, train **7** shorts by its axles rails **121** and **122** and hence is detected by transmitting means **3** and receiving means **4**.

[0055] Control unit **5** sets the state of enabling/disabling means **51** and **52** for low-frequency signal transmitting means **32** and receiving means **42** to be enabled and high-frequency signal transmitting means **31** and receiving means **41** to be disabled. The circuit for track segment **12** transmits a low-frequency signal, designated as BF, which provides the carrier to be encoded with the information to be transmitted to the receiving units in train **7**, those signals being transmitted by ground-based transmitting means **32** to the train-based means through rails **121** and **122** of track segment **12**.

[0056] Thus, electric joints **2** and **2'** not only electrically insulate track segments **11** and **12** but also allow communication via low-frequency signals, through impedance **23**, by maintaining a short-circuit state between rails **121** and **122**.

[0057] In FIG. **2***c*, train **7** has moved past track segment **12** and runs on track segment **11**. Train **7** no longer shorts rails **121** and **122**, and its absence is detected by transmitting means **3** and receiving means **4**, which use control unit **5** and enabling/disabling means **51** and **52** to transmit the enabling state for high-frequency signal transmitting means **31** and receiving means **41**, and the disabling state for low-frequency signal transmitting means **32** and receiving means **42**, thereby restoring the initial condition for track segment **12** as shown in FIG. **2***a*.

[0058] However, in track segment **11**, train **7** shorts by its axles rails **111** and **112** and hence is detected by transmitting means **3** and receiving means **4**.

[0059] Control unit **5** sets the state of enabling/disabling means **51** and **52** for low-frequency signal transmitting means **32** and receiving means **42** to be enabled and for high-frequency signal transmitting means **31** and receiving means **41** to be disabled. The circuit for track segment **11** transmits a low-frequency signal, designated as BF, which provides the carrier to be encoded with the information to be transmitted to the receiving units in train **7**, those signals being transmitted by ground-based transmitting means **32** to the train-based means through rails **111** and **112** of track segment **11**.

[0060] Like before, electric joints **2** and **2'** not only electrically insulate track segments **11** and **12** but also allow communication via low-frequency signals, through impedance **23**, by maintaining a short-circuit state between rails **111** and **112**.

[0061] Once train **7** completes its run on track segment **11**, communication occurs in track segments **11** and **12** via high-frequency signals, thereby restoring the initial state as shown in FIG. **2***a*.

[0062] FIGS. **3***a* and **3***b* show two possible configurations of electric joints for the track circuit of the present invention.

[0063] In particular, FIG. **3***a* shows a possible embodiment of electric joint **2** for the track circuit of the present invention.

[0064] The electric joint **2** is composed of two half-joints **21** and **22** which form the two loops of the S shape of the joint. Each half-joint **21**, **22** forms an oscillatory circuit, with a capacitive impedance **23** inserted between the two oscillatory circuits **21** and **22**.

[0065] Thus, impedance **23** is placed outside the resonant loop of electric joint **2** and is hence unaffected by the resonance current of the joint.

[0066] As described above, capacitive impedance **23** of FIG. **3***a* should assume values of about 75 microfarads to obtain an input current for the receiving means that asymptotically tends to constant values.

[0067] FIG. **3***b* shows an alternative embodiment of electric joint **2**. Here, impedance **23** is asymmetrically connected with respect to the two loops of joint **21** and **22** and hence is placed within one of the two oscillatory circuits, in particular, in the oscillatory circuit that forms loop **21**.

[0068] Joint **2** as depicted in FIG. **3***b* should assume values of about 1000 microfarads to obtain an input current for the receiving means that asymptotically tends to constant values.

[0069] FIGS. **4***a* and **4***b* show the electric joints of the two possible configurations of the circuits of FIGS. **3***a* and **3***b*.

[0070] In FIG. **4***a*, electric joint **2** is composed of two half-joints **21** and **22** that form the two loops of the S shape of the joint. In this embodiment, an impedance **23** is inserted in a middle area of the conductor that forms joint **2** and more particularly at the center of the middle section of said conductor, which is oriented perpendicular to tracks **111** and **112**.

[0071] In FIG. **4***b*, electric joint **2** is composed of two half-joints **21** and **22** that form the two loops of the S shape of the joint. In this embodiment, an impedance **23** is inserted in one of the two conductor sections that form the S-shaped joint and that are connected to one end of said middle section of the conductor, which is oriented perpendicular to tracks **111** and **112**.

[0072] In FIG. **4***b*, impedance **23** is located in section **221** parallel to track **112** of loop **22**, although in variant embodiments impedance **23** might be placed either in section **222** perpendicular to track **112** of loop **22**, as shown by broken lines, and in the section parallel or perpendicular to track **112** of loop **21**.

[0073] While the invention has been described in connection with the above described embodiments, it is not intended to limit the scope of the invention to the particular forms set forth, but on the contrary, it is intended to cover such alternatives, modifications, and equivalents as may be included within the scope of the invention. Further, the scope of the present invention fully encompasses other embodiments that may become apparent to those skilled in the art and is limited only by the appended claims.

What is claimed is:

1. A track circuit for railway systems or the like comprising:

a track segment of predetermined length, a plurality of track segments forming a rail;

an electric joint connecting an end of the track segment to an end of an adjacent track segment, the electric joint comprising a conductor and being configured to electrically insulate the track segment from the adjacent track segment, the electric joint comprising two loops arranged in a S-shape and disposed longitudinally in a space between rails, the S-shape comprising arms extending toward the rails;

a transmitting unit which transmits electric signal and a receiving unit each operatively coupled to the electric joint, the electric joint having connected thereto the transmitting unit and the receiving unit of the track segment and the transmitting unit and the receiving unit of the adjacent track segment;

a ground-based transmitting unit comprised within the transmitting unit and a ground-based receiving unit comprised within the receiving unit, the ground-based transmitting and receiving units being configured to transmit and respectively receive high-frequency signals for detection of a train on the track segment;

a second ground-based transmitting unit comprised within the transmitting unit and a second ground-based receiving unit comprised within the receiving unit, the second ground-based transmitting and receiving units being configured to transmit and respectively receive low-frequency signals forming a carrier encoded with information to be transmitted to a receiving unit in the train, wherein the high- and low-frequency signals are transmitted from the ground-based units to the train-based unit through the rails comprising the track segment when the train runs on the track segment;

an enabling/disabling unit configured to alternately enable/disable the high-frequency signal transmitting and receiving units, and an enabling/disabling unit configured to enable/disable the low-frequency signal transmitting and receiving units; and

an impedance disposed within the electric joint.

2. The track circuit of claim **1**, wherein the impedance is of a capacitive type.

3. The track circuit of claim **2**, wherein the high-frequency signals are in a frequency range from 2 to 20 kHz, and wherein the low-frequency signals are in a frequency range from 50 to 178 Hz.

4. The track circuit of claim **1**, wherein the enabling/disabling units enable the low-frequency signal transmitting and receiving units and disable the high-frequency signal transmitting and receiving units when a train is detected within the track circuit, and disable the low-frequency signal transmitting and receiving units and enable the high-frequency signal transmitting and receiving units when no train is detected within the track circuit.

5. The track circuit of claim **1**, wherein transmitting unit and receiving units are operatively coupled to a control unit configured to control the enabling/disabling units, such to set an enabling/disabling state of the transmitting and receiving units as a function of the train detection signal for the track segment.

6. The track circuit of claim **1**, wherein the track circuit is configured to encode the transmitted and received signals as digital signals.

7. The track circuit of claim **1**, wherein the impedance is disposed between the two loops of the S-shape of the electric joint.

8. The track circuit of claim **1**, wherein the impedance is disposed asymmetrically with respect with the two loops of the S-shape of the electric joint.

9. The track circuit of claim **1**, wherein a capacitance value in each electric joint is determined by a value of the impedance such that current within the receiving unit asymptotically tends to constant values in relation to a length of the track segment.

10. The track circuit of claim **1**, wherein capacitance of the electric joint is from 50 to 100 microfarads.

11. The track circuit of claim **1**, wherein capacitance of the electric joint is from 800 to 1200 microfarads.

* * * * *