

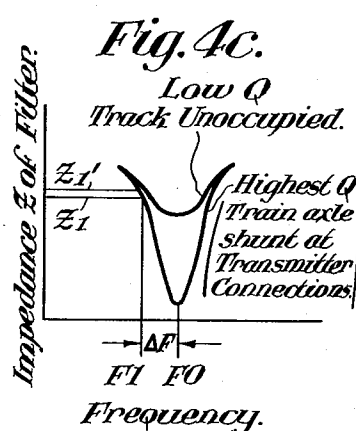
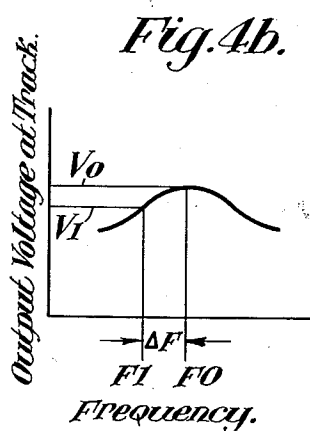
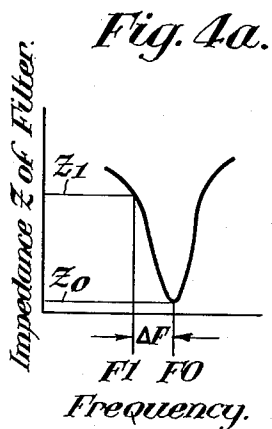
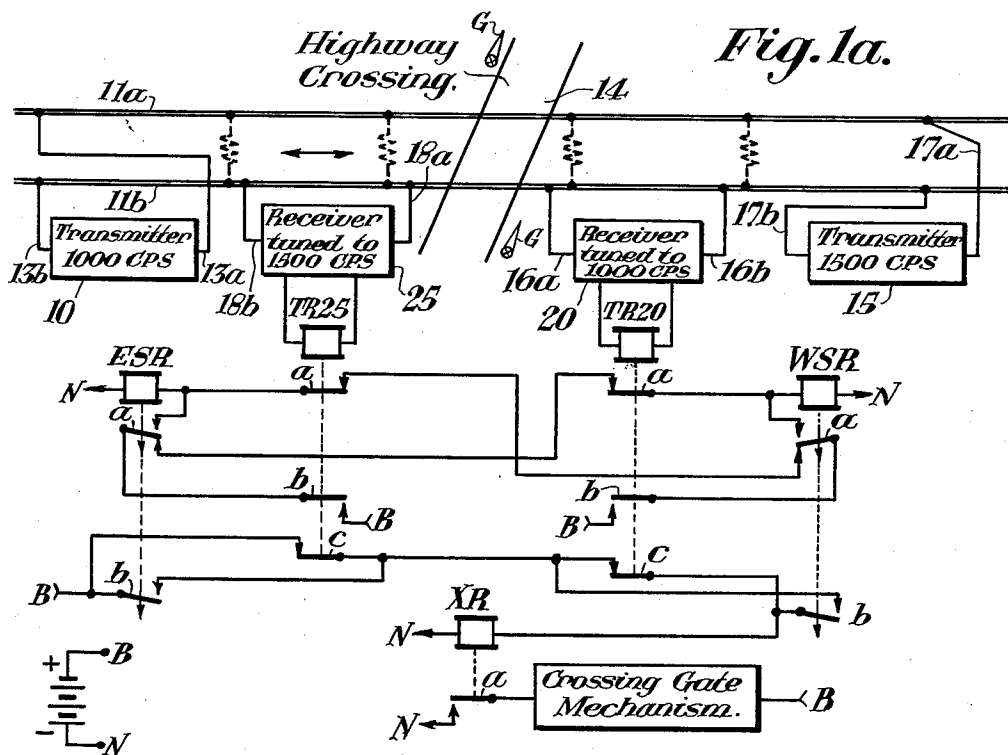
July 24, 1962

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CONTROL CIRCUITS

3,046,392

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4 Sheets-Sheet 1



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4 Sheets-Sheet 2

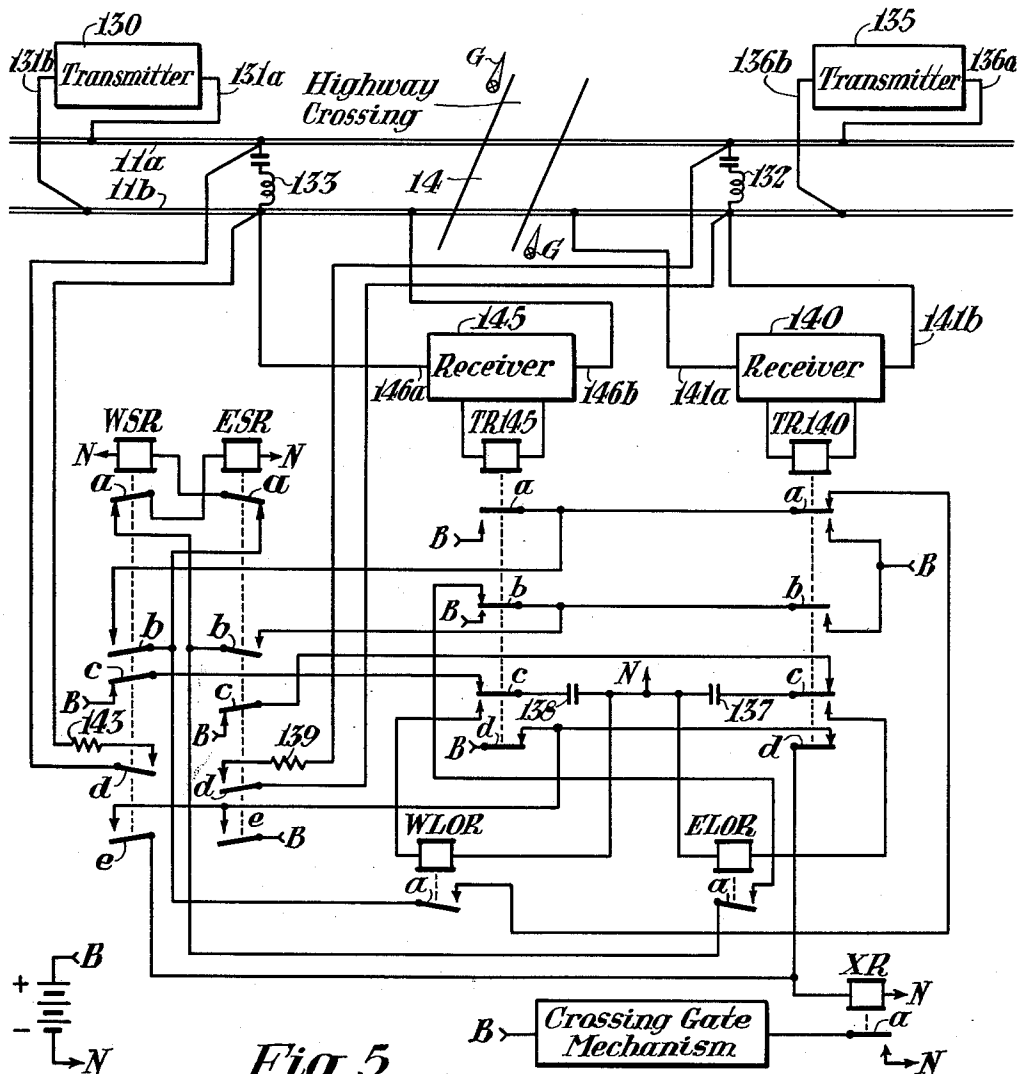


Fig. 5.

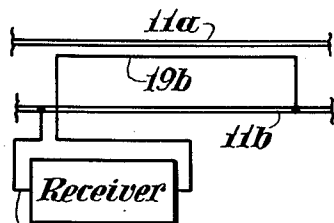


Fig. 1b.

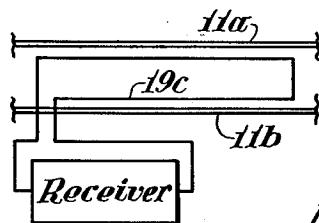


Fig. 1c.

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4 Sheets-Sheet 3



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4 Sheets-Sheet 4

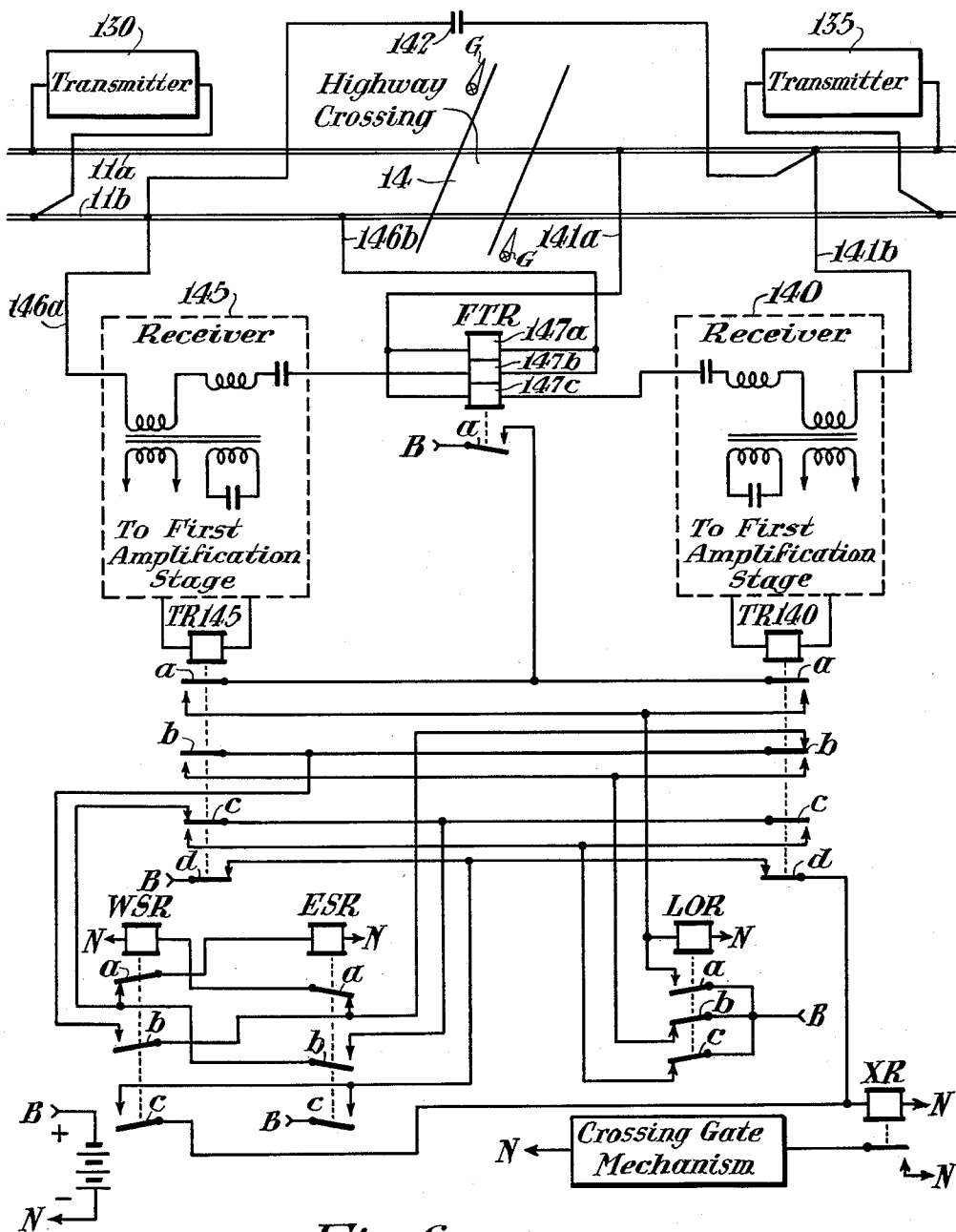


Fig. 6.

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1

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CONTROL CIRCUITS

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13 Claims. (Cl. 246—130)

My invention relates to control circuits, and more particularly to the organization of such circuits into control systems for railroads arranged to provide at a given point a warning or indication that a train is approaching to or receding from said point.

Equipment providing a means of superimposing one or more extra circuits on the same conducting medium used by a prime circuit without any mutual interference is in particular demand in the railroad field. If, for example, two track rails already form a direct or alternating current track circuit for signal control, by means of so-called overlay circuits a portion of these rails may form an additional circuit which may be used to operate a highway crossing warning mechanism, independently of the limits of the principal circuit. One type of 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 to the rails. If the superimposed overlay track circuit is connected to track rails having no insulating joints the operating limits of the overlay track circuit cannot be clearly defined. One reason for this lack of definition is the large variance in the resistance values of the track ballast due to climatic conditions. For example, the shunt detecting area for an overlay track circuit operating at audio frequency and having its transmitter and receiver connections separated by a distance of 50 feet would vary from about 90 feet to about a maximum of 140 feet beyond the track connection points of both the transmitter and receiver. The shunt detecting area of an overlay track circuit operating at audio frequency and having the transmitter and receiver connections separated by 150 feet could vary from 190 feet to 300 feet. Thus it can be seen that the greater the length of the overlay 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 highway crossing warning systems. It is to be noted that the present circuit is particularly useful in connection with electrically continuous track rails. Insulating joints are undesirable due to their high installation and maintenance costs.

Accordingly, it is a principal object of my invention to provide a track circuit in which the limits of said circuit are constant and clearly defined.

It is still another object of my invention to provide a track circuit in which both the approaching and receding limits are constant and clearly defined.

It is yet another object of my invention to provide a track circuit for use as a highway crossing warning system.

In the attainment of the foregoing objects I provide a track circuit in which a transmitter of electrical energy operating at a given frequency is connected across the rails. The electrical energy flowing in a predetermined length of at least one track rail is coupled to a receiver tuned to the frequency at which said transmitter is operating. Reactance means may be connected across said rails to provide a path for said electrical energy at said operating frequency independently of the ballast resistance existing across said rails.

A principal advantage of my control circuit is that a means of maintaining sufficient rail current flowing under

2

all conditions of track ballast is built-in or inherent in the circuit.

Another advantage of this type of receiver connection is that the receivers may be made very sensitive without being affected by interference from other track circuits operating on the same section of track.

Yet, another advantage of my invention is the elimination of the requirement for insulated joints on any circuit where it is desired to cause a relay to pick up or release when a train reaches a certain specified point in the track circuit.

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

FIG. 1a shows one embodiment of a control circuit to provide a bi-directional highway crossing control arrangement in accordance with my invention;

FIG. 1b and FIG. 1c are views showing alternative means of connecting a receiver to the rails;

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

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

FIGS. 4a, 4b and 4c are graphical illustrations useful in describing the operation of my control circuits;

FIG. 5 shows another embodiment in accordance with my invention; and

FIG. 6 shows yet another embodiment in accordance with my invention.

I shall first describe the above embodiments of the control circuits 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 control 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 few feet from a designated point. However, my control circuit will be described only as applied to a highway crossing warning system since it is believed such a description will satisfactorily describe the operation of my circuit.

Referring to FIG. 1a, a section of track rails 11a and 11b is shown as intersected by a highway crossing 14. In one practical embodiment, my control circuit includes a first transmitter 10 connected by terminal leads 13a and 13b across rails 11a and 11b, respectively, at a desired point, say between 300 and 4000 feet distance to the left, as oriented in the drawings, of the highway crossing. Transmitter 10 is tuned to operate at 1000 c.p.s. At a designated distance necessary to provide clearance, which may be a minimum distance of 15 feet from the center of the highway, on the other or right side of the highway crossing, a first input lead 16a to receiver 20 connects to rail 11b. At a designated distance, in one instance 50 feet from the connection of lead 16a to rail 11b, a second input lead 16b to receiver 20 also connects to rail 11b. 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 17a and 17b to rails 11a and 11b, respectively, at a desired point, say between 300 and 4000 feet distance to the right of highway crossing 13. Transmitter 15 is tuned to operate at 1500 c.p.s. At a designated distance, as above, on the left side of the highway crossing 14 a first input lead 18a to a receiver 25 connects to rail 11b. About 50 feet from the connection of lead 18a to rail 11b, a second input lead 18b to receiver 25 also connects to rail 11b. Receiver 25 is tuned to the operating frequency of transmitter 15 and operates in conjunction therewith.

It will be understood that the distances 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 the highway crossing to the point at which the transmitters connect to the rails is limited only by the available transmitting power. The distance between receiver connections is determined by receiver sensitivity. Receiver 20 may be connected to one rail and receiver 25 to the other rail, however, it has been found that connecting both receivers to the same rail simplifies installation of the circuit.

If the ballast resistance, shown by the dashed resistance symbols, is relatively low and evenly distributed, as is normally the case, current from both transmitters 10 and 15 will be flowing in the rails 11a and 11b. Rail current due to each transmitter will be different at different points along rails 11a and 11b and will decrease exponentially with distance from each transmitter. 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 across which they are connected. Should the ballast resistance increase, for any reason, the rail current at any specified point along rails 11a and 11b will tend to decrease if the transmitter output voltages are held constant and the track circuit is considered to be infinitely long in electrical length. If the track circuit is terminated in an impedance of the order of the lowest value of ballast resistance at a distance in the order of 4000 feet or less this rail current however will tend to increase as the ballast resistance raises.

The output connections of the transmitters to the rails will now be briefly described. Referring to FIG. 2, a series tuned filter 21 tuned to the desired frequency and consisting of condenser 22 and inductance 23 is connected to secondary winding 24 of transformer 27 in the output circuit of each transmitter. As noted above, transmitters 10 and 15 are similar, transmitter 10 is tuned to oscillate at 1000 c.p.s., and transmitter 15 is tuned to oscillate at 1500 c.p.s. Filter 21 and secondary winding 24 in one transmitter are so designed that their impedance to the frequency at which the other transmitter is transmitting energy is still of a low order. For example, should the ballast resistance become infinite, the impedance of filter 21 and secondary winding 24 in transmitter 15 to 1000 c.p.s. energy will still be low enough to cause sufficient current to flow through rail 11b to maintain receiver 20, which is tuned to 1000 c.p.s., energized to keep its associated relay TR20 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 to maintain receiver 25 energized. Thus, the circuit inherently provides a means of maintaining sufficient rail current flowing over any range of track ballast resistance that might be encountered.

The placement of the receiver leads designated generally as 16 and 18 as shown in FIG. 1a is flexible to a degree determined by the sensitivity of receivers 20 and 25, as noted above. Receivers 20 and 25 and their leads 16 and 18 are connected in similar relation to each other and to rail 11b. The operating relation of the leads 19a and 19b of FIG. 1b, and of lead 19c in FIG. 1c are generally similar to the relation of leads 16 and 18. The reason for connecting the receivers to the rails as shown in FIGS. 1b and 1c will be discussed hereinafter. Since the operating relation of the leads connecting the receivers to the rails are similar, a description of receiver 20 and leads 16a and 16b is considered sufficient to the understanding of my invention.

Lead 16a 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 TR20 to pick up to actuate the crossing gate mechanism to its normal or raised position as shown in the drawings. The elements designated as G are 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 rail 11b so that a shunt at a point to the right of connection 16a, a distance of about only 10% to 15% of the total distance between the connections of leads 16a and 16b will energize receiver 20 and pick up receiver relay TR20. Under conditions of low battery voltage and low ballast impedance a shunt at a point to the right of connection 16a, a distance of about 70% to 80% of the distance between the connections of leads 16a and 16b is required to energize the receiver 20 sufficiently to pick up relay TR20. Therefore, the leads 16a and 16b are connected to the rail so that under maximum voltage and infinite ballast conditions, the train will always be off the highway before the associated receiver relay picks up. However, the distance from the highway to the adjacent receiver lead 16a 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.

It has been found that the sensitivity of a receiver can be increased by positioning one of the wire leads, connecting the receiver to the rail, adjacent a length of one of the rails as shown for example in FIG. 1b. From FIG. 1b, it will be appreciated that a voltage will be induced in lead 19b by current flowing in rail 11a. This induced voltage will tend to add to the voltage developed by current flowing along the length of rail 11b to in effect provide a higher input signal to the receiver.

In propulsion territory it has been found that the high harmonics of the propulsion current may interfere with the satisfactory operation of the control circuit of my invention. To eliminate any such interference the receivers are inductively coupled to the rails as shown for example in FIG. 1c. Lead 19c which couples the electrical energy from the rails to the receiver is positioned such that a portion of lead 19c is adjacent a predetermined equal length of each of the rails 11a and 11b, and spaced approximately the same distance from each rail. In one practical embodiment lead 19c was positioned along a length of approximately 50 feet of each of rails 11a and 11b. Since the propulsion current normally flows in the same direction along both rails, the voltage induced in lead 19c due to the propulsion current flowing in the rail 11a will be in opposing or bucking relation to the voltage induced in lead 19c due to the propulsion current flowing in rail 11b. Thus, the voltages developed in lead 19c due to the flow of propulsion current cancel out and will not affect operation of my control circuit. However, the associated transmitters of my control circuit as discussed above provide current flow in rails 11a and 11b in opposite directions, hence the voltages induced in each portion of the lead 19c will tend to add and provide a high signal voltage to the receiver.

Further positioning the receiver wires along the rail so that there is no electrical connection to the rail provides excellent broken rail protection in that if a break in the rail occurs along the length of rail across which the receiver is coupled, the receiver will not be energized even if a capacitor in its input circuit is shorted.

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

Referring to FIG. 2, a transistor oscillator 31 includes a base electrode 32, emitter electrode 33, and a collector electrode 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 condenser 36 and the primary winding 37 of a transformer

5

38. As noted above, the oscillator 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 42 and a signal current by-pass condenser 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 44 is coupled through primary winding 37 to the collector 34. The positive terminal of source 44 is coupled through resistances 47 and 42, and feedback winding 41 to the emitter 31. Base 32 is connected to the junction of resistances 48 and 49, which resistances are connected across source 44.

One terminal of secondary winding 39 of transformer 38 couples through output level adjusting resistances 51 to the base 52 of a class A transistor amplifier 53. The other terminal of secondary winding 39 couples to the junction point of resistances 56 and 57, which resistances are connected across the source 44. The collector 54 of amplifier 53 couples to a wave shaping circuit consisting of a condenser 56 connected in parallel to the primary winding 61 of transformer 62. The emitter 55 of amplifier 53 couples through resistance 64 to the positive terminal of source 44. A condenser 65 provides a signal current by-pass around resistances 64 and 56.

The secondary winding 63 of transformer 62 couples in parallel to the base electrodes 65 and 72 of normally cut-off, push-pull connected class B power amplifiers 64 and 71, respectively. The emitters 66 and 73 of amplifiers 64 and 71 are directly coupled to one another. The collector electrodes 67 and 74 of amplifiers 64 and 71 are coupled to opposite terminals of an output parallel tuned circuit 76 consisting of condenser 75 connected in parallel to the primary winding 26 of transformer 27. A biasing resistance 69 connects the emitters 66 and 73 through center tapped secondary winding 63 of transformer 62 to base electrodes 65 and 72, respectively. To provide proper biasing potentials the positive terminal of source 44 is connected to the center tap of secondary winding 63 of transformer 62 and the negative terminal of source 44 is connected to the center of primary winding 26 of transformer 27.

Two factors that normally fix the amount of derating necessary on a transistor are the voltage variations which will be encountered, and the maximum ambient temperature in which the transistor will operate. The power rating of a transistor is usually designated at room temperature and at a given voltage. Derating as will be discussed hereinafter concerns reducing the designated power rating of a transistor by an amount considered necessary to provide suitable operation in the event of considerable variations in operating parameters. Such derating of the transistors is necessary so that the internal dissipation in the transistor is controlled to prevent the transistor from destroying itself when such variations do occur. In addition to voltage and temperature variations an important design consideration in transistorized circuits is the load impressed on the transistor devices. In my control circuit, the transmitter output is connected across the rails so that the impedance from rail to rail may be considered as the load. It is evident this load may vary from a relatively high value at high ballast and unoccupied track condition to zero when the axles of a train are shunting the track at the transmitter output connections.

Resistance R_L represents the load across the rails 11a and 11b which under operating conditions may change from a value of 20 ohms or more to zero. As indicated in FIG. 2, E_b represents the direct current voltage across the source 44; V_p represents a sine wave signal voltage across the parallel tuned circuit 76, and I_1 represents the average current flowing in the circuit including the source 44, into a nominal load that would occur with the track circuit unoccupied. The effective current flowing in the

6

circuit is approximately 1.1 times I_1 , the average current.

The power delivered by the source to the circuit is given by

$$E_b \times I_1$$

- 5 The power delivered into the primary of the output transformer will be given

$$\frac{V_p \times I_1 \times 1.1}{2}$$

- 10 where I_1 is average current.

The difference between these two quantities, except for a relatively small amount of power consumed by emitter bias resistor 69 which may, for purposes of this discussion, be neglected, represents the power dissipation in the two transistors.

Referring now to FIGS. 4a, 4b and 4c as well as FIG 2, if the load resistance R_L is reduced to zero and the transmitter output filter 21 is tuned to the transmitter signal or drive frequency F_0 , voltage V_p will decrease to a small value but the current I_1 will increase slightly. The decrease of V_p is due to the fact that the only resistance presented to the secondary 24 of transformer 27 is the effective resistance of the series filter 21 consisting of inductance 23 and capacitance 22. Design requirements dictate that the resistance of filter 21 be of a low value, in the order of one tenth the nominal resistive value of the load; and, consequently with zero load a low impedance is reflected back to the primary 26 of the transformer 27. The primary 26 of transformer 27 becomes in effect a short circuit to alternating current under these conditions and the voltage V_p reduces to a very low value. Since the signal voltage impressed on transistors 64 and 71 remains approximately the same, current I_1 remains substantially constant. From the above equations it is evident the power deliver to the circuit given by

$$E_b \times I_1$$

will remain approximately the same. However, the power delivered to the transformer 27 is greatly reduced due to the reduction in V_p , so that considerably greater power is being dissipated in the transistors.

To derate the transistors sufficiently under the normal operating condition to handle the short circuit condition would result in little useful power output from the transistors. To solve the problem I provide a means of feeding a useful amount of power to the rails in both the occupied and unoccupied conditions of the track section without the danger of overloading the transistors.

Assume a larger load impedance could be reflected back to the primary 26 of the transformer 27 when R_L was zero, voltage V_p under this condition could be maintained at a constant value and the power being delivered to the output transformer 27 and hence the transistor dissipation could be kept constant. This can be done with only a small sacrifice in available output power.

In FIG. 4a the impedance Z of the filter 21 is plotted versus the operating frequency of the circuit. The plotted curve indicates the impedance the secondary 24 of the output transformer 27 would see with the rails 11a and 11b shunted so that R_L equals zero. Filter 21 being series tuned will have a minimum impedance Z_0 at the tuned frequency as shown in FIG. 4a. At a frequency F_1 , which is ΔF frequency different from the tuned frequency F_0 the impedance Z_1 of filter 21 increases markedly. The curve is very selective when R_L is zero since in effect, the Q of the circuit is given by

$$Q = \frac{X_L}{R_L} + R \text{ coil } 23$$

- 70 R coil 23 is quite small as the Q of the coil is high.

FIG. 4b shows a curve of transmitter output voltage delivered to the rails under the normal load condition, that is, with no train occupying the track section and a nominal ballast resistance from rail to rail. At frequency F_0 the output voltage delivered to the track rails is a maximum

voltage V_0 . At frequency F_1 the output voltage V_1 is somewhat less than the maximum. The selectivity of the curve is rather poor since the load resistance R_L has been introduced into the output circuit.

It will now be noted from a study of FIGS. 4a and 4b that by selecting for operation a frequency F_1 , differing from the tuned frequency F_0 of the filter by an amount ΔF the change in output voltage or the difference between V_0 and V_1 will be very small; however, the change in impedance or the difference between Z_1 and Z_0 will be very great. In other words, if the oscillator frequency F_1 is selected for operation and the output circuit including filter 21 consisting of inductance 23 and capacitance 22 is tuned to F_0 , there will be relatively little loss in output voltage. However, the impedance Z_1 under track occupied conditions reflected back into the primary 26 of transformer 27 will allow the voltage V_p to remain at a relatively high value since it is almost the same value that would be obtained under track unoccupied conditions. This latter point is illustrated in FIG. 4c where impedance curves of identical circuits are drawn with the exception that one circuit has a much higher Q . At a frequency F_1 which is ΔF different from the tuned frequency, the impedance Z_1 of the track occupied, high Q , circuit is very nearly equal to Z_1 or the impedance of the track unoccupied, low Q , circuit. In accordance with the foregoing, in one practical embodiment transmitter 10 is tuned to generate a frequency of 1000 c.p.s. and its associated filter 21 is tuned to 850 c.p.s. Likewise transmitter 15 is tuned to generate a frequency of 1500 c.p.s. and its associated filter 21 is tuned to 1250 c.p.s.

Referring to FIG. 3 each receiver includes a sharply tuned input circuit consisting of an inductance 81 and condenser 82, connected in series to the primary winding 83 of transformer 84. The input circuit of receiver 20 is tuned to a frequency of 1000 c.p.s. while the input circuit of receiver 25 is tuned to a frequency of 1500 c.p.s. A trimmer condenser 86 is connected in parallel to condenser 82. A secondary winding 85 on transformer 84 couples to a class A transistor amplifier 92 including a base 91, collector 93, and emitter 94 electrodes. A parallel tuned circuit 87 consisting of a tertiary winding 88 on transformer 84 and condenser 89 provides a sensitive means for selectively tuning the receiver input to the associated transmitter frequency using a moderate size condenser. One terminal of secondary winding 85 connects to base electrode 91. The collector 93 of amplifier 92 couples through a parallel tuned circuit consisting of a condenser 95 and the primary winding 96 of transformer 97 to the negative terminal of a source of potential 103. The emitter 94 of amplifier 92 couples through a parallel circuit consisting, in one arm, of resistance 104 and in the other arm of condenser 101 connected in series with the variable resistance 102 to the positive terminal of source 103.

Resistance 102 serves to adjust the signal input level to amplifier 92. By inserting resistance 102 in the emitter 94 circuit, an additional safety feature is added. Since if now resistance 102 opens the sensitivity of the receiver will decrease and cause the associated receiver relay to be released to indicate a fault condition. With the input sensitivity control connected in the usual parallel fashion, that is, with a resistance connected across winding 85, and an output tapped from the resistance, and if a lead at one end of the potentiometer opens the receiver may become more sensitive, which is undesirable. Further, insertion of a sensitivity control in series with base 91 may create poor temperature stability of amplifier 92 with resultant thermal runaway at high operating temperatures.

The other terminal of secondary winding 85 couples to the junction point of resistances 99 and 100. Resistances 99 and 100 are connected across source 103. The secondary winding 98 of transformer 97 couples in parallel to the base electrodes 107 and 109 of push-pull 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 are directly coupled to one another. The collector electrodes 106 and 112 are coupled to opposite terminals of an output parallel tuned circuit consisting of condenser 113 and the primary winding 114 of transformer 115. The biasing arrangement for amplifiers 105 and 110 includes a temperature compensating thermistor 117 connected in series with resistance 118, the two elements then being connected across the terminals of source 103. The function of the temperature compensating thermistor is to maintain a constant receiver sensitivity over a wide range of temperature. The use of thermistor 117 serially connected to resistor 118 tends to prevent an increase in receiver sensitivity in the event of loss of either the thermistor or resistor 118. The base electrodes 107 and 109 are connected through center tapped secondary 98 to the junction of thermistor 117 and resistance 118. Emitters 108 and 111 are connected through resistance 119 to the positive terminal of source 103. Condenser 121 provides a signal current by-pass around resistance 119. Collectors 106 and 112 are connected through a center tap of primary 114 of transformer 115 to the negative terminal of source 103. 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 receiver relay.

The operation of the overall system as shown in FIG. 1a 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 control circuits.

In the track unoccupied condition transmitter 10 effects an alternating current flow in rails 11a and 11b at a frequency of 1000 c.p.s. Current flow in the section of rail 11b across which leads 16a and 16b are connected is sufficient to energize receiver 20 to keep its associated relay TR20 picked up. As noted hereinbefore the output filter 21 and secondary winding 24 of transformer 27 in transmitter 15 provide an electrical path across the rails 11a and 11b for the 1000 c.p.s. energy. Transmitter 15 oscillating at 1500 c.p.s. likewise energizes receiver 25 to keep relay TR25 picked up. Assume a train movement from West to East. A train axle occupying an intermediate position between the point where transmitter 10, leads 13a and 13b connect to rails 11a and 11b, and the point at which receiver 20, lead 16a connects to rail 11b will effect a shunt across the rails to stop current flow in rail 11b between connections 16a and 16b and receiver 20 will be deenergized. Accordingly, relay TR20 will release and interrupt the circuit extending from terminal B through front contact c of relay TR25, 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 N through back contact a of relay XR and through the crossing gate mechanism to terminal B to actuate said mechanism. Release of relay TR20 also causes a circuit to be completed from terminal B, through back contact b of relay TR20, back contact a of west stick relay WSR, and front contact a of relay TR25 to the energizing coil of slow release east stock relay ESR to pick up its contacts. As the train axle moves to a position adjacent the point where receiver 25 lead 18a connects to rail 11b, the current normally flowing in rail 11b between connections 18a and 18b will be shunted across the rails 11a and 11b. 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 connections of leads 16a and 16b to rail 11b, as discussed above in relation to the flexible placement of the receiver leads, receiver 20 will cause relay TR20 to pick up. The crossing relay XR will now be picked up 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 picks up the circuit from terminal N through back contact *a* of relay XR and the crossing gate mechanism to terminal B is interrupted thus deactuating said mechanism 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 picked up over the circuit previously traced, remains picked up 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 picked up the circuit from terminal B, through front contact *b* of relay ESR, and front contact *c* of relay TR20 through the operating winding of relay XR to terminal N keeps relay XR picked up. When the train axle passes the transmitter 15 connections 17*a* and 17*b*, relay TR25 will be picked up interrupting the stick circuit to relay ESR, as traced above, and relay ESR will release slowly. The crossing relay XR will however remain picked up 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.

A second embodiment of my invention is shown in FIG. 5. This embodiment is particularly useful in cases where my control circuit is to operate over extremely long track lengths and it is desired to make the rail current flow from a transmitter to its associated receiver as great as possible, or in cases where my control circuit is to operate in conjunction with unidirectional train movements. In the latter case only one transmitter and receiver combination would be required.

Transmitters 130, 135, and receivers 140 and 145 are similar to transmitters 10, 15 and receivers 20 and 25, respectively. The required return path for transmitter 130 in addition to that provided by transmitter 135 is provided by a filter 132 consisting of a series connected inductance and condenser which are tuned to the operating frequency of transmitter 130. Likewise the return path for transmitter 135 is provided by a filter 133 consisting of a series connected inductance and condenser tuned to the operating frequency of transmitter 135. Filters 132 and 133 maintain a current path for energy at their tuned frequency regardless of any increase in ballast impedance. Receiver 140 leads 141*a* and 141*b* connect to rail 11*b* at points to the right of the highway crossing as shown in FIG. 5 and receiver 145 leads 146*a* and 146*b* connect to rail 11*b* at points to the left of the highway crossing as shown in FIG. 5.

To assure that a loss of filter sections 132 and 133 does not result in an unsafe condition, a means for detecting the failure of said filters, and thereby creating a lockout so that the gate crossing mechanism will remain actuated, that is, down when the filters fail is also shown in FIG. 5. For this purpose an east lockout relay ELOR and a west lockout relay WLOR are included in the circuit. Relay ELOR and relay WLOR are energized by means of condensers 137 and 138, respectively. Condenser 137 is in turn charged over a circuit extending from terminal N, through condenser 137 itself, front contacts *c* of relay TR140, and the back contact *c* of the east stick relay ESR to terminal B. Likewise condenser 138 is charged over a circuit extending from terminal N, through condenser 138 itself, front contact *c* of relay TR145, and the back contact *c* of the west stick relay WSR to terminal B.

The operation of the circuit is similar for movement of a train in either direction so that a description of an east to west movement is deemed sufficient for an understanding of the circuit.

With no train in either approach circuit, condensers 137 and 138 are in a charged condition. Assume a train movement from west to east, left to right as oriented in the drawings. When the train axle occupies a position

intermediate the point at which transmitter 130 leads 131*a* and 131*b* connect to rails 11*a* and 11*b*, and the point at which receiver 140 lead 141*a* connects to rail 11*b* the receiver 140 will be deenergized and cause relay TR140 to release. Release of relay TR140 causes condenser 137 to be discharged over the back contact *c* of relay 140, and the operating coil of east lockout relay ELOR causing relay ELOR to pick up. This allows east stick relay ESR to pick up over a circuit extending from terminal B, through back contact *b* of relay TR140, front contact *b* of relay TR145, front contact *a* of relay ELOR, back contact *a* of west stick relay WSR, and through the operating coil of relay ESR to terminal N.

It will be obvious that if condenser 137 is defective, relay ELOR will not pick up. Relay ESR would thus be prevented from picking up. With relay ESR released the circuit from terminal B through front contact *e* of relay ESR, and front contact *d* of relay TR140, through the operating winding of relay XR is opened causing relay XR to be in a released position. This would cause the crossing gate mechanism to remain down even after the last train axle has passed the highway crossing.

Should a failure of either filter 132 or 133 occur, the associated TR relay would be released. The operation of the circuit is similar in the event of failure of either filter, so that a description of the circuit when filter 132 fails is deemed sufficient. Assume for example that filter 132 is open circuited at a time when a train does not occupy the circuit. This will cause relay TR140 to release. Release of relay TR140 will cause relay ELOR to pick up due to the discharge of condenser 137. Relay ESR will then be picked up over the front contact *a* of relay ELOR and the circuit previously traced. When relay ESR picks up its front contact *d* will connect a low impedance resistance 139 from rail 11*a* to rail 11*b* in parallel to filter 132 to provide a path for current flow. Sufficient current will then again flow through that portion of rail 11*b* between the points at which receiver leads 141*a* and 141*b* connect to rail 11*b* to cause relay TR140 to pick up. When relay TR140 picks up, the stick circuit for relay ESR from terminal B over back contact *b* of relay TR140, front contact *b* of relay ESR, back contact *a* of relay WSR, and through the operating winding of relay ESR to terminal N will be interrupted and relay ESR will release. After relay ESR releases relay TR140 will release since the track shunt provided over front contact *d* of relay ESR is opened. The period of time between the release of relay ESR and the release of relay TR140 will not be long enough to charge the condenser 137 to a sufficient magnitude to cause relay ELOR to be subsequently picked up when condenser 137 discharges through the operating coil of relay ELOR over the back contact *c* of relay TR140. With relay LOR released and its front contact *a* open, stick relay ESR will not pick up even though relay TR140 is released. Subsequent train movements from either direction will result in both stick relays ESR and WSR remaining down after the movement is completed. Since relay TR140 will remain down due to the open filter 132, the crossing gate mechanism will remain actuated or down. This occurs since the circuit from terminal B over front contact *d* of relay TR145 and front contact *d* of relay TR140 through the operating coil of relay XR to terminal N is interrupted. The crossing gate mechanism will remain down until the defective filter 132 is repaired.

A variation of the embodiment of FIG. 5 is shown in FIG. 6. In FIG. 6 a condenser 142 is connected across the rails, and in effect replaces filters 132 and 133 shown in FIG. 5. Condenser 142 is selected to have a suitable reactance to both 1000 c.p.s. and 1500 c.p.s. so that sufficient current at both frequencies will flow in those portions of rails 11*a* and 11*b* between the receiver 140 connections 141*a* and 141*b*, and receiver 145 connections 146*a* and 146*b*, to effect pick up of relays TR140 and TR145.

However, in the embodiment of FIG. 6 circuitry is added to check the integrity of the transmitters and receivers as well as the condition of condenser 142. For this purpose a relay FTR having triple windings, and arranged for operation from normal direct current or coded direct current flowing in the rails, is connected to rails 11a and 11b. Relay FTR operates from signal energy due to other track circuits until a train axle shunts the rails 11a and 11b at which time it will release.

When a lockout relay LOR is in a released position, battery will be applied to stick relays ESR and WSR over the following circuits. In a condition when relay LOR and relay TR140 are in a released position, battery will be applied to relay ESR, over a circuit extending from terminal B, through back contact c of relay LOR, back contact c of relay TR140, front contact c of relay 145, back contact a of relay WSR, and through the operating winding of relay ESR of relay ESR to terminal N. In a condition when relay LOR and relay TR145 are in a release position, battery will be applied to relay WSR over a circuit extending from terminal B, back contact b of relay LOR, back contact b of relay TR145, front contact b of relay TR140, back contact a of relay ESR and through the operating winding of relay WSR to terminal N.

When either relay TR140 or TR145 is released, and relay FTR is picked up, indicating a failure in the circuit, relay LOR is picked up over a circuit extending from terminal B through front contact a of relay FTR, and back contacts a of either relay TR140 or TR145, through the operating coil of relay LOR to terminal N. Relay LOR will remain picked up over a stick circuit extending from terminal B, and its own front contact a, through its operating winding to terminal N. Relay LOR being picked up will interrupt the circuit extending from terminal B through back contacts b and c of relay LOR over the energizing circuits for relays ESR and WSR traced above. This will deenergize relays ESR and WSR causing the crossing gate mechanism to remain actuated or down since for example the circuit from terminal B through front contact c of relay ESR, front contact d of relay TR140, and through the operating winding of relay XR to terminal N would be opened. Thus if a failure of any of the transmitting or receiving apparatus occurs when a train is not in the circuit relay LOR will become energized over circuits, previously traced, over front contact a of relay FTR and back contact a of one of the TR relays and permanent lockout will occur.

Failure of condenser 142 may result in one or both relays TR140 and TR145 being released in which case lockout will also occur. If sufficient current still flows in the rails to keep the TR relays picked up in spite of failure of condenser 142, there is in effect no unsafe condition and the circuit will operate normally.

Failure of FTR relay due to opening of its operating coil windings due to lightning or other causes will also be checked. Auxiliary operating coils 147b and 147c are inductively coupled to the main winding 147a of the FTR relay. The load on the main winding 147a is determined by the reactance of capacitor 142. The impedance reflected by winding 147a into the auxiliary windings 147b and 147c connected to receivers 145 and 140 respectively is relatively low when the main winding 147a and condenser 142 are in a normal operating condition. The resultant voltage drop in each receiver input circuit due to the reflected reactance is thus relatively low, and a large portion of the voltage impressed across the track connections will appear across the receiver input circuit. If, however, winding 147a of relay FTR should open, the impedance reflected to auxiliary windings 147b and 147c will become relatively high and a much larger voltage drop will appear across said auxiliary windings. The large impedance developed across windings 147b and 147c will then in effect reduce the voltage impressed across the receiver input circuits sufficiently so that one

or both TR relays will be released. This will cause the crossing gate mechanism to be actuated down and to remain so until the failure is repaired.

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. In combination with electrically continuous first and second track rails, a track circuit comprising, a transmitter of electrical energy operating at a given frequency and connected across said track rails at a first location, a receiver, means coupling inputs of said receiver at spaced points along the length of said first track rail and spaced from said first location, said receiver being tuned to the operating frequency of said transmitter and adapted to be energized by electrical energy at its tuned frequency flowing in said rails, and reactance means connected to said first rail at a location spaced from said length and on the opposite side from said first location and connected to said second rail to provide an electrical path for electrical energy at said operating frequency whereby the shunting action across said rails by a train axle occupying a position intermediate the transmitter and receiver connections actuates said track circuit at definite predetermined points independently of the ballast impedance existing across said rails.

2. In combination with electrically continuous track rails, a pair of transmitters of electrical energy each tuned to a discrete frequency and having an output impedance connected across said track rails, a receiver associated with each of said transmitters, each of said receivers tuned to the frequency of its associated transmitter, means coupling inputs of each of said receivers at spaced points along the length of at least one rail and located between said transmitters, the output impedance of each transmitter being low at the frequency of the other transmitter to provide electrical paths for said electrical energy at the frequency of said transmitters whereby the shunting action across said rails by a train axle actuates said track circuits at definite predetermined points independently of the ballast impedance existing across said rails.

3. A track circuit, for a section of electrically continuous track rails including a controlled area, comprising a first transmitter operating at a first frequency connected across said rails at a point towards one direction from said controlled area, a first receiver tuned to said first frequency, first means coupling the input of said first receiver at spaced points along the length of at least one rail, said first coupling means being positioned towards the opposite direction from said controlled area, a second transmitter operating at a second frequency connected across said rails at a point towards said opposite direction from said controlled area and beyond said first coupling means, a second receiver tuned to said second frequency, means coupling the input of said second receiver at spaced points along the length of at least one rail, said second coupling means being positioned towards said first direction from said controlled area and between said transmitter, each of said transmitters including a filter circuit 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 frequency energy of both transmitters.

4. A track circuit for a section of electrically continuous track rails comprising a pair of transmitters operating at discrete frequencies, each being connected across said track rails, and a receiver associated with each transmitter and tuned to the operating frequency thereof, means coupling inputs of each receiver at spaced points along the length of at least one track rail located be-

tween said transmitter, said transmitters including output filters which are tuned such that the output filter of one transmitter provides a return electrical path for electrical energy at the frequency of the other transmitter.

5. A track circuit for a section of electrically continuous track rails comprising a pair of transmitters operating at discrete frequencies, each being connected across said track rails, and a receiver associated with each transmitter and tuned to the operating frequency thereof, means including a length of wire positioned along at least one of said rails coupling each receiver at spaced points across a length of at least one track rail located between said transmitter, said transmitters including output filters which are tuned such that the output filter of one transmitter provides a return electrical path for electrical energy at the frequency of the other transmitter.

6. In combination with a section of electrically continuous track rails including a controlled area, a first transmitter tuned to a first frequency and connected across said rails to the left of said controlled area, a first receiver associated with said first transmitter and tuned to said first frequency, said receiver having its input terminals coupled at spaced points along the length of the same rail in a direction to the right of said controlled area, a second transmitter tuned to a second frequency and connected to the right of said controlled area beyond said first receiver, a second receiver associated with said second transmitter and tuned to said second frequency, said second receiver having its input terminals coupled at spaced points along the length of the same rail to the left of said controlled area and between said transmitters, the electrical path from said first transmitter to said first receiver overlapping the electrical path from said second transmitter to said second receiver, and reactance means connected across said rails to provide an electrical path for energy at both frequencies, each of said transmitters energizing its respective receiver until a train shunts the electrical path from a transmitter to its associated receiver.

7. In combination with a section of electrically continuous track rails, a track circuit comprising a first transmitter connected from a first rail to a second rail for providing electrical energy at a first frequency to said rails, a first receiver having its input terminals coupled at spaced points along the length of one of said rails, the receiver connections to said rail being at a predetermined distance from the transmitter connections so said rails, said first receiver being tuned so as to be energized only by electrical energy from said first transmitter, a second transmitter connected from said first rail to said second rail for providing electrical energy at a second frequency to said rails, a second receiver having its input terminals coupled at spaced points along the length of one of said rails, said second receiver connections to said rail being at a predetermined distance from said second transmitter connections to said rail, said second receiver being tuned so as to be energized only by electrical energy from said second transmitter, the electrical path along said rails of said first transmitter to said first receiver overlapping a portion of the electrical path along said rails of said second transmitter to said second receiver, and reactance means connected across said rails for providing a low impedance electrical path including said spaced points for the electrical energy of said transmitters, the presence of a train axle at a point in the electrical path from one transmitter to its associated receiver shunting the electrical energy from its associated receiver, said shunt being effective until said train axle is at a point past the connection of said receiver to said rail which is nearest its associated transmitter, said point being determined by the sensitivity of said receiver.

8. In combination with a section of electrically continuous track rails including a signal area controlled by the approach and recession of a train axle from definite points on said track section; a track circuit comprising a first transmitter connected across said rails at a des-

ignated distance in a first direction from said signal area, a first receiver associated with said transmitter and being connected to spaced points along the length of one of said rails at a designated distance in an opposite or second direction from said signal area, a second transmitter connected across said rails at a designated distance in the second direction from said signal area, a second receiver associated with said second transmitter and being connected to spaced points along the length of one of said rails at a designated distance in the first direction from said signal area, said first transmitter and said first receiver being operable at a first frequency, said second transmitter and said second receiver being operable at a second frequency, and an output filter in each of said transmitters being tuned to present a relatively low impedance to energy at the operating frequency of the other transmitter whereby a relatively low impedance path for the electrical energy of one transmitter is provided through the output filter of the other transmitter independently of the ballast impedance across said rails.

9. In combination with a section of the electrically continuous track rails including a control area having signals actuated by the approach and recession of a train axle from definite points on the said track section, a track circuit comprising a first transmitter connected across said rails at a designated distance in a first direction from said control area, said transmitter including an oscillator operating at a first frequency and an output filter tuned to a frequency slightly removed from said first frequency, a first receiver associated with said first transmitter and tuned to said first frequency, said first receiver being coupled to a length of one of said rails at a designated distance in a second direction from said control area, a second transmitter connected across said rails at a designated distance in the second direction of said control area, said second transmitter including an oscillator oscillating at a second frequency and an output filter tuned to a frequency slightly removed from said second frequency, a second receiver associated with said second transmitter and tuned to said second frequency, said second receiver being couple to a length of one of said rails at a designated distance in the first direction from said control area, the output filter in each of said transmitters being tuned to present a relatively low impedance to energy at the operating frequency of the other transmitter to provide a relatively low impedance for the electrical energy of the other transmitter, said difference in frequency between said oscillators and said output filters in each transmitter providing a means of assuring that the load reflected back to the transmitter by the track rail when occupied by a train axle and when unoccupied by a train axle will be at all times sufficiently high to tend to maintain the internal power dissipation of said transmitter constant.

10. A track circuit for a section of track rails intersected by a highway crossing, said track circuit controlling a highway crossing warning system comprising a first transmitter operating at a first frequency connected across said rails at a point towards one direction from the highway crossing, a first receiver tuned to said first frequency having its input terminals coupled at spaced points along the length of one of said rails and towards the opposite direction from said highway crossing, a second transmitter operating at a second frequency connected across said rails at a point towards said opposite direction from said highway crossing, a second receiver tuned to said second frequency connected to spaced points on one of said rails and towards said first direction from said highway crossing, the electrical path from said first transmitter to said first receiver overlapping the electrical path from said second transmitter to said second receiver, and reactance means connected across said rails for providing an electrical path for the energy of both transmitters whereby said highway crossing warning system is actuated

15

by trains approaching to and receding from definite points adjacent said highway crossing.

11. A track circuit for a section of track rails intersected by a highway crossing for controlling a highway crossing warning system comprising a first transmitter operating at a first frequency connected across said rails at a point towards one direction from the highway crossing, a first receiver tuned to said first frequency having its input terminals coupled to spaced points along the length of one of said rails and towards the opposite direction from said highway crossing, a second transmitter operating at a second frequency connected across said rails at a point towards said opposite direction from said highway crossing, a second receiver tuned to said second frequency having its input terminals coupled to spaced points along the length of one of said rails and towards said first direction from said highway crossing, the electrical path from said first transmitter to said first receiver overlapping the electrical path from said second transmitter to said second receiver, a condenser connected across said rails for providing an electrical path for the energy at said first and second frequencies, a track relay associated with each of said receivers and maintained in an energized or picked up position when said receiver is energized, stick relays for assuring that movement of a train in one direction causes said crossing mechanism when once actuated by a train moving in one direction to be unaffected when said train moves from the electrical path of one transmitter and its associated receiver to the electrical path of the other transmitter and its associated receiver, a floater relay for checking the integrity of said track circuit, said floater relay being picked up when electrical energy other than at said first and second frequencies flows through said section of rails, a failure condition of the track circuit being indicated by said floater relay being picked up and at least one of said track relays being released, a lockout relay being energized over the front contacts of said floater relay to pick up to interrupt the electrical path from a source potential to said stick relays when a failure condition exists, and a crossing relay arranged to be deenergized when at least one of said track relays releases, energization of said crossing relay causing the highway crossing mechanism to be actuated when a failure condition exists.

12. A track circuit for a section of track rails intersected by a highway crossing said track circuit controlling a highway crossing warning system comprising a first transmitter operating at a first frequency connected across said rails at a point towards one direction from the highway crossing, a first receiver tuned to said first frequency having its input terminals coupled to spaced points along the length of one of said rails and towards the opposite direction from said highway crossing, a second transmitter operating at a second frequency connected across said rails at a point towards said opposite direction from said highway crossing, a second receiver tuned to said

16

second frequency having its input terminals coupled to spaced points along the length of one of said rails and towards said first direction from said highway crossing, the electrical path from said first transmitter to said first receiver overlapping the electrical path from said second transmitter to said second receiver, a first and second filter means consisting of inductance and capacitance connected across said rails and tuned to provide an electrical path for said first and second frequencies respectively, a track relay associated with each of said receivers, lockout relays associated with each of said track relays, a capacitor associated with each of said lockout relays, bridging relays associated with each of said track relays, said condensers adapted to be charged from a source of potential over the back contacts of one of said bridging relays and the front contacts of one of said lockout relays, failure of one of said filter means interrupting electrical energy at its tuned frequency and causing its associated track relay to release, said capacitor then discharging over a back contact of said track relay and the operating winding of a lockout relay associated therewith to pick up said lockout relay, said bridging relay associated with said track relay then being picked up over a front contact of said lockout relay and the back contact of said track relay, a suitable low impedance being connected across said rails in parallel to said filter means over the front contacts of said bridging relay so that sufficient current will flow through said rails to energize said associated receiver to pick up its track relay causing said bridging relay to release to interrupt the electrical path through said low impedance, and a crossing relay being deenergized when said track relay releases causing said highway crossing mechanism to be actuated due to failure of said filter.

13. In combination with electrically continuous track rails, a track circuit comprising, a transmitter of electrical energy operating at a given frequency and connected across said track rails at a first location, reactance means connected across said rails at a second location to provide a path for said electrical energy at said operating frequency, a receiver, and means responsive to current flow in a length of at least one track rail intermediate said locations coupling to said receiver, said receiver tuned to the operating frequency of said transmitter and adapted to be energized by electrical energy at its tuned frequency flowing in said rails.

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