Oct. 4, 1938. W. H. HOPPE 2,131,735

CONTINUOUS INDUCTIVE TRAIN CONTROL SYSTEM

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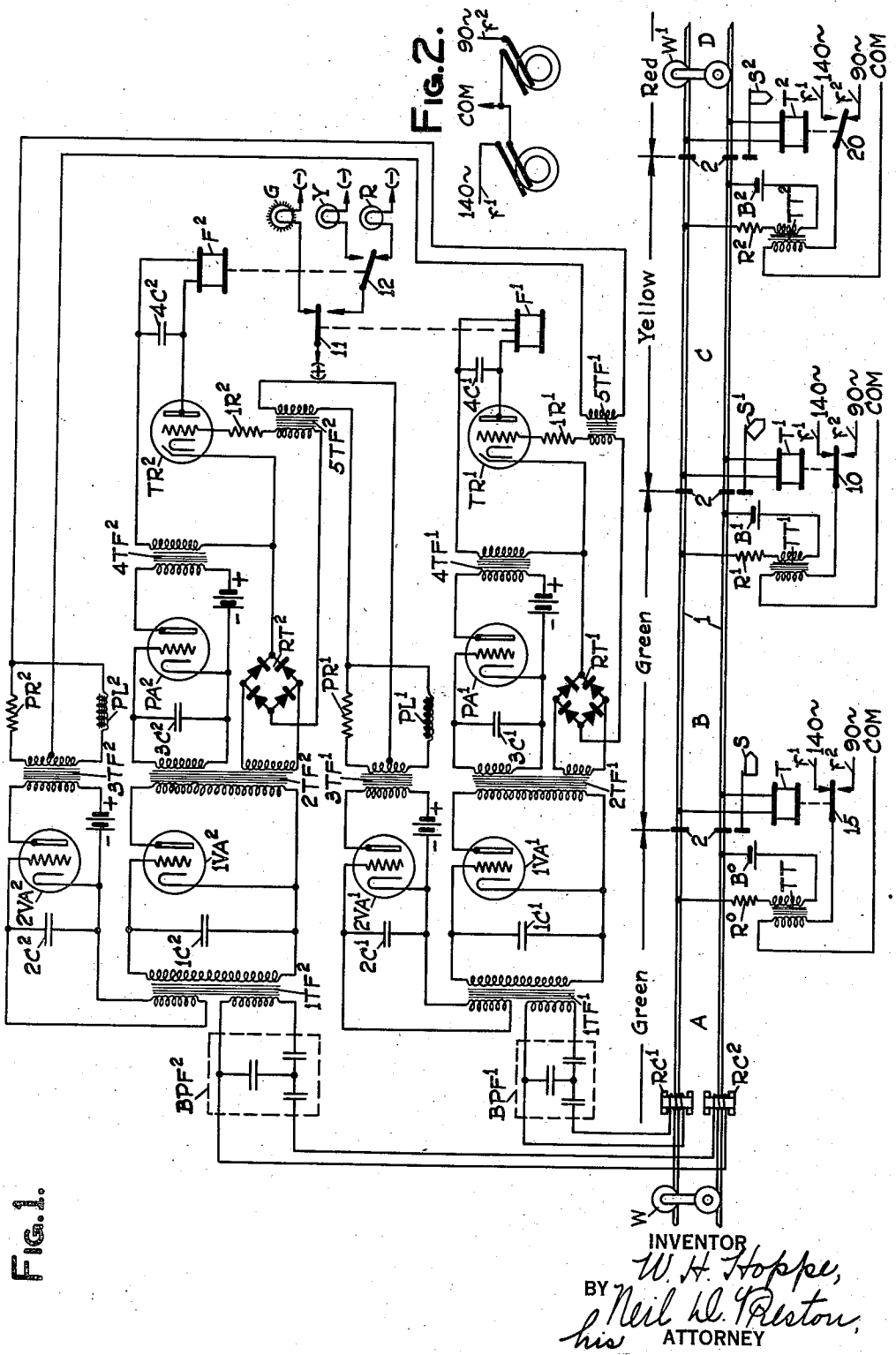


Fig. 2.

Fig. 1.

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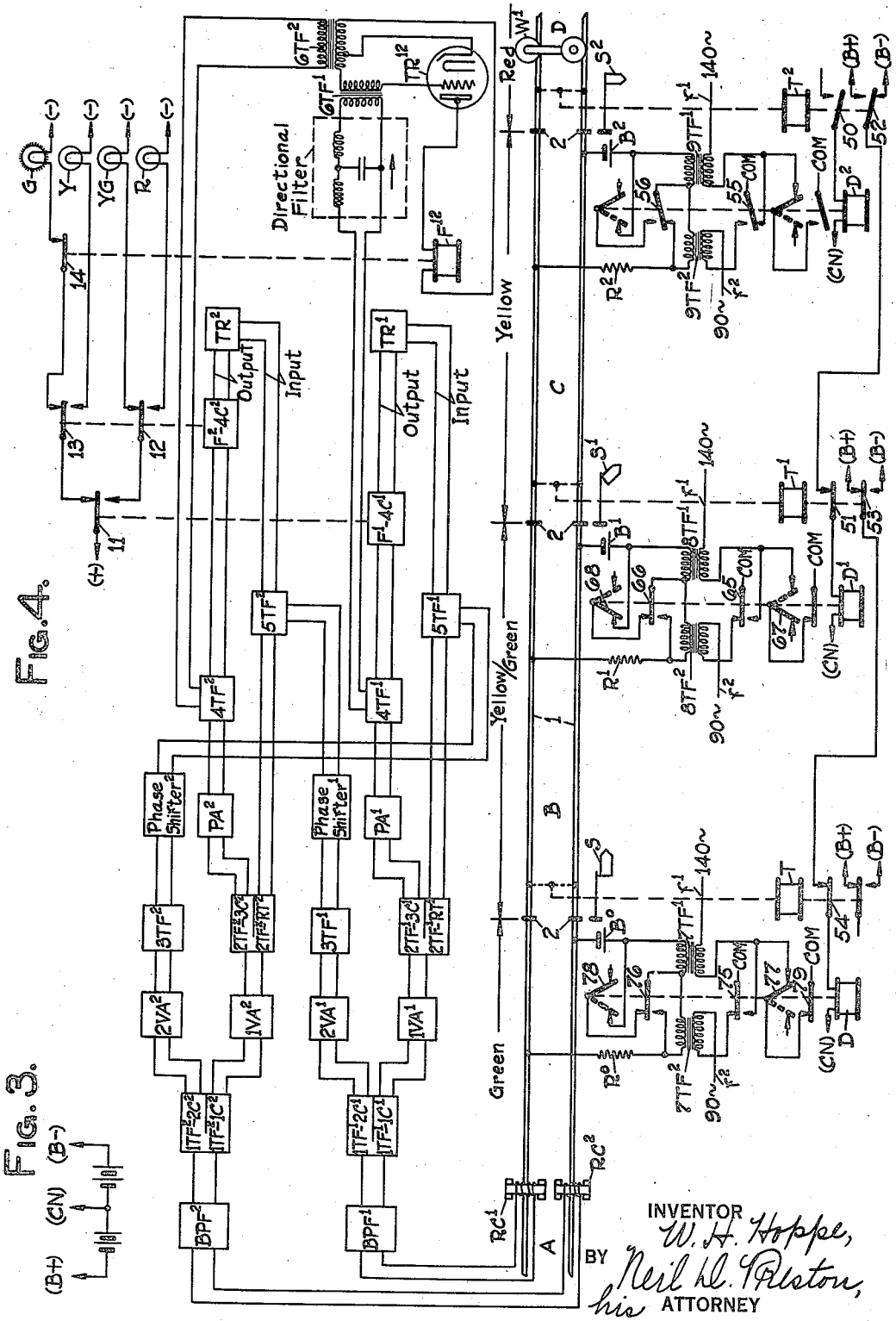


Fig. 4.

Fig. 3.

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2,131,735

CONTINUOUS INDUCTIVE TRAIN CONTROL SYSTEM

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14 Claims. (Cl. 246—63)

This invention relates to automatic train control systems for railroads and it more particularly pertains to systems commonly known as the continuous inductive track circuit type.

The present invention is in the nature of an improvement in the invention disclosed in Bushnell-Reichard application, Ser. No. 112,858, filed November 27, 1936.

Generally speaking and without attempting to define the nature or scope of the invention, it is proposed to provide a three indication, continuous inductive system dependent upon current in both track rails, the track circuit being automatically and continuously checked for occupancy, broken rails, cross connections and the presence of rail current in each rail.

More specifically, the present invention makes use of phase and magnitude controlled gaseous arc discharge vacuum tubes, which are selectively responsive to different frequencies and combinations of frequencies of alternating current applied to the track rails in accordance with traffic conditions, for producing the various indications on a moving vehicle.

One type of phase and magnitude controlled gaseous arc discharge tube employed in the present invention is of such construction that when the anode or plate swings positive and a certain potential is applied to the grid or control electrode, the tube will "fire" and current will flow from the anode to the cathode or filament. As soon as the plate current begins to flow the grid is instantly surrounded by a sheath of positive ions and the grid has no further effect in controlling the plate current. This sheath, usually only a fraction of a millimeter thick, contains the whole voltage drop due to the grid voltage, increasing the grid voltage merely changes the thickness of the sheath and has no effect on the potential of the rest of the space unless the plate current flowing is of very small magnitude and/or unless the grid control energy can be tremendously increased. Practical application, however, excludes the last two possibilities. Therefore the grid loses control over the plate current, when once it is started and plate current flow can only be stopped by removing the plate voltage.

The function of the grid may therefore be likened to a trigger, the amount of power required to start the tube being exceedingly small and when the tube is once "fired" it continues to conduct until plate energy is removed. From the above discussion it will be apparent that an alternating current voltage applied to the plate circuit of such a tube can only be controlled during positive swings of this voltage for effecting plate current flow, with the negative swings being ineffective because the proper polarity is not applied to the plate. A thermionic tube having the characteristics above discussed is disclosed in Langmuir Patent No. 1,289,823. The name "Thyratron" has been applied to tubes of this type and in the following description TR^1 and TR^2 of Fig. 1 will be referred to as "Thyratron" tubes.

Regarding the phase and magnitude control of the "Thyratron tube", when an alternating voltage is applied to the plate circuit, the grid has an opportunity of regaining control once each cycle and can delay the starting of the arc for as long a period during the subsequent positive half cycle as the grid voltage is sufficiently negative. This means that the grid can control the average current flowing through the tube and this averaging can be made as "fine grained" as desired by increasing the frequency of interruption. From the above it will be apparent that current flow in the plate circuit of the "Thyratron" tube depends upon the proper phase relation between the plate circuit voltage and the grid circuit voltage, as well as upon the proper polarity and magnitude of these voltages.

From the above discussion and as later pointed out in detail, it will be observed that absence of current in the track rails, denoting occupancy or broken rails, as well as abnormal circuit conditions due to the presence of current in each rail flowing in the same instantaneous direction, are ineffective to effect the control of the relays in the output circuits of the illustrated "Thyratron" tubes.

One object of the present invention is the provision of a three indication, continuous inductive system of control, whereby trackway conditions will determine the presence of current of one frequency, current of another frequency and the absence of current in the track rails.

Another object of the present invention is the transmission of these frequencies to a moving vehicle in a simple and direct manner and the positive selective operation of indicating devices on the vehicle in response to the reception and non-reception of alternating current of the two frequencies.

Still another object of the present invention is the protection against false reception or operation of the indication mechanism, due to stray currents in the track rails, such as might be caused by interference from nearby power circuits, broadcast stations, lightning and the like.

Various other objects, advantages and characteristic features of the organization of parts and circuits constituting the invention will be in part apparent and in part pointed out as the description progresses.

The accompanying drawings show in a simplified and diagrammatic manner one preferred form and one modification of track apparatus and cooperating car carried equipment for illustrating the features of the present invention.

Fig. 1 illustrates in diagrammatic form one embodiment of trackway apparatus and associated car carried equipment, together with the circuit organization in accordance with the present invention.

Fig. 2 illustrates that the two sources of alternating current f^1 and f^2 have a single common return COM.

Fig. 3 indicates the arrangement of the intermediate tap battery used in Fig. 4, having end terminals (B+) and (B—) and intermediate terminal (CN).

Fig. 4 illustrates in diagrammatic form a modified form of trackway apparatus and associated car carried equipment, together with the circuit organization in accordance with the present invention.

Apparatus

Referring to Fig. 1, the trackway apparatus has been illustrated as applied to a railway track having rails 1 divided by insulating joints 2 into sections A, B, C and D.

Each section is provided with a track circuit comprising the track rails themselves, a circuit including a supply transformer TT (with suitable exponent) connected in series with a track battery B and limiting resistance R (with suitable exponent) at the exit end of the section for supplying direct current and superimposed alternating current to the rails. These band pass filters BPF^1 and BPF^2 allow a band of frequencies embracing both frequencies f^1 and f^2 to flow. The track circuit includes a track relay T (with suitable exponent) at the entrance end of each section.

Although wayside signals are ordinarily located at the entrance to each section and controlled in accordance with traffic conditions, for the sake of simplicity these signals S, S^1 and S^2 are merely indicated, with their control circuits omitted, since their control forms no part of the present invention.

A first source of alternating current (for example, 90 cycles) and a second source of alternating current (for example, 140 cycles) are provided at the entrance of each section and selectively applied to the exit end of the next section to the rear by means of the transformer in accordance with the position of the track relay. For example, frequency f^1 (140 cycles) is applied to the exit end of the next section to the rear when the track relay is picked up and frequency f^2 (90 cycles) is applied to the same section when the track relay is dropped away.

Mounted in advance of the wheels and axles W of the vehicle are receiving coils RC^1 and RC^2, so located that the current flow at any instant through one rail in one direction and back through the other rail in the other direction induces currents in these receiving coils of the same frequency as that flowing in the track rails. Under these normal conditions the separate voltages induced in receivers RC^1 and RC^2 are fed to voltage amplifiers, the voltage of receiver RC^1 being applied to the input circuits of the voltage amplifier comprising vacuum tubes $1VA^1$ and $2VA^1$, by way of band pass filter BPF^1 and transformer $1TF^1$. The voltage induced in the winding of receiver RC^2 is applied to the input circuits of the voltage amplifier comprising vacuum tubes $1VA^2$ and $2VA^2$, by way of band pass filter BPF^2 and transformer $1TF^2$. These band pass filters BPF^1 and BPF^2 allow a band of frequencies embracing both frequencies f^1 and f^2 to flow. Transformers $1TF^1$ and $1TF^2$ have their primaries connected to the output of the associated band pass filters and each transformer has two secondary windings, one tuned to frequency f^1 and the other tuned to frequency f^2, so that frequency f^1 appears in the output circuit of tubes $1VA^1$ and $2VA^2$, while frequency f^2 appears in the output circuits of tubes $1VA^2$ and $2VA^1$.

The secondary windings of transformers $1TF^1$ and $1TF^2$ have such leakage reactance values that condensers $1C^1$, $2C^1$, $1C^2$ and $2C^2$ connected across these windings render them selectively responsive only to the frequencies as above discussed. It will be understood that tubes $1VA^1$, $2VA^1$, $1VA^2$ and $2VA^2$ are of the ordinary voltage amplifier type.

The output circuits of tubes $1VA^1$ and $1VA^2$, which amplify currents of frequency f^1 and frequency f^2, respectively, when currents of these frequencies flow in the track rails, are connected to the input circuits of power amplifier tubes PA^1 and PA^2, respectively, by means of secondary windings of transformers $2TF^1$ and $2TF^2$ connected in the output circuits of the voltage amplifier tubes. These secondary windings are tuned to frequencies f^1 and f^2 by condensers $3C^1$ and $3C^2$, respectively. It will be understood that tubes PA^1 and PA^2 are of the ordinary power amplifier type.

Frequency f^1 appearing in the plate circuit of power amplifier PA^1 is applied to the plate circuit of "Thyratron" TR^1 by means of transformer $4TF^1$ and in this plate circuit is connected relay F^1 tuned to be responsive to frequency f^1 by means of condenser $4C^1$.

Frequency f^2 appearing in the output of power amplifier PA^2 is applied to the plate circuit of "Thyratron" TR^2, being connected in the "Thyratron" plate circuit and tuned to frequency f^2 by condenser $4C^2$.

The input or grid circuit of "Thyratron" TR^1 receives a negative grid bias voltage from current of frequency f^1 by means of the lower secondary winding of transformer $2TF^1$ in series with rectifier unit RT^1. The grid or input circuit of "Thyratron" TR^2 has induced therein a negative grid bias voltage derived from frequency f^2 applied thereto by means of the lower secondary winding of transformer $2TF^2$, with rectifier unit RT^2 connected in this circuit. These rectifiers and circuit connections to the input circuits of the "Thyratron" tubes are for the purpose of applying the proper negative bias to the grids of these tubes when these "Thyratron" tubes are called upon to function.

A phase shifter connected to the secondary winding of transformer $3TF^1$ and comprising inductance PL^1 and resistance PR^1 applies frequency f^2 to the input of "Thyratron" tube TR^2 by means of transformer $5TF^2$. A phase shifter comprising inductance PL^2 and resistance PR^2 connects the secondary winding of transformer $3TF^2$ to the input circuit of "Thyratron" tube TR^1 by means of transformer $5TF^1$, so that frequency f^1 is applied to the input of tube TR^1. Other components may be used, such as resist-

ance and capacity, or inductance and capacity to give frequency selective response. It may be pointed out that in these phase-shifters PR—PL the resistance PR^1 and inductance PL^1 in series, for instance, constitute a lagging low power-factor load derived from the entire secondary winding of transformer $3TF^1$, so that the voltage drop over the resistance PR^1 is a lagging voltage, lagging less than 90 degrees behind the impressed voltage. This voltage itself, (not the voltage drop, the current in this resistance PR^1 flowing against the voltage across this resistance) with respect to the voltage in the secondary winding of this transformer (swinging the vector through an angle of 180 degrees) is however a leading voltage, leading more than 90 degrees the impressed voltage. If this leading voltage is then combined with the voltage in the upper portion of the secondary winding the resultant vector sum is a leading voltage, leading probably less than 90 degrees and to an extent to properly fire the tube.

Indication lamps G, Y and R, assumed to be green, yellow and red respectively, are shown connected to the contacts of relays F^2 and F^1 and it will be understood that the circuits controlled by these two relays may be used for other purposes such as the automatic control of brake valves or the like.

Operation of Fig. 1

The lines indicated green, green, yellow and red appearing above and parallel with the track, indicate the signal which will be displayed by the car-carried apparatus when corresponding sections of track are traversed and a vehicle W^1 is occupying section D.

It will first be assumed that track section D is occupied as illustrated by the presence of wheels W^1 assumed to be associated with a train in this section. The shunt across the rails of this section provided by such a train deenergizes track relay T^2, which energizes the primary winding of transformer TT^2 with alternating current of frequency f^2 over a circuit extending from one side of the current supply of frequency f^2, back contact 20 of relay T^2 and primary winding of transformer TT^2 to COM, which is assumed to be the common terminal of supply currents of frequencies f^2 and f^1, as clearly indicated in Fig. 2.

Track relay T^1, associated with block C remains energized due to the flow of direct current from battery B^2 and frequency f^1 is applied to section B by way of transformer TT^1 and resistor R^1. Transformer TT^1 is energized with frequency f^1 over a circuit extending from one side of this frequency circuit, front contact 10 of relay T^1 and primary winding of transformer TT^1 to COM.

Track relay T remains energized because of direct current in track section B from battery B^1 and frequency f^1 is connected to the primary winding of transformer TT by way of front contact 15 of relay T. Frequency f^1 is applied to section A from the secondary winding of transformer TT and the limiting resistance R^0 in series with battery B^0. It will be understood that frequency f^2 applied to the rails of section C and frequency f^1 applied to the rails of sections B and A have no effect on the direct current track relays.

With the vehicle having receiving coils RC^1 and RC^2 in section A as illustrated, frequency f^1 flowing in series through the rails of this section induces currents of frequency f^1 in the windings of these two receiver coils, from where it is impressed on the primary windings of transformers $1TF^1$ and $1TF^2$ because band pass filters BPF^1 and BPF^2 allow either of the frequencies f^1 and f^2 to pass.

The voltage of frequency f^1 induced in receiving coil RC^1 is amplified by voltage amplifier $1VA^1$, because this frequency is impressed on its input circuit by way of the secondary winding of transformer $1TF^1$, this circuit being tuned to frequency f^1 by condenser $1C^1$. Frequency f^1 is applied to the input circuit of power amplifier PA^1 by means of transformer $2TF^1$, the input circuit of this power amplifier being tuned to frequency f^1 by condenser $3C^1$.

Frequency f^1, amplified by tubes $1VA^1$ and PA^1 is applied to the plate circuit of tube TR^1, having relay F^1 in series therewith, by means of transformer $4TF^1$ and because of the voltage and power amplification of this frequency, a voltage of considerable magnitude of frequency f^1 is applied to the plate of tube TR^1.

Frequency f^1 is induced in receiving coil RC^2 and is amplified by voltage amplifier $2VA^2$ and from the output circuit of this tube the amplified voltage is applied to the input of tube TR^1 by means of transformer $3TF^2$, the upper phase shifter PR^2—PL^2 and transformer $5TF^1$.

Since the "Thyratron" tubes are of the positive control type and since the plate and grid circuits are both controlled from the same source, the proper phase relations must exist between the voltages applied to these circuits to cause the tube to rectify and pass plate current. Obviously if the grid voltage is displaced (leading or lagging) exactly 180 degrees with respect to the plate voltage no firing can take place, because no positive grid control voltage is present through any part of the positive swing of the plate voltage. Since it would be desirable to fire the tube at the early part of a positive swing of the plate voltage the grid voltage is preferably of a phase to lead the plate voltage, to an extent so that it is of an appreciable positive value when the plate voltage enters upon a positive swing. During each positive voltage swing of the upper terminal of the secondary winding of transformer $4TF^1$, with respect to its lower terminal, positive potential is applied to the plate of tube TR^1. The proper magnitude of voltage is applied to the grid circuit of tube TR^1 and the phase of this voltage with respect to that applied to the plate is so determined by the upper phase shifter PR^2—LR^2, to cause this grid voltage to lead between say 10 and 90 degrees the voltage applied to the plate, as above pointed out, whereby the tube is "fired" and plate current flows for operating relay F^1. The relation between the direction of turns in the primary and secondary windings of transformers $1TF^1$, $2TF^1$, $3TF^1$, $4TF^1$, $5TF^1$, $1TF^2$, $2TF^2$, $3TF^2$, $4TF^2$ and $5TF^2$ is preferably such that if current of frequency f^1 is flowing in the track circuit the grids of tubes $1VA^1$, PA^1 and $2VA^2$ will have the voltage applied thereto swing positive at substantially the same time as will also the alternating voltage applied to the plate of tube TR^1, but the voltage applied to the grid of tube TR^1 will, by reason of the inclusion of the phase shifter PR^2—PL^2, have this voltage applied thereto swing positive earlier to an extent of say from 10 to 90 degrees. The same relationship is true of tubes $1VA^2$, PA^2, $2VA^1$ and TR^2 when frequency f^2 is applied to flow in the track circuit. During each negative swing of the voltage on

the plate of tube TR^1, this tube TR^1 fails to conduct, but since the grid regains control once each cycle, the tube conducts during positive half cycles of plate voltage and relay F^1 is maintained in its operated position because the frequency is sufficiently high to prevent its release during negative half-cycles, this effect being augmented by the tuning of relay F^1 by condenser $4C^1$.

Since frequency f^2 is not being received, relay F^2 is not energized. A circuit is closed for lamp G which extends from (+), front contact 11 of relay F^1 and lamp G, to (—).

When the train moves into section B, frequency f^1 continues to be received because front contact 10 of relay T^1 is closed and relay F^1 remains picked up for lighting lamp G.

When the train moves into section C, the received frequency is changed to f^2 because back contact 20 of relay T^2 is closed. Frequency f^2 is amplified by voltage amplifier $1VA^2$ and power amplifier PA^2 and then applied to the plate circuit of tube TR^2, to which relay F^2 is connected. Frequency f^2 is also amplified by voltage amplifier $2VA^1$ and applied to the input of TR^2 by way of the lower phase shifter PR^1—PL^1, all in a similar manner already explained for tube TR^1. Relay F^2 is energized by positive swings of the plate and it remains picked up during negative swings of the plate. In this case frequency f^1 is not received, relay F^1 remains down and a circuit is closed for lamp Y extending from (+), back contact 11 of relay F^1, front contact 12 of relay F^2 and lamp Y, to (—).

When the train moves into occupied section D, neither frequency f^1 nor f^2 is received because of the short circuit ahead of coils RC^1 and RC^2 provided by W^1. In this case, relays F^1 and F^2 both drop and lamp R is lighted over a circuit extending from (+), back contact 11 of relay F^1, back contact 12 of relay F^2 and lamp R, to (—).

From the above description it will be observed that the grid voltage must be in proper phase relation with the plate voltage and of sufficient magnitude to overcome the bias provided by the circuit including the associated rectifier RT, for the "Thyratron" tube to "fire" and the associated relay to operate. Considering frequency f^1, for example, failure of either the proper phase relation or the failure of any one or more of the tubes $1VA^1$, PA^1, $2VA^2$ and TR^1, will cause relay F^1 to release and light lamp R, which is a danger indication.

Considering frequency f^2, failure of either the proper phase relation or the failure of any one or more of the tubes $1VA^2$, PA^2, $2VA^1$ and TR^2, will prevent the operation of relay F^2, so that yellow lamp Y cannot be energized and lamp R will be lighted because frequency f^1 is not being received. It will thus be seen that it requires the reception of the authorized frequency to give the proper signal indication and that the loss of either frequency, when it should be received, gives the red or danger indication.

In the event of a broken rail in the block ahead of a train, the loop circuit including the track rails is open and no current is received for picking up either F^1 or F^2, consequently the red lamp is energized.

Stray currents ordinarily exist in one rail and ground or in both rails and ground, so that they do not flow over the loop circuit for causing response of the receiving apparatus and the resultant operation of an F relay. In other words, the proper frequency must flow up one rail and down the other to operate a signal control relay and this is due to the fact that instantaneous voltages of the proper frequency must appear across the terminals of both coils RC^1 and RC^2 in proper phase to cause the pick up operation of a relay.

Modification

The above description relates to a three indication arrangement, that is, the lighting of lamp G, lamp Y or lamp R in response to the receipt of frequency f^1, f^2 or neither, respectively. It will now be explained how a fourth indication is provided, which indication requires the receipt of both frequencies f^1 and f^2.

The modification illustrated in Fig. 4 has certain portions of the apparatus and circuits illustrated in block diagrams because the apparatus and circuits represented by these block diagrams are the same as illustrated in detail in Fig. 1.

In Fig. 4, for example, the block labeled BPF^1 refers to the same band pass filter illustrated by BFP^1 in Fig. 1. Certain of these block diagrams indicate more than one piece of apparatus, for example $1TF^1$—$2C^1$ indicates that portion of transformer $1TF^1$ of Fig. 1 having its secondary connected to condenser $2C^1$. That portion of the same block indicated $1TF^1$—$1C^1$ refers to the same transformer with the secondary winding which is connected to condenser $1C^1$ of Fig. 1. Furthermore, the blocks labeled F^1—$4C^1$ and F^2—$4C^2$ refer to the corresponding relays and condensers of Fig. 1 and for simplicity the contacts controlled by these relays are so indicated by means of dotted lines associating them with the respective blocks.

The trackway apparatus and circuits are modified to provide the fourth indication and in the following explanation the conditions assumed in connection with Fig. 1 will be considered in connection with Fig. 4, but in reverse order. It will first be explained how the red lamp is lighted when the train carrying receiver coils RC^1 and RC^2 enters block D, with this block occupied as indicated by wheels W^1.

With blocks A, B and C unoccupied and block D occupied, track relay T^2 is deenergized and relays T^1 and T are energized. The circuit to relay D^2 is interrupted at open front contact 50 so that relay D^2 has its neutral contacts in their dropped away positions. Relay D^1 is energized in the proper direction for picking up its neutral contacts and for positioning its polar contacts to the left as shown, over a circuit extending from (CN), winding of relay D^1, front contact 51 of relay T^1 and back contact 52 of relay T^2, to (B—). Relay D is energized in the proper direction for picking up its neutral contacts and for positioning its polar contacts to the right over a circuit extending from (B+), front contact 53 of relay T^1, front contact 54 of relay T and winding of relay D, to (CN).

As indicated by the notations immediately above the track, a train entering block D will receive the red signal indication because no current is received on the car carried apparatus and relays F^1 and F^2 are deenergized, which closes a circuit for lighting lamp R extending from (+), back contact 11 of relay F^1, back contact 12 of relay F^2, and lamp R, to (—).

A train entering block C will receive the yellow indication, this being due to the receipt of frequency f^1 by the car carried apparatus. Frequency f^1 is applied to section C over a circuit

which may be traced from the right hand upper winding of transformer 9TF¹, through battery B² to the lower rail and from the left hand terminal of the upper winding of transformer 9TF², through resistance R² to the upper rail. The secondary of transformer 9TF¹ has frequency f^1 induced therein because of the energization of its primary winding over a circuit extending from one side of the source of frequency f^1, lower winding of transformer 9TF¹ and back contact 55 of relay D² to the other side of the source indicated COM. At this time the secondary winding of transformer 9TF² is short-circuited at back contact 56 of relay D² for the purpose of removing the impedance of this winding from the track circuit, in order that the circuit constants of the track circuit may be of proper value for the most efficient transmission of frequency f^1. It will be observed that frequency f^2 is not applied to the primary winding of transformer 9TF² because of open front contact 55 of relay D².

The circuits associated with the exit ends of blocks A, B, and C are the same and it will now be pointed out how frequency f^2 is applied to section B. The primary winding of transformer 8TF² is energized from the f^2 source of current over an obvious circuit including front contact 65 of relay D¹. The primary winding of transformer 8TF¹ is not energized with frequency f^1 because of open back contact 65 and because contact 67 of relay D¹ is in its left hand position. The secondary winding of transformer 8TF¹ is short-circuited to remove its impedance, by means of a circuit including front contact 66 and contact 68 of relay D¹ in its left hand position. Frequency f^2 is applied to the lower track rail of section B over a circuit which may be traced from the right hand upper terminal of transformer 8TF², front contact 66 of relay D¹, contact 68 of relay D¹ in its left hand position and battery B¹. The other side of this frequency source is connected to the upper track rail over a circuit extending from the left hand upper terminal of transformer 8TF² and resistance R¹.

Both frequencies f^1 and f^2 are applied to the rails of section A under the condition assumed, both secondary windings on transformers 7TF¹ and 7TF² having the short-circuit removed therefrom because of contacts 76 and 78 of relay D being in the positions illustrated. The primary winding of transformer 7TF¹ is energized from one side of the source of frequency f^1, lower winding of transformer 7TF¹, contact 77 of relay D in its right hand position and front contact 79 of relay D, to the other side of the source of frequency f^1, indicated COM.

The lower winding of transformer 7TF² is energized from the source of frequency f^2 over an obvious circuit completed at front contact 75 of relay D. Since neither secondary winding of transformers 7TF¹ nor 7TF² is short-circuited, they are connected in series and to the track rails of block A by means of an obvious circuit.

It has already been pointed out that the red or most restrictive indication is provided by lighting lamp R when neither frequency f^1 nor f^2 is received, thus effecting the dropping of both relays F¹ and F². The next most restrictive indication (yellow) is given when frequency f^1 is transmitted to the car carried apparatus, in which case this frequency is passed through band filters BPF¹ and BPF² by way of transformers and condensers 1TF²—2C² and 1TF¹—1C¹ to voltage amplifiers 2VA² and 1VA¹ respectively. The amplified frequency is transmitted from the outputs of these two voltage amplifiers by way of transformer 3TF² to phase shifter² and by way of transformer condenser combinations 2TF²—3C¹ and power amplifier PA¹ to transformer 4TF¹.

The output of phase shifter² passes frequency f^1 in the proper phase to transformer 5TF¹ and transformer rectifier combination 2TF¹—RT¹ passes frequency f^1 to transformer 5TF¹. Transformer 4TF¹ applies plate or output energy to tube TR¹ by way of relay condenser combination F¹—4C¹ and transformer 5TF¹ applies the grid control energy to the input circuit of tube TR¹, which grid control energy is of proper phase as determined by phase shifter² and the grid is properly biased by means of the rectifier current provided by rectifier RT¹. The above described operation relating to the transmission of frequency f^1 to the car carried apparatus is the same as in the arrangement of Fig. 1. Relay F¹ is therefore picked up and relay F² is dropped away (because frequency f^2 is not being received) and lamp Y is lighted over a circuit extending from (+), front contact 11 of relay F¹, back contact 13 of relay F² and lamp Y, to (—).

A train in section B receives frequency f^2, which is transmitted by an arrangement similar to that described in connection with frequency f^1, for applying proper energy to the output of tube TR² and energy of the proper phase to the input of tube TR² for picking up relay F². Since frequency f^1 is not being received, relay F¹ is down and relay F² is picked up for closing a circuit through back contact 14 and front contact 12 for lighting lamp YG.

In the Fig. 4 arrangement, transformer 4TF¹ has an additional secondary winding leading through the directional filter to the primary winding of transformer 6TF¹. Since the secondary of transformer 6TF¹ is connected to the input circuit of tube TR¹², frequency f^1 is applied to the input circuit of this tube. Furthermore, transformer 4TF² has an additional secondary winding which leads to the primary winding of transformer 6TF². One secondary winding of transformer 6TF² supplies plate energy to tube TR¹², with relay F¹² connected in the plate circuit. Another secondary winding of transformer 6TF² is connected in series with the secondary winding of transformer 6TF¹ and the input circuit of tube TR¹².

The above arrangement of the circuits for tube TR¹² provides a means for picking up relay F¹² by combining plate energy developed at frequency f^2 with grid "firing" voltage developed at frequency f^1. The grid voltage for tube TR¹² is derived by combining frequency f^2, provided by transformer 6TF², 180° out of phase with frequency f^2 (the same frequency) applied to the plate circuit of tube TR¹², with a voltage of frequency f^1 developed by power amplifier PA¹ and supplied to the input circuit of tube TR¹² from the extra winding of transformer 4TF¹ by way of the directional filter. With this arrangement, the component of grid voltage due to frequency f^2 makes tube TR¹² inoperable during intervals when f^2 is received alone. This is because, as above mentioned, the grid and plate voltages supplied to TR¹² from transformer 6TF² are 180° out of phase. Combining this grid voltage with the voltage produced by f^1 (through the directional filter) causes the "firing" of the tube and the picking up of relay F¹². The directional filter is for the purpose of preventing feed back from the circuits containing frequency f^2, to the circuits containing frequency f^1 and

it will be understood that a one way repeater, repeating from left to right, could be used in place of the directional filter.

Since frequency f^1 is received, relay F^1 is picked up, since frequency f^2 is received, relay F^2 is picked up and as above described, relay F^{12} is picked up because of the receipt of both frequencies f^1 and f^2. The circuit is now closed for lighting lamp G which extends from (+), front contact 11 of relay F^1, front contact 13 of relay F^2, front contact 14 of relay F^{12} and lamp G, to (—).

From the above description it will be observed that a double check is provided for the green signal indication, that is, relays F^1, F^2 and F^{12} must all be picked up to light this particular lamp. The system would operate without relay F^{12} by connecting lamp G to front contact 13 of relay F^2, which would require both relays F^1 and F^2 picked up and the receipt of both frequencies f^1 and f^2 to light the green lamp. However, in the present arrangement one or the other of relays F^1 and F^2 could stick in its operated position, with the other one receiving an authorized frequency, without operating the cleared signal, because relay F^{12} would be down and the circuit to lamp G opened at front contact 14.

It is obvious that the invention may be embodied in a variety of other forms without departing from the spirit or essential attributes thereof and therefore I do not desire to be limited to the exact modification shown and described but contemplate all variations thereof that come within the scope of the appended claims.

What I claim is:—

1. A system of continuous inductive control for railway vehicles comprising; in combination with a track circuit including two track rails provided with alternating current of one of a plurality of different frequencies applied across the rails at the exit end of a section of track and flowing in opposite directions in the rails; two receiving coils on the vehicle each inductively associated with a different track rail, vacuum tube detecting and amplifying means on the vehicle for detecting the magnitude and the phase relation of the potentials induced in said receiving coils, and means distinctively responsive to currents delivered by said detecting and amplifying means depending on the particular frequency of said plurality of frequencies flowing in the track rails and the phase relation of the potentials induced in said receiving coils at a particular time.

2. In combination, a railway track, a source of alternating current connected across the two track rails at the exit end thereof, two car carried windings one in inductive relation with one and the other in inductive relation with the other of said two track rails respectively, and train governing mechanism including a phase controlled gaseous arc discharge device having its plate circuit energized in response to current induced in one of said windings and having its grid activated in accordance with current induced in the other of said windings and responsive only to the energization of both windings in response to current flowing through the two track rails in opposite directions.

3. In combination; a car carried receiving apparatus including two receivers for receiving indications in accordance with track conditions; a source of alternating current energy applied across the rails of the track at the exit end of a section so that current flows in opposite directions in the track rails, said apparatus including an electrostatically controlled arc discharge device having its in-put and out-put circuits energized by amplified energy derived respectively from the two receivers one in inductive relation to one track rail and the other in inductive relation to the other track rail; and means for determining the phase relation of the energy applied to said in-put and said out-put circuits so that said device is rendered active only when the alternating currents in the track rails flow in opposite directions.

4. In a train control system for railroads; trackway apparatus for selectively applying alternating currents of one or more of different frequencies to the rails in series so as to flow in opposite directions in the track rails and of a frequency or frequencies in accordance with traffic conditions; two car carried receiving coils one over one rail and the other over the other rail for receiving currents of said frequency or frequencies from the rails; de-coding means on the car controlled by said receiving apparatus and selectively responsive to said different frequencies for delivering currents characterizing varying restrictive traffic conditions, said de-coding means including a plurality of phase controlled vacuum tubes selectively responsive to currents induced in said coils of said different frequency or frequencies only if these currents are in response to currents flowing in opposite directions in said rails; and signals controlled by said de-coding means for causing the display of the most restrictive indication in the absence of currents of any of said frequencies.

5. In a train control system for railroads; trackway apparatus for selectively applying to the rails at the exit end of a section an alternating current of a first frequency; a second frequency or both frequencies concomitantly as determined by traffic conditions so as to cause such current to flow in opposite directions in the track rails; car carried receiving apparatus for receiving currents of said frequencies from the rails including two receiving coils one inductively associated with one track rail and the other inductively associated with the other track rail; de-coding means on the car controlled by current from said receiving apparatus and selectively responsive to current of said first frequency, of said second frequency and of both of said frequencies concomitantly; said de-coding means being selectively responsive to currents of said frequencies singly and combined only when flowing in opposite directions in said track rails; and signals controlled by said de-coding means to display the least restrictive indication when said currents of plurality of frequencies are simultaneously received.

6. In a train control system for railroads; trackway apparatus for selectively applying across the rails at the exit end of a track section an alternating current of a first frequency, a second frequency or both frequencies concomitantly as determined by traffic conditions; car carried receiving apparatus including a coil over each rail for receiving currents of said frequencies from the rails; de-coding means on the car controlled by said receiving apparatus and selectively responsive to current of said first frequency, said second frequency and both of said frequencies concomitantly, said de-coding means including electrostatically controlled detectors and amplifiers which have their electrode circuits individually connected to said coils and are selectively

responsive to currents induced in said coils of said frequencies singly and combined only when flowing in opposite directions in said rails; and signals controlled by said de-coding means for in the absence of currents of both of said frequencies causing the display a most restrictive indication.

7. In a train control system for railroads; trackway apparatus for selectively applying to the rails at the exit end of a section of track alternating current of either or both of two different frequencies as determined by traffic conditions; car carried apparatus including two receivers one in inductive relation with one track rail and the other in inductive relation with the other track rail energized by said alternating currents in said rails; two electronic tubes each having a plate element and a grid element and each having one of its elements activated in response to voltage induced in one of said receivers and having its other elements activated in accordance with voltage induced in the other of said receivers; a first relay and a second relay each controlled by one of said tubes and each responsive if current of a different one of said frequencies flows in said rails; and means controlled by said relays for distinctively displaying danger, caution and clear indications in accordance with whether current of neither frequency, current of one frequency or current of both of said frequencies, respectively, is flowing in the rails of said section.

8. In a train control system for railroads; a plurality of blocks; means associated with each block for selectively impressing across the rails at the exit end alternating current voltages of one of several frequencies determined by the condition of traffic in the next block in advance to cause current to flow in opposite directions in the track rails; a pair of car carried receiving coils disposed in front of the first pair of wheels and axles of the car one in inductive relation with one rail and the other in inductive relation with the other rail; a pair of gaseous arc discharge tubes each having a grid circuit and a plate circuit and each having one of its circuits controlled by one of said coils and having its other circuit controlled by the other of said coils; indication receiving means controlled by said tubes; means including circuit connections between each of said coils and both of said tubes for applying voltages of a predetermined phase relationship to the grid circuits and the plate circuits of said tubes so that currents of a definite phase relation must exist in said coils as obtained only if currents flow in opposite directions in said track rails to energize said indication receiving means.

9. In a system of cab signals or train control for railroads, in combination with a railway track having its rails divided into blocks; means for causing the flow of alternating current in opposite directions in the rails of each block; car-carried apparatus including one receiver over one of said rails and another receiver over another of said rails; an electronic tube on the vehicle having its plate circuit energized externally of the tube in accordance with voltage induced in one of said receivers and having its grid circuit activated in accordance with the voltage induced in the other of said receivers; and indicating means controlled by the out-put circuit of said tube.

10. In a system of cab signals or train control for railroads, in combination with a railway track divided into blocks; a track circuit for each block including a source of direct current connected across the rails at the exit end and a direct current relay connected across the rails at the entrance end of the block, means controlled by the track relay at the entrance end of the block next in advance for causing the flow of alternating current in opposite directions in said rails; car-carried apparatus including a receiver over one rail and another receiver over the other rail; an electronic tube on the vehicle having its plate circuit energized externally of the tube in accordance with voltage induced in one of said receivers and having its grid circuit activated in accordance with the voltage induced in the other of said receivers; and indicating means controlled by the out-put circuit of said tube.

11. In a system of cab signals or train control for railroads, in combination with a railway track divided into blocks; means for causing the flow of alternating currents of two different frequencies in opposite directions in the track rails; car-carried apparatus including a receiver over one rail and a second receiver over the other rail; an electronic tube on the vehicle having its plate circuit energized in accordance with alternating voltage of one frequency induced in one of said receivers and having its grid circuit activated in accordance with alternating voltage of another frequency induced in the other of said receivers; and indicating means controlled by the out-put circuit of said tube.

12. In a system for controlling cab signals or brake control apparatus on a railway vehicle; in combination with a pair of track rails comprising the rails of a track circuit energized from the exit end to produce the flow of alternating current in opposite directions in said track rails; means for applying current of one frequency or current of another frequency to such track circuit depending upon traffic conditions in advance; car-carried apparatus including two receivers one located in inductive relation with one of said track rails and the other located in inductive relation with the other of said track rails; an amplifying means for each receiver for amplifying the voltages induced in said receivers; and two electronic tubes, one of said tubes having its plate circuit potential derived from one of said amplifying means and having its grid circuit activated by potential derived from the other one of said amplifying means, and the other tube having its plate circuit potential supplied from said other of said amplifying means and having its grid circuit activated by said one of said amplifying means; an electro-responsive means included in the out-put circuit of each of said tubes; and car-carried apparatus controlled in accordance with whether one of said electro-responsive means, the other of said electro-responsive means, or both of said electro-responsive means are energized.

13. In a system for controlling cab signals or brake control apparatus on a railway vehicle; in combination with a pair of track rails comprising the rails of a track circuit energized from the exit end to produce the flow of alternating current in opposite directions in the rails; means for applying current of one frequency or the other frequency to such track circuit depending upon traffic conditions in advance; car-carried apparatus including two receivers one located in inductive relation with one and the other located in inductive relation with the other of said track rails; an amplifying means for each receiver for amplifying the voltages induced in said receivers; and two electronic tubes, one of said tubes having its plate circuit potential derived from one of said amplifying means and having its grid circuit

activated by potential derived from the other one of said amplifying means, and the other tube having its plate circuit potential supplied from said other of said amplifying means and having its grid circuit activated by said one of said amplifying means; an electro-responsive means included in the out-put circuit of each of said tubes; and car-carried apparatus controlled in accordance with whether one of said electro-responsive means, the other of said electro-responsive means, or neither of said electro-responsive means are energized, respectively.

14. In a system for controlling cab signals or brake control apparatus on a railway vehicle; in combination with a pair of track rails comprising the rails of a track circuit energized from the exit end to produce the flow of alternating current of either or both of two frequencies in opposite directions in the track rails in accordance with traffic conditions in advance; car-carried apparatus including two receiving coils one located in inductive relation with one track rail and the other located in inductive relation with the other of said track rails; an amplifying means for each receiving coil for amplifying the voltages induced in such coil; three electronic tubes on the car, one of said tubes having its plate circuit energized by alternating potential of one frequency derived from one of said amplifying means and having its grid circuit activated by alternating potential of said one frequency derived from the other one of said amplifying means, the second tube having its plate circuit energized by alternating potential of the other frequency supplied from said other of said amplifying means and having its grid circuit activated by alternating potential of said other frequency derived from said one amplifying means, and the third electronic tube having its plate circuit energized by alternating potential of one frequency derived from one of said amplifying means and having its grid circuit activated by alternating potential of said other frequency derived from said other amplifying means; and vehicle carried apparatus controlled by the out-put circuits of said electronic tubes.

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