

Dec. 15, 1936.

P. N. BOSSART

2,064,641

APPARATUS FOR RAILWAY TRAIN COMMUNICATION SYSTEMS

Original Filed March 17, 1936 3 Sheets-Sheet 1

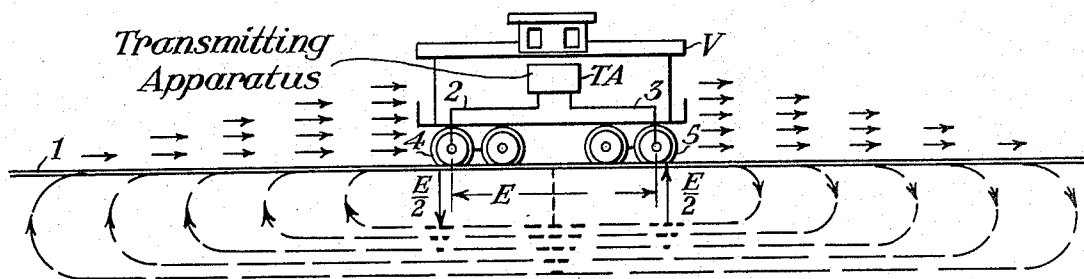


Fig. 1.

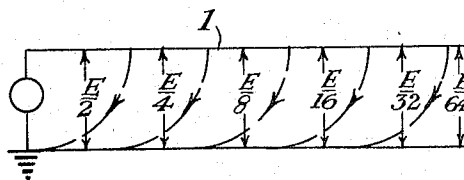
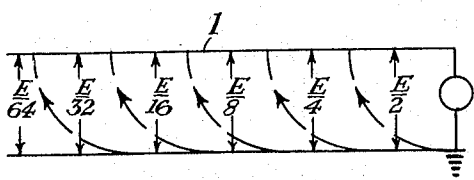


Fig. 1a.

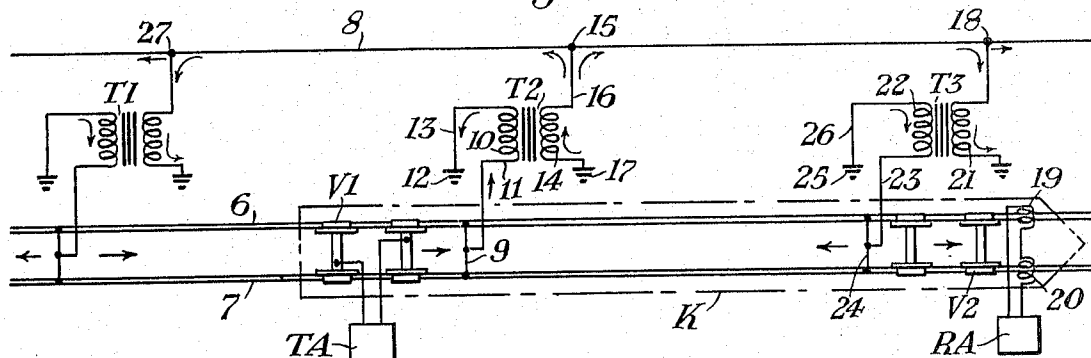


Fig. 2.

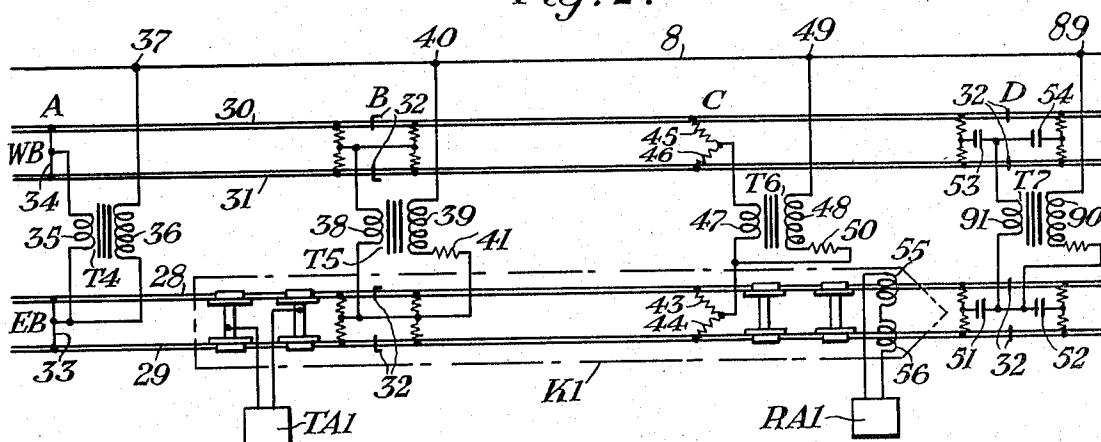


Fig. 3.

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APPARATUS FOR RAILWAY TRAIN COMMUNICATION SYSTEMS

Original Filed March 17, 1936 3 Sheets-Sheet 2

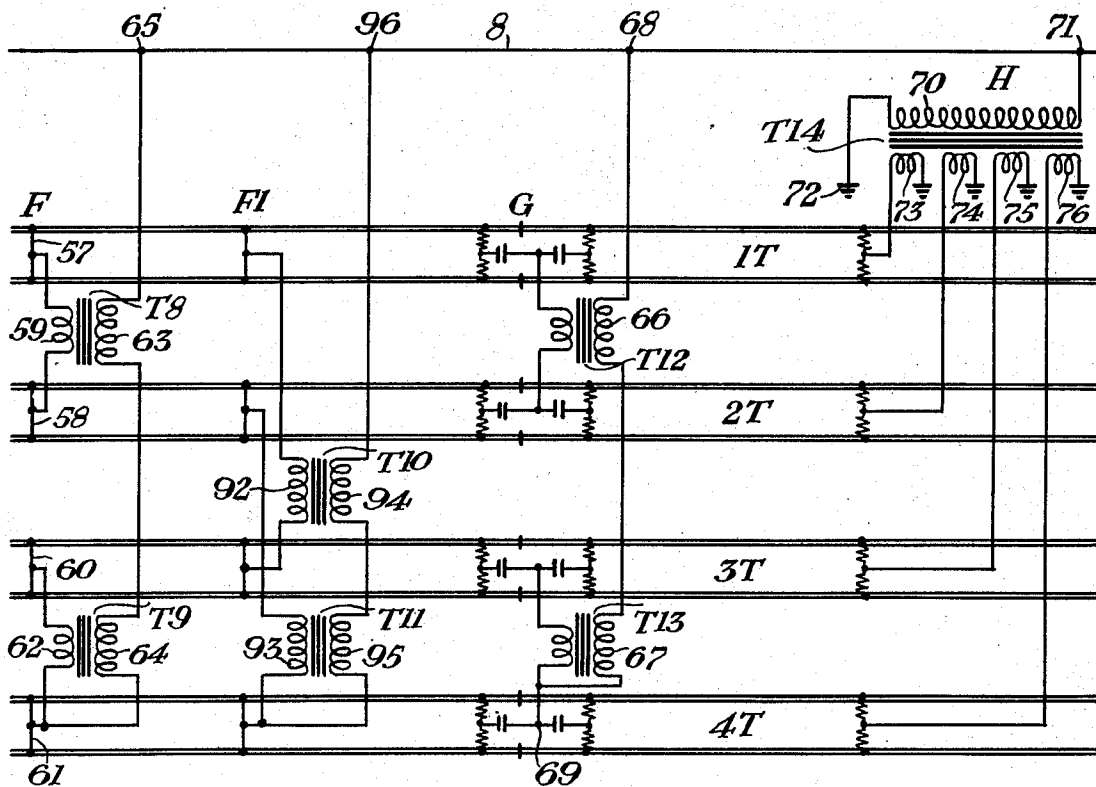


Fig. 4.

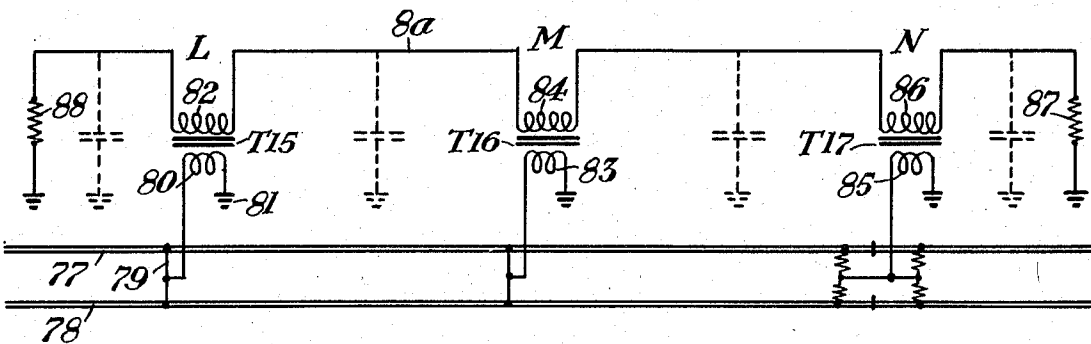


Fig. 5.

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Original Filed March 17, 1936 3 Sheets-Sheet 3

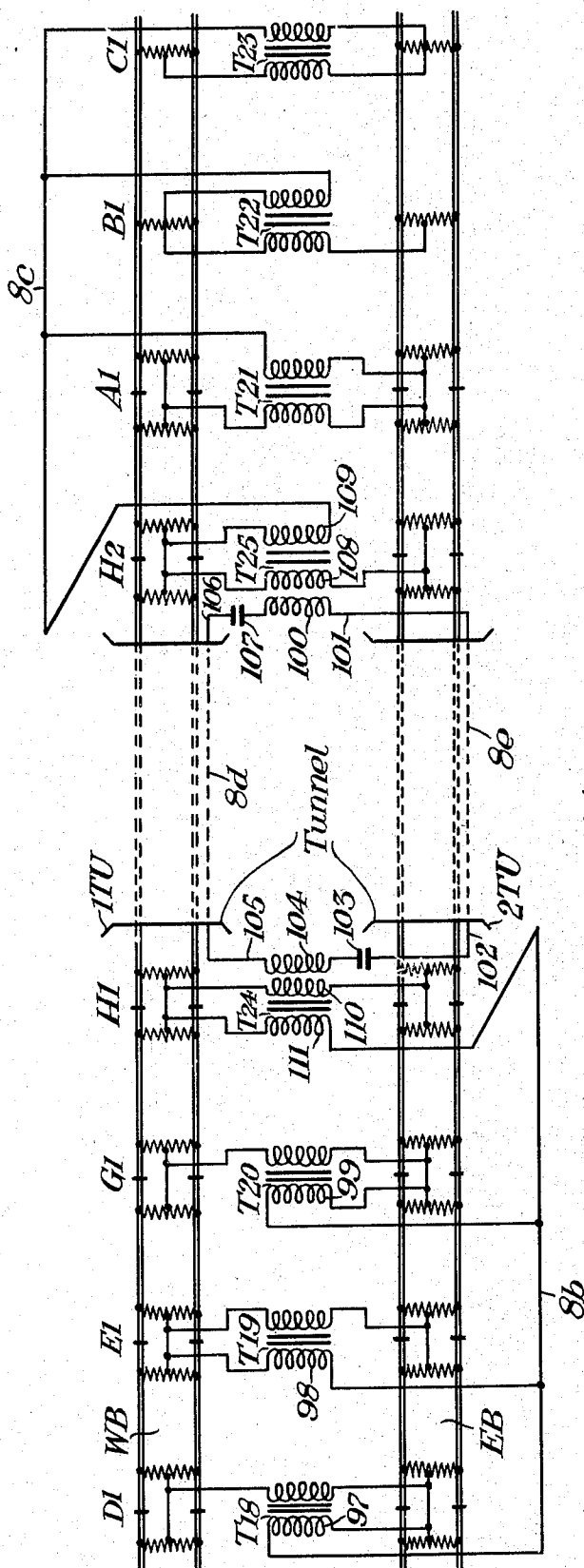


Fig. 6.

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APPARATUS FOR RAILWAY TRAIN COMMUNICATION SYSTEMS

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Application March 17, 1936, Serial No. 69,353
Renewed October 7, 1936

22 Claims. (Cl. 246—8)

My invention relates to apparatus for railway train communication systems, and particularly to apparatus for railway train telephone systems.

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

A feature of my invention is the provision of novel and improved apparatus operative to transmit a communication current along a railway track. A further feature of my invention is the provision of novel and improved apparatus effective to match the characteristic impedance of the track rails and a line conductor for efficient transmission of a communication current along a railway track. Other features and advantages of my invention will appear as the specification progresses.

A train signaling system has been proposed in the United States application for Letters Patent, Serial No. 450,135, filed May 6, 1930, by L. O. Grondahl, for Electric train signaling system, and which system utilizes the track rails in multiple as a communication channel for transmitting current from one location on a train to a remote location, and which latter location may be at another point on the same train or on a different train or at a wayside station. My present invention may be considered as an improvement on this Grondahl system.

In such systems, the signaling current is preferably a modulated carrier current, such as, for example, a carrier telephone current, and furthermore, the current is preferably supplied directly to the rails at the sending location and is picked up from the rails at the receiving location.

To accomplish two-way communication in such systems, each location is provided with equipment which comprises transmitting apparatus and receiving apparatus together with means operative to effectively couple either the transmitting apparatus or the receiving apparatus with the track rails. When the transmitting apparatus at a location is rendered effective, communication current is supplied to the rails and an electromotive force of corresponding frequency is created therein. As a result of such electromotive force, current flows in the rails in multiple in both directions from the point where the electromotive force is created and returns through the ground. When the receiving apparatus of a location is made effective, it receives an electromotive force in response to such communication current flowing in the rails.

In accordance with my invention, transmission of communication current from the point where it is supplied to the rails to a point where it is to be picked up from the rails is accomplished in part through the medium of a line conductor effectively coupled with the track rails at selected points. To put it another way, the communication current supplied to the track rails first flows in a track circuit including the rails in multiple and ground, is then transferred to a line conductor and carried along the line conductor in both directions, and from this line conductor the current is transferred at selected points back to other track circuits each of which includes the rails in multiple and ground, the current thus transferred back to the particular track circuit at the location of the cooperating receiving apparatus being picked up from the rails for influencing such receiving apparatus. By utilizing a line conductor which has relatively low attenuation for such communication current, as the intermediary for transmitting the current between a point in the traffic rails near the sending location to a point in the rails near the receiving location, a relatively small attenuation of the communication current at a distance equal to the length of an ordinary freight train may be obtained even at localities where low ballast resistance and other unfavorable transmitting conditions exist. Furthermore, apparatus and circuits constructed in accordance with my invention are effective to match the characteristic impedance of the track rails with that of the line conductor notwithstanding the large difference in such impedances, and a relatively high transmission is efficiently obtained. I am aware that it has been proposed to transmit carrier communication current along a railway track by applying an electromotive force created across a certain length of track to a loop circuit one side of which is a line wire and the two remaining sides of which are coupling units having direct connection with the rails and the line wire. In contradistinction with such systems, transmission in accordance with my invention is accomplished over two relatively short track circuits and a line conductor, one track circuit being at the transmitting location and the other track circuit being at the receiving location and the line conductor serving as a connecting channel between these two track circuits.

For a better understanding of my invention, reference may be had to the accompanying drawings, in which Figs. 1 and 1a are diagrammatic views illustrating the varying voltage which ex-

ists between the track rails and ground as the result of an electromotive force created in the rails, and also illustrating the flow of current through the rails and ground as the result of such voltage. Fig. 2 is a diagrammatic view of apparatus embodying my invention where only one track is to be equipped. Fig. 3 is a diagrammatic view of preferred apparatus embodying my invention when a double track railway is to be equipped. Fig. 4 is a diagrammatic view of apparatus that may be used for a four-track railway and which apparatus embodies my invention. Fig. 5 is a diagrammatic view of a modified form of apparatus applied to a single track and which apparatus also embodies the invention. Fig. 6 is a diagrammatic view of the apparatus of Fig. 3 applied to a stretch of double-track railway passing through tunnels, or along other points where difficult construction conditions are encountered.

In each of the several views, like reference characters designate similar parts.

In Fig. 1, the reference character V designates a vehicle of a railway train, such as, for example, the caboose of a freight train, and on which vehicle communication equipment including transmitting and receiving apparatus is mounted, but of which equipment only the transmitting apparatus TA is shown. This transmitting apparatus TA may be any one of several types and is shown conventionally only for the sake of simplicity since its specific structure forms no part of my invention. Communication current is supplied from the transmitting apparatus TA to the track rails designated by the reference character 1 by virtue of the output terminals of the transmitting apparatus being connected with the rails over wires 2 and 3, and the truck wheels 4 and 5 at the opposite ends of the vehicle V, the wires 2 and 3 being preferably connected with the wheels 4 and 5, respectively through their journal bearings. It follows that with the transmitting apparatus TA made active, communication current flows in the rails between the wheels 4 and 5 of vehicle V, and a voltage across this length of the rails is created and which voltage I shall designate E. When this voltage is applied to the rails, it may be considered that the average voltage of this length of rails to ground is unchanged but that the point of wheel 5 is during one-half cycle of the current

$$\frac{E}{2}$$

volts above ground potential and the point of wheel 4 is

$$\frac{E}{2}$$

volts below ground potential and during the other half cycle of the current, these voltage conditions are reversed. As a result of this voltage created in the rails between the opposite ends of the vehicle, communication current flows in the rails in each direction from the vehicle and returns through the ground path as illustrated by the broken lines in Fig. 1. It follows that at all points where the current flows through the rails, a voltage between the rails and ground exists, the current diminishing in value as the distance from the vehicle is increased. This diminishing value of the current and hence of the voltage between the rails and ground is illustrated by arrows placed on Fig. 1, and is further illustrated quantitatively in Fig. 1a. It will be apparent that under relatively high ballast resistance the attenuation of the current and of the

voltage between rails and ground will be relatively small, but that under low ballast resistance, the attenuation will be relatively high with the result that at a relatively short distance away from the vehicle little communication current may be detected under the low ballast resistance condition. The manner whereby this voltage thus created between the rails and ground is utilized for transmitting communication current along the railway track over a line conductor having low attenuation of the current will now be described.

Referring first to Fig. 2, the reference characters 6 and 7 designate the track rails of a railway track which is non-signaled, that is, the rails 6 and 7 are not divided by insulated rail joints into track sections such as are customarily provided for way-side signal systems. A conductor 8 extends along the railway track. This conductor 8 may be of any suitable size and material and may be an aerial wire on a pole line some distance away from the track, or it may be in an underground or an aerial cable and which cable may have a grounded metallic sheet. This conductor may extend from one division terminal to the next or along any desired stretch of railway. As a matter of fact, the conductor 8 may be used only on relatively short stretches where low ballast resistance and other unfavorable transmission conditions exist. At selected locations along the conductor 8 are located transformers, three such transformers T1, T2, and T3 being shown in Fig. 2. While only three transformers are shown in Fig. 2, it will be understood that such transformers are spaced at designated locations along the entire length of conductor 8, the desired spacing and locations for these transformers being referred to hereinafter. These transformers T1, T2, and T3 are each effective to couple the track rails 6 and 7 with the line conductor 8, and since the connections of the transformers are all alike except for the alternation of connection polarity mentioned above, it is thought a description of the connections for one transformer will suffice for an understanding of all. Looking at transformer T2, the rails 6 and 7 adjacent this transformer are electrically tied together by a tie wire 9, and one terminal of a winding 10 of transformer T2 is connected with tie wire 9 over wire 11, and the other terminal of winding 10 is connected with a ground electrode 12 over wire 13. One terminal of the other winding 14 of transformer T2 is connected to a junction 15 of the conductor 8 over wire 16, while the other terminal of winding 14 is connected with a ground electrode 17. In other words, the transformer T2 has one winding 10 interposed between the track rails 6 and 7 and ground, and has another winding 14 interposed between the conductor 8 and ground. As stated hereinbefore, the remaining transformers of Fig. 2 are connected in a similar manner except for the alternation of connection polarity mentioned above. The relative polarity of a transformer with respect to that of the transformer at the next location may be changed by interchanging the connections of either winding but not of both windings at the same time. Hence, a voltage between the rails and ground at the point where the tie wire 9 is connected between the rails will cause current to flow from the wire 9 to ground through the winding 10 of transformer T2, the circuit being completed through the ballast resistance of rails 6 and 7 on each side of tie wire 9. This current flowing in the winding 10, when an alternating current,

will induce an electromotive force in the winding 14 and when the current is a carrier communication current as described for Fig. 1, the electromotive force induced in the winding 14 will have a frequency corresponding to the frequency of the current supplied by the vehicle apparatus. The electromotive force induced in winding 14 will in turn cause current to flow in the conductor 8 in both directions from the junction 15 and return through the connections between conductor 8 and ground at the several transformer locations on each side of junction 15, the circuit being completed from these several connections through the ground and the ground electrode 17 connected to the lower terminal of winding 14.

To better describe the apparatus of Fig. 2, I shall assume specific conditions for the track, line conductor and communication current, and to that end I shall consider the ballast resistance of the track including the rails 6 and 7 to be relatively low, say, 3 to 6 ohms per thousand feet of track, that the communication current has a frequency of the order of 8000 cycles per second, and the line conductor 8 to be of a size to provide a desired characteristic impedance to be referred to hereinafter. The characteristic impedance of the track rails in multiple under such conditions of ballast and communication current frequency will be from 3.5 to 5 ohms. Hence if the connection from the tie wire 9 to ground through the winding 10 of transformer T2 presents an impedance of about 5 ohms, substantially one-half of the current caused by the voltage between the rails and ground at the point of the tie wire 9 will flow to ground through the circuit connection including winding 10. As a matter of fact, this circuit connection through winding 10 may be so proportioned that its impedance is less than 5 ohms and something over one-half of the current flows from rail to ground through the connection should it seem desirable to do so, since the current flowing in the rails beyond the point of tie wire 9 performs no useful function in the case of a long train. However, I shall in the following description consider this circuit connection to present an impedance of 5 ohms so that the current divides at tie wire 9, substantially one-half flowing to ground through winding 10 and one-half flowing to ground through the distributed ballast resistance.

The connections between conductor 8 and ground at the locations of transformers T1, T2, and T3 are equivalent to lumped leakage conductances for conductor 8. If two of these transformers are connected per mile, the characteristic impedance of conductor 8 will be about 105 ohms at 8000 cycles per second, the size and location of conductor 8, here assumed an open wire line, affecting this value considerably. The turns ratio and mutual winding impedance are so selected for the transformers T1, T2, and T3 that the characteristic impedance of the track rails of about 5 ohms approximately matches the 105 ohm characteristic impedance of conductor 8. With such proportioning of parts, the winding 14, when an electromotive force is induced therein in response to communication current flowing in winding 10, functions as a current source having 125 ohms impedance and will sufficiently well match a line conductor having a characteristic impedance of 105 ohms in each direction from the junction with the conductor, or about 53 ohms total, and a relatively high efficient transmission of the communication current, about 85% of the theoretical maximum, is effected.

With winding 10 of transformer T2 proportioned to match 5 ohms impedance and the winding 14 proportioned to match 125 ohms impedance, the turns ratio of the transformer should be about 1 to 5. Although specific values have here been recited, it is readily to be seen that this system is very flexible and that any desired relation between track impedance and line impedance may be well matched at the transformer.

K represents a train occupying the track rails 6 and 7 of Fig. 2, and of which train, V1 and V2 represent two spaced vehicles, such as the caboose and locomotive of a freight train, and each of which vehicles is provided with communication equipment capable of sending and receiving communication current. However, only the transmitting apparatus TA of vehicle V1 and the receiving apparatus RA of vehicle V2 are shown conventionally since the specific structure of such equipment, as stated hereinbefore, forms no part of my present invention. The significant thing to be noted is that the transmitting apparatus TA is conductively coupled with the rails through the wheels of vehicle V1 in the manner described for Fig. 1, and the receiving apparatus RA of vehicle V2 is inductively coupled with the rails by virtue of inductor coils 19 and 20 mounted on vehicle V2 in inductive relation with the rails 6 and 7, respectively.

In describing the operation of the apparatus of Fig. 2, I shall assume the transmitting apparatus TA is made active to supply communication current which flows in the length of rails 6 and 7 between the forward and rear wheels of the vehicle V1 with the result that a voltage is created between the rails and ground, such voltage having a frequency equal to that of the communication current supplied by apparatus TA. This voltage between the rails and ground causes current to flow in the rails in both directions from vehicle V1, the current and voltage being as illustrated by Figs. 1 and 1a. Assuming the vehicle V1 to be relatively close to the point where tie wire 9 is connected between rails 6 and 7, a relatively large voltage will exist between the rails and ground adjacent this tie wire and a relatively large current will flow from rails to ground through winding 10 of transformer T2 with the result a corresponding electromotive force will be induced in winding 14 of transformer T2. The energy transferred to winding 10 will be approximately one-half the energy available at tie wire 9 since, as stated above, winding 10 matches the rail impedance and substantially one-half of the current flows to ground through winding 10. If the transformer T2 is assumed to be 100% efficient, this energy transferred to winding 10 will be transferred without loss to winding 14, and in turn will be transferred to line conductor 8, the current flowing in line conductor 8 dividing into two equal parts at the junction 15, one-half of the current flowing in each direction from the junction. At the junction 18 next to the right along conductor 8, the current will again subdivide into approximately equal parts and one-half of the current will flow to ground through winding 21 of transformer T3 and the other half will flow in conductor 8 and to ground at the other connections to the right of junction 18. The current flowing through winding 21 of transformer T3 will induce an electromotive force in winding 22 of that transformer and which electromotive force will in turn set up a current flow in a circuit which

may be traced from the lower terminal of winding 22, wire 23, tie wire 24 connected between rails 6 and 7, the rails in multiple to each side of wire 24, rail to ground resistances, ground, ground electrode 25, and wire 26 to the top terminal of winding 22. Approximately one-half of the current flowing to the tie wire 24 will flow in the rails in each direction from the tie wire. With the vehicle V2 to the right and relatively near to the location of tie wire 24, the current flowing in the rails to the right of that tie wire will induce an electromotive force in the inductors 19 and 20 and thereby effectively influence the receiving apparatus RA. Arrows have been added to Fig. 2 to indicate the flow of currents in these several circuit connections at a particular instant. The arrows shown indicate also the direction of energy transfer, and it is assumed the transformer windings are connected to produce relative polarities such that the currents are as shown. Starting at the location of tie wire 9, the current approximately halves at points 9, 15, 18, and 24. Neglecting track attenuation between vehicle V1 and tie wire 9, and between tie wire 24 and vehicle V2, and assuming 100% efficiency of transformers T2 and T3, and zero ground resistances, substantially one-sixteenth of the current flowing in the rails to the right of vehicle V1 will reappear in the track at vehicle V2 as a result of the energy transferred over line conductor 8. If a factor of two is introduced to take care of transformer efficiencies and ground resistances, then about one thirty-second of the current supplied to the track at vehicle V1 will flow in the rails at the vehicle V2, assuming, of course, the vehicles are close to the respective tie wires. In the case the vehicles are spaced the distance of two connections along conductor 8, say from junction 27 to junction 18, another factor of two will be introduced so that about one sixty-fourth of the current sent out from one vehicle will reach the point of the other vehicle, since there will be one additional point where the current divides.

The limiting factor in determining the spacing of the transformers along conductor 8 will be the attenuation of the current in the track between the vehicles and the tie wires. I have found that with a preferred form of communication equipment attenuation of 20,000 to 1 may be permitted. If the attenuation through the line conductor, as explained above, is 64 to 1, then attenuation of 300 to 1 in the track between the vehicles and the tie wires may be permitted. A communication current of 8000 cycles flowing in the track rails halves about every 275 feet at localities where the ballast resistance is only three ohms per thousand feet of track. Assuming such attenuation for the track rails, an attenuation of 300 to 1 occurs in about 2300 feet of track, and, consequently, under conditions here assumed for illustration, the transformers T1, T2, and T3 should be spaced about 2300 feet apart. Practically two transformer locations to a mile probably would be satisfactory. In the case of a freight train of 100 cars, approximately one mile in length, reliable transmission of communication current between the two ends of a train by apparatus constructed as shown in Fig. 2, will be accomplished even at localities where the ballast resistance is not greater than three ohms per thousand feet of track, whereas an attenuation of the order of 600,000 to 1 would result by transmission through the rails and ground alone under such ballast conditions. It should be noted that that portion

of the communication current flowing in the rails to the right of tie wire 9, will, due to the high attenuation, be negligible at the tie wire 24, and thus current transmitted between these two locations through the rails would not appreciably affect the current transmitted between these two locations over the conductor 8 in the manner explained above.

Fig. 3 discloses how the system may be applied to a double track railway. The reference characters 28 and 29 designate the track rails of an eastbound track EB, and 30 and 31 designate the track rails of a westbound track WB. At the right-hand side of Fig. 3, these track rails are divided by insulated rail joints 32 to form insulated track sections such as commonly employed for wayside signal systems but at the left-hand side of Fig. 3, the track rails are non-sigaled. A line conductor 8 is provided in Fig. 3 the same as in Fig. 2. When two tracks are available, the rails of each track may be used as the ground electrode for the apparatus associated with the other track and at each location a single transformer may be made effective to transfer energy between the rails of either track and the line conductor 8. A railway track having a 3 ohm ballast resistance has a resistance between rail and ground of only about 2 ohms. Hence, the rails of an adjoining track represents a better ground electrode than is practical to get by means of the usual ground rods or plates. At location A of Fig. 3, the two rails 28 and 29 of track EB are tied together by tie wire 33, and the two rails 30 and 31 of track WB are tied together by tie wire 34. The winding 35 of a transformer T4 has its two opposite terminals connected with these two tie wires 33 and 34, respectively, while the other winding 36 of transformer T4 has its two opposite terminals connected between a junction 37 of line conductor 8 and tie wire 33. It is to be seen that the winding 35 of transformer T4 is interposed between the rails of track EB and a ground electrode which electrode is the rails of the track WB, and on the other hand, the winding 35 is interposed between the rails of the WB track and a ground electrode which electrode is the rails of the EB track. The winding 36 of transformer T4 is interposed between the line conductor 8 and a ground electrode, which electrode is the rails of the eastbound track EB. The transformer T4 is designed and proportioned to impedance match the track rails and the line conductor in the manner similar to that described for Fig. 2, and it is thought that it need not be again repeated. It is clear that communication current supplied to the rails of the westbound track WB near the location of tie wire 34 will create a voltage between the rails and ground at tie wire 34 and current will flow to ground through winding 35 and the rails 28 and 29 serving as a ground electrode, the value of the current in winding 35 being proportional to the voltage existing between rails 30 and 31 and ground. Such current will induce an electromotive force in winding 36 of transformer T4 and consequently current will flow in conductor 8 in both directions from junction 37, and thence to ground through the rails 28 and 29 at the transformer locations on each side of junction 37, such, for example, as transformer location B where a winding 39 of a transformer T5 is interposed between a junction 40 of conductor 8, and the rails of the eastbound track. The current thus caused to flow in winding 39 of transformer T5 will induce an electromotive force in winding 38 of that transformer and which electromotive

force will, in turn, cause current to flow in the rails 30 and 31 adjacent the location B where it will be available for influencing train carried receiving apparatus. In a similar manner communication current supplied to the rails of the eastbound track EB near the tie wire 33 will create a voltage between these rails and ground which will cause current to flow to ground through winding 35 of transformer T4 and the rails 30 and 31 serving as a ground electrode. Again, an electromotive force will be induced in the winding 36 which will set up a current flow in the conductor 8 in each direction from the junction 37 and current will be transferred from the line conductor 8 back to the rails 28 and 29 at locations on each side of location A. At location B, the transformer T5 is connected with the rails of the two tracks EB and WB and with the line conductor 8 in a manner similar to the connection of transformer T4 at location A except for the fact a balance circuit network is provided for bridging around the insulated rail joints 32 at location B. This network is of the usual construction and is proportioned and adjusted to effectively block the flow of track circuit current for the wayside signal system as well as to serve the dual purpose of permitting communication current to flow around the insulated joints and for furnishing neutral points in the rail to ground connections for winding 38 of transformer T5, and in the ground connection for winding 39 of that transformer. A small resistor 41 may be interposed between winding 39 and the rail connection to assure ample resistance in shunt to a possible broken rail, so the detection furnished by the wayside signal system is not adversely affected.

At location C, a transformer T6 is provided for transferring communication current between the rails of the two tracks and the conductor 8. The connections for transformer T6 are those that might be employed in wayside signaling territory, but where the connections to the rails are not made at insulated rail joints. At this location C, the two rails 28 and 29 of track EB and the two rails 30 and 31 of track WB are in each case tied together through two resistors, resistors 43 and 44 being connected between rails 28 and 29 and resistors 45 and 46 being connected between rails 30 and 31. The winding 47 of transformer T6 is connected between the mid point of resistors 43 and 44, and the mid point of resistors 45 and 46, while winding 48 of transformer T6 is connected between a junction 49 of conductor 8 and the mid point of resistors 43 and 44. A small resistor 50 may also be interposed in this latter connection.

At location D, the connections for transformer T7 are the same as the connections for transformer T5 at location B except for the fact that condensers 51 and 52 are interposed in the jumper between the mid points of the resistors tying the rails 28 and 29 together on the opposite sides of the insulated rail joints, and condensers 53 and 54 are interposed in the jumper between the mid points of the resistors tying the rails 30 and 31 together on the opposite side of the insulated rail joints of track WB. It is clear that with proper proportioning of parts, the transformers T5, T6, and T7 will effectively transfer communication current between the rails of either track EB or WB and the conductor 8 in the same manner as described for transformer T4. The spacing of the transformers of Fig. 3 and the transformer windings would be selected to match

the track impedance with the line impedance in the manner described for Fig. 2.

K1 represents a train occupying the track EB, the front end of the train being near the location D, and the rear end of the train being near the location B. Receiving apparatus RA1 is shown diagrammatically on the front vehicle of the train and transmitting apparatus TA1 is shown diagrammatically on the rear vehicle of the train, the receiving apparatus RA1 including two inductors 56 and 55 mounted in inductive relation with the track rails, and the transmitting apparatus TA1 being conductively coupled with the track rails by virtue of the output terminals of the transmitting apparatus being connected with the rails through the truck wheels at the opposite end of the vehicle in a manner similar to that described for the apparatus of vehicle V of Fig. 1. Current supplied by the apparatus TA1 will flow in the rails 28 and 29 between the truck wheels at the opposite end of the vehicle and a voltage between the rails and ground will be created thereby. This voltage will cause current to flow in the rails in the manner explained for Fig. 1. At location B, a portion of this current will flow from the rails 28 and 29 to ground through the winding 38 of transformer T5 and the track rails 30 and 31 acting as a ground electrode. An electromotive force will be induced in the winding 39 of transformer T5 in response to the current flowing in winding 38 and this electromotive force will in turn set up a current flow in conductor 8 which current divides at junction 40, substantially one-half flowing in each direction from that junction. The current appearing at junction 40 of conductor 8 will divide and part flow to ground through winding 90 of transformer T7. The electromotive force induced in winding 91 of transformer T7 in response to current flowing in winding 90 will in turn create a current flow in the rails 28 and 29 in both directions from the location D, and the receiving apparatus RA1 will be effectively energized by that portion of the current flowing in the rails to the left of location D. In other words, current supplied to the track rails at the rear end of the train K1 is transferred to line conductor 8 at location B which is near the rear end of the train and is transferred back from the line conductor to the track rails at selected locations, the location D which is near the head end of the train receiving a portion of the current. It is to be noted that that portion of the current which flows in the rails to the right of location B, that is, that portion which does not pass to ground through winding 38, will be attenuated at a relatively high rate due to the low ballast resistance and the current which appears at locations C and D through the rail and ground circuit alone will be negligible in value compared to the current transferred to these locations over the line conductor. Again, only a small portion of the current passed through winding 38 to the rails 30 and 31 will flow in the metallic loop formed by the rails 30 and 31 in multiple to the right of location B, resistors 45 and 46, winding 47, resistors 43 and 44, and rails 28 and 29 in multiple back to location B, since the impedance of the rails is high for current of a frequency of 8000 cycles per second, whereas, the ballast impedance is relatively low for such current.

If the receiving apparatus RA1 on the train K1 were at some point halfway between transformer locations so that it was receiving about an equal amount of energy from each transformer

location, it might happen that the phases of the currents received would be such as to oppose each other. This effect can be minimized by alternating the polarity of adjacent transformers as mentioned hereinbefore. I have found this neutralization of certain frequencies at certain times does exist, but that this neutralization does not interfere in receiving a telephone current which includes the voice band of frequencies, since the wave length of the track is different for different frequencies. It should be pointed out that this neutralization can occur for a given single frequency only at one point between transformer locations, and it is necessary that the phases be in exact opposition at the particular point and, if the train is in motion, this condition would exist for a very short time only.

Fig. 4 discloses four different arrangements that may be used for applying the invention to a four-track railway, the tracks being designated by the reference characters 1T, 2T, 3T, and 4T. The line conductor 8 of Fig. 4 extends along the railway the same as in previous cases. At location F, the connections are what may be used in nonsignal territory and are similar to location A of Fig. 3, being in effect two pairs of two tracks each. The rails of tracks 1T and 2T are tied together by tie wires 57 and 58, respectively, and the opposite terminals of winding 59 of transformer T8 are connected with these two tie wires. Hence, the rails of track 1T serve as a ground electrode for communicating current supplied to the rails of track 2T and vice versa. In like manner, the rails of tracks 3T and 4T are tied together by tie wires 60 and 61, respectively, and the winding 62 of transformer T9 is connected between these two tie wires with the result that the rails of track 3T serve as a ground electrode for current supplied to the rails of track 4T and vice versa. The other winding 63 of transformer T8 and the other winding 64 of the transformer T9 are serially connected between a junction 65 of line conductor 8 and the tie wire 61 of track 4T, and hence the rails of track 4T serve as a ground electrode for this line connection.

At location F', the connections are similar to those at location F except that tracks 1T and 3T form one pair and the tracks 2T and 4T form a second pair. That is, the winding 92 of transformer T10 is interposed between the rails of track 1T and the rails of track 3T, and the winding 93 of transformer T11 is interposed between the rails of track 2T and the rails of track 4T, the windings 94 and 95 of the two transformers being serially connected between a junction 96 of line conductor 8 and the rails of track 4T. This line connection may be to any track other than track 4T, but it should be so chosen that the line current flowing to ground at the point will be in phase with the current to ground from the other winding connected at this same point. Also, the advantage of the arrangement at location F' is that current flowing from conductor 8 to ground creates current in tracks 1T and 2T that are in phase with each other and the inductive effects on an inductor on a train on either track 1T or 2T will add, and likewise for tracks 3T and 4T.

At location G of Fig. 4, the connections are substantially double those of location D of Fig. 3 except for the fact that winding 66 of transformer T12 associated with tracks 1T and 2T and the winding 67 of transformer T13 associated with tracks 3T and 4T are serially connected between a junction 68 of the line conductor and a

neutral point 69 of the network bridging the insulated rail joints of track 4T.

Another possibility is shown at location H of Fig. 4. A transformer T14 is provided with one winding 70 connected between the junction 71 of line conductor 8 and a ground electrode 72, and is also provided with four other separate windings 73, 74, 75, and 76 each of which is connected to the rails of a particular one of the tracks and ground as will be readily understood by an inspection of Fig. 4. It is clear that transformer connections in each of the four cases of Fig. 4 may be so proportioned as to effectively impedance match the track rails with the line conductor. In view of the foregoing, it is clear that the apparatus of Fig. 4 will be effective to transfer communication current supplied to any one of the tracks to the line conductor and to then transfer this current back from the line conductor to the track rails of the same track at selected points.

It will be possible to use a line conductor not connected to ground at any point except at the terminals by connecting one winding of each of the spaced transformers in series with the conductor. In Fig. 5, the reference characters 77 and 78 designate the track rails of a railway along which a line conductor 8a extends. At location L, the rails 77 and 78 are tied together by tie wire 79 and winding 80 of a transformer T15 is connected between tie wire 79 and ground electrode 81. The other winding 82 of transformer T15 is serially interposed in the line conductor 8a. At location M, a transformer T16 is provided with connections for its two windings 83 and 84 similar to those just described for transformer T15. At location N, connections for an insulated rail joint location are disclosed. Here the winding 85 of a transformer T17 is connected between a ground electrode and the neutral point of the network spanning the insulated rail joints while the other winding 86 of the transformer is serially interposed in the line conductor 8a. In this form of the apparatus, the opposite ends of conductor 8a may be grounded through resistors 87 and 88, respectively. Although only three locations are disclosed in Fig. 5, it will be understood that similar locations would be provided at selected points along the entire length of track equipped. It is clear that voltage created between track rails 77 and 78 and ground at tie wire 79 will cause current to flow to ground through winding 80 of transformer T15 and will induce an electromotive force in the winding 82 of that transformer. This electromotive force will cause current to flow in the line conductor in each direction from location L and return through the ground path. A portion of the energy will be transferred back to the rails at each of the transformer locations on each side of location L and which energy will be available for effectively influencing train carried receiving apparatus in the same manner as described for previous cases. Such an arrangement as disclosed in Fig. 5 would be useful for communicating from one end of a division of a railway to a train throughout the division or over a relatively long stretch of track.

Fig. 6 discloses a specific adaptation of the invention to a double track railway at a locality where unusual construction conditions are encountered. In Fig. 6, the two tracks WB and EB of a railway pass through the single track tunnels 1TU and 2TU, respectively, the two tunnels being substantially parallel to each other and relatively long. The provision of a line conductor

for conveying communication current along the track through such tunnels is very desirable because high attenuation of communication current along the track rails occurs due to the wet ballast conditions. Transformer locations within such tunnels for coupling the rails to a line conductor are undesirable and expensive due to the construction conditions. One method which may be used for coupling the rails to a line conductor through tunnels will now be described. Four transformer locations are provided at each side of the tunnels of Fig. 6, locations D1, E1, G1, and H1 being to the west or left-hand side of the tunnels, and locations H2, A1, B1, and C1 being at the east or right-hand side of the tunnels. The two locations H1 and H2 are preferably close to the respective tunnel entrances while the other locations are spaced along the tracks as desired. It will be understood, of course, that the invention is not limited to four transformer locations and the locations of Fig. 6 are for illustration only.

A line conductor 8b extends from location D1 up to the west entrance of the tunnels, and at the east end a line conductor 8c extends from location C1 up to the east entrance of the tunnels. These two conductors 8b and 8c may be similar to the line conductor 8 of Fig. 3.

The transformers T18, T19, and T20 at the locations D1, E1, and G1, respectively, are each connected with the track rails and with the line conductor 8b in the manner explained for the transformer at location B of Fig. 3 and need not be repeated. It is to be noted, however, that in this instance, the line to rail connection for these transformers as well as that for transformer T24 at location H1 are connected with the rails of one track at one location and then with the rails of the other track at the next location. That is, winding 97 of transformer T18 at location D1 is interposed between line conductor 8b and the rails of track EB, winding 98 of transformer T19 at the next location E1 is interposed between conductor 8b and the rails of track WB, winding 99 of transformer T20 at the next location G1 is interposed between conductor 8b and the rails of track EB, and winding 111 of transformer T24 is interposed between the conductor 8b and the rails of track WB.

The connections for the transformers T21, T22, and T23 at locations A1, B1, and C1, respectively, will be readily understood by an inspection of Fig. 6, and need not be further discussed. It is to be noted that locations B1 and C1 are locations in track-circuited territory at points other than insulated rail joint locations.

The transformers T24 and T25 at the tunnel entrance locations H1 and H2, respectively, are similar to the other transformers except that each is provided with three windings, two of the windings in each case being interposed in rail to ground and line to ground connections the same as already described for the other transformers D18, etc. The third winding of each of these transformers is used to couple to a line wire loop circuit to be now described.

A line wire loop circuit for coupling between the line conductors 8b and 8c is provided and which loop circuit includes line conductors 8d and 8e, extending through the tunnels 1TU and 2TU, respectively. These conductors 8d and 8e are here shown as mounted on the south wall of the respective tunnel and are preferably supported on insulators secured to the tunnel walls, the arrangement being such that the conductors 8d and 8e

are about 5 feet above the top of the rails. These conductors 8d and 8e may be of any convenient size and are preferably insulated to avoid leakage as much as possible. It will be understood, of course, that other mounting of the conductors 8d and 8e may be provided if desired. The complete loop circuit is made up of winding 100 of transformer T25, wire 101, line conductor 8e through tunnel 2TU, wire 102, a condenser 103, winding 104 of transformer T24, wire 105, line conductor 8d through tunnel 1TU, wire 106, a condenser 107, and thence to the winding 100 of transformer T25. The winding 100 of transformer T25 is proportioned and adjusted to efficiently transfer energy to this loop circuit from either winding 108 or 109 of transformer T25, or to transfer energy from the loop circuit to windings 108 and 109. Likewise, the winding 104 of transformer T24 is proportioned and adjusted to efficiently transfer energy with the other two windings 110 and 111 of that transformer.

Taking the communication current to be as assumed hereinbefore, a side band of carrier of 8000 cycles per second modulated at voice frequencies, the condensers 103 and 107 tune the loop to the geometric means frequency of the pass band, and then the turns of windings 100 and 104 are so proportioned and adjusted that this loop circuit is impedance matched at the edges of the frequency band of the communication current, and which makes its matching impedance about one-fifth of the line reactance. Such adjustment will give the best quality with the highest transmission efficiency for the given band of frequencies. Two condensers 103 and 107 are preferably used because I have found that with a long wire having fairly high capacitance to ground and possibly of considerable leakage, series tuning is more effective if the condensers are installed at two or more points distant from each other. Such tuning will give a relatively high current level in the loop circuit. It has been proposed for railway train communication systems of the type here being considered to mount the receiving inductors, such, for example, as inductors 55 and 56 of Fig. 3, above the body of the vehicle. In such cases, the line conductors 8d and 8e through the tunnels will be almost as close to the receiving inductors as the rails. Consequently, these line conductors may be effective for direct induction to the train carried inductors. Including these tunnel conductors in a closed loop circuit avoids the necessity of a ground return with its added resistance.

Assuming a train such as train K1 of Fig. 3 occupies the track EB of Fig. 6 with the forward vehicle within the tunnel 2TU and the rear vehicle near, say, location E1, communication current supplied to the rails by the rear vehicle equipment will, through transformer T19, transfer current to the line conductor 8b in the manner described in the former cases. A portion of the current flowing in the line conductor 8b will pass to ground through the winding 111 of transformer T24 and will induce an electromotive force in the winding 104 of that transformer. Such electromotive force induced in winding 104 will set up a current in the loop circuit, and hence will flow in the line conductor 8e through the tunnel 2TU. This current flowing in conductor 8e will be effective to induce an electromotive force in the receiving inductors of the forward vehicle. Current supplied to the rails by the transmitting equipment of the forward vehicle will cause a current to flow in the rails in each direction from such vehicle. Although high attenuation of such

current will occur due to the wet ballast conditions within the tunnel, an electromotive force will be induced in the line conductor 8e due to the induction of the rails to the line conductor and current will flow in the loop circuit. Current flowing in the loop circuit will, through transformer T24 transfer energy to the line conductor 8b, and current flowing in conductor 8b will transfer energy to the rails of track EB at location E1 through transformer T19. Current thus transferred to the rails of track EB at location E1 will be effective to influence the receiving inductors of the rear vehicle of the train. When the train advances to a point where the forward vehicle is near, say, location B1 and the rear vehicle is in the tunnel, communication will be effected between these two vehicles through line conductor 8c and the loop circuit in a manner similar to that described above. Again, assuming the forward vehicle of the train is near the location A1 and the rear vehicle is near location G1 on the opposite side of the tunnel, communication current supplied to the rails at the rear vehicle will be transferred through transformer T20 to line conductor 3b, then to the loop circuit through transformer T24, from the loop circuit to conductor 8c through transformer T25, and from conductor 8c to the rails at location A1 through transformer T21. In a similar manner communication current supplied to the rails at the forward vehicle will be transferred over line conductor 8c, loop circuit, line conductor 8b, and to the rails at location G1 for effectively influencing the receiving apparatus at the rear vehicle. It is clear that the apparatus of Fig. 6 will be effective to transfer communication current for a train occupying the track WB in a manner similar to that described for the train operating on the track EB.

It will be understood that the values indicated in the foregoing description are simply for explaining the system and that they may be widely varied while still retaining the principle of the invention.

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. In combination, a railway track, a train adapted to travel on said track, train-carried means operative to supply communication current to the rails for creating a voltage between the rails and ground, a conductor extending along the track, a plurality of transformers one at each of selected locations along the track, means for each transformer to connect one of its windings between the rails and ground and to connect another one of its windings between the conductor and ground, said transformers operative to transfer energy between the rails and said conductor at one location due to said voltage and to transfer such energy from the conductor back to the rails at other locations, and receiving means effectively influenced by such energy transferred back to the rails.

2. In combination, a railway track, a train adapted to travel on said track, train-carried means operative to supply communication current to the rails for creating a voltage between the rails and ground, a conductor extending along the track, a plurality of transformers one

at each of selected locations along the track, means for each transformer to connect one of its windings between the rails and ground and to connect another one of its windings between the conductor and ground, said transformers operative to transfer energy between the rails and said conductor at one location due to said voltage and to transfer such energy from the conductor back to the rails at other locations, said transformers so designed as to match the characteristic impedance of the track rails with that of said conductor for efficient transmission of the energy, and receiving means effectively influenced by the energy transferred back to the rails at a particular one of said other locations.

3. In combination, a railway track, a train adapted to travel on said track, train-carried means operative to supply communication current to the rails for creating a voltage between the rails and ground, a line conductor extending along the track, a plurality of transformers spaced along the track, a first circuit connection for each transformer to connect one of its windings between the rails and ground, a second circuit connection for each transformer for effectively coupling another winding of the transformer with said conductor, said circuit connections so designed as to match the characteristic impedance of the track rails with that of said conductor whereby said transformers are operative to transfer energy between the rails and the conductor at one location due to said voltage and to transfer such energy from the conductor back to the rails at other locations on each side of said one location, and receiving apparatus effectively influenced by the energy transferred back to the rails at a particular one of said other locations.

4. In combination, a railway track, a train adapted to travel on said track, train-carried means operative to supply communication current to the rails for creating a voltage between the rails and ground, a line conductor extending along the track, a plurality of transformers one at each of selected locations along the track, circuit means at each such location to effectively connect the two rails together, a first circuit connection at each such location to connect one winding of the transformer between the circuit means and ground, a second circuit connection at each location to effectively couple another winding of the transformer with said conductor, said windings of each transformer designed to match the characteristic impedance of the track rails in multiple with that of said conductor whereby energy in the rails due to said voltage is transferred to the conductor at the location adjacent said train-carried means and is transferred from the conductor back to the rails at locations on each side of said adjacent location.

5. In combination, a railway track, a line conductor extending along the track, a transformer located at a selected location along the track, circuit means at said transformer location to effectively connect the two rails together, a first circuit connection to connect a mid point of said circuit means with ground and including one winding of the transformer, a second circuit connection to couple another winding of the transformer with the conductor, said transformer windings designed to match the characteristic impedance of the rails at a given frequency with the characteristic impedance of the line conductor at said given frequency, transmitting apparatus operative to create a voltage of said frequency between the rails and ground for causing

current to flow through said one winding and thereby cause such current to flow in the conductor, and receiving apparatus remote from said transmitting apparatus effectively influenced by the current transferred over said conductor.

6. In combination, a railway track, a line conductor extending along the track, a transformer, means to connect one winding of the transformer between the rails in multiple and ground and to connect another winding of the transformer between said conductor and ground, and said windings designed to match the characteristic impedance of the rails at a given carrier frequency with the characteristic impedance of the line conductor at said frequency.

7. In combination, a railway track, a line conductor extending along the track, a transformer, means to connect one winding of the transformer between the rails in multiple and ground and to connect another winding of the transformer between said conductor and ground, said windings designed to match the characteristic impedance of the rails at a given frequency with the characteristic impedance of said line conductor at said given frequency, transmitting apparatus operative to create a voltage of said frequency between the rails and ground for causing current to flow through said one winding and thereby cause such current to flow in the conductor, and receiving apparatus remote from the transmitting apparatus effectively influenced by the current transferred to the conductor.

8. In combination, a railway track, a line conductor extending along the track, a transformer, a first circuit means to connect the rails in multiple with ground and including one winding of the transformer, said circuit means designed to present an impedance for a carrier current of a given frequency substantially equal to the rail and ballast impedance for such current, a second circuit means to connect the conductor with ground and including another winding of the transformer, said second circuit means designed to present an impedance to said carrier current substantially equal to the characteristic impedance of the line conductor for said current, transmitting apparatus operative to create a voltage of said frequency between the rails and ground for causing current to flow to ground through said first circuit means and thereby transfer current to the line conductor, and receiving apparatus remote from the transmitting apparatus effectively influenced by current transferred to the line conductor through said transformer.

9. In combination, a railway track, a train adapted to travel on said track, a conductor extending along the track, a plurality of transformers one at each of selected locations along the track, means for each transformer to connect one of its windings between the rails and ground and to connect another one of its windings between the conductor and ground, each of said transformers operative to cause a communication current to flow in the conductor in both directions from that location in response to voltage created between the rails and ground at the same location and to cause such current to flow in the rails in both directions from this location when such current flows in the conductor at the location, and train-carried means including transmitting apparatus effective to supply communication current to the rails for creating a voltage between the rails and ground and also including

receiving apparatus effectively influenced by such current flowing in the rails.

10. In combination, a railway track, a train adapted to travel on said track, a conductor extending along the track, a plurality of transformers one at each of selected locations along the track, means for each transformer to connect one of its windings between the rails and ground and to connect another one of its windings between the conductor and ground, each of said transformers operative to cause a communication current to flow in the conductor in both directions from that location in response to voltage created between the rails and ground at the same location and to cause such current to flow in the rails in both directions from this location when such current flows in the conductor at the location, said windings of each of the transformers so proportioned as to match the characteristic impedance of the track rails for the communication current to the characteristic impedance of the line conductor for the current, and train-carried means including transmitting apparatus effective to supply communication current to the rails for creating a voltage between the rails and ground and also including receiving apparatus effectively influenced by such current flowing in the rails.

11. In combination, a railway track, a train adapted to travel on said track, train-carried means including a source of carrier frequency current and having connection with the rails to create a voltage between the rails and ground, a conductor extending along the track, a transformer, a first circuit connected between the rails and ground and including a first winding of the transformer, a second circuit connected between the conductor and ground and including a second winding of the transformer, said first circuit operative to induce an electromotive force in said second winding in response to communications flowing between the rails and ground as the result of said voltage, said second circuit operative to cause communication current to flow in the conductor in both directions from the transformer and return through the ground in response to said electromotive force, and receiving apparatus effectively influenced by such current flowing in the conductor.

12. In combination, a railway track, a train adapted to travel on said track, train-carried means including a source of carrier frequency current and having connections with the rails to create a voltage between the rails and ground, a conductor extending along the track, a transformer, a first circuit between the rails and ground and including a first winding of the transformer, a second circuit connected between the conductor and ground and including a second winding of the transformer, said first circuit operative to induce an electromotive force in said second winding in response to communication current flowing between the rails and ground as the result of said voltage, said second circuit operative to cause communication current to flow in the conductor in both directions from the transformer and return through the ground in response to said electromotive force; said first and second transformer windings designed for said first winding to match the characteristic impedance of the rails for such current, said second winding to match the characteristic impedance of the conductor for such current and said windings having turns ratio for maximum energy transfer; and receiving apparatus effective-

tively influenced by such current flowing in the conductor.

13. In combination, a first and a second railway track, a conductor extending along said tracks, a transformer, means to connect the opposite terminals of one winding of the transformer with the rails of the first and second track respectively, other means to connect the opposite terminals of another winding of the transformer with the conductor and the rails of the second track respectively, said first mentioned means effective to pass current from the rails of either one of the tracks to ground through the rails of the other track in response to voltage created between rails of the one track and ground, and said other means effective to cause current to flow in the conductor in both directions from the transformer and return through the rail to ground resistance of the second track on each side of the transformer in response to current flowing in the first mentioned means.

14. In combination, a first and a second railway track, a conductor extending along said tracks, a plurality of transformers one at each of selected locations along the tracks, a first circuit means at each transformer location to connect a rail of the first track with a rail of the second track and including a first winding of the transformer, a second circuit means at each such location to connect the conductor with a rail of the second track and including a second winding of the transformer, said first circuit means each operative to pass current from either one of the tracks to ground through the rail of the other track when a carrier frequency voltage is created between the rail of the one track and ground or to inductively receive an electromotive force for causing current to flow in the rail of either track when current of such frequency flows in the second circuit means at the same location, and said second circuit means each operative to inductively receive an electromotive force for causing current to flow in the conductor in both directions from the location when current flows in the first circuit means of the same location or to pass current from the conductor to ground when such current flows in the conductor.

15. In combination, a first and a second railway track, a conductor extending along said tracks, a transformer, means to connect the opposite terminals of one winding of the transformer with the rails of the first and second track respectively for passing current from the rails of either track to ground through the rails of the other track in response to voltage created between the rails of a track and ground, and other means to connect another winding of the transformer between said conductor and ground to cause current to flow in the conductor in both directions from the transformer in response to current flowing in said one winding.

16. In combination, a first and a second railway track, a train adapted to travel on the tracks, train-carried means including a source of carrier frequency current and having connections with the rails to create a voltage between the rails and ground, a conductor extending along the tracks, a plurality of transformers one at each of selected locations along the tracks, a first circuit at each transformer location to connect the rails of the first track with the rails of the second track and including a first winding of the transformer, a second circuit means at each such location to connect the conductor

with the rails of the second track and including a second winding of the transformer, whereby energy is transferred from the rails to the conductor at the transformer location adjacent the point where said voltage is created and is transferred from the conductor back to the rails of the same track at locations remote from the sending location, and train-carried means remote from the first mentioned train-carried means effectively influenced by the energy transferred back to the rails.

17. In combination, a railway including a plurality of tracks, a train adapted to travel on said tracks, communication equipment at each of two spaced locations on the train each including transmitting apparatus operative to supply communication current to the rails to create a voltage between the rails and ground and receiving apparatus operative to receive such current in response to communication current flowing in the rails, a conductor extending along the railway, a plurality of transformers one at each of selected locations along the railway, a first circuit means for each transformer location to connect the rails of the tracks together and including a first winding of the transformer, and a second circuit means at each such location to connect the conductor to the rails of at least one of the tracks and including a second winding of the transformer, whereby voltage created between the rails of any one of the tracks and ground will cause current to flow in the conductor from the location adjacent where the voltage is created and will transfer such current back to the rails of the same track at locations remote from said adjacent location.

18. In combination, a four-track railway, a conductor extending along the railway, two transformers, a first circuit means to connect the rails of two of the tracks together and including a winding of one of the transformers, a second circuit means to connect the rails of the other two of the tracks together and including a winding of the other transformer, and a third circuit means to connect the conductor with the rails of at least one of the tracks and serially including another winding of each of the transformers.

19. In combination, a railway comprising four tracks 1T, 2T, 3T, and 4T and arranged with tracks 1T and 4T as the outside tracks; a conductor extending along the railway, two transformers, a first circuit means to connect the rails of tracks 1T and 3T together and including a winding of one of the transformers, a second circuit means to connect the rails of tracks 2T and 4T together and including a winding of the other transformer, and a third circuit means to connect the conductor with the rails of at least one of the tracks and serially including another winding of each of the transformers, and said transformer windings arranged in said circuit connections so that alternating current flowing from the conductor to the rails of said one track creates currents in the rails of tracks 1T and 2T that are in phase and creates currents in the rails of tracks 3T and 4T that are in phase.

20. In combination, a stretch of double-track railway, a first conductor extending along a portion of the railway at one end of the stretch, a second conductor extending along a portion of the railway at the opposite end of the stretch, a loop circuit including a third conductor extending along one track for the intermediate portion between said end portions and a fourth conductor extending along the other track for such inter-

mediate portion of the stretch, a first and a second transformer each having three windings, said first transformer located adjacent said one end portion of the stretch and said second transformer located adjacent said opposite end portion of the stretch, means for each transformer to connect one of its windings between the rails of the two tracks, means for each transformer to connect a second one of its windings between ground and the conductor extending along the associated end portion, and means for each transformer to interpose the third one of its windings in said loop circuit.

21. In combination, a stretch of double-track railway formed into a first, a second and a third portion; a loop circuit including a first line conductor extending along one track of said second portion and a second line conductor extending along the other track of said second portion, a first and a second transformer, means for interposing a winding of each of said transformers in said loop circuit, means for coupling another winding of said first transformer with the rails of both tracks of said first portion, and other means for coupling another winding of said second transformer with the rails of both tracks of said third portion.

22. In combination, a stretch of double track railway formed into a first, a second and a third portion; a loop circuit including a first line conductor extending along one track of said second portion and a second line conductor extending along the other track of said second portion, a third line conductor extending along said first portion, a fourth line conductor extending along said third portion, a first and a second transformer, means for interposing a winding of each of said transformers in said loop circuit, means for interposing another winding of said first transformer between said third conductor and ground, means for interposing another winding of said second transformer between said fourth conductor and ground, means including a first series of transformers for coupling said third conductor with the rails of each track at selected points along said first portion, and other means including a second series of transformers for coupling said fourth conductor with the rails of each track at selected points along said third portion.

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