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TERMINATION CIRCUIT FOR RAIL VEHICLE DETECTION SYSTEM

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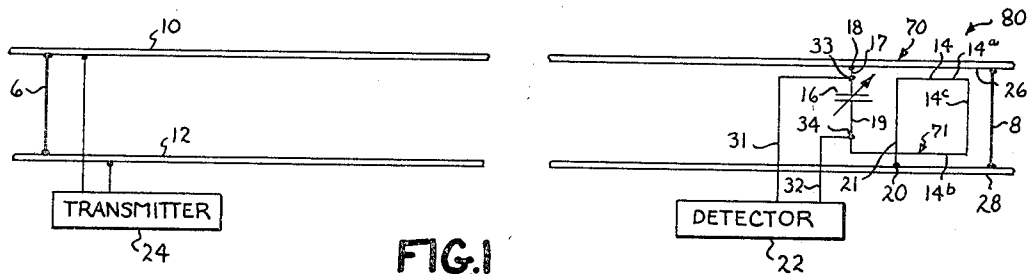


FIG. 1

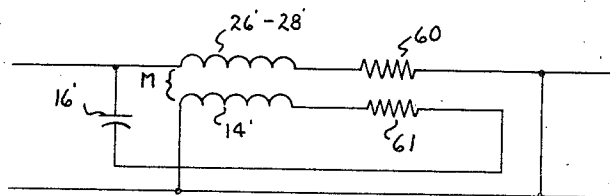


FIG. 2

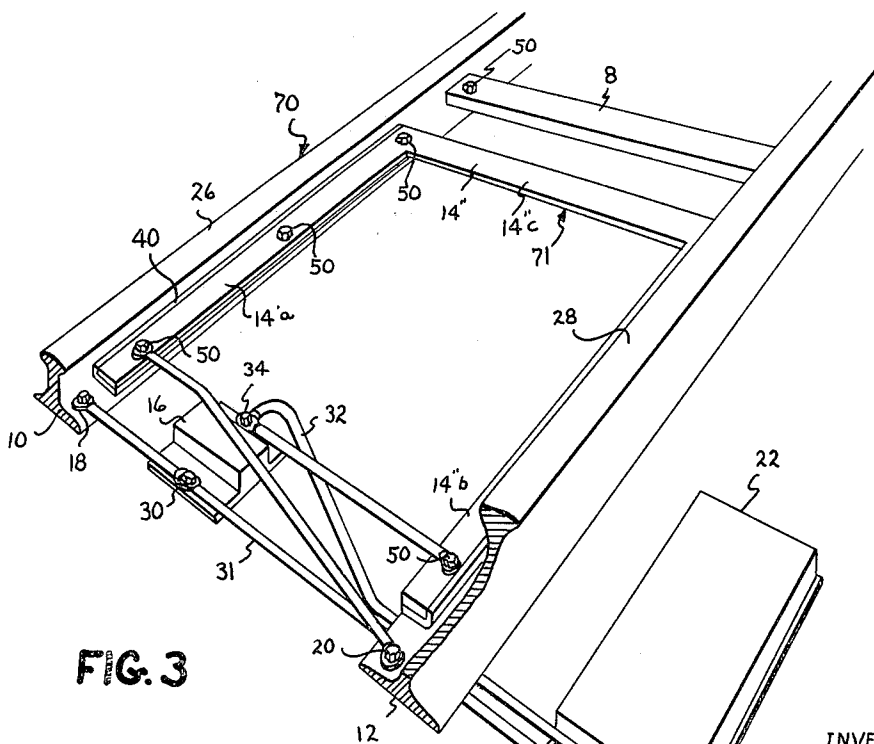


FIG. 3

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TERMINATION CIRCUIT FOR A RAIL VEHICLE DETECTION SYSTEM

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10 Claims

ABSTRACT OF THE DISCLOSURE

A termination circuit for a track circuit of the type wherein short circuits established a series of zones along a length of rail and signals are transmitted along the rails in each zone, being confined to the zones by the short circuits. The termination circuit is established adjacent at least one short circuit of each zone and includes a capacitor, portions of the rails, the short circuit and an inductor, with the inductor paralleling the rail portions so as to establish a mutual inductance between the inductor and the rail portions. The capacitor is tuned to place the termination circuit in parallel resonance. A detector responsive to characteristics of the signal transmitted along the zone is associated with the termination circuit to detect the presence or absence of a train within the zone.

BACKGROUND OF THE INVENTION

The present invention relates to rail vehicle location detection systems and more particularly to an improved system of detection of zone occupancy.

In the regulation of trains such as in subways, rapid transits or the like, travelling in the same direction on the same track, it is desirable that a succeeding train receive continuous or periodic indications of the position of an advance train. Such information is particularly essential where the system is designed for automatic operation without a motorman or operator.

One form of system for accomplishing the aforesaid regulation involves the division of the rails along the right of way into a plurality of sequential zones, each of which is electrically isolated from the other. A signal is transmitted along the rails in each zone by a transmitter, and detected by a detector located adjacent the end of the zone. When a train enters the zone, it changes the electrical characteristics of the detected signal thereby indicating zone occupancy. A relay system then relays the detected zone occupancy information back to the succeeding train which then slows or stops, depending on its prearranged programming.

In order to prevent signals transmitted in one zone from being detected in adjacent zones by detectors tuned to the same frequency, some form of signal suppression means, such as insulated joints or short circuits, is often provided at the zone borders. The use of short circuits instead of insulated joints is preferable since it permits the use of continuously conductive track with the known advantages over the insulated type joints. However, there has been a problem in the use of short circuits in the past as it was necessary to transmit high frequency signals in the zone circuits so that sufficient impedance existed in the rail section between the short circuit and the detector to prevent the short circuit from shorting out the detector. The use of high frequencies placed an undesirable restriction on maximum zone length due to the attenuation of high frequency signals. Very low frequencies to obtain longer zone length could not readily be used since it was necessary to connect the detector so far from the short circuit that the distance was greater than the length of the train to be detected. As a result, a blind spot where a train could not be detected was created between the

short circuit and the detector thereby rendering such approach useless at very low frequencies such as 5 kHz.

SUMMARY OF THE INVENTION

The invention generally contemplates the use of a novel terminating circuit including an inductor connected across the rail sections adjacent a short circuit with a portion of the inductor being disposed sufficiently close to the rail sections and/or short circuit so as to provide a mutual inductance. A capacitor is placed across the rails in series with the inductor and tuned to provide parallel resonance with the total inductance of the termination circuit at the transmitter frequency. In a more specific aspect of the invention, the inductor is a single turn generally U-shaped bar. By the aforesaid arrangement, a system is provided which permits the use of low signal frequencies, such as in the range of 5 kHz. with accompanying long zone length, yet with the distance between the detector and the short circuit being less than the length of the shortest train which is to be detected, thereby eliminating any blind spots. The single turn bar inductor provides a structure which may be securely fastened to the rails, such as through insulated bolts, thereby providing a system wherein the mutual inductance may be maintained at a substantially constant and maximum level despite vibration and shifting movement of the rails. By such arrangement, the close proximity of the legs of the inductor to the rail sections is sustained even under conditions of extreme vibration, thereby preserving the parallel resonant condition. The invention provides an improved system with minimum additional equipment and minimum additional cost to establish an improved termination means at the end of the zone which is rugged and capable of withstanding great wear and tear.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a fragmentary partially broken schematic view of one zone in accordance with the present invention;

FIG. 2 is an equivalent circuit of the operation of the novel inductor and associated capacitor; and

FIG. 3 is a fragmentary perspective view on an enlarged scale of a novel inductor assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

One preferred embodiment of the invention is illustrated in FIG. 1. A detection zone is established by a pair of short circuits 6 and 8 connected across a pair of rails 10 and 12, with a transmitter 24 being connected across the rails 10 and 12 adjacent the short circuit 6 at one end of the zone. A novel termination circuit 80, including a rail loop branch 70 and an inductor loop branch 71 is established in association with a detector 22 adjacent the other end of the zone. The inductor loop circuit 71 is connected across the rails 10 and 12 near the short circuit 8, as at points 18 and 20, and includes conductor 17, capacitor 16, conductor 19, inductor 14, and conductor 21. The rail loop circuit 70 includes the short circuit 8 and the rail sections 26 and 28, which are the rail sections located between the short circuit 8 and the points 18 and 20 of connection of the inductor loop 71 to the rails. By such arrangement, the capacitor 16 is electrically in series with the inductor 14 and inductor 14 is electrically in series with the rail loop circuit 70. Portions of the inductor 14, such as portions 14a and 14b are disposed sufficiently close to the rail sections 26 and 28 to establish a mutual inductance between the rail loop 70 and the inductor loop 71. The capacitor 16 is tuned to place the termination circuit 80 in parallel resonance. That is,

capacitor 16 is tuned to parallel resonance with the series combination of inductor 14 and rail loop 70.

By the foregoing arrangement, a high impedance is established adjacent the short circuit 8. If a detector is properly associated with the termination circuit, the coupling of the detector may be disposed very close to the short circuit 8, such as 25 feet from the short circuit even at very low frequencies, such as 5 kHz. In addition, a less sensitive detector is needed since the reduction in the voltage detected by the detector when a train enters the zone is much greater than would be the case without the novel termination circuit. A preferred means of associating the detector 22 with the termination circuit 80 is for the detector to be connected across the capacitor 16 as by conductors 31 and 32, as at points 33 and 34.

Portions of the inductor 14, such as portions 14a and 14b should be disposed as close as possible to the adjacent portions of the rail sections 26 and 28 so as to establish a mutual inductance between the rail loop 70 and the inductor loop 71. This mutual inductance increases the impedance of the termination circuit 80.

An equivalent circuit illustrating the establishment of the mutual inductance is shown in FIG. 2. The inductance 26'-28' represents the self inductance of the rail loop 70, including rail sections 26 and 28 and short circuit 8. This is the same inductance which the rail loop would have if there were no novel termination circuit. Such self-inductance is not sufficient to permit the detector 22 to be coupled to the rails in the desired proximity to the short circuit at low frequencies. The inductance 14' represents the self-inductance of the inductor loop 71 including sections 14, 21 and 19; and the letter M represents the additional mutual inductance provided by the inductive coupling of the inductor loop 71 to the associated rail loop 70. Resistance 60 represents the total resistance of the rail loop 70 including sections 26 and 28 and short circuit 8; and the resistance 61 represents the resistance of the inductor loop 71 and its associated conductors. The capacitance 16' represents the capacitance of the capacitor 16. The capacitance 16' is selected of such value that the capacitor 16 is tuned to be in parallel resonance with the total inductance of the termination circuit 80, including the mutual inductance M. By the foregoing arrangement, the zone termination impedance is increased appreciably thereby allowing the detector 22 to be coupled to the rails much closer to the zone termination short circuit 80 than would otherwise be possible at very low frequencies.

The aforesaid mutual coupling between the rail loop 70 and the inductor loop 71 increases the inherent inductance of the rail sections by the following multiplication factor:

$$\frac{(1+KN)^2}{1+N}$$

where N is the turns ratio of the inductor loop 71 to the rail loop 70, and K is the coefficient of coupling between the loops. The coefficient of coupling K is defined by the formula:

$$K^2 = M^2 / L_R L_I$$

where M is the mutual inductance, L_R is the self-inductance of the rail loop 70 and L_I is the self-inductance of the inductor loop 71.

The self-inductance of the rail loop 70 at a particular frequency may be represented by the formula:

$$QwL$$

where Q is the figure of merit (the reactance of the rails divided by the resistance of the rails), w is 2 pi times the operating frequency, and L_R is the inductance of the rail loop 70.

Thus the total inductance for the rail loop 70, due to the aforesaid mutual coupling M is:

$$QwL \frac{(1+KN)^2}{1+N}$$

While an increase in the turn ratio increases the zone termination impedance, it has been found that improved operational results are achieved by using a single turn impedance in the form of a general U-shaped bar 14'' (FIG. 3) which may be securely fastened adjacent the rail section 26 and 28 so as to maintain the bar inductor 14'' as close to the rails as possible without establishing actual contact. The minimum spacing is determined by the minimum possible thickness of an adequate insulator 40 disposed between the inductor 14'' and the confronting surfaces of the rail section 26 and 28. A preferred range of spacing between the inductor 14'' and the rail section 26 and 28 is between 1/8'' and 1 1/2''.

The preferred shape of the bar inductor 14'' is a general U-shape as shown, with the bar having a cross-piece 14''c and a pair of depending legs 14''a and 14''b. The bar may be made of aluminum or other suitable conducting material and may be of unitary construction as shown, or of multiple construction such as three pieces suitably joined together. The inductor 14'' may be rigidly fastened to the rails as by insulated bolts 50; the bar inductor 14'' need not extend the length of the rail sections 26 and 28. The length of the inductor 14'' will be determined by an optimum arrangement of the factors discussed hereinafter.

It is to be understood that where an adequate positioning of a multiple turn winding or bar can be made, and such structure is economically feasible, such a bar or winding can be used if desired. Similarly, where deemed advantageous, the insulation 40 may cover the entire inductor 14'' to insure against short circuiting between the inductor 14'' and the rail sections 26 and 28, due to extraneous causes. In addition, where desired, the cross-piece 14''c may be disposed adjacent and suitably insulated from the short circuit 8 which is bolted to the rails so as to further increase the mutual inductance, M. It will also be understood that capacitor 16 for making the termination circuit resonant need not be mounted between the rails as illustrated in the drawings, but may be located wherever convenient or desirable, such as for example, within the detector.

The detector 22 may be any suitable means for detecting one or more characteristics, such as level or frequency, of a signal received by it. For example, the detector may be a threshold level detector which ceases to produce an output when the signal received by it is below the predetermined threshold level. When a rail vehicle (not shown) is disposed along the rails 10 and 12 between the transmitter 24 and the detector 22, the wheels and axle of the train will shunt a signal from the transmitter 24 thus causing the level of the signal received by the detector 22 to drop below the threshold level of the detector. Because of the arrangement of the present invention, the magnitude of change of detected voltage between train and no train conditions will be substantial, thereby requiring a less sensitive detector. Where the detector 22 is to operate to relay zone occupancy signals from advance zones it may also be frequency sensitive, as is known in the art.

The impedance for the termination circuit 80 will depend generally upon:

- (1) The frequency of the signal.
- (2) The unit length inherent inductance of the inductor 14.
- (3) The length of the inductor portions 14a and 14b.
- (4) The length of the rail portions 26 and 28.
- (5) The unit length inductance of the rail portions 26 and 28.
- (6) The spacing between the inductor portions 14a and 14b and the respective adjacent rail portions 26 and 28.
- (7) The capacitance of the capacitor 16.

The following values illustrate an example of one assembly in accordance with the invention;

Insulator material=air

Insulator thickness=1/4'' air gap

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Spacing between the inductor 14 and rail portions 26 and 28=1"

Inductor 14 material=aluminum

Inductor 14 cross-section= $3'' \times 1'' \times \frac{1}{8}''$ channel

Length of legs 14a and 14b of inductor=16 ft.

Length of rail portions 26 and 28=16 ft.

Per unit inductance of rail sections 26 and 28=50 microhenries per 100 ft.

Capacitance of capacitor 16=15 mfd.

Frequency of transmitter 24=8000 kHz.

Impedance of detector 22=100 ohms

Total impedance of the termination circuit 80=7 ohms

Mutual inductance M=7.2 microhenries

Turns ratio N=1

Coefficient of coupling K=0.9.

While a zone having one transmitter and one detector is shown, it is to be understood that suitable variations may be employed, such as utilizing a transmitter in the center of the zone with a detector having an associated inductor 14 disposed adjacent the short circuits at each end of the zone.

Suitable means known in the art may be provided to relay the detected zone occupancy information to an oncoming train. For example, suitable switching means (not shown) may be operably connected between the detector of an advance zone and the transmitter of a preceding zone to modulate the signal transmitted in the preceding zone to indicate to a succeeding train (not shown) carrying a modulation detector inductively coupled to the tracks, that a train is present in an advance zone. Where a modulation system of transmission is used, the zone termination circuit is made to be resonant at the carrier frequency.

Since the shunting impedance of the wheels and axle of a train is between zero and 2 ohms, it is preferred that the impedance of the terminating circuit 80 be at least 4 ohms. It is to be understood that when a train enters the area of the zone between the points 18 and 20 and the short circuit 8, its presence will still be detected due to its shorting of sufficient portions of the impedance of rail sections 26 and 28 until it is close to the short circuit 8. At such time the non-shorter impedance will be sufficiently high that the signal detected is above threshold level. The actual "blind spot" is then between this point (not shown) and the short circuit. This ultimate "blind spot" may be 14 feet. Thus, where desired, the "blind spot" may be further shortened by computing the distance at which detection no longer occurs, and establishing this distance as the minimum length train which can be detected.

It is to be understood that the present system could be used to connect a transmitter to the rails, using the inductor 14 as an inductive coupling for coupling the output of the transmitter to the rails.

By the arrangement of the present invention, a system is provided whereby a detector may be located near a short circuit even at very low frequencies and without an accompanying blind spot.

While only preferred embodiments of the present invention have been described in detail herein, it will be understood that various changes and modifications will readily occur to those skilled in the art. It is intended, therefore, that the appended claims cover all such changes and modifications as fall within the true spirit and scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a rail vehicle detection system comprising a pair of rails, at least one detection zone, short circuit means connected across the rails adjacent at least one end of said zone, capacitance means, inductance means serially

connected with said capacitance means across said rails at points spaced from said short circuit means, at least a portion of said inductance means disposed adjacent at least a portion of said rails between said points and said short circuit means so as to provide a mutual inductance between said inductance means and said rail portions, said capacitance means being tuned to place the termination circuit in parallel resonance.

2. A detection zone system in accordance with claim 1, including detection means associated with said capacitance means to detect at least one characteristic of the said signal.

3. A rail vehicle detection zone system comprising a pair of rails, a zone termination circuit adjacent at least one end of the zone including short circuit means connected across said rails, capacitance means, inductance means serially connected with said capacitance means across said rails at points spaced from said short circuit means, at least a portion of said inductance means being disposed adjacent at least a portion of at least one of said rails between said points and said short circuit means and disposed sufficiently close to said rails to provide a mutual inductance for said rail portion, said capacitance means being tuned so as to establish a parallel resonant condition in said circuit, a detection means associated with said circuit and adapted to detect at least one characteristic of a signal, and transmission means to transmit said signal within the frequency range of said parallel resonance.

4. A detection zone in accordance with claim 3, wherein the impedance of said termination circuit is greater than the shunting resistance of the wheel and axle assembly of any rail vehicle which is to be detected within the zone.

5. A detection zone in accordance with claim 3, wherein said inductance means is a single turn bar.

6. A detection zone in accordance with claim 5, wherein electrical insulation means are disposed between said bar and said rails, and wherein at least portions of said bar are fastened to portions of each of said rail sections between said points and said short circuit.

7. A detection zone in accordance with claim 5, wherein said inductance means includes a bar inductor fastened to at least one of the rails.

8. A detection zone in accordance with claim 3, wherein said inductance means includes an inductor bar, said bar comprising a cross member adapted to be disposed transversely between said rails and a pair of oppositely disposed legs extending from said cross member, said legs adapted to be disposed in generally parallel relationship with said rails in the assembled position of said bar.

9. A detection zone in accordance with claim 8, including insulation means disposed between said legs and the confronting surfaces of the respective rails.

10. A detection zone in accordance with claim 8, wherein said cross member and legs together define a generally U-shape configuration, in plan.

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