June 17, 1969

J. R. WHITTEN

3,450,874

RAILWAY TRACK CIRCUIT

Filed March 31, 1967

Sheet 1 of 3

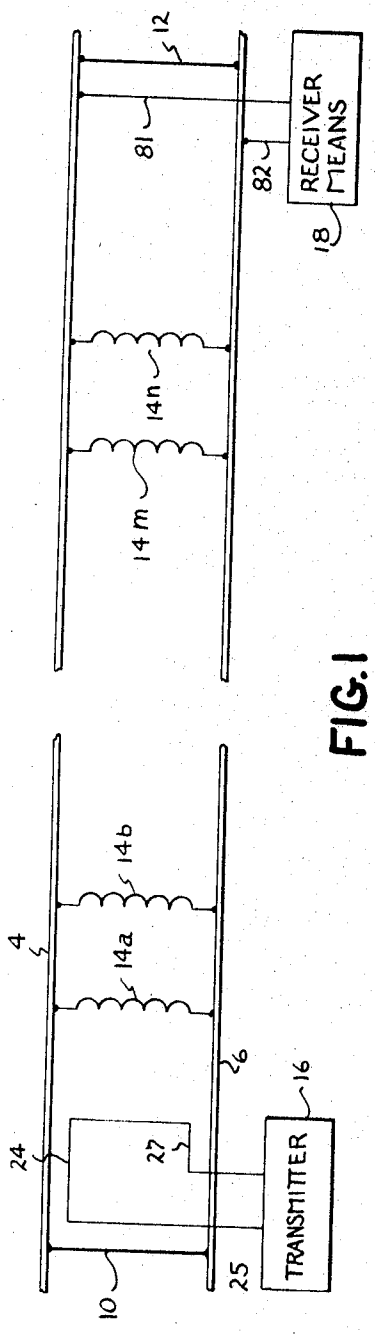

FIG. 1

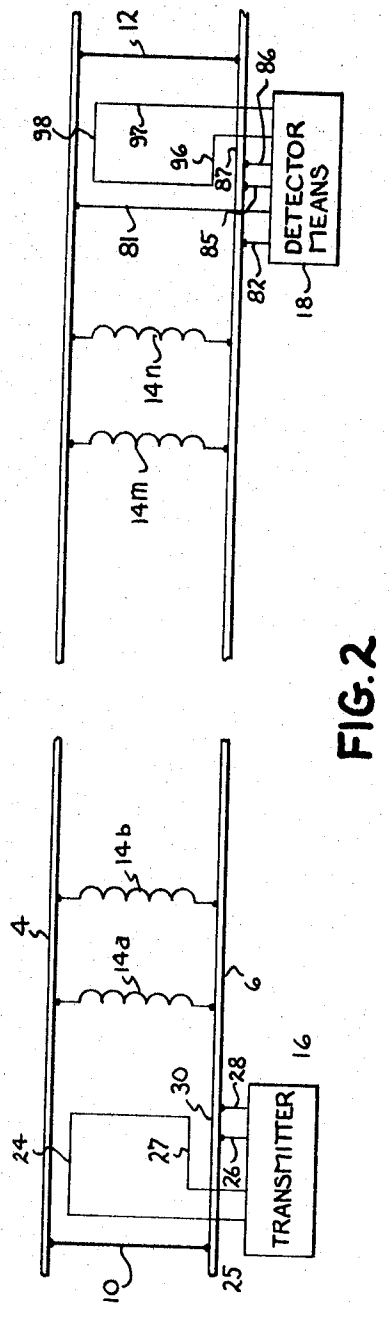

FIG. 2

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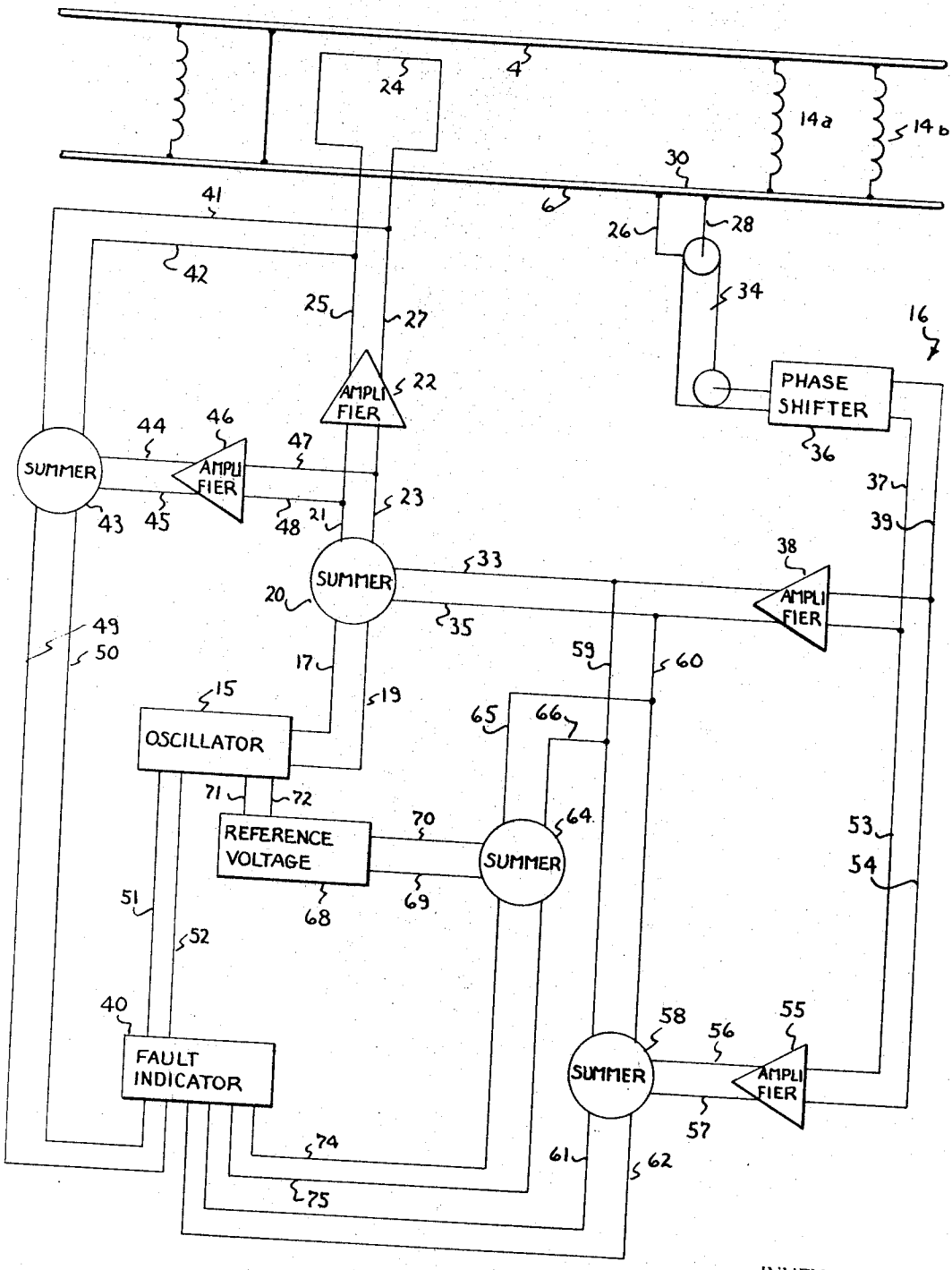

FIG. 3

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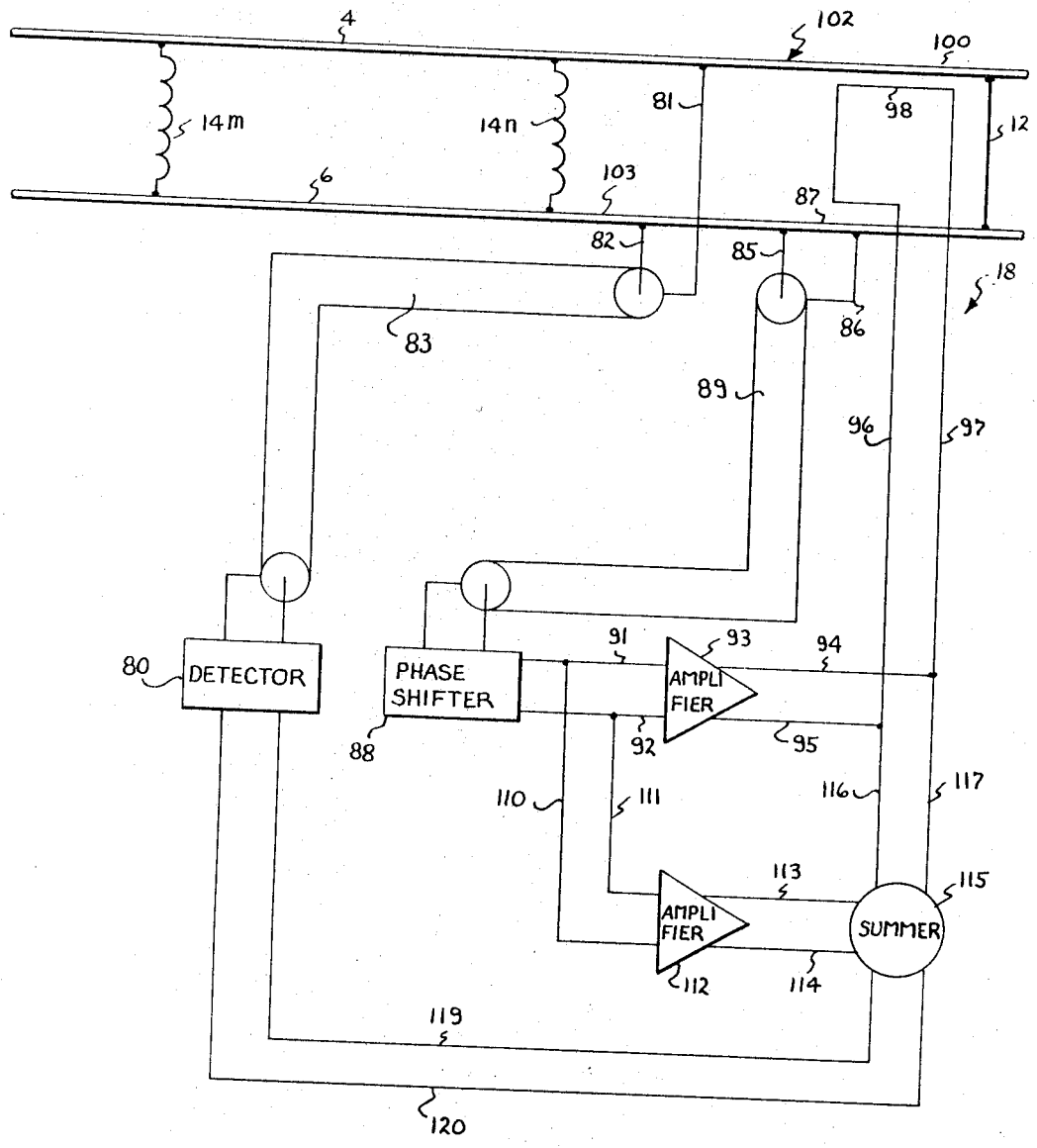

FIG. 4

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RAILWAY TRACK CIRCUIT

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Int. Cl. B61l 21/00, 25/00
U.S. Cl. 246—34 17 Claims

ABSTRACT OF THE DISCLOSURE

A track circuit for a section of railway track wherein a source of A-C signal energy is coupled to one end of the section, a receiver is coupled to the other end thereof to receive the signal energy from the source and a number of inductances are connected across the track rails in spaced relation along the section. Either in addition to or instead of the spaced inductances, at least one feed-back means is provided—positive feed-back at the receiver, negative feed-back at the source or both of such feed-back arrangements; the feed-back signal being derived from the track circuit and proportional to the signal energy therein.

The present invention relates to rail vehicle detection systems and more particularly relates to a track circuit of the alternating current type for a section of railway track.

In the automatic control of rail or track vehicles such as trains, subways, rapid transits and the like, it has been necessary to control the travel of the vehicle relative to the position of another vehicle travelling in advance thereof and on the same track to avoid sudden stoppings or actual collision between the vehicles. One common method of detecting the location of the advance rail vehicle is to divide the right of way into a plurality of zones with the rails disposed wtihin such zones forming a part of a zone electrical circuit. A transmitter transmits a signal along the zone and a detector detects the level of the signal. The presence of a train is detected by a drop in the signal level when a train enters a zone due to the shunting effects of the train wheel and axle assembly. A difficulty with the zone detection method of detecting train presence as used in the prior art has been that rain, snow, ice, or the like cause changes in the ballast impedance which also causes a change in signal level due to changes in shunting and leakage effects. As a result, it was difficult to determine whether the drop in signal level received by the detector was due to the shunting effect of the wheels and axle of the train within the zone or due to a drop in level produced by changes in ballast impedance due to weather conditions.

Accordingly, an object of the present invention is to produce a system of rail vehicle detection wherein the change in signal level due to changes in weather is minimized.

A further object is to produce a system of train detection wherein compensation is provided for the effect of variations in ballast impedance due to weather.

A further object is to produce a system which is substantially independent of weather variations.

Briefly stated, in accordance with one aspect of this invention, a new and improved track circuit for a section of railway track comprises a plurality of inductance means connected across the track rails of the section, a transmitter of alternating current signal energy coupled to the track rails and a receiver coupled to the track rails for receiving the signal energy from the transmitter. In the track circuit, the inductance means are operative to improve the ability of the receiver to distinguish the shunting effect across the track rails due to variation in ballast impedance due to weather and that of the wheels

and axle assembly of a vehicle present on the track section.

In another aspect of the invention further improvement may be obtained by employing positive feed-back means at the receiver or negative feed-back means at the transmitter; still greater improvement being achieved by a combination of positive feed-back means at the receiver and negative feed-back means at the transmitter and the inductance means wherein the inductance means coact with such feed-back means.

Referring now to the drawings:

FIG. 1 is a fragmentary schematic view of a track occupancy zone in accordance with the present invention;

FIG. 2 is a fragmentary schematic view of a track occupancy detection zone in accordance with another embodiment of the invention and wherein feed-back arrangements are provided to the track occupancy zone shown in FIG. 1 at both ends of the zone;

FIG. 3 is a fragmentary schematic view illustrating the transmitter negative feed-back arrangement; and

FIG. 4 is a fragmentary schematic view illustrating the detector positive feed-back arrangement.

In FIG. 1 there is shown occupancy zone or "block" including a source of alternating current signal energy, shown as transmitter means **16**, coupled at one end of the zone and a receiver **18** coupled at the other end thereof for receiving the signal energy from the source. In order to increase the length of the zone while still achieving reliable occupancy detection in spite of varying ballast conditions, a plurality of inductances **14** are connected across the track rails in spaced apart relationship along the zone. The limits of the zone are defined in any suitable manner, shown as low impedance cross connectors **10** and **12**. Alternatively, resonant circuits, series resonant at the frequency of the signal energy may be employed for this purpose. Also, if desired, insulated joints may be employed for this purpose as is well known.

As shown in FIG. 1, a transmitter **16** of alternating current signal energy is coupled in any suitable manner to the train occupancy zone circuit such as by the inductive coupling means **24** disposed between the track rails **4** and **6**, to apply A-C signal energy to the zone. A receiving means **18** may be similarly inductively coupled to the circuit or may be connected, as shown, directly across the rails **4** and **6** by suitable conductors. Inductances **14***a*, **14***b*, **14***m* and **14***n* are connected across the rails **4** and **6** at spaced intervals throughout the zone as shown. Preferably, the inductances **14** are of a combined shunting impedance which is less than the resistive shunting effect of the worst weather conditions, but greater than the resistive shunting effect of the wheels and axle of a train to be detected.

The use of the inductances functions to increase the sensitivity of the receiver to the presence of a train within the zone especially in regard to the shunting effects due to varying ballast conditions (for example, as between wet or dry weather conditions) on the ability of the receiver to differentiate between a change in inter-rail potential due to verying ballast conditions and a change in inter-rail potential due to the actual presence of a train in the zone. Since the detection sensitivity is increased, the use of spaced inductances along the zone makes possible an increase in the zone length in which reliable detection may be accomplished.

The value of the inductances, the spacing and the "Q" thereof, and the frequency of the signal energy are all factors which must be considered since they determine the zone length, detection sensitivity, worst case weather detection and worst case train resistance detection. In a particular operable arrangement, reliable detection was achieved in a zone 2,500 feet long with as few as

two inductances equally spaced therein each of which had an inductance of 0.3 millihenry. In the foregoing particular arrangement, the minimum weather shunting resistance was taken as 10 ohms per 100 feet of track.

Referring to the drawings, FIG. 2 illustrates a preferred embodiment of the invention wherein, in addition to the spaced inductances, there is also provided negative feed-back at the transmitter and positive feed-back at the receiver. It is to be understood that the use of feed-back only (either at transimtter or receiver or both) without the use of spaced inductances provides for increased detection sensitivity over previously known arrangements.

As shown in FIG. 2, the right of way is divided into a plurality of identical zones in a manner similar to that shown in FIG. 1 wherein each zone is defined by rail sections **4** and **6** and shorting means **10** and **12** which together establish an electrical circuit. A plurality of spaced inductances such as at **14***a*, **14***b*, **14***m* and **14***n* are connected across the rails at spaced intervals throughout the zone. Again inductors **14** are of a combined shunting impedance which is preferably less than the resistive shunting effect of the worst weather conditions, but greater than the resistive shunting effect of the wheels and axle of any train which is to be detected. A transmitter means **16**, including a negative feed-back arrangement (FIG. 3) is operably connected to the zone circuit to apply alternating current signal energy thereto. A receiver means **18**, including a positive feed-back arrangement (FIG. 4), is operably connected to the zone circuit so as to detect the level of the signal energy received by it from the transmitter **16** and thereby detect the presence of a train within the zone. The inductances function in the manner previously described in connection with FIG. 1.

In the embodiment of FG. 2, transmitting means **16** includes a negative feed-back arrangement whereby the current in the track section tends to remain at a constant level so that the signal energy transmitted in the zone is independent of variations in ballast impedance caused by changes in weather conditions. One arrangement for achieving such negative feed-back together with associated fail-safe features is shown in FIG. 3. As shown, an oscillator **15** generates a continuous wave signal which is fed by conductors **17** and **19** to a summer **20** where the signal is combined with the feed-back signal from the feedback conductors **33** and **35**. The output of summer **20** is fed by conductors **21** and **23** to an amplifier **22** where the combined signal is amplified. The amplified combined signal is then coupled to the zone circuit by a suitable means, such as by way of conductors **25** and **27** to inductive coupling means **24** where the signal is inductively coupled to the rails.

Conductors **26** and **28** are connected to one of the rails at a spaced interval to derive a signal which is proportional to track current. This arrangement provides the voltage drop across the rail portion **30** between the conductors **26** and **28**. In order to avoid the pick up of stray or extraneous signals, the conductors **26** and **28** may be shielded as indicated schematically at **34**. The conductors **26** and **28** connect the proportional to track current signal to a phase shifter **36** where the phase is shifted so as to be of a different phase than the original signal in the track rails. The output of phase shifter **36** is fed by conductors **37** and **39** to an amplifier **38**. The output of amplifier **38** feeds by conductors **33** and **35** to the summer **20** where the feed-back signal is combined with the original signal from oscillator **15** and fed to the zone circuit by coupling means **24**. Thus, the feedback is current feed-back which is operative to tend to hold the transmitter output current constant.

Since the resistance shunting effect caused by lowered ballast impedance due to adverse weather conditions such as snow, rain, sleet and the like, tends to increase the track current, the negative feed-back arrangement is used to hold this current constant. By this means a transmitted signal will be of a more constant level resulting in a higher effective source impedance and improved detection of trains. Thus, where there is a drop in signal level being detected by the receiver means, the drop will be greater due to the presence of a train than to changes in weather due to the differences in shunting impedance.

The phase shifting means **36** may be any standard phase shifting network which provides a negative feedback when the load across the track circuit is inductive. By such phase shifting arrangement the voltage picked up across conductors **26** and **28** is shifted in phase by an amount sufficient to cause the feed-back current to be out of phase with the original current so as to maintain constant current at the transmitter. Thus as the current at the transmitter tends to increase as the shunting resistance due to weather decreases, the voltage feedback to the amplifier operates to lower the the output of the amplifier proportionally. As a result, more constant current at the transmitter is achieved.

In order that the system be fail-safe with respect to a malfunction of the transmitting means, a fault indicating means **40** is provided to send an output along conductors **51** and **52** to turn off the oscillator **15** when the fault indicating means **40** receives an input signal from any one of several checking circuits. The fault indicating means may be a static or dynamic switching deivce which provides a single output upon receipt of any of several input signals.

The first input signal is from a first checking circuit which is designed to guard against malfunction of the amplifier **22**. Should the amplifier **22** independently oscillate due to some defect, its output would become independent of the feed-back and a signal frequency shift may occur. In order to shut down the system should this occur, a checking circuit consisting of conductors **41** and **42**, summer **43**, conductors **44** and **45**, amplifier **46** and conductors **47** and **48** is connected across the amplifier **22**. The amplifier **6** is selected so as to have the same gain as amplifier **22**. Summer **3** provides a difference between the output of amplifier **46** and the output of amplifier **22**. Where the aforesaid amplifier outputs are equal, the summer output which feeds along conductors **49** and **50** to the fault indicating means **40** is zero. Should the output of amplifier **22** be different from the output of amplifier **46**, an output would appear at summer **43** and be transmitted by conductors **49** and **50** to the fault indicating means **40** thereby causing an output at the fault indicating means which is fed by conductors **51** and **52** to turn off the oscillator **15** by a suitable switch (not shown) located in the oscillator.

A second checking circuit is connected across amplifier **38** and operates in the same manner as was described for the first checking circuit for amplifier **22**. The second checking circuit consists of conductors **53**, **54**, amplifier **55**, conductors **56** and **57**, summer **58** and conductors **59** and **60**. Amplifier **55** is of the same gain as amplifier **38** and thus the output at summer **58** is zero when the amplifier **38** is functioning properly. Should amplifier **38** oscillate or otherwise fail, there will be an output at summer **58** which is fed by conductors **61** and **62** to the fault indicator **40**, the output of which will be fed by conductors **51** and **52** to the oscillator **15** where the switch (not shown) shuts off the oscillator.

A third checking circuit checks for a fault in the feedback loop. For this purpose a summer **64** is connected by conductors **60** and **65**, and **59** and **66** across the output of amplifier **38** which is in the feedback loop. A reference voltage from a reference voltage source **68** is fed into the summer **64** by conductors **69** and **70**. The reference voltage from source **68** should be established so as to

have the same frequency, amplitude and phase as the normal output of amplifier **38**. These values may be determined by analyzing the output of amplifier **38** when it is operating properly. The reference voltage may be conveniently produced by feeding a portiton of the output of the oscillator **15** by conductors **71** and **72** to the voltage source **68** wherein the proper phase and magnitude is obtained by suitable transformer and phase shifting means (not shown). By feeding both the reference voltage and the output of amplifier **38** to summer **64** any change in the feedback loop will cause an output at summer **64** which feeds by conductors **74** and **75** into the fault indicator **40** and thence by conductors **51** and **52** to a switch (not shown) in the oscillator **15** to turn it off.

In accordance with a further aspect of this invention, receiver means **18** includes a positive feedback arrangement (FIG. 4) whereby the difference in signal level between train and no train conditions is made to be much greater than it would be without the feed-back and whereby such feed-back is upset or destroyed by the presence of a train, thereby enhancing the ability to distinguish between changes in signal level due to variations in ballast impedance caused by adverse weather conditions and changes in signal level due to the presence of a train.

For example, the presence of a train within the zone is detected by the difference in the level of the signal energy from the transmitter at receiver means **18**. To this end, receiver means **18** may include a suitable detector operative to indicate the presence or absence of a train within the zone by the difference in the level of signal energy in the track circuit. The detector may be, for example, a threshold detector known in the art whereby the output of the detector indicates the presence of a train when the signal detected across the track rails is below the preselected threshold. However, the level of the signal detected across the track rails may also be lowered by the shunting resistive effect of changing ballast impedance due to changing weather conditions, thereby making it difficult to distinguish between changes caused by a train and changes caused by weather.

Accordingly, it is desirable to produce a signal whereby differences in signal change due to shunting by weather and shunting by a train are maximum. The presence of the inductances and/or the positive feed-back at the receiver means **18** provide such difference whereby the shunting effect due to weather has a much lesser effect than a train on signal level.

One arrangement for achieving the foregoing positive feed-back at the receiver is shown in detail in FIG. 4. As shown, a suitable detector **80** is coupled to the track rails **4** and **6** for detecting the change in signal energy therein from the transmitter means **16** when a train is present within the track section. Conveniently, detector **80** may be connected across the rails **4** and **6** by the conductors **81** and **82** of a suitable coaxial line **83** which provides shielding from stray or extraneous signals.

A feed-back signal proportional to the signal energy in the track circuit at the receiver is obtained and suitably shifted in phase so as to be in phase with the voltage at the receiver when the track circuit shunting impedance is predominantly inductive—which is the case when there is no train present within the track section.

To this end, conductors **85** and **86** of a suitable coaxial line **89** are connected in spaced apart relation along rail **6**. The voltage across the rail portiton **87** between conductors **85** and **86**, therefore, is proportional to the current in the rail. This voltage signal is then fed to a phase shifting network **88** and thence over conductors **91** and **92** to an amplifier **93**.

The output of amplifier **93** is applied over conductors **94** and **95** to drive a coupling loop **98** which is disposed in inductive relationship with the track rails **4** and **6** so that a voltage proportional to the current in the rail and having the same phase angle is induced therein; the proper phase angle having been provided by phase shifting network **88**.

Preferably, coupling loop **98** is disposed as shown between the zone terminating shorting bar **12** and the detector connections **81** and **82**. The voltage feed-back signal is thus applied to the feed-back circuit **102** composed of rail portion **100**, inductance **14*n***, rail portion **103** and shorting bar **12**.

It is to be understood that a portion of the feed-back signal would also appear in the circuits which include all of the inductances such as **14*a***, **14*b*** and **14*m*** up to the other shorting bar **10**. However, the first inductance **14*n*** is the most significant inductance and establishes the effective circuit for the feed-back purposes.

Since the voltage induced in the track feed-back circuit **102** is in phase with the original voltage resulting from the signal current from the transmitting means **16**, it is positive feed-back thereby increasing the magnitude of the voltage detected across conductors **81** and **82**. The phase shift network **88**, therefore, is made to have the right amount of phase shift so that with an inductance **14*n*** across the tracks, the original current and the induced voltage will constitute positive feed-back.

The induced voltage is fixed by the gain of the amplifier **93** to be a constant, complex multiplier of the signal current from the transmitting means **16**. The signal current is constant due to the series impedance of the track section between transmitter **16** and detector **80**. The impedance of rail portion **100** is effectively increased by the positive feed-back to increase the sensitivity of the detector **80** to the presence of a train. Thus, the voltage at the input terminals of detector **80** is the sum of the voltage drop due to the impedance of the rails and the induced voltage. By suitable selection of the gain, the impedance at the detector is increased, thereby increasing the detection sensitivity.

It is to be noted that inductance **14*n*** and the other inductances were selected to be of an impedance value preferably less than the impedance value of the resistive shunting effect due to weather; thus variations in the shunting effect due to such weather will have little effect on the feed-back since the impedance of the inductances is less than the lowest impedance of weather shunting effects. However, when a train appears in the zone, the wheels and axle assembly of the train, having a resistance of between zero and two ohms, shunts the inductance and destroys the necessary phase relationships to achieve the positive feed-back thereby causing a substantial drop in the voltage across points **81** and **82**. Thus, the present system, rather than merely detecting the difference in signal level between the shunting effect of adverse weather and the shunting effect of the wheels and axles of a train, detects the presence of a train by destroying feed-back thereby resulting in a more substantial signal drop which is independent of weather.

In order to provide a fail-safe feature, a checking circuit is connected across the input and output of amplifier **93** whereby a check is provided against oscillation of the amplifier **93**. The checking circuit consists of conductors **110** and **111**, amplifier **112**, conductors **113** and **114**, summer **115** and conductors **116** and **117**. As was the case with the transmitter checking arrangement, the amplifier **112** has the same gain as the amplifier **93**. Under ordinary operating conditions the output of summer **115** will be zero. However, should the amplifier **93** oscillate or otherwise malfunction and thereby become independent of the feedback relationship, an output will appear at summer **115** and be fed by conductors **119** and **120** to a suitable switch (not shown) in the detector to shut off the detector, thereby resulting in a zero detector output.

It is to be understood that the information concerning the presence or absence of a train within a zone can be relayed to a succeeding train if desired by suitable means known in the art.

While preferred results are achieved by utilizing the combination of negative feed-back at transmitter **16**, positive feed-back at detector **18** and a plurality of inductance means disposed across the rails, it is to be understood that significantly improved results over the prior art may be obtained by utilizing either of the foregoing features only. That is, either negative feed-back at the transmitter, the positive feed-back at the detector or the plurality of inductance means disposed across the rails, or any combination thereof.

Having shown preferred embodiments of an improved train detection system, it is believed obvious that other modifications and variations of the invention are possible in the light of the above teachings.

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

1. A track circuit for a section of railway track comprising:

(a) a transmitter of signal energy coupled to said section of railway for applying signal energy thereto;

(b) a receiver coupled to said section of railway track for receiving the signal energy from said transmitters; and

(c) a plurality of inductance means connected across the track rails in spaced relation along said section of railway track between said transmitter and said receiver operative to increase the change in the level of the signal energy at said receiver between the conditions when no vehicle is present within the section of railway track and the condition when a vehicle is present therein.

2. The track circuit of claim **1** including at least one feed-back means operably coupled to said track circuit for deriving a signal from said track circuit, shifting the phase thereof and feeding the phase shifted signal so produced back to said track circuit.

3. The track circuit of claim **1** wherein said transmitter is provided with means to produce a negative feed-back signal proportional to the signal energy in said track circuit and means applying said feed-back signal to said transmitter so that the signal energy in said track circuit tends to be maintained at a constant level.

4. The track circuit of claim **1** wherein said receiver includes means for producing a positive feed-back signal proportional to the signal energy in said track circuit and means applying said positive feed-back signal to said receiver.

5. The track circuit of claim **3** wherein said receiver includes means for producing a positive feed-back signal proportional to the signal energy in said track circuit and means applying said positive feed-back signal to said receiver.

6. A system for detecting the presence of a rail vehicle according to claim **2** wherein the impedance of said inductance means is greater than the resistive impedance of the wheel and axle assembly of any train which is to be detected.

7. A system for detecting the presence of a rail vehicle according to claim **6** wherein said inductance means exhibits less shunting impedance than the minimum circuit shunting resistance which may be produced by variations in track ambient conditions due to weather conditions.

8. A system for detecting the presence of a rail vehicle according to claim **2** wherein said feed-back means is a negative feed-back means associated with said rails adjacent said transmission means, whereby a portion of said signal is picked up from the rails and fed back to the transmission means with the phase of the feed-back signal shifted so as to reduce variations in the current output of the transmission means.

9. A system for detecting the presence of a rail vehicle according to claim **8** wherein the phase and amount of the feed-back signal is adjusted as the shunting resistance between the rails decreases so as to maintain the current output of the transmission means substantially constant as the shunting impedance of the rail circuit varies due to variations in track ambient conditions.

10. A system for detecting the presence of a rail vehicle according to claim **2** wherein said feed-back means is a positive feedback means associated with said rails whereby a portion of said signal is picked up from the rails and fed back to the rails with the phase of the feed-back signal shifted so as to increase the signal input to the receiver means.

11. A system for detecting the presence of a rail vehicle according to claim **10** whereby the phase of the feed-back signal is determined by the impedance of said inductance means when a train is absent from the circuit and by the resistance of the train wheel axle assembly when a train is present in the circuit whereby positive feed-back is established by the absence of a train and destroyed by the presence of a train.

12. A system for detecting the presence of a rail vehicle comprising: a pair of rails; means to establish a circuit which includes said rails; transmission means operably connected to said circuit for transmitting a signal in said circuit; receiver means operably connected to said circuit for detecting said signal; negative feed-back means associated with said circuit adjacent said transmission means whereby a portion of said signal is picked up from the circuit and fed back to the circuit with the phase of such feed-back signal shifted so as to reduce variation in the current output at the transmission means.

13. A system for detecting the presence of a rail vehicle comprising: a pair of rails; means to establish a circuit which includes said rails; transmission means operably connected to said circuit for transmitting a signal in said circuit; receiver means operably connected to said circuit for detecting said signal; positive feed-back means associated with said circuit adjacent said receiver means whereby a portion of said signal is picked up from the circuit and fed back to the circuit with the phase of such signal shifted so as to be the same as the original signal to increase the voltage level of the signal at the receiver means.

14. A system for detecting the presence of a rail vehicle according to claim **13**, wherein a train travelling on the rails within the circuit provides a resistive shunting impedance which shifts the phase of the feed-back signal thereby destroying the positive feed-back so as to cause a decrease in the signal level at the receiver means input.

15. The track circuit of claim **1** wherein the impedance of said inductance means is greater than the resistive impedance of the wheel and axle assembly of the train to be detected and less than the minimum circuit shunting resistance which may be produced due to variations in track ambient conditions.

16. The track circuit of claim **15** including at least one feed-back means operably coupled to said track circuit for deriving a signal therefrom, shifting the phase of said signal and feeding the phase-shifted signal so produced back to said track circuit.

17. The track circuit of claim **5** wherein the impedance of said inductance means is greater than the resistive impedance of the wheel and axle assembly of the train to be detected and less than the minimum circuit shunting resistance which may be produced due to variations in track ambient conditions.

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ARTHUR L. LA POINT, *Primary Examiner.*

U.S. Cl. X.R.

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