March 7, 1933. P. N. BOSSART 1,900,412

ELECTRIC TRAIN SIGNALING SYSTEM

Filed Dec. 3, 1931 3 Sheets-Sheet 1

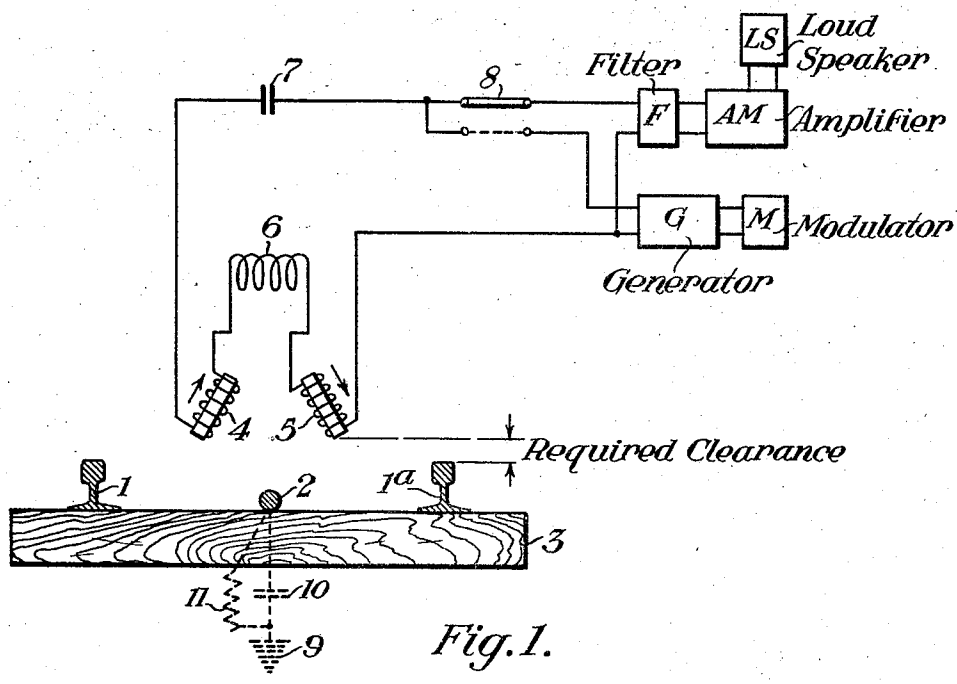


Fig. 1.

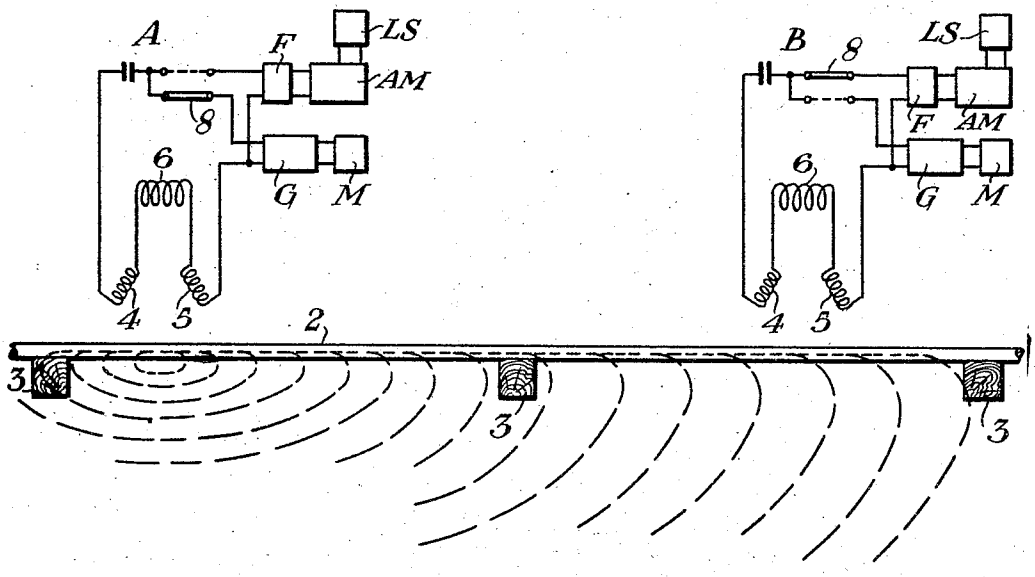


Fig. 2.

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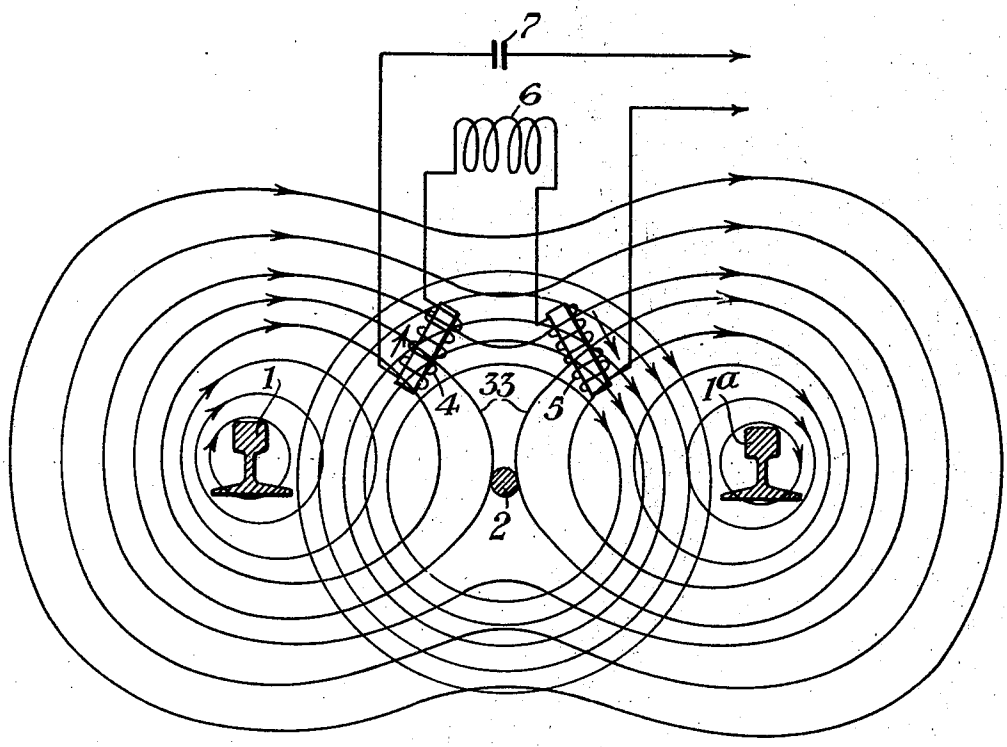


Fig. 3.

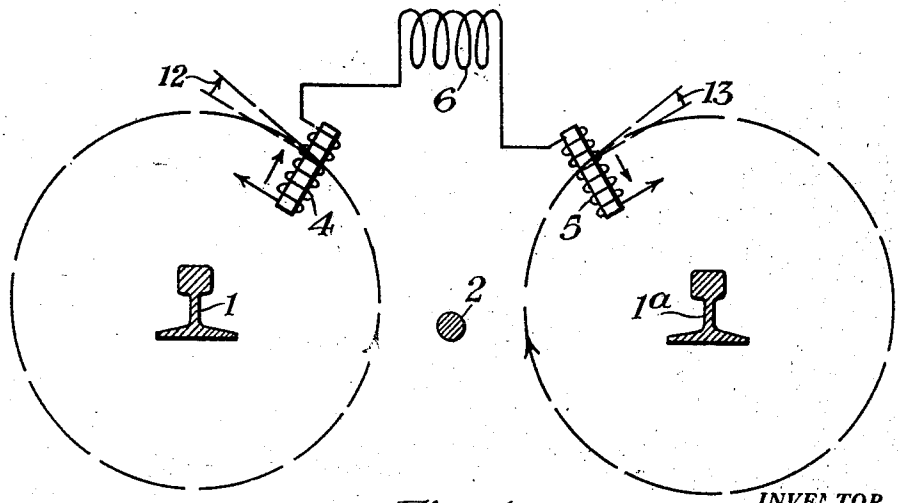


Fig. 4.

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ELECTRIC TRAIN SIGNALING SYSTEM

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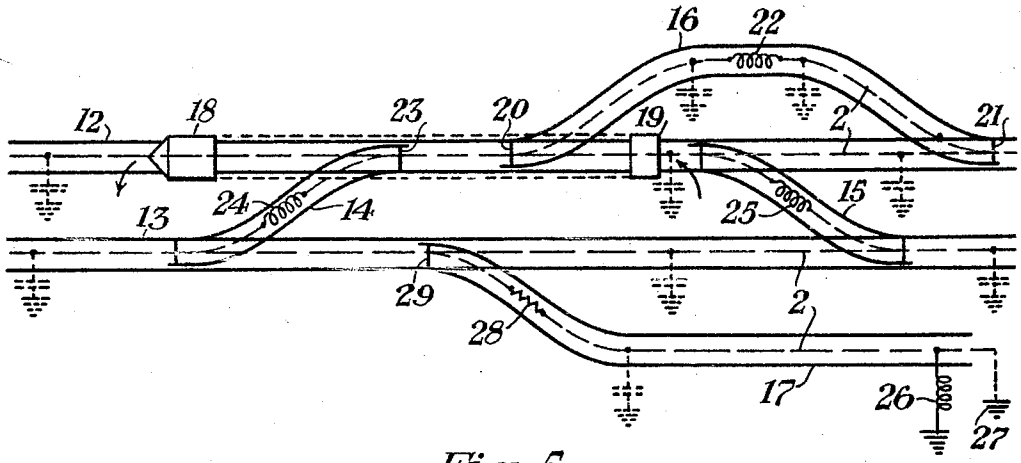


Fig. 5.

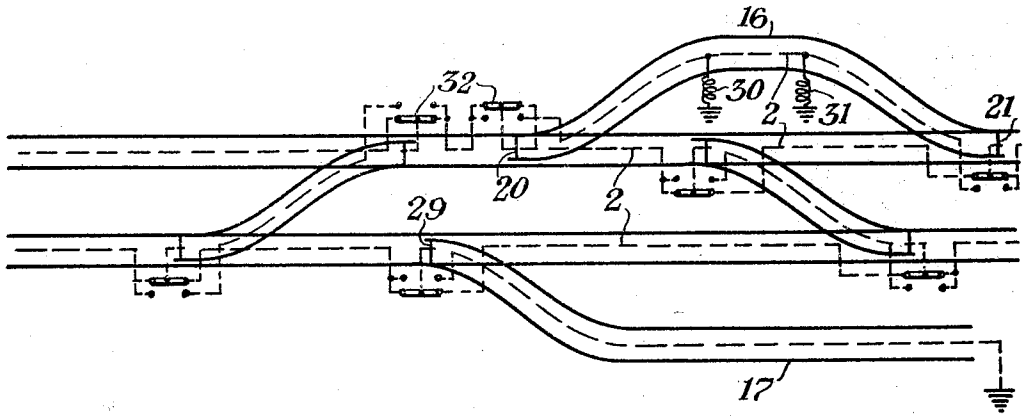


Fig. 6.

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UNITED STATES PATENT OFFICE

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ELECTRIC TRAIN SIGNALING SYSTEM

Application filed December 3, 1931. Serial No. 578,645.

My invention relates to communicating systems for railway trains, and has for an object the provision of means for signaling between spaced points on a train, or between two trains, or between the train and a wayside station, that will be substantially immune from interference due to currents flowing in the traffic rails and to foreign space magnetic fields.

I will described certain forms of apparatus embodying my invention, and will then point out the novel features thereof in claims.

In the accompanying drawing, Figs. 1 and 2 constitute a diagrammatic view of one form of apparatus embodying my invention. Fig. 3 is a magnetic field diagram showing the relationship between the apparatus of my invention and the magnetic fields set up about the traffic rails by current flowing in the same direction in the two rails. Fig. 4 is a diagram showing the effect of a current flowing in opposite directions in the traffic rails as far as the apparatus of my invention is concerned. Fig. 5 is a diagrammatic view showing one method of applying the controlling conductor to a given track layout, while Fig. 6 is a diagrammatic view showing a second method of arranging the controlling conductor to a similar track layout.

Similar reference characters refer to similar parts in each of the several views.

Referring to Figs. 1 and 2 the reference character 2 indicates a conductor fastened to the top of the ties 3 of a railway approximately halfway between the two traffic rails 1 and 1a for the full length of the railway. This conductor 2 should be of sufficiently large size so that it will withstand the mechanical abuse it will be subjected to. It may or may not be insulated, but it does not need to be. Preferably it should have a resistance not greater than its inductive reactance at the frequency of the signaling current to be used, but this condition will in practice always be realized in any conductor having proper mechanical strength; for example, a copper clad steel wire of say one-fourth inch in diameter.

When my invention is to be utilized for communicating between two spaced points on the same train, for example, between the locomotive and the caboose of a freight train, the apparatus as indicated at point A in Fig. 2 will be located on the locomotive and similar apparatus as shown at B will be mounted in the caboose. If communication is to be carried on between two different trains then the apparatus at A will be installed on one train and that of B on the second train. When communication is to be between a wayside station and a train then the apparatus of A will be on the train and that of B at the wayside station. In the latter case, of course, the wayside apparatus must be installed with proper clearance for all rolling stock of the railway. In this case the pick-up coils corresponding to coils 4 and 5 will be beneath instead of over the conductor 2 and greater efficiency can be obtained by positioning them closer to the wire 2 since no clearance below the wire is necessary.

4, 5 and 6 are inductor coils provided at each location and installed in an inductive relation with the conductor 2. The coils 4 and 5 are each preferably but not necessarily provided with a magnetizable core and are mounted with their axes transverse to the trackway at an acute angle with the horizontal plane in such a manner that the axes intersect approximately at the vertical center line of the traffic track. Coil 6 extends transverse to the trackway in a horizontal position but at a considerably greater distance above the conductor 2 than the coils 4 and 5. Coil 6 is necessary only for adjusting against space-uniform fields and is not required to balance out currents in the traffic rails. Under those conditions where practically all the interference comes from the traffic rails, coil 6 may be eliminated. The manner of positioning these coils will be fully discussed later on in the specification. The coils 4, 5 and 6 are connected in series in such a manner that the electromotive forces induced in the coils 4 and 5 by current flowing in the conductor 2 at any given instant will add their effects, while that induced in coil 6 will oppose that of coils 4 and 5. Likewise, when current is supplied to these coils from a local generator to be referred to later the two coils 4 and 5

act together to induce an electromotive force in the conductor 2, while the coil 6 due to its connection in the circuit will oppose the influence of coils 4 and 5. The position of coil 6 with respect to the conductor 2, however, will render its influence small in comparison with that of the coils 4 and 5 as will appear later. These coils 4, 5 and 6 are connected through a tuning condenser 7 to either a receiving circuit or a transmitting circuit as the case may require. With the contact 8 in the position as shown in Fig. 1 the coils are connected to the input side of a filter F through which current is passed to an amplifier AM whose output actuates a loud-speaker LS or other indicating devices. With the contact 8 lowered to its dotted line position the coils 4, 5 and 6 are connected to the output of a generator G of carrier current whose output is preferably modulated in the usual manner by a modulator M. The frequency of generator G may be of any convenient frequency, such as five thousand cycles per second. The frequency of the modulator M should be within the audible range if a loud-speaker is to be utilized as the indicating device and in fact when spoken messages are to be transmitted the modulator M will take the form of a voice transmitter and the modulation will be that of the voice frequencies. The filter F, amplifier AM, loud-speaker LS, generator G and modulator M may take any of many well-known forms for such devices and as their specific form constitutes no part of my invention they are indicated in the drawings diagrammatically only. The contact 8 may be manually operated between its two positions so that an operator can connect the coils 4, 5 and 6 to either the receiving means or to the transmitting means at will, or contact 8 may be automatically operated and the receiving and transmitting means alternately connected to the inductor coils.

The conductor 2 forms one side of a closed circuit which is completed through the ground by virtue of the distributed impedance between conductor 2 and ground and the ground path. This distributed impedance between the conductor 2 and the ground is visualized by dotted lines in Fig. 1 by a capacity 10 to ground 9 and a leak resistance 11. The approximate paths taken by the current are indicated by the broken lines of Fig. 2. The manner whereby current induced in a conductor will flow through the closed circuit formed by the distributed impedance and the ground is fully described and claimed in the L. O. Grondahl application for Letters Patent, Serial No. 450,135, filed May 6, 1930, for electric train signaling system, and it is thought not necessary to repeat the discussion in detail in the present application. It is to be noted, however, that in the above-mentioned application the two traffic rails in parallel act as the metallic conductor whereas in my system the special conductor 2 is employed. In the case where a special conductor such as 2 is employed the shunt capacity 10 is relatively more important than the resistance 11 since the leakage between the conductor 2 and ground will be much less than where the traffic rails are used.

It is apparent, therefore, that with the apparatus at A of Fig. 2 mounted on the locomotive of a train and placed in its transmitting condition, modulated carrier current from its generator G will be induced in the conductor 2 by means of the coils 4, 5 and 6. This induced current will flow in the closed circuit formed by the conductor 2, the distributed impedance between the conductor and ground and the ground path. With the apparatus at B of Fig. 2 placed in its receiving condition the current in conductor 2 will induce an electromotive force in its coils 4, 5 and 6 which when passed through the filter F and amplified by the amplifier AM will actuate the loud-speaker LS. It is understood, of course, that the filter F at B is tuned to pass current at the frequency of the current supplied by the generator G and modulated by M at location A. With the contacts 8 of locations A and B reversed then the apparatus at B will supply current from its generator G modulated by its modulator M to the conductor 2 which will flow in the closed circuit formed by the conductor, the distributed impedance and ground and current will now be induced in the coils 4, 5 and 6 of location A. With the filter F of location A tuned to pass current at the frequency of the generator G and modulated by M at B this current picked up by the inductor coils at A will be amplified by the amplifier AM and made to actuate the loud-speaker LS or other indicating devices. With synchronized operation of the two contacts 8 an alternative exchange of messages can be carried on between the apparatus of locations A and B.

Fig. 5 shows diagrammatically a track layout to which the conductor 2 as shown by dash lines is applied. This layout consists of the main tracks 12 and 13, crossovers 14 and 15, siding 16 and a spur track 17. The distributed shunt capacity between the conductor 2 and ground is visualized in the drawings by showing condensers in dotted lines at several points. Suppose a train with locomotive 18 and a caboose 19 occupies the main track 12 as indicated and that both the locomotive 18 and caboose 19 are equipped with apparatus as shown at A and B of Fig. 2, respectively. During certain instances in the operation of my system the caboose apparatus will induce a current in the conductor 2 which flows in the conductor 2 towards the locomotive 18. At the switch 20 there is a tendency for this current to pass along the conductor 2 for the siding 16 and then back to the conductor 2 for the main track 12 at

the switch 21 at the opposite end of the siding and thereby complete a short circuit loop that might prevent the control current from reaching the locomotive. For this reason an impedance 22 is connected in series with the siding conductor 2 and chosen of such value that the control current at switch 20 is approximately equally divided between the two parallel paths. That is to say at least half of the current will flow along the conductor 2 towards the locomotive 18 from the switch 20. Again at the switch 23 of the crossover 14 an impedance 24 is placed in series with the conductor 2 through the crossover and chosen of such a value that the signal current flowing in the conductor 2 of the main track 12 will divide substantially equally between the path through the crossover 14, conductor 2 of track 13 and the crossover 15 back to the conductor 2 at the caboose 19, and the path leading along the conductor 2 of track 12 to the locomotive 18. Thus by inserting the several impedances in the conductor 2 as shown in Fig. 5 a sufficient current will flow through the normal path to insure reliable operation of the system. The impedances 22, 24 and 25 may be resistances if desired, however, if the signal current is to be modulated at the voice frequencies so that the current in the conductor 2 has a wide range of frequencies it would be better to use inductive reactance since it will then vary in impedance the same as conductor 2. At the end of the spur track 17 there is located an impedance 26 between the conductor 2 and ground of a value equal to that of say about five thousand feet of track. An alternate method for the spur track would be to connect conductor 2 directly to ground at 27 and insert a resistance 28 in series with the conductor 2 at the switch 29 leading from track 13 to the spur 17.

Fig. 6 shows another method of arranging the conductor 2 through this track layout. Here the operation of each switch is made to actuate a common switch circuit controller 32 in the usual manner. Contacts of the switch circuit controller connect the conductor 2 to the route set up for traffic and disconnects it from other routes as will be readily understood by an inspection of Fig. 6. In this arrangement the end of the conductor 2 for the spur track 17 is preferably connected to ground directly since it would not be connected to the main track of conductor 2 unless the switch 29 is set for the spur. In the case it is desired to operate on the siding 16 at a time when both switches 20 and 21 are set for the main track, shunt impedances 30 and 31 should be connected between the conductor 2 for the siding 16 and ground near each switch as shown in Fig. 6. While the arrangement shown in Fig. 5 will have less first cost the arrangement of Fig. 6 results in practically no loss of control current due to possible branches or loop circuits. These two Figs. 5 and 6 will serve to illustrate how the special conductor 2 may be applied to track layouts involving crossovers, siding and spur tracks.

I will now point out how my system is made practically immune to the influence of currents in the traffic rails and to foreign space magnetic fields. As stated above the coils 4 and 5 are to be mounted transverse to the trackway and at an angle to the horizontal plane and just above the required clearance to the track, as shown in Fig. 1. When two equal currents flow in the same direction in two parallel conductors such as the rails 1 and 1^a, the lines of flux follow the so-called Cassinian ovals as sketched about the rails in Fig. 3. It will be noted that at the halfway point between the two rails 1 and 1^a there exist substantially no magnetic flux. The oval lines 33 in Fig. 3 illustrate the boundary between the region where the flux lines surround only one rail and the region where they surround two rails. It will be recalled that the conductor 2 is to be located midway between the rails and thus it is placed at a point where it will have approximately no electromagnetic induction with the rails 1 and 1^a carrying equal parallel currents and hence changes in these two currents will cause no voltage to be induced in the conductor 2. No induced current will therefore flow in the conductor 2 that might influence the coils 4 and 5. It will be further seen from Fig. 3 that the angle at which the coils 4 and 5 are mounted is such that the axis of each winding is substantially at right angles to the average flux created by the parallel currents flowing in the rails 1 and 1^a and hence no voltage will be induced in the coils 4 and 5 directly as a result of the parallel currents in the traffic rails. It will appear from Fig. 3 that the locating of the coils 4 and 5 at a point where no voltage will be induced in them by current flowing in the traffic rails in parallel is not critical as their positions can be readily adjusted both as to their horizontal distance from the center line of the track and as to the angle at which they are mounted.

It follows, therefore, that coils 4 and 5 are positioned to be influenced by magnetic fields created by a current in the conductor 2 as indicated by the circular lines in Fig. 3 and yet are so positioned as to be practically immune from the influence of the magnetic fields created about the traffic rails as the result of equal currents flowing in the same direction in the two rails. At the same time the position of the conductor 2 is such that it lies at a point where it has approximately no electromagnetic induction with the rails 1 and 1^a carrying equal parallel currents and hence changes in these currents will cause no voltage to be induced in the conductor 2

that might in turn influence the coils 4 and 5.

Fig. 4 shows the effect of a current flowing in opposite directions in the two traffic rails, such for example as the usual track circuit current. The dash lines with their arrows show the approximate direction of the flux lines for a given instant. It will be noted that these lines give small upward components as represented by the lines 12 and 13 along the axes of the coils 4 and 5, respectively. No matter at what angle the axes of the coils 4 and 5 may be so long as they are symmetrical with respect to the center line of the track these upward components represent the induction of the flux lines about the rails created by current flowing in opposite directions in the two rails and both will be either upward or both downward at any given instant. But the coils 4 and 5 are connected to add the voltage induced therein by current flowing in the conductor 2. That is to say, coils 4 and 5 are aiding when the flux in one coil is upward and the flux in the other coil is downward at any given instant. It follows that the effect of a current down one rail and back the opposite rail will be cancelled by the opposing of the two equal induced voltages in the coils 4 and 5. It is to be seen, therefore, that the coils 4 and 5 are so connected as to be practically immune from the electromagnetic fields created about the rails by a current flowing down one rail and back the opposite rail.

Any distribution of currents between the two rails may be considered as made up of an equal current in the same direction in each rail and another current down one rail and back the other. In the foregoing discussion it has been shown that my system is balanced for either alone, and hence by the principle of superimposing of linear effects it is balanced for any combination of these currents. For example ten amperes in one rail and six in the other may be considered as a parallel current of eight amperes in each rail and two amperes circulating down one rail and back the other. Again ten amperes in one rail alone can be considered as five amperes in each rail in the same direction and a circulating current of five amperes.

Considering next a changing magnetic field uniform in space, such for example as that which might be created by a transmission line or nearby generator, the axes of coils 4 and 5 will be each perpendicular to the component of the space magnetic field parallel with the track and hence they will have no induction with that component. To the vertical component of any space magnetic field the coils 4 and 5 are symmetrical and will oppose each other due to the fact that they are so connected that they add their effects when the induction of one is upward and that of the other downward at any given instant.

The coils 4 and 5 will have, however, induction with the mutually perpendicular component of the space magnetic field that is transverse to the trackway and the voltage induced in the coils 4 and 5 will be in a direction to add their effects. It is to balance out this component of the space magnetic field transverse to the trackway that the coil 6 is provided. Coil 6 is located symmetrically with respect to the two track rails with its axis transverse to the trackway and is preferably placed in the same vertical plane as the coils 4 and 5. It will be recalled that the coil 6 is so connected in the circuit with the coils 4 and 5 that the voltage induced therein by current flowing in the conductor 2 opposes the induction in coils 4 and 5 and for this reason is located at a considerably greater distance from the conductor 2 than the coils 4 and 5 so that its induction with 2 will be much less than either of the other coils. I prefer to so locate coil 6 that it does not reduce the normal value induced in the coils 4 and 5 by more than say twenty-five per cent which loss I have found can be sustained and yet have reliable operation of the receiving apparatus. On the other hand the transverse component of the space magnetic field will be substantially uniform for all three coils and coil 6 in this instance is in a position to be much more effective than either coils 4 and 5 due to the fact that its axis is parallel to this transverse component. I propose to so proportion the windings of these coils, and the size of their cores, that the induction of coil 6 from this transverse component of the space magnetic field will be substantially equal to the combined induction of the coils 4 and 5 to the same component. By such proportioning of the coils the influence of the transverse component of the space magnetic field is balanced out. To this end coil 6 may be an iron core coil, the same as the coils 4 and 5, of proper section and number of terms to insure a balance. I prefer to employ an air core coil for coil 6 since it may then be built with a much lower factor and hence smaller power loss than an iron core coil. Coil 6 is not needed for sending and it may be switched out of circuit at that time with a resultant increase in the voltage induced in 2

Such a system as here disclosed is substantially immune to effects of any distribution of any currents in the two traffic rails and at the same time immune to the effects of any space-uniform magnetic field.

Although I have herein shown and described only certain forms of apparatus embodying my invention, it is understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. Train signaling apparatus including, three windings mounted on a train disposed in inductive relation with a single trackway conductor characterized by the fact that two of said windings add their inductive effects created by current flowing in said conductor while the third winding opposes, said third winding so positioned and proportioned as to cause but a relatively small cancelling of the induction by current in the conductor while balancing out the induction of said first two windings due to any space-uniform magnetic field.

2. Train signaling apparatus including, three windings mounted on a train disposed in inductive relation with a conductor located midway between the two traffic rails characterized by the fact that two of said windings add their inductive effects created by current flowing in the conductor while the third winding opposes, said two windings so positioned as to be practically immune to any distribution of current in the traffic rails, while said third winding is so positioned and proportioned as to cause but a relatively small cancelling of the induction by current in the conductor while approximately balancing out the induction due to any space magnetic field of foreign origin.

3. Train signaling apparatus including, three windings mounted on a train disposed in an inductive relation with a conductor extending along the trackway characterized by the fact that two of said windings add their inductive effects created by current flowing in the conductor while the third winding opposes, said windings so positioned and proportioned that there will be but a small cancelling by the said third winding of the electromotive forces induced in the windings by current in said conductor but that the electromotive forces induced in the windings by fluxes from sources adjacent the trackway will be substantially balanced out.

4. Train signaling apparatus including, two windings mounted on a train disposed in inductive relation with a conductor located midway between the two traffic rails, said windings connected in series in such a manner that the electromotive forces induced therein by current flowing in the conductor are additive, and said windings so positioned with respect to the traffic rails that they are approximately immune to the fluxes created by any distribution of current in said traffic rails.

5. Train signaling apparatus including, a conductor extending along each track of a railway and mounted on the ties to form with the distributed impedance between said conductor and ground and the ground path a closed circuit for signaling, and means associated with each switch leading from the main track of the railway to prevent a portion of the conductor for the main track from becoming short-circuited by the conductor for the auxiliary track leading from the switch.

6. Train signaling apparatus including, a conductor extending along each track of a railway and mounted on the ties to form with the distributed impedance between said conductor and ground and the ground path a closed circuit for signaling, and an impedance connected in series with the conductor for an auxiliary track leading from a switch of the main track to prevent the short-circuiting of a portion of the conductor for the main track by the conductor for the auxiliary track.

7. Train signaling apparatus including, a conductor extending along each track of a railway to form with the distributed impedance between said conductor and ground and the ground path a closed circuit for signaling, and means operated by each switch of the railway to connect the conductor the way the track is set up for traffic and to disconnect the conductor from other branches of the conductor.

8. A control system for railway trains including, a transmitting circuit and a receiving circuit at each end of the train; a closed trackway circuit comprising a single conductor extending along the trackway, the distributed impedance between said conductor and ground and the ground path; an inductor at each end of the train disposed in inductive relation to said conductor, means at each end of the train to connect the inductor at the same end to either the transmitting circuit or to the receiving circuit at that end of the train, and means for each receiving circuit for amplifying the control signals transmitted from the opposite end of the train.

9. A control system for railway trains including, a transmitting circuit and a receiving circuit at each end of a train; a closed trackway circuit comprising a single conductor extending along the trackway, the distributed impedance between said conductor and ground and the ground path; three windings connected in series at each end of the train disposed in inductive relation with the said conductor and arranged to be substantially immune to the influence of magnetic fields created by currents flowing in the traffic rails and to space magnetic fields created by nearby sources, and means at each end of the train to connect the three windings at the same end of the train to either the transmitting or receiving circuit at that end of the train for communicating signals between the two ends of the train.

10. A control system including, a transmitting device and a receiving device at each of two spaced locations, a closed circuit ex-

tending between said two locations comprising a single conductor, the distributed impedance between said conductor and ground and the ground path; three windings at each location connected in series disposed in inductive relation with the conductor and arranged to be substantially immune to the influence of space magnetic fields created by nearby sources, and means at each location to connect the three windings of a location to either the transmitting device or the receiving device at the same location for communicating signals between the two locations.

11. A control system including, a transmitting device and a receiving device at each of two spaced locations; a closed circuit extending between said two locations comprising a single conductor, the distributed impedance between said conductor and ground and the ground path; three windings at each location disposed in inductive relation with said conductor and arranged that two of said windings add their inductive effects produced by current flowing in said conductor while the third winding opposes, said windings so positioned and proportioned that there is but a small cancelling by the said third winding of the electromotive forces induced in the windings by current in said conductor but the electromotive forces induced in the windings by fluxes from sources adjacent the conductor are substantially balanced out, and means at each location to connect the three windings of a location to either the transmitting device or the receiving device at that location for communicating signals between the two locations.

12. A control system for railways including, a single conductor extending along the trackway and positioned to be substantially immune to the influence of magnetic fields created by currents flowing in the traffic rails, transmitting means for inducing in said conductor a signaling current which flows in both directions in the conductor from the point of induction and returns through the distributed impedance between said conductor and ground and the ground path, and a receiving means responsive to current flowing in said conductor due to said transmitting means for controlling a signaling device.

13. A control system for railways including, a single conductor extending along the trackway and positioned to be substantially immune to the influence of magnetic fields created by currents flowing in the traffic rails, transmitting means for inducing in said conductor a signaling current which flows in both directions in the conductor from the point of induction and returns through the distributed impedance between said conductor and ground and the ground path, and a receiving means including a pair of windings disposed in inductive relation with said conductor and which are so positioned as to be substantially immune to the influence of the magnetic fields created by currents flowing in the traffic rails but responsive to current flowing in said conductor due to said transmitting means for controlling a signaling device.

In testimony whereof I affix my signature.

PAUL N. BOSSART.