May 15, 1962 P. H. LUFT 3,035,167

RAILWAY TRACK CIRCUIT

Filed Dec. 3, 1958 2 Sheets-Sheet 1

Fig. 1a.

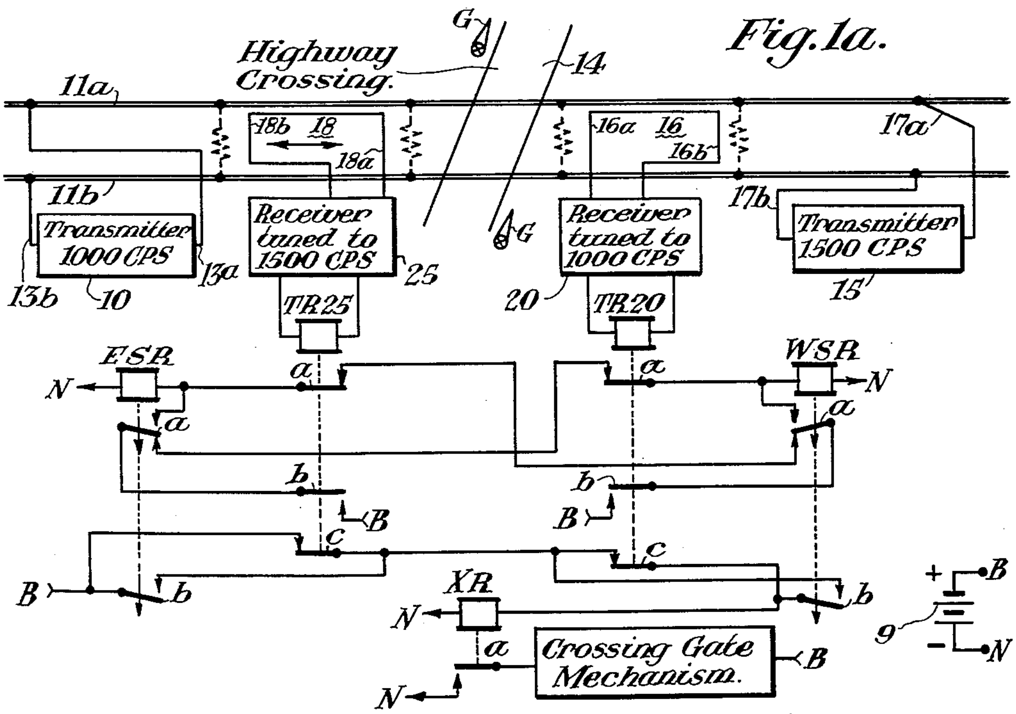


Fig. 4a.

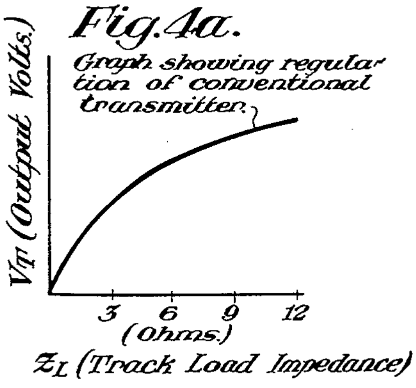


Fig. 4b.

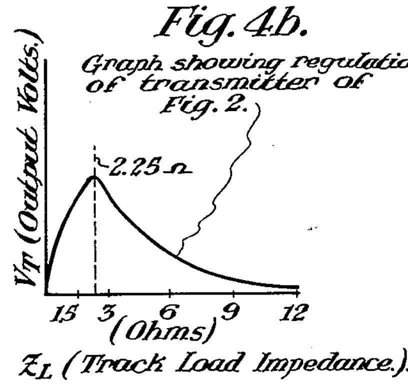
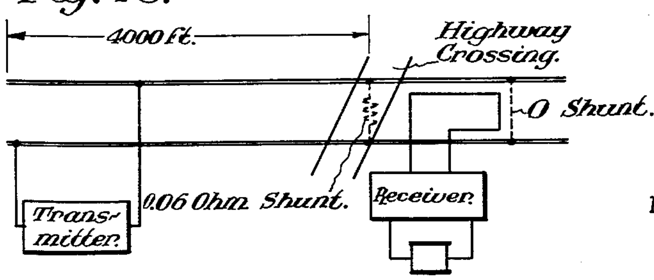


Fig. 4c.



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RAILWAY TRACK CIRCUIT

Filed Dec. 3, 1958 2 Sheets-Sheet 2

Fig. 2.

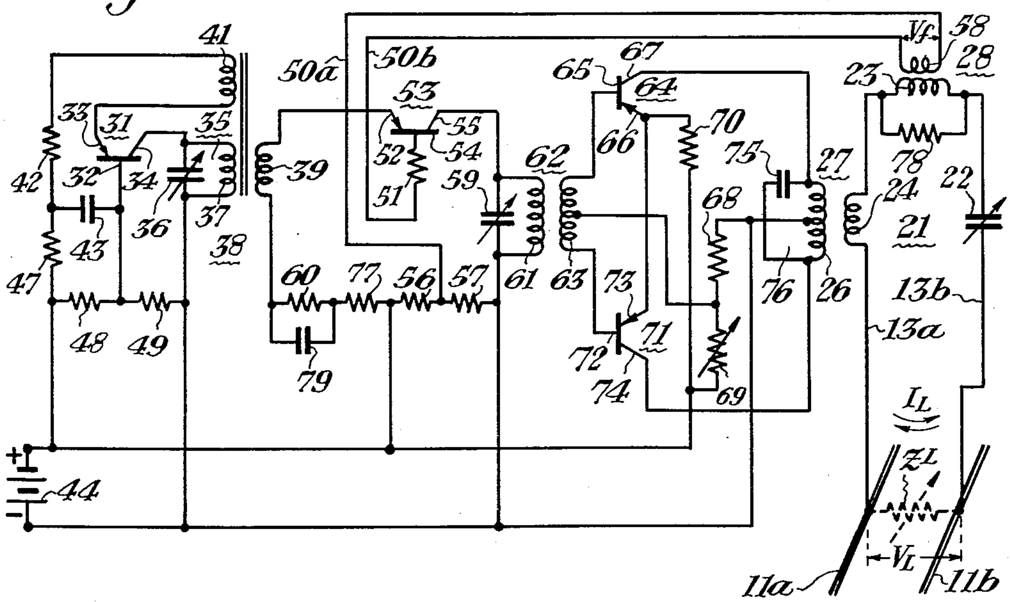


Fig. 3.

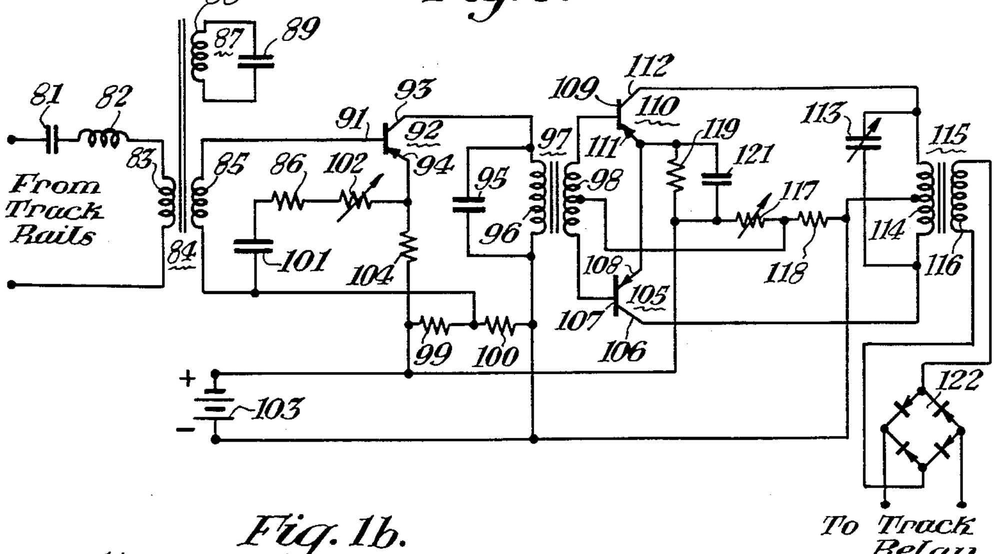
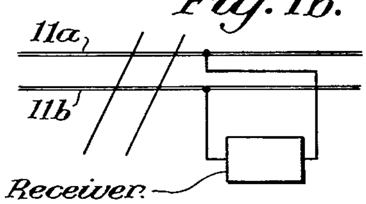


Fig. 1b.



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3,035,167
RAILWAY TRACK CIRCUIT

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Filed Dec. 3, 1958, Ser. No. 778,022
9 Claims. (Cl. 246—130)

My invention relates to railway track circuits, and more particularly to a railway track circuit including new and improved transmitter and receiver units which provide a means of positively defining the limits of said track circuit.

This application is a continuation-in-part of copending application Serial No. 718,557 filed on March 3, 1958, by Philip H. Luft for Control Circuits and assigned to the same assignee as this application.

Track circuits for use in conjunction with continuous track rails, that is, track rails having no insulating joints which track circuits have positively defined limits are in particular demand in the railway art for various applications such as railway crossing indicating systems and other superimposed track circuits for localized train detection. One type of superimposed or overlay track circuit with which I am familiar comprises a transmitter connected across the rails, and receiver leads also connected across the rails at a predetermined distance from the transmitter connections. It has been found that as the length of the above type track circuit increases, that is the distance between the transmitter and its associated receiver increases, its operating limits become less clearly defined. The operating limits of track circuits above 2500 feet have heretofore been almost impossible to define. One reason for this lack of definition is the large variance in the impedance values of the track ballast due to climatic conditions. For example, the shunt detecting area for a track circuit operating at audio frequency and having the transmitter and receiver connections separated by 150 feet might vary only from 10 feet to 20 feet. However, the shunt detecting area of a similar track circuit having its transmitter and receiver connections separated by a distance of 4000 feet would vary from about 20 feet to a maximum of several hundred feet beyond the points where the receiver connects to the rails. Thus it can be seen that the greater the length of the track circuit, the greater the possible variance in shunt detecting area. Such a degree of variance undesirably affects a number of operations where the shunt or control area must be clearly defined, such as for example, highway crossing warning systems.

Heretofore adequate definition of the limits of the track circuits has been hampered by the characteristics of the transmitters and receivers used in the track circuits.

Accordingly, it is a principal object of my invention to provide a track circuit including a new and improved transmitter for providing constant and clearly defined track circuit limits.

It is another object of my invention to provide a track circuit including a new and improved receiver for providing constant and clearly defined track circuit limits.

It is another object of my invention to provide an improved transmitter for compensating for variations in the load into which it feeds.

It is another object of this invention to provide a new and improved temperature compensated receiver.

In the attainment of the foregoing objects I provide a track circuit including a transmitter of signal energy operating at a given frequency and having a regulation curve which initially peaks, and then becomes inversely proportional to the ballast or load impedance existing across the rails. The signal energy from the transmitter is coupled through the track rails to a sensitive receiver tuned to the

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frequency at which said transmitter is operating for controlling the operation of a track relay.

Other objects and advantages of my invention will become apparent from the following description and the accompanying drawings in which:

FIG. 1*a* is a view showing one embodiment of a track circuit to provide a bi-directional highway crossing control arrangement in accordance with my invention and showing one means of coupling signal energy from the rails to the receiver;

FIG. 1*b* is a view showing a second means of coupling signal energy from the rails to a receiver;

FIG. 2 is a schematic diagram of a transmitter employed in my track circuits;

FIG. 3 is a schematic diagram of a receiver employed in my track circuits;

FIGS. 4*a*, 4*b* and 4*c* are graphical illustrations useful in describing the operation of my track circuit.

I shall first describe one embodiment of my track circuit including the new transmitter and receiver in accordance with my invention and shall then point out the novel features thereof in the appended claims.

It will be understood at the outset that a track circuit according to my invention may be employed in any application where it is desired to actuate a device when a train approaches or recedes a minimum number of feet from a designated point. However, my track circuit will be described only as applied to a highway crossing warning system since it is believed such a description is sufficient for the understanding of the operation of my circuit.

Referring to FIG. 1*a*, a section of track rails **11***a* and **11***b* is shown as intersected by a highway crossing **14**. In one practical embodiment, my track circuit includes a first transmitter **10** connected by leads **13***a* and **13***b* across rails **11***a* and **11***b*, respectively, at a desired point, say between 2500 and 4000 feet distance to the left, as oriented in the drawings, of the highway crossing. In one practical embodiment, transmitter **10** is tuned to operate at 1000 c.p.s.

A loop of wire **16** inductively coupled to rails **11***a* and **11***b* is placed between said rails on the other or right side of the highway crossing and is connected to the input circuit of receiver **20**. Loop **16** is positioned such that a portion of the loop is adjacent a predetermined equal length of each of the rails **11***a* and **11***b*, and spaced approximately the same distance from each rail. As is obvious the sketch of loop **16** in the figures is not to scale. The left hand end of loop is placed at a designated distance, which may be a minimum distance of 15 feet from the center of the highway to provide adequate clearance, that is to assure that a railway vehicle is completely off the highway before its rear wheels affect the operation of the loop as will hereinafter be described. Loop **16** extends along rails **11***a* and **11***b* for a designated distance, in one embodiment about 100 feet, to insure satisfactory signal coupling between the rails and the loop. For purposes of simplifying the following description, the extreme left and right hand ends of loop **16** are designated as leads **16***a* and **16***b* respectively. Receiver **20** is tuned to the operating frequency of transmitter **10** and operates in conjunction therewith.

A second transmitter **15**, similar to transmitter **10**, is connected by terminal leads **17***a* and **17***b* to rails **11***a* and **11***b*, respectively, at a desired point, say between 2500 and 4000 feet distance to the right of highway crossing **13**. In one practical embodiment, transmitter **15** is tuned to operate at 1500 c.p.s. A second loop **18** similar to loop **16** is positioned at a designated distance, a minimum of 15 feet on the left side of the highway crossing **14** and couples signal energy from rails **11***a* and **11***b* to a receiver **25**. As above, the extreme left and right hand ends of loop **18** are designated as leads **18***b* and **18***a* respectively. Receiver **25** is tuned to the operating frequency of transmitter **15** and operates in conjunction therewith.

If the track circuits do not exceed 2500 feet in length, that is the distance between a transmitter and the associated receiver does not exceed 2500 feet, the receivers may be connected to the rails in the usual manner as shown in FIG. 1*b* and the limits of the track circuit will be adequately defined. However, it has been found by tests that for track circuits of long lengths, say from 2500 feet to 4000 feet, it is necessary to inductively couple the signal energy to the receivers **20** and **25** through loops **16** and **18** respectively in order that the track circuit limits still be constant and clearly defined.

It has also been found that loop coupling eliminates interference to the receivers **20** and **25** in, for example, propulsion territory where the high harmonics of the propulsion current may interfere with the satisfactory operation of the control circuit of my invention. Since the propulsion current normally flows in the same direction along both rails, the voltage induced in loop **16** due to the propulsion current flowing in rail **11***a* will be in opposing or bucking relation to the voltage induced in loop **16** due to the propulsion current flowing in rail **11***b*. Thus, the voltages developed in loop **16** due to propulsion current cancel out and will not affect operation of my track circuit. However, each of transmitters **20** and **25** provide current flow in rails **11***a* and **11***b* in opposite directions, hence the voltages induced in each portion of the loops will tend to aid or add and provide a high signal voltage to the associated receiver.

It will be understood that the distance referring to the points at which the electrical connections are made are given only as representative examples and are not intended as limiting in any way. The distance from one receiver, essentially located at the highway crossing, to the point at which the associated transmitter connects to the rails is limited only by the available transmitting power while he length of the loop is determined by receiver sensitivity.

The means for coupling the signal energy of the transmitters to the rails will now be briefly described. Referring to FIG. 2, the output circuit for each transmitter includes the secondary winding **24** of output transformer **27** connected in series and tuned to filter **21** which is tuned to the operating frequency of the associated transmitter. One terminal of secondary winding **24** is connected to rail **11***a* by lead **13***a* and the other terminal thererof is connected to filter **21** which consists of the primary winding **23** of a feedback transformer **28** in series with a capacitor **22**. The other terminal of capacitor **22** is connected to rail **11***b* by lead **13***b*. A resistor or resistance **78** is connected across primary winding **23** for purposes hereinafter described. The terms resistor and resistance are herein used interchangeably.

As noted above, transmitters **10** and **15**, and receivers **20** and **25** are similar. Transmitter **10** and associated receiver **20** are tuned to opearte at 1000 c.p.s., while transmitter **15** and associated receiver **25** are tuned to operate at 1500 c.p.s. Filter **21** and secondary winding **24** in one transmitter, although tuned to the operating frequency of their associated transmitter, are so designed that their impedance to the frequency at which the other transmitter is transmitting signal current energy is still of a low order. For example, even if the ballast impedance becomes infinite, filter **21** and secondary winding **24** in transmitter **15** still will present a relatively low impedance to 1000 c.p.s. energy so that sufficient current from transmitter **10** will flow through rails **11***a* and **11***b* to maintain receiver **20** energized to keep its associated relay TR**20** picked up. Filter **21** and secondary **24** in transmitter **10** will likewise effect a relatively low impedance electrical path for 1500 c.p.s. energy so that transmitter **15** can maintain receiver **25** energized. Thus, the circuit inherently provides a means of maintaining sufficient rail current flowing over any range of track ballast impedance that might be encountered. It will be understood that if the area to be controlled is a single direction track and only one transmitter and one receiver are used, a circuit tuned to the operating frequency may be coupled to the rails to provide a complete electrical circuit for the transmitter operating frequency.

The operating relation of the loops coupling signal energy from the rails to the receivers is similar, so that a description of receiver **20** and loop **16** is considered sufficient to the understanding of my invention. As noted above, loop **16** is located so that on an eastward move, toward the right as oriented in the drawings, the last axle of the train will have cleared the highway crossing before current flow energizes receiver **20** to cause the associated relay TR**20** to pick up to actuate the crosing gate mechanism to its normal or raised position as shown in the drawings. The elements designated as G indicate the gates which are actuated by the crossing gate mechanism. It has been found that under conditions of high battery voltage and infinite ballast impedance, sufficient current flows in the rails so that a shunt at a point to the right of lead **16***a* a distance of about only 10% to 15% of the total distance between the leads **16***a* and **16***b* will energize receiver **20** and pick up receiver relay TR**20**. Under conditions of low battery voltage and low ballast impedance, a shunt at a point to the right of lead **16***a* a distance of about 70% to 80% of the distance between leads **16***a* and **16***b* is required to energize the receiver **20** sufficiently to pick up relay TR**20**. Therefore, the lead **16***a* that is the left hand end of loop **16** is positioned relative to the highway crossing so that under maximum voltage and infinite impedance ballast conditions, the train will always be off the highway before the loop couples sufficient energy to the associated receiver to pick up its relay. However, the distance from the highway to receiver lead **16***a* is desirably as short as possible so that the period of time the crossing gate mechanism is actuated down is held to a minimum after a train has passed the highway crossing **14**.

The crossing gate mechanism may be of any suitable known type and does not per se form a part of my invention.

FIGS. 2 and 3 show the details of the transmitter and receiver circuits which employ transistor devices. Transistors of the three-electrode PNP type are employe; however, transistors of the NPN type could likewise be employed by proper arrangement of the biasing potentials as is well-known to those skilled in the art.

The details of the transmitter circuit will now be described. Referring to FIG. 2, a transistor oscillator or signal generator **31** includes a base **32**, emitter **33**, and a collector **34**. The collector **34** is connected to a parallel resonant circuit **35** which determines the operating frequency of oscillator **31** and which consists of a capacitor **36** and the primary winding **37** of a transformer **38**. As noted above, the osciliator of transmitter **10** is tuned to oscillate at 1000 c.p.s., while the oscillator of transmitter **15** is tuned to oscillate at 1500 c.p.s. The emitter **33** is connected through a feedback winding **41**, resistance or resistor **42** and a signal current by-pass capacitor **43** to the base **32** to provide a feedback path to sustain oscillations. To provide proper biasing potentials for oscillator operation, the negative terminal of a suitable source of potential indicated as a battery **44** is coupled through primary winding **37** to the collector **34**. The positive terminal of source **44** is coupled through resistors or resistances **47** and **42**, and feedback winding **41** to the emitter **31**. Base **32** is connected to the junction of resistors **48** and **49**, which resistors are connected across source **44**.

One terminal of a secondary winding **39** of transformer **38** is connected to the emitter **52** of a transistor

53 which is a class A amplifier. The other terminal of winding **39** is connected through resistors **60** and **77** to the positive terminal of source **44**. A capacitor **79** connected in parallel to resistor **60** provides a signal current by-pass therefor. The junction of a pair of resistors **56** and **57** which are connected across source **44** is connected through lead **50***a*, secondary winding **58** of feedback transformer **28**, lead **50***b*, and resistor **51** to the base **54** of transistor **53**. The collector **55** of transistor **53** is connected to one terminal of a tuned wave-shaping circuit consisting of a condenser **59** connected in parallel to the primary winding **61** of a transformer **62**; the other terminal of the tuned circuit is connected to the negative terminal of source **44**.

The secondary winding **63** of transformer **62** is connected to the base electrodes **65** and **72** of normally cut-off, push-pull connected transistors **64** and **71** which are class B amplifiers. One terminal of secondary winding **63** is connected to base **65** while its other terminal is connected to base **72**. The emitters **66** and **73** of transistors **64** and **71** are directly connected to one another, and the collectors **67** and **74** are connected to opposite terminals of an output tuned circuit **76** consisting of capacitor **75** connected in parallel to the primary winding **26** of an output transformer **27**. A series circuit consisting of resistor **68**, a thermistor **69** having a negative temperature coefficient, and a resistor **70** is connected from a center tap on primary winding **26** of transformer **27** to the emitters **66** and **73** of transistors **64** and **71**. To provide the proper operating or biasing potentials, the positive terminal of source **44** is connected through resistor **70** to emitters **66** and **73**, and through thermistor **69** and a center tap on secondary winding **63** of transformer **62** to bases **65** and **72**. The negative terminal of source **44** is connected through the center tap on primary winding **26** of transformer **27** to collectors **67** and **74**. As is known, the total impedance across the emitter to base of a transistor is inversely related to temperature. Thermistor **69** compensates for variations in temperature by controlling the bias potential applied to transistors **64** and **71** inversely with relation to temperature.

As noted above, secondary winding **24** and filter **21** couple the signal energy from the transmitter to the rails **11***a* and **11***b*. For simplicity, the total ballast or load impedance existing across the track rails **11***a* and **11***b* is indicated as a single variable impedance Z_L. It will be appreciated that the load impedance existing across the rails and presented to said transmitter consists essentially of an assumed plurality of rail imedances and parallel resistances as indicated in FIG. 1*a*.

The standards set forth by the various railroads for equipment to be used at highway crossings in which the rails have no insulated rail joints stipulate that the track relay operated from a receiver must in all cases pick up if the last vehicle of the train is some distance past the crossing. However, various State Commerce Commissions require that the said track relay must not pick up, or rail to release, if a train is standing in such a position that it is blocking the highway and one pair of wheels is shunting the track rails with zero (0) ohms impedance at a point 100 feet distant on the opposite side of the crossing from the transmitter and another pair of wheels is shunting the track rails with 0.06 ohms impedance in the crossing itself, see FIG. 4*c*. It has been found that if a track circuit is in the order of 4000 feet long and a transmitter having a conventional or normal output regulation curve as shown in FIG. 4*a* is employed in the track circuit, the shunt combination mentioned in the previous sentence will not in all cases cause the track relay to release. This is due to the fact that in a track circuit in the order of 4000 feet operating at a frequency of 1500 c.p.s. and in the case of infinite ballast impedance conditions wherein each 1000 feet of rail provides 3 ohms impedance, a shunt 4000 feet from the transmitter will cause a 12 ohm load impedance to appear across the transmitter. Thus with a transmitter having conventional regulation as shown in FIG. 4*a*, the output voltage at the track will be relatively high and a shunt combination as discussed above and shown in FIG. 4*c* will not release the track relay.

In order to provide a means for assuring that the track relay will positively release under the conditions mentioned above I have found it necessary to provide a novel transmitter having an output regulation curve as shown in FIG. 4*b*. To obtain a regulation as indicated in FIG. 4*b*, I provide a feedback voltage from the output circuit of the transmitter through feedback transformer **28** to the first or intermediate stage of amplification comprising transistor **53**. The turns of secondary winding **58** of transformer **28** are wound such as to couple a voltage to the base **54** of transistor **53** which is of such a polarity and phase to aid or add to the signal voltage applied to emitter **52** of transistor **53** from oscillator **31**. This provides a regenerative, or positive feedback to transistor **53** which tends to increase the signal voltage. If the track load or ballast indicated as impedance Z_L is low, the current I_L will be high, and the feedback voltage V_f developed across secondary winding **58** of transformer **28** will be relatively large. If the current I_L is small due to a high Z_L, the feedback voltage V_f developed will be low. Thus the total input voltage to transistor **53** will be large when Z_L is low and small when Z_L is high. The voltage V_L delivered to the track rails will follow the total input voltage to transistor **53**, as shown in FIG. 4*b*.

As can be noted from FIG. 4*b*, the feedback resistor **51** connected in the base **54** of transistor **53** is selected and the circuit is adjusted to give maximum voltage output at about 2.25 ohms. This allows the output voltage at 1.5 ohms to equal the output at 3 ohms. This is desirable for it allows the transmitter to deliver the same output voltage to a track circuit having a 3.0 ohms per thousand feet impedance either by connecting the transmitter at the end of the track circuit or at the center of the track circuit. As is known, at finite ballast impedance conditions and for track circuits of 1000 feet and longer the circuits may be considered as infinitely long lines and the transmitter sees the characteristic impedance of the circuit which is determined largely by the ballast impedance.

Resistor **51** in conjunction with secondary winding **58** shifts the phase and magnitude of feedback voltage V_f so that it will be in proper phase relation to input signal voltage developed across secondary **39** of transformer **38**. The loading resistor **78** is connected across primary winding **23** of transformer **28** to minimize the change in phase of the feedback voltage V_f so that one value of resistor **51** will suffice for different load conditions presented by the track circuit. For example, a track load Z_L will change phase depending on whether the track circuit is a center-fed, low ballast circuit, in which case the impedance might be 1.5 ohms at nearly unity power factor, or whether infinite ballast conditions are present and a train shunt exists 500 feet from the transmitter, in which case the impedance might look like 1.5 ohms at 80 degrees. Loading resistor **78** tends to minimize any adverse affects due to this change in phase between the two aforementioned cases.

Feedback voltage V_f is large enough in proportion to the input signal voltage developed across secondary winding **39** of transformer **38** so that the transmitter output will fall to zero when the windings **23** or **58** of feedback transformer **28** are short circuited. Likewise the base **54** of transistor **53** will be open and the output voltage will be zero if the feedback windings **23** or **58** become open circuited. Thus, in either case transformer **28** is fail-safe. As is well known in the railway art, in this type of circuit the term fail-safe implies that a circuit or component is self checking and upon the failure of said circuit or component the track relay releases to give a danger indication.

The details of the receiver circuit will now be described. Referring to FIG. 3, each receiver includes a sharply tuned input circuit consisting of an inductance 82 and capacitor 81 connected in series to the primary winding 83 of transformer 84. The input circuit of receiver 20 and each amplifying stage therein is tuned to a frequency of 1000 c.p.s. while the input circuit of receiver 25 and each amplifying stage therein is tuned to a frequency of 1500 c.p.s. Receivers 20 and 25 are sufficiently sensitive to be energized as long as some finite value of current, in the order of 3 or 4 milliamperes at their respective tuned frequencies, is flowing in that portion of rail to which loops 16 and 18 are inductively coupled.

A secondary winding 85 on transformer 84 couples to transistor 92 which is a class A amplifier including base 91, collector 93, and emitter 94 electrodes. As is known transformer 84 matches the input impedance of the transistor 92 to the track rails. A parallel tuned circuit 87 consisting of a tertiary winding 88 on transformer 84 and capacitor 89 provides a sensitive means for selectively tuning the receiver input to the associated transmitter frequency while using a moderate size capacitor. One terminal of secondary winding 85 of transformer 84 connects to base 91, and its other or second terminal connects to the junction of two resistors 99 and 100 connected across a source of potential indicated as a battery 103. The collector 93 of transistor 92 couples through a parallel tuned circuit consisting of a capacitor 95 and the primary winding 96 of transformer 97 to the negative terminal of a source 103. The emitter 94 of transistor 92 couples through resistor 104 to the positive terminal of source 103.

A capacitor 101 is connected in series with resistors 86 and 102 from emitter 94 to the second terminal of winding 85. Resistors 86 and 102 provide a sensitivity control to adjust the signal input level to transistor 92. Resistor 102 is variable to permit fine adjustment control. By inserting the sensitivity control in the emitter 94 circuit, a safety feature is added to the circuit since if resistors 86 or 102 would now open the sensitivity of the receiver will be decreased to cause the associated track relay to be released to indicate a false condition and thus be fail-safe. The over-all sensitivity of the unit would be decreased because the capacitor 101 would no longer provide a by-pass for alternating current. The other possibility, that is, that resistors 86 and 102 will short circuit to zero impedance is believed to be remote. Since the resistances 86 and 102 are in the emitter circuit instead of, as is conventional, in the base circuit they have little effect on the direct current characteristics of the transistor. Removing the sensitivity control from the base 91 circuit tends to increase the temperature stability of transistor 92 since resistors in said base circuit may cause thermal runaway at high operating temperatures. Further, had the input sensitivity control been connected in a conventional manner as a potentiometer across winding 85 with the tap on the potentiometer being connected to the base circuit of transistor 92, and if a lead at one end of the potentiometer opened the received would become more sensitive. This would not be acceptable for railroad fail-safe type circuits.

The secondary winding 98 of transformer 97 connects in parallel to the bases 107 and 109 of push-pull connected class B amplifiers 105 and 110, respectively, which are biased to be slightly conducting during the period when no signal is being received in the receiver. The emitters 108 and 111 of amplifiers 105 and 110 are directly coupled to one another, and the collectors 106 and 112 of amplifiers 105 and 110 are coupled to opposite terminals of an output parallel tuned circuit consisting of capacitor 113 and the primary winding 114 of transformer 115.

The biasing or operating potential for amplifiers 105 and 110 is obtained from a source 103. The bases 107 and 109 are connected through a center tap on secondary 98 to the junction of a temperature compensating thermistor 117 having a negative temperature coefficient, and resistor 118. Emitters 108 and 111 are connected through resistor 119 to the positive terminal of source 103. Capacitor 121 provides a signal current by-pass for resistor 119. Collectors 106 and 112 are connected through a center tap of primary winding 114 of transformer 115 to the negative terminal of source 103. Thermistor 117 is connected in series with resistor 118, the two components then being connected across the terminals of source 103. The function of the thermistor 117 is to maintain a constant receiver sensitivity over a wide range of temperature, in one embodiment from −30° F. to +150° F. A constant receiver sensitivity is required for once the sensitivity is set it must remain at a fixed point for fail-safe operation. Further, the circuit used to obtain this fixed sensitivity with respect to temperature must be self-checking so that if the thermistor 117 opens or shorts, the output will be reduced and the sensitivity decreased. The foregoing is accomplished as follows. As noted above, one terminal of thermistor 117 is connected in series to a resistor 118 which has a relatively low resistance, across source 103. Emitters 108 and 111 are connected through a resistor 119, which has a low power dissipation rating in one embodiment 0.5 watts, to the positive terminal of source 103, and to the other terminal of thermistor 117. If thermistor 117 becomes short circuited the forward bias in the push-pull stage will become zero, that is, the same relative potential will be applied to bases 107 and 109 as is applied to emitters 108 and 111 and the output signal will be reduced markedly. If on the other hand, thermistor 117 opens and since the value of resistor 118 is selected to be relatively low, the bases 107 and 109 respectively will be approximately at the negative potential of source 103. Hence, the base current will become excessive, and as is known, the emitter to collector currents in amplifiers 105 and 110 will increase toward their maximum rated value. This causes resistor 119 to be destroyed or burned-up since it is not capable of handling the current now flowing in the emitter circuits. As soon as resistor 119 is destroyed current flow through amplifiers 105 and 110 will cease, causing the track relay to release.

The output of the receiver is taken from the secondary 116 of transformer 115 and coupled through a balanced rectifying device 122 to the associated track relay.

The receiver is rendered insensitive to 120 cycle alternating current ripple that may appear across the alternating current floating storage battery system as normally used in railway circuits. This is accomplished by tuning both transformers 97 and 115 to have a high impedance only to the frequency being passed. The primary and secondary inductances of transformers 97 and 115 are chosen to give optimum selectivity in these circuits and toroidal coils are used throughout because of their inherently higher Q compared to conventional transformers. The presence of several tuning stages in the receiver circuit also precludes the possibility that the receiver may be tuned to the adjacent transmitter frequency through possible changes in tuning capacitor values.

The operation of the over-all system as shown in FIG. 1*a* will now be described. The operation of the circuits is bi-directional, that is, operation is similar for either a west to east movement, left to right as oriented on the drawings, or an east to west movement. Only a west to east movement will be described since this is deemed sufficient for an understanding of my track circuit.

In the track unoccupied condition, transmitter 10 effects an alternating current flow in rails 11*a* and 11*b* at a frequency of 1000 c.p.s. and induces a voltage in loop 16 sufficient to energize receiver 20 to keep its associated relay TR20 energized. As noted hereinbefore the output filter 21 and secondary winding 24 of transformer 27 in transmitter 15 provide an electrical path across the rails 11*a* and 11*b* for the 1000 c.p.s. energy.

Transmitter **15** oscillating at 1500 c.p.s. likewise energizes receiver **25** to keep relay **TR25** energized since output filter and secondary winding of the output transformer in transmitter **10** provide an electrical path for 1500 c.p.s. energy.

Assuming now a train movement from west to east. A train axle, occupying an intermediate position between the point where leads **13***a* and **13***b* from transmitter **10** connect to rails **11***a* and **11***b*, and lead **16***a*, that is, the left hand end of loop **16**, will effect a shunt across the rails to stop current flow in that portion of rails **11***a* and **11***b* adjacent to which loop **16** is positioned; thus, receiver **20** will be deenergized. Accordingly, relay TR**20** will release and interrupt the circuit extending from terminal B of a source of potential indicated as a battery **9** through front contact *c* of relay TR**25**, and front contact *c* of relay **TR20** through the energizing coil of crossing relay XR to terminal N. Interruption of the foregoing circuit will cause relay **XR** to release. Release of relay XR completes a circuit from terminal B through the crossing gate mechanism and back contact *a* of relay XR to terminal N to actuate said mechanism, that is, to cause said mechanism to block the highway crossing. Release of relay **TR20** also causes a circuit to be completed from terminal B, through back contact *b* of relay TR**20**, back contact *a* of a slow release west stick relay WSR, and front contact *a* of relay TR**25** through the energizing coil of slow release east stick relay ESR to terminal N to pick up the contacts of relay ESR. As the train axle moves to a position adjacent the point where loop **18** couples to rails **11***a* and **11***b*, the current normally flowing in that portion of the rails will be shunted by the train axle. Accordingly, receiver **25** will be deenergized and relay **TR25** will release.

When the last train axle moves to the right of the highway to a predetermined position between the position of leads **16***a* and **16***b* as discussed above in relation to the flexible placement of the receiver leads, receiver **20** will cause relay **TR20** to be energized. The crossing relay XR will now be energized over the circuit extending from terminal B, through the front contact *b* of relay ESR, front contact *c* of relay **TR20**, and the operating coil of relay XR to terminal N. When relay **XR** is energized, the circuit from terminal B through the crossing gate mechanism and back contact *a* of relay XR to terminal N is interrupted, thus deactuating said mechanism, that is, causing it to clear the highway at a relatively predetermined short distance after the train passes the highway crossing.

Although the train axle will still occupy a position between transmitter **15** and its associated receiver **25**, relay ESR being initially energized over the circuit previously traced, remains energized over a stick circuit extending from terminal B, through back contact *b* of relay **TR25**, front contact *a* of relay ESR and the operating winding of relay ESR to terminal N. With relay ESR energized, the circuit extending from terminal B, through front contact *b* of relay ESR, and front contact *c* of relay **TR20** and the operating winding of relay XR to terminal N keeps relay XR energized. When the train axle passes the transmitter **15** connections **17***a* and **17***b*, relay **TR25** will be energized, interrupting the stick circuit to relay ESR, as traced above, and relay ESR will release slowly. The crossing relay XR will, however, remain energized over a circuit extending from terminal B, front contact *c* of relay **TR25**, and front contact *c* of relay **TR20** through the operating coil of relay XR to terminal N.

While my invention has been described with reference to particular embodiments thereof, it will be understood that various modifications may be made by those skilled in the art without departing from the invention. The appended claims are therefore intended to cover all such modifications within the true spirit and scope of the invention.

Having thus described my invention, what I claim is:

1. A track circuit for a section of railway track having the usual variable ballast impedance existing across the track rails; said track circuit comprising a transmitter including a signal energy generator operating at a given frequency, amplifier means having input and output portions, means coupling said generator to the input portion of said amplifier means, an output circuit coupling the output portion of said amplifier means across said track rails, and means coupling a regenerative feedback voltage from said output circuit to the input portion of said amplifier means for providing a signal output regulation curve which initially peaks with an increase in the ballast impedance and then decreases as said impedance continues to increase; a receiver of signal energy tuned to the operating frequency of said transmitter; and, means coupling said receiver to said rails to receive signal energy from said transmitter.

2. A track circuit for a section of railway track comprising a transmitter of signal energy operating at a given frequency, said transmitter including an oscillator, an intermediate amplifier coupled to said oscillator, an output amplifier coupled to said intermediate amplifier, and an output circuit coupling said output amplifier across the track rails and thus across the load or ballast impedance existing across said track rails, means coupling regenerative feedback energy from said output circuit to said intermediate amplifier whereby the total signal energy coupled to said load impedance is initially proportional and then becomes inversely proportional to said impedance as said impedance increases; a receiver of signal energy tuned to the operating frequency of said transmitter; means coupling said receiver to said track rails to receive signal energy from said transmitter; means connected across said track rails for completing the electrical path for signal energy at said operating frequency; and, track occupancy indicating means controlled by said receiver.

3. In a track circuit for a section of railway track, a transmitter including a signal generator, amplifier means having input and output portions, means coupling said generator to the input portion of said amplifier means, an output circuit coupling signal energy from the output portion of said amplifier means to said track rails, and means coupling a regenerative feedback voltage from said output circuit to the input portion of said amplifier means whereby a signal output regulation curve is obtained which initially peaks with an increase in the load impedance existing across said track rails and then decreases as said impedance continues to increase.

4. In a track circuit for a section of railway track, a transmitter including an oscillator of signal energy, an intermediate amplifier, means coupling signal energy from said oscillator to said intermediate amplifier, an output amplifier, means coupling said signal energy from said intermediate amplifier to said output amplifier, an output circuit coupling signal energy from said output amplifier across said track rails, and means coupling a feedback voltage from said output circuit to said intermediate amplifier which is regenerative with respect to said signal energy whereby a signal output regulation curve is obtained which initially peaks with an increase in the impedance existing across said track rails then decreases as said load impedance continues to increase.

5. A track circuit for a section of railway tracks intersected by a highway crossing, said track circuit comprising a first transmitter operating at a first frequency and having its output circuit connected across said rails at a point towards one direction from said highway crossing; a first receiver tuned to said first frequency; first means inductively coupling said first receiver across a length of said track rails, said first coupling means being positioned towards a second direction from said highway crossing; a second transmitter operating at a second frequency having its output circuit connected across said rails at a point towards said second direction from said highway crossing;

a second received tuned to said second frequency; second means inductively coupling said second receiver across a length of said track rails, said second coupling means being positioned towards said first direction from said highway crossing; and, each of said transmitters including a signal generator, amplifier means having input and output portions, means coupling said generator to the input portion of said amplifier means, means coupling the output portion of said amplifier means to its associated output circuit, and means coupling a regenerative feedback voltage from said associated output circuit to the input portion of said amplifier means for providing a signal output regulation curve which initially peaks with an increase in the ballast impedance existing across said track rails and then decreases as said impedance continues to increase, the output circuit of each of said transmitters having a low reactance to the frequency energy of the other transmitter whereby a low impedance electrical path across said rails is provided for the signal energy at the operating frequency of each of said transmitters.

6. A track circuit for a section of railway tracks intersected by a highway crossing, said track circuit comprising a first transmitter transmitting signal energy at a first frequency and having an output circuit connected across said rails at a point towards one direction from said highway crossing, a first receiver tuned to said first frequency, first means coupling said first receiver to said rails to receive signal energy from said tranmitter positioned towards a second direction from said highway crossing, a second transmitter transmitting signal energy at a second frequency having its output circuit connected across said rails at a point towards said second direction from said highway crossing, a second receiver tuned to said second frequency, second means coupling said second receiver to said rails to receive signal energy from said transmitter positioned towards said first direction from said highway crossing, each of said transmitters including a signal generator, amplifier means having input and output portions, means coupling said generator to the input portion of said amplifier means, means coupling the output portion of said amplifier means to its associated output circuit, and means coupling a regenerative feedback voltage from said associated output circuit to the input portion of said amplifier means for providing a signal output regulation curve which initially peaks with an increase in the ballast impedance existing across said track rails and then decreases as said impedance continues to increase.

7. A track circuit which comprises a pair of rails, means for generating signal energy of a given frequency, amplifying means connected to the former means for amplifying the signal energy, the output of the amplifying means being coupled to the rails, and feedback means coupled to the output of the amplifying means for feeding a portion of the amplified signal energy which varies inversely to the impedance across the rails back to the input of the amplifying means in phase with the generated signal energy.

8. A track circuit which comprises a pair of rails, means for generating signal energy of a given frequency, amplifying means connected to the former means for amplifying the signal energy, the output of the amplifying means being coupled to the rails, feedback means coupled to the output of the amplifying means for feeding a portion of the amplified signal energy which varies inversely to the impedance across the rails back to the input of the amplifying means in phase with the generated signal energy, and means coupled to the rails for receiving the signal energy at the given frequency.

9. A track circuit which comprises a pair of rails, means for generating signal energy of a given frequency, amplifying means connected to the former means for amplifying the signal energy, the output of the amplifying means being coupled to the rails, feedback means coupled to the output of the amplifying means for feeding a portion of the amplified signal energy which varies inversely to the impedance across the rails back to the input of the amplifying means in phase with the generated signal energy, means coupled to the rails for receiving the signal energy at the given frequency, and track occupancy indicating means controlled by the means for receiving the signal energy.

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