Jan. 17, 1956 C. F. STAFFORD 2,731,550

CAB SIGNALLING SYSTEM FOR RAILROADS

Filed June 30, 1950 6 Sheets-Sheet 1

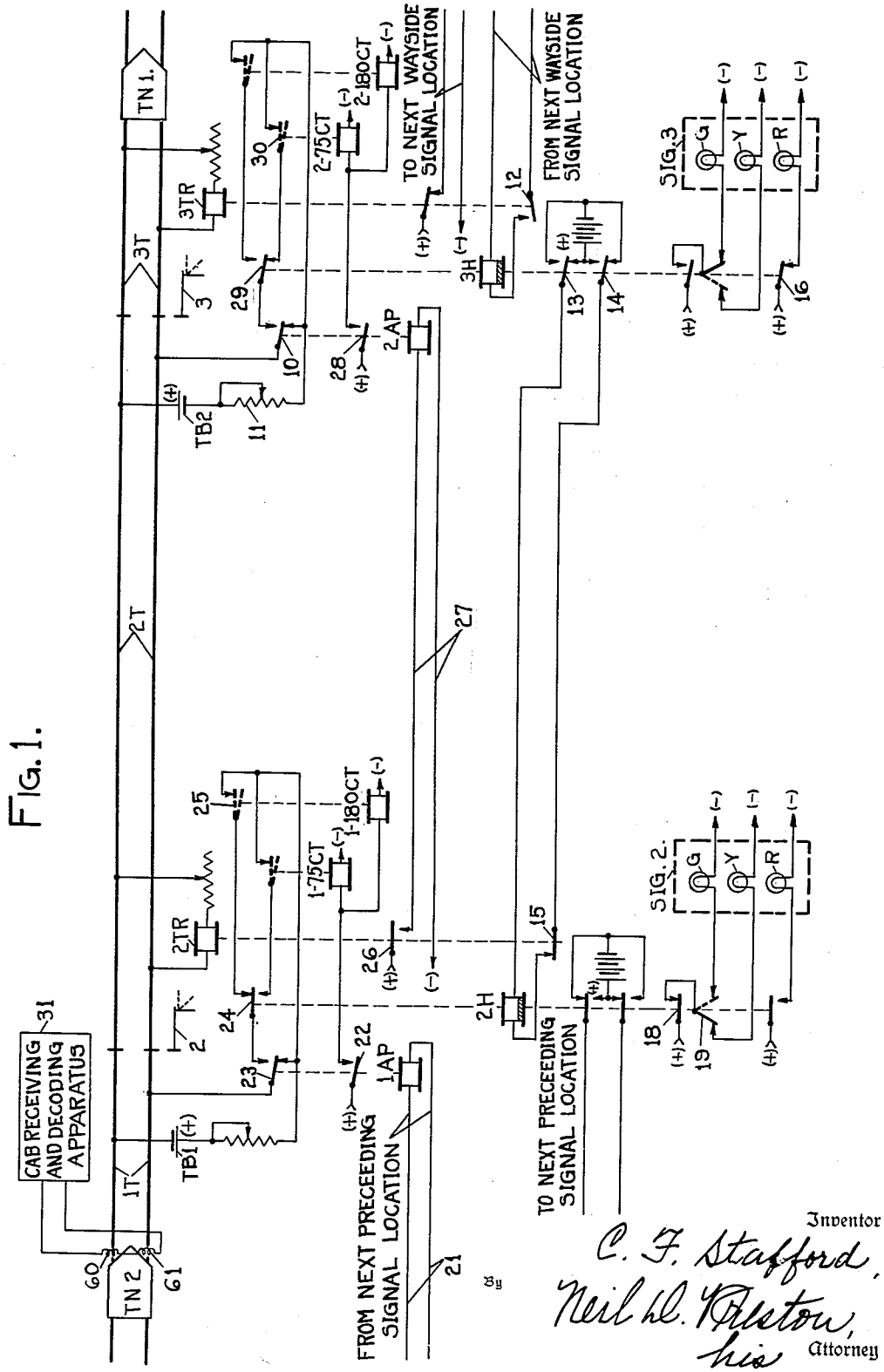


FIG. 1.

Inventor
C. F. Stafford,
By Neil H. Preston,
his Attorney

Jan. 17, 1956 C. F. STAFFORD 2,731,550

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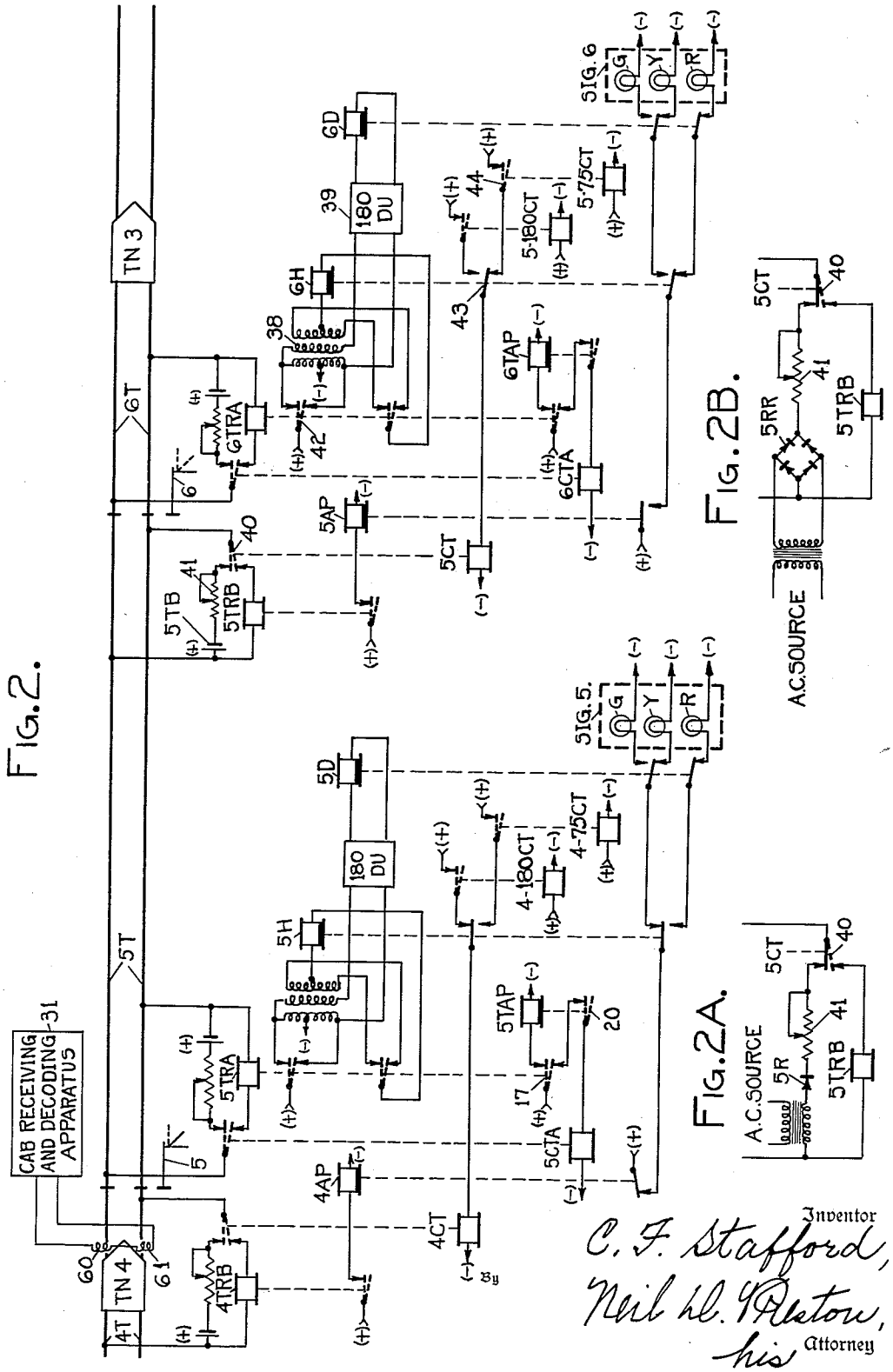


FIG. 2.

FIG. 2B.

FIG. 2A.

Inventor
C. F. Stafford,
Neil W. Preston,
his Attorney

Jan. 17, 1956 C. F. STAFFORD 2,731,550

CAB SIGNALLING SYSTEM FOR RAILROADS

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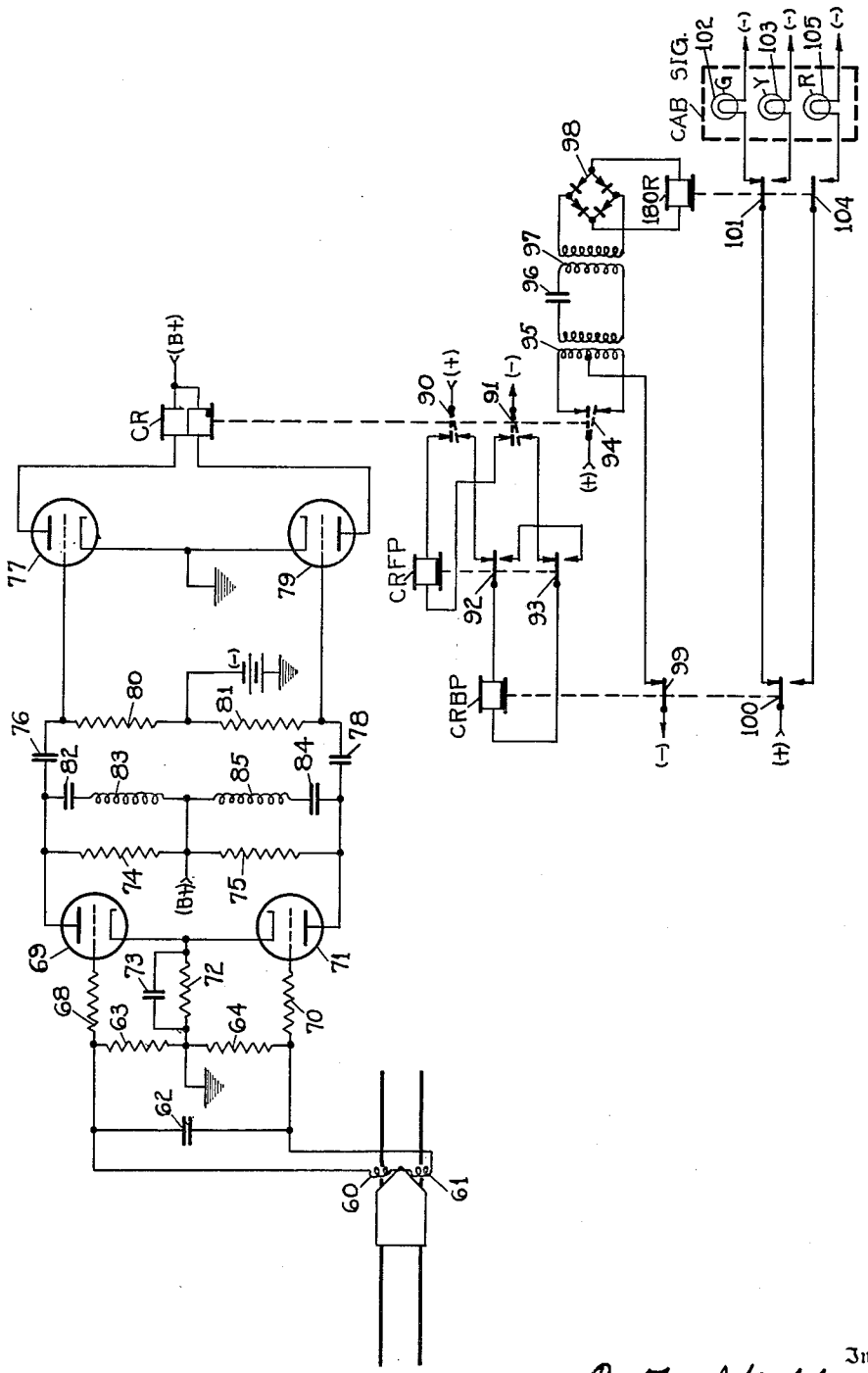


FIG. 3.

Inventor
C. F. Stafford,
By Neil W. Preston,
his Attorney

CAB SIGNALLING SYSTEM FOR RAILROADS

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FIG. 4.

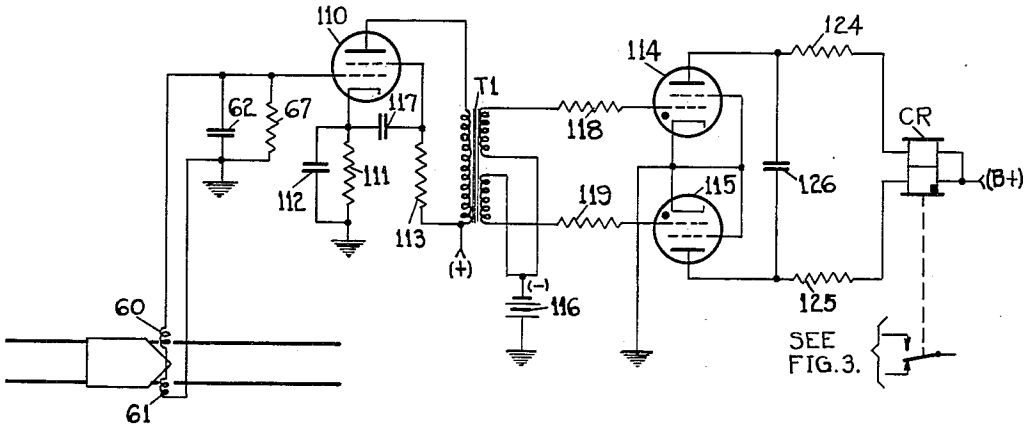
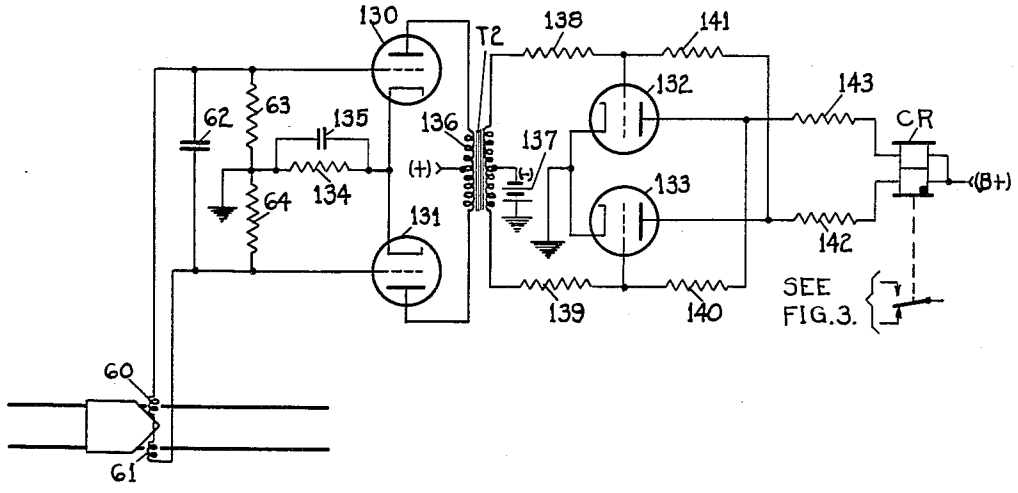


FIG. 5.



Inventor
C. F. Stafford,
By Neil W. Peterson,
his Attorney

Jan. 17, 1956 C. F. STAFFORD 2,731,550

CAB SIGNALLING SYSTEM FOR RAILROADS

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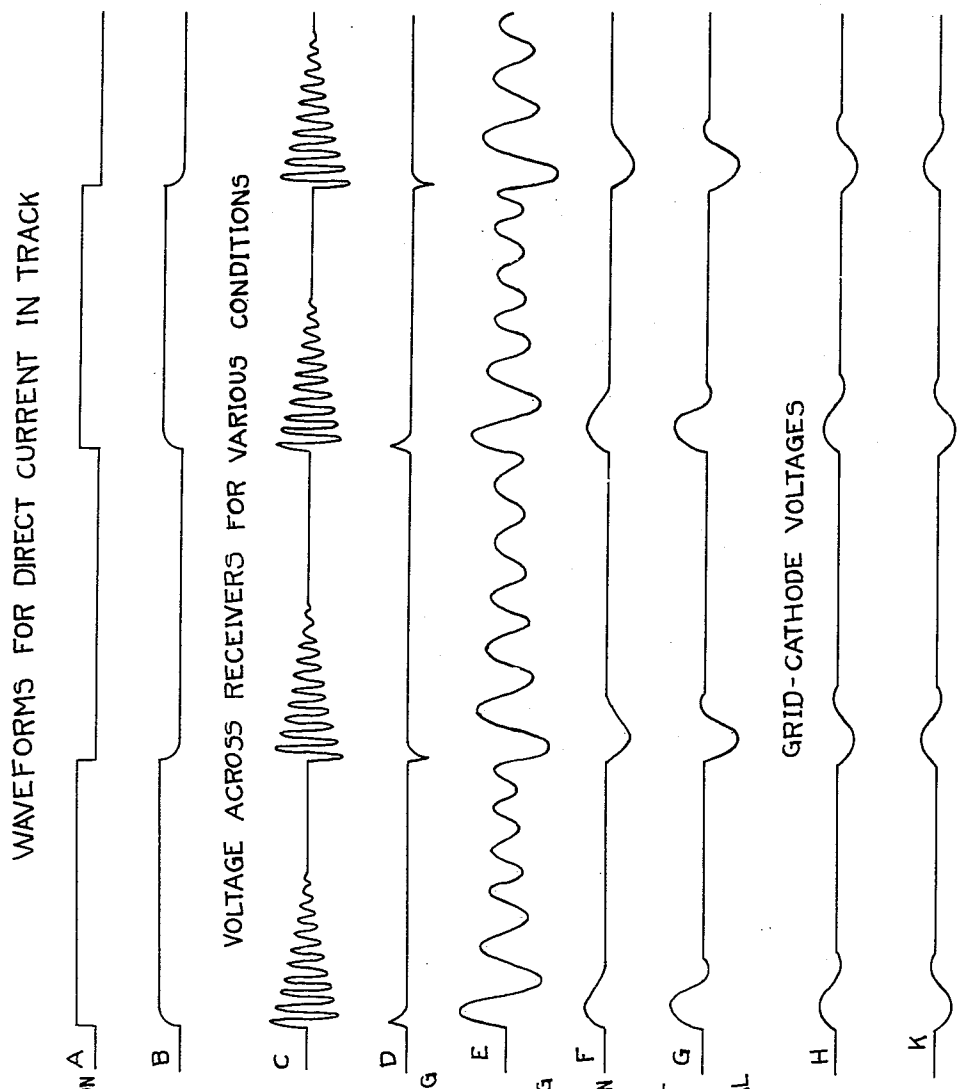


FIG. 6.

Inventor

C. F. Stafford,

By Neil W. Preston,

his Attorney

Jan. 17, 1956 C. F. STAFFORD 2,731,550

CAB SIGNALLING SYSTEM FOR RAILROADS

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FIG. 7.

FIG. 8.

Inventor

C. F. Stafford,

By Neil H. Preston, his Attorney

United States Patent Office 2,731,550 Patented Jan. 17, 1956

2,731,550

CAB SIGNALLING SYSTEM FOR RAILROADS

Chester Friend Stafford, Rochester, N. Y., assignor to General Railway Signal Company, Rochester, N. Y.

Application June 30, 1950, Serial No. 171,423

15 Claims. (Cl. 246—63)

This invention relates to a railway signalling system and more particularly to a signalling system providing for the control of train cab signals as well as the usual wayside signals.

To control cab signals on a train, electrical pulses occurring at distinctive rates are generally applied to the track rails. The code rates most commonly used are 75, 120, and 180 pulses per minute although other suitable rates could also be used. Train-carried apparatus is then employed to detect the presence of the pulses in the track rails and also to decode the information contained therein to operate the cab signals. Because the characteristics of the code detection and decoding means used in most prior cab signalling systems are such that the inductive transfer of energy from the rails to the train cannot satisfactorily take place when only direct-current pulses are used, the electrical pulses applied to the rails are required to be of alternating current or at least contain a component of alternating current. For this reason, many signalling systems employing direct current coded track circuits cannot be readily used for cab signalling, because the necessary additions to provide alternating-current pulses to the rails entail considerable expense.

The present invention, however, provides an organization in which the train-carried apparatus is properly responsive to trackway apparatus employing direct-current coded impulses. Suitable decoding means is used to obtain positive operation of the cab signals with these direct-current pulses, but at the same time this decoding means is constructed to be unresponsive to foreign currents. The expense entailed, therefore, in adding cab signalling to an existing direct-current coded track signalling system has been considerably reduced. Also, signalling systems using line wire control rather than coded track may also readily be adapted for cab signalling by means of this invention, since the existing direct current track circuits of such a system can readily be converted to direct current coded track circuits.

In addition, the cab signalling apparatus of this invention is operable over territory in which the code pulses applied to the track consist of rectified but unfiltered alternating current. This track current may be either full-wave or half-wave rectified alternating current of the usual commercial power frequency, such as 60 cycles per second for example. Despite the ability of the system to operate properly in regions where rectified alternating track current is used, the apparatus does not respond to stray alternating track currents even when such stray currents have a frequency equal to that of the source of the rectified track current. Various other safety features are also incorporated into this cab signalling organization to prevent a false signal aspect from being displayed under certain conditions.

Other objects, purposes, and characteristic features of this invention will be in part obvious from the accompanying drawings and in part pointed out as the description of the invention progresses.

In describing the invention in detail, reference will be

made to the accompanying drawings in which like reference characters designate corresponding parts throughout the several views, and in which:

Fig. 1 illustrates a line wire signalling system using direct current coded pulses in the trackway for cooperating with the code receiving and decoding apparatus of this invention;

Fig. 2 similarly illustrates a direct current coded track signalling system for cooperating with the code receiving and decoding apparatus of this invention;

Figs. 2A and 2B respectively show how the code applying apparatus of Fig. 2 can be modified to provide track code pulses of half-wave or full-wave rectified alternating current;

Fig. 3 shows the preferred form of the code receiving and decoding apparatus using a balanced amplifier circuit;

Fig. 4 shows an alternative form of code receiving and decoding apparatus using thyratron output tubes;

Fig. 5 illsutrates still another form of code receiving and decoding apparatus in which an Eccles-Jordan trigger circuit is used; and

Figs. 6, 7, and 8 are waveform diagrams for use in connection with the discussion of one possible theory of operation of the code receiving and decoding apparatus as it responds respectively to direct-current, half-wave alternating current, and full-wave alternating current coded track circuits.

The parts and circuits of this invention are shown diagrammatically and conventional illustrations are used to simplify the drawings and the explanations. The drawings have been made to make it easy to understand the principals and manner of operation rather than to show the specific construction and arrangement of parts that would be used in practice. The relays and their contacts are shown in a conventional way. Symbols are used to indicate connections to the terminals of a battery or other source of electric power instead of showing all of the wiring connections to these terminals. The symbols (+) and (—) indicate the positive and negative terminals, respectively, of a suitable source of direct-current of relatively low voltage. The symbol (B+) and the symbol for ground, indicate connections to the positive and negative terminals, respectively, of another direct-current source of higher potential suitable for the plate-cathode voltages of the electron tubes used.

Trackway apparatus of Fig. 1

Fig. 1 shows the way in which a block signalling system, wherein signal controls are transmitted over line wires, may be adapted for a cab signalling system. A stretch of track, divided in a plurality of track sections by insulated joints, is signalled for east-bound traffic, i. e., from left to right, by signals such as signals 2 and 3 that govern the entrance of trains into track section 2T and 3T, respectively. A track battery is normally connected across the rails of each track section as shown, for example, by track battery TB2 connected through back contact 10 of relay 2AP to the rails of track section 2T. Each track battery has connected in series therewith a current-limiting resistor such as variable resistor 11 in series with track battery TB2.

A retained neutral-polar line relay is included with the apparatus at each signal location. For example, relay 3H at the signal 3 location is a relay of this kind. The energization of this line relay at each signal location is dependent upon the energization of the track relay, or relays associated with the track section governed by the signal at such signal location. The polarity of such energization is determined by the energized or deenergized condition of the corresponding home relay H for the next signal in advance. Relay 3H can, therefore, be energized only when front contact 12 of track relay 3TR is closed,

and its polarity of energization depends upon the energization of the H relay associated with the next track section in advance. Thus, relay 2H is energized with current passing from left to right through its winding, so that its polar contacts are actuated to their right-hand position when relay 3H is energized with its front contacts 13 and 14 closed. Conversely, the direction of current is from right to left through the winding of relay 2H so that its polar contacts are actuated to their left-hand positions when relay 3H is deenergized with its back contacts 13 and 14 closed as shown. Because of the retained neutral characteristics of these H relays, their neutral contacts remain in an energized position when the polarity of the current through the relay winding is reversed.

Assuming that there is a train TN1 occupying track section 3T, the shunting effect produced across the rails of this track section causes track relay 3TR to drop away. The opening of front contact 12 of track relay 3TR then deenergizes the home relay 3H. After a brief interval corresponding to the slow release time of relay 3H caused by its retained neutral characteristics, this relay drops away thereby closing its back contacts. With back contact 16 of relay 3H closed, lamp R of signal 3 is illuminated causing this signal to display a red aspect. Assuming that there is no train occupying track section 2T, front contact 15 of relay 2TR is closed and, with relay 3H dropped away, relay 2H is then energized with a polarity to actuate its contacts to their left-hand positions. With this relay 2H energized as described, a circuit is completed through front contact 18 and left-hand contact 19 to energize lamp Y of signal 2. This signal then displays a yellow aspect.

When a train such as train TN2 enters track section 1T, the track relay associated with that track section drops away. Because the circuit organization at the signal location governing the entrance of trains into track section 1T is similar to that at the signal 2 location, the dropping away of the track relay places energy on line wires 21 to energize relay 1AP at the signal 2 location. The closing of front contact 22 of relay 1AP then completes a circuit to energize code transmitters 1–75CT and 1–180CT. These code transmitters are preferably of the kind that intermittently close their contacts at specified rates when energized. Code transmitter 1–75CT is actuated at the rate of 75 times per minute, and code transmitter 1–180CT is energized at the rate of 180 times per minute. Other rates may, of course, be used if desired; the 75 and 180 rates are proposed because they are commonly used in coded signalling systems.

With both relays 1AP and 2H at the signal 2 location energized, a circuit is then intermittently completed through front contacts 23 and 24 of these relays, respectively, and through front contact 25 of the code transmitter 1–180CT to apply direct-current pulses to the rails of track section 1T. These pulses are then transmitted over track section 1T toward the next signal location to the rear of signal 2, but are shunted by train TN2 before reaching such signal. As will subsequently be shown, the "cab receiving and decoding apparatus" 31 associated with train TN2 responds to the coding of the track current by causing a green aspect to be displayed in the cab of train TN2 as long as pulses of the 180 rate are applied to track section 1T.

When train TN2 moves eastward into track section 2T, track relay 2TR drops away and in doing so closes its back contact 26 thereby completing a circuit over line wires 27 to energize relay 2AP. The energization of relay 2AP then opens the circuit through its back contact 10 to remove the steadily applied direct current that is normally applied to the rails of track section 2T. The closing of front contact 28 of relay 2AP energizes both code transmitters 2–75CT and 2–180CT. As already shown, relay 3H is deenergized because the occupancy of track section 3T by train TN1 has caused the opening of front contact 12 of relay 3TR. Therefore, with back contact 29 of relay 3H closed, a circuit is then intermittently completed

through front contact 10 of relay 2V, back contact 29 of relay 3H, and front contact 30 of code transmitter 2–75CT. Because front contact 30 is closed at the rate of 75 times per minute, direct-current pulses are applied to the rails of track section 2T at this rate of 75 times per minute. As will later also be shown, the "cab receiving and decoding apparatus" 31 causes a yellow aspect to be displayed in the cab of train TN2 as long as pulses of the 75 rate are applied to the rails of track section 2T.

As train TN2 crosses into track section 3T behind train TN1, no code is received by the "cab receiving and decoding apparatus" 31 because of the shunting effect on the rails of track section 3T by train TN1. As a result, a red aspect is displayed in the cab of train TN2.

As a train moves out of a track section into the track section in advance, the normal conditions previously described must quickly be restored. For example, as train TN2 moves eastward out of track section 2T into track section 3T (assuming train TN1 to have vacated section 3T), the direct-current pulses applied to the rails of track section 2T when this track section 3T is occupied, can be transmitted all the way to the signal 2 location because train TN2 no longer shunts track section 2T. The first of these transmitted pulses causes track relay 2TR, therefore, to become energized and open its back contact 26. The resulting removal of energy from line wires 27 then releases relay 2AP and, since this relay 2AP is a quick-releasing relay, its back contact 10 is quickly closed to apply steady direct current again to the rails of track section 2T. In this way, the coding of track section 2T is quickly terminated and steady direct current is applied to track section 2T to hold track relay 2TR in an energized condition. Relay 2AP must have quick releasing characteristics so that the picking up of track relay 2TR will quickly cause back contact 10 of relay 2AP to close and place steady energy on the rails of track section 2T. This rapid application of steady energy to the rails is necessary to hold relay 2TR picked up following its energization by a code pulse for, unless relay 2TR can be held in its picked up condition, relay 2AP will drop away and again cause code pulses to be applied to track section 2T.

Trackway apparatus of Fig. 2

Fig. 2 shows a typical block signalling system using direct current coded track circuits. Since the signal controlling organization is similar to that of prior kinds of coded track systems, a description of the operation of the apparatus in Fig. 2 will be given only in general terms. In a coded track circuit signalling system of this kind, pulses of direct current are applied to the exit end of each track section. These "on" periods of the code occur at a selected rate that is indicative of traffic conditions in adjacent track sections; and, together with the "off" periods, they comprise a "driven" code. At the other end of each track section, a code-following track relay connected across the rails is energized by each "on" period of the code. Contacts of this track relay act upon code responsive means that decode the pulses according to their rates and selectively control the aspects displayed by wayside signals. At the end of the track section receiving the driven code, direct-current pulses are applied to the rails during the "off" periods of the driven code for transmission to the other end. This latter code is generally termed an "inverse code." A code-following track relay receives these inverse code pulses and acts upon suitable decoding means for approach lighting control and the like.

In Fig. 2 the organization shown is arranged for a normal traffic direction of west to east, corresponding to left to right in this drawing. The driven code in each track section is transmitted, therefore, in the opposite direction, from east to west with the inverse code transmitted in the normal direction of traffic. In this way, the entrance of a train into a track section prevents the driven code from being received at such entrance end. Because the track relay at that end cannot then be energized, no inverse code

can be transmitted to the exit end. The driven code will still, however, be transmitted toward the train and each pulse will cause a voltage to be induced in inductors 60 and 61. In a manner to be described, the induced voltages applied to the "cab receiving and decoding apparatus" 31 cause the proper signal aspect to be displayed in the cab of the train.

At each end of each track section shown in Fig. 2, a contact of a coding relay selectively connects either a winding of a track relay or a track battery across the rails of the associated track section. At the exit or right-hand end of track section 5T, for example, the closure of back contact 40 of relay 5CT connects the winding of track relay 5TRB across the rails of track section 5T. When front contact 40 is closed, track battery 5TB is connected through current-limiting resistor 41 to the rails of track section 5T. At the entrance end of track section 5T a similar organization is provided except that the circuit selection is made by a contact of relay 5CTA. Relay 5CTA is an inverse code transmitting relay at the exit end of track section 5T which is momentarily picked up at the end of each driven code pulse.

At each signal location a contact of a track relay, in combination with a decoding transformer and a rectifying contact of the track relay cooperate to hold an H relay energized whenever code of any rate is received over the adjoining track section. At the signal 6 location, for example, the alternate closing of front and back contact 42 of track relay 6TRA causes relay 6H to be picked up. The decoding apparatus of Fig. 2 also includes a conventional decoding unit such as the 180 rate decoding unit 39. Because of the characteristics of this decoding unit in combination with the decoding transformer 38, the operation of the decoding organization is such that only if the code received over track section 6T is of the 180 rate, is relay 6D picked up.

The code transmitters at each signal location such as the code transmitters 5–180CT and 5–75CT at the signal 5 location are continuously energized and close their front contacts 180 and 75 times per minute respectively. The driven code transmitting relay CT at each signal location is energized at a rate depending upon whether the associated H relay is energized or deenergized. If relay 6H is dropped away, code transmitting relay 5CT is energized through back contact 43 of relay 6H and through front contact 44 of code transmitter 5–75CT. Code transmitting relay 5CT is then energized at the rate of 75 times per minute thereby completing a circuit through its back contact 40 to apply direct-current pulses at that rate to track section 5T. Similarly, if relay 6H is picked up and its front contact 43 closed, direct-current pulses of the 180 rate are applied to track section 5T.

The apparatus at the entrance end to each track section includes an inverse code transmitting relay such as relay 5CTA at the signal 5 location. The operation of this relay 5CTA is dependent not only upon a contact 17 of the track relay 5TRA at that location, but also upon the response of contact 20 of a front repeater relay 5TAP of the track relay which determines the length of the inverse code pulses. The inverse code thus provided allows for approach lighting of the wayside signals in the usual manner.

The rate at which code pulses are applied to any track section is selected dependent upon the energization of the H relay at the exit end of that track section. The energization of that H relay is, in turn, dependent upon the occupancy of the next track section in advance. Assume the conditions shown in Fig. 2 where a train TN3 occupies track section 6T. Since no driven code pulse can then be received at the entrance end of this track section, both relays 6H and 6D drop away. The closing of back contact 43 of relay 6H then causes a 75 code to be transmitted to the signal 5 location.

Since there is no train occupying track section 5T, the driven code transmitted from the signal 6 location is received at the signal 6 location and causes relay 5H to be picked up. Therefore, a 180 code is transmitted westward from the signal 5 location. The "cab receiving and decoding apparatus" mounted on train TN4 responds to the 180 code appearing in the rails of track section 4T by causing a green aspect to be displayed in the cab of train TN4.

When train TN4 moves eastward to track section 5T, driven code pulses of the 75 rate are still applied to the rails of track section 5T and the "cab receiving and decoding apparatus" responds to this 75 code to display a yellow aspect in the cab. If train TN4 were to move into track section 6T, no code pulses could be received by the "cab receiving and decoding apparatus" and the cab signal would then display a red aspect. Thus, the block signalling sysem shown using direct current coded track circuits not only provides for the control of the usual wayside signals but also places pulses upon the track rails which can operate the cab signals and thereby provide signal indications in the cab of a train informing the crew of existing traffic conditions.

Train carried equipment

Three forms of the code receiving and decoding apparatus 31 of Figs. 1 and 2 are shown as embodying this invention. In each embodiment, the train-carried apparatus includes inductive elements 60 and 61, commonly known as receivers, mounted adjacent the track rails. These series-connected receivers are so connected with respect to each other that the voltages induced therein are additive. The receivers 60 and 61 are shunted by a capacitor 62 to constitute a parallel tuned circuit. This tuned circuit is then shunted in turn, by a resistance of a magnitude selected in accordance with the principles of the present invention. In the embodiments shown in Figs. 3 and 5 the shunting resistance consists of two equal series-connected resistors 63 and 64; whereas, in the embodiment illustrated in Fig. 4 the shunting resistance includes only a single resistor 67.

The receiver circuit is responsive to the coding of the track current to supply a distinctive output voltage at the beginning and end of each track code pulse. Briefly, the distinctive voltage variations are caused by a shock excitation of the previously described tuned circuit at the beginning and end of each track code pulse. The shock excitations are caused by the voltage induced in the receivers by each successive application and removal of track current. By properly damping these oscillations, only the desired distinctive voltage variations are retained to characteristically represent the beginning and end of each track code pulse. These distinctive output voltages are then suitably amplified and control the operation of an electromagnetic code following relay causing the contacts of this relay to be actuated to one position at the beginning of each track code pulse and to the opposite position at the end of each track code pulse. A decoding organization controlled by this electromagnetic relay governs the energization of a cab signal so that the particular aspect displayed at any time is dependent upon the rate of response of this code following relay and is, therefore, in turn dependent upon the rate of application of code pulses to the track rails.

In the preferred form of the code receiving and decoding means, shown in Fig. 3, the voltage appearing across the receivers is applied to both channels of a balanced amplifier comprising tubes 69 and 71. The output of each channel of this first amplifier is then applied to the corresponding channel of a second amplifier with the output of this latter amplifier controlling the operation of a code following relay CR. The code following relay CR in turn controls decoding apparatus comprising front and back contact repeating relay CRFP and CRBP, transformers 95 and 97, condenser 96, rectifier 98, and relay 180R. The relays CRBP and 180R control the cab signal having green, yellow, and red lamps G, Y and R, respectively.

In the embodiment shown in Fig. 5, the output of the

first balanced amplifiers 130 and 131 is transformer-coupled with the control grids of two triode tubes 132 and 133 included in a dual-triode trigger or flip-flop circuit. A code following relay CR is controlled by the response of these triode tubes and, in turn, controls the operation of the decoding apparatus so that the proper cab signal aspect is displayed, as shown in detail in Fig. 3.

The third embodiment of the code receiving and decoding apparatus shown in Fig. 4 has but a single electron discharge tube 110 in the first amplifier stage. The output of this amplifier is transformer-coupled to the grids of two gaseous discharge or thyratron tubes 114 and 115. The outputs of these thyratrons then selectively control the energization of a code following relay CR with this relay then controlling the decoding apparatus in the usual way, as shown in detail in Fig. 3.

Operation

Referring to either Fig. 1 or Fig. 2, it should be noted that the code applying contact is preferably controlled to produce a code having substantially equal "on" and "off" periods regardless of the particular rate at which the coding contact is then operated. This positive opening and closure of the coding contact, such as contact 40 of relay 5CT in Fig. 2, abruptly connects and disconnects the battery 5TB across the track rails of section 5T. The operation of such a coding contact is graphically illustrated at line "A" of Fig. 6.

It will be appreciated that the track rails of the section have an inductive effect upon the rise and decay of the current in the rails, while there is also a certain amount of distributed capacity and also a considerable amount of ballast leakage under most circumstances. Thus, at the beginning of each "on" period, the track current rises over a period of time to a particular steady state value for the remainder of that pulse period. At the end of each "on" period of the code, the track current decays after a corresponding period to a zero value for the remainder of such "off" period. The particular rate of current rise or decay will vary from time to time as the ballast conditions change, but the voltage of the battery 5TB is made sufficient to provide a proper code pulse at the entrance end to the track section under the most adverse conditions. This current rise and decay in the track rails has been roughly indicated in the graphic illustration of line "B" in Fig. 6 merely to illustrate that the track circuit conditions do have an effect upon the rate of current change at the leading and trailing edges of the code pulses.

As a train enters a track section and progresses towards the exit end thereof, a greater portion of the track rails and associated ballast is shunted out of the track circuit so that the rate of rise and decay of track circuit current is increased as the train approaches the exit end of the section. Thus, assuming that the code pulses are of proper value for most adverse conditions (i. e., low ballast and train at entrance end of section), the resulting code pulses during the passage of a train are always sufficient to operate the cab receiving and decoding apparatus 31.

With reference to the drawings, it will be readily apparent that the coils 60 and 61 are inductively coupled to the track rails so that any current change in the track rails causes a change in the magnetic field surrounding the rails to in turn induce a voltage in the coils 60 and 61. Specifically, the rise in flux at the beginning of each pulse in the track rails induces a voltage in the windings 60 and 61 of a particular polarity, while the decay of flux at the end of each pulse in the track rails induces a voltage in the windings 60 and 61 of the opposite polarity. These induced voltages are of course very momentary; but, since the windings 60 and 61 are tuned to resonance, a momentary voltage shock excites this tuned circuit so as to produce transient oscillations therein.

It will be appreciated that the receiver coils 60 and 61 are highly inductive due to their iron cores which are used to increase the mutual inductive coupling between the coils and the track rails. Also, such windings have a small amount of distributed capacitance which exists between the turns of wire in the receiver windings which in effect is in multiple with the windings causing them to act as parallel tuned circuits. If the condenser 62 were not connected to the coils 60 and 61, this natural resonant frequency of the receivers would be relatively high; and, upon the application of each direct current code pulse to the track rails, a voltage would be induced in the receivers which would set up a train of oscillations having a frequency corresponding to this relatively high natural resonant frequency of the windings. Similarly, at the end of each code pulse of direct current in the track rails a voltage would likewise be induced in the windings which would then set up a train of oscillations having a frequency also corresponding to the natural resonant frequency of the windings. Since the windings must of necessity have a certain amount of resistance, these trains of oscillations would be damped to some extent as graphically illustrated by the trains of oscillations in line "C" of Fig. 6.

It will be noted that the first half cycle of the train of oscillations produced at the beginning of a pulse is a positive half cycle; whereas, the train of oscillations at the end of a pulse begins with a negative half cycle (assuming one set of connections). However, if trains of oscillations such as indicated in line "C" of Fig. 6 are applied to the amplifiers 69 and 71 of Fig. 3, there is no way in which the amplifiers can distinguish as to whether any particular train belongs to the beginning or the end of a code pulse period. In other words, the difference in the polarity of the first half cycle of any train of oscillations cannot be distinguished if the entire train of oscillations is applied to the amplifier.

In accordance with the present invention, it is proposed to provide the resistors 63 and 64 of Fig. 3 to damp the trains of oscillations produced in the receiver windings to substantially the critical value of damping. If this critical damping were applied to what may be termed the natural resonant frequency of the receivers 60 and 61, the resulting half wave transient appearing across the windings would be of very short duration. Since the embodiment of the present invention shown in Fig. 3 preferably includes a code following relay, it is desirable to have the damped transients appearing at the beginning and end of each pulse of sufficient duration and amplitude to effect the operation of such code following relay. To provide such a transient, the condenser 62 is used to resonate the windings 60 and 61 to a relatively low frequency, such as in the order of 5 to 20 cycles per second. In one embodiment of the invention, the resonant frequency was selected as 14 cycles per second and the provision of resistors 63 and 64 of a proper value for critical damping gave entirely operative results. In this instance, the voltage across the receiver appeared as graphically illustrated in line "F" of Fig. 6.

When the resistors 63 and 64 are of such a value as to give the conditions of critical damping, all oscillations of each train of waves are eliminated except the first half cycle of each train. This degree of damping also decreases, to some extent, the amplitude of each first half cycle of a train of waves. For this reason, it has been found that the resistance value of resistors 63 and 64 may advantageously be increased to a value where near critical damping takes place (i. e. slightly above critical damping). In one embodiment of the invention, it has been found that the value of the resistors 63 and 64 may be approximately twice their value for critically damped conditions. This causes the voltages across the receivers to appear as graphically shown in line "G" of Fig. 6 where the first half cycle of each train is of relatively long duration and high amplitude; whereas the accompanying second half cycle is of such a relatively small amplitude that

its duration is of no particular consequence. However, it should be understood that the embodiment of the invention should not depart too far from the conditions of critical damping else the train of waves will not be reduced to a characteristic or distinctive half cycle for the beginning and end of each pulse. For example, assuming that the resistors 63 and 64 provide only slight damping, then the voltages appearing across the receivers would be successive trains of transient oscillations somewhat as shown in line E of Fig. 6. Obviously, the amplifying organization could not distinguish between these trains as to whether they related to the beginning or end of a pulse, and for this reason it is highly desirable to use substantially critical damping.

Over-damping will also produce but a single pulse at the beginning and end of each code pulse, but with such over-damping the single pulse produced for each train waves will be of lower amplitude than for critical damping and also it will be of longer duration. Accordingly, the amount of over-damping should not be too great otherwise the amplitude of the resulting pulse would be below an operative value.

For the purpose of this disclosure, especially the form of Fig. 3, it should be understood that critical damping or near critical damping should be employed, it being preferable in most cases to use slightly less than critical damping for reasons above explained. In other words, the receiving circuit should be tuned to a relatively low frequency and then damped to substantially critical damping conditions.

If the condenser 62 should inadvertently become disconnected so as to not tune the receiver circuit at the relatively low frequency, then the circuit assumes its natural characteristic involving the distributed capacitance of the windings 60 and 61 and the connecting leads. With the resistors 63 and 64 so selected as to provide substantially critical damping for the receiver circuit tuned to the relatively low frequency by condenser 62, their resistance is of such a low value as to provide considerable over-damping for the natural resonant frequency of the receiver circuit without the condenser 62. Thus, accidental disconnection of the condenser 62 would result in a voltage pulse appearing across the receiver circuit of one polarity for the beginning of a pulse and of the opposite polarity for the end of such pulse, but, these pulses would be of such short duration and low amplitude as to be ineffective to cause normal operation of the cab signal equipment. Such over-damped voltage pulses in the receiver circuit are illustrated graphically in line D of Fig. 6.

The voltage appearing across the tuned receiving circuit comprising inductors 60 and 61 and condenser 62 appears also across the series-connected resistors 63 and 64 shown in Fig. 3. Because resistors 63 and 64 have an equal value of resistance, one-half of the voltage across the tuned circuit appears across each of these resistors. Since the cathodes of tubes 69 and 71 are both connected through resistor 72 to the junction of resistors 63 and 64, connecting the grids of these tubes through respective grid resistors 68 and 70 to the remaining terminals respectively of these resistors causes the grid-cathode voltages of these tubes to be of opposite polarity. The grid voltages of the respective tubes 69 and 71 are not only of opposite polarity, but are both substantially of an amplitude equal to one-half the amplitude of the total voltage across resistors 63 and 64 because only relatively small voltage drops appear across grid resistors 68 and 70 and common cathode resistor 72. These grid input voltages have been graphically indicated at lines H and K of Fig. 6.

Tubes 69 and 71 are operated as class A, balanced amplifiers. Both tubes are provided with self-bias by common cathode resistor 72. Resistor 72 has connected in parallel with it condenser 73 which provides sufficient by-passing to avoid degeneration of the amplified signal. Grid resistors 68 and 70 are used to avoid improper operation of the circuit in the event that an intermittent short circuit should occur between control grid and plate of either tube 69 or 71. A short circuit between plate and control grid of either of these tubes would cause the plate voltage to be applied across the parallel tuned circuit and would shock excite this tuned circuit with the result that spurious impulses would then occur. Because resistors 68 and 70 are of relatively large value of resistance, the shorting of plate to grid of either tube 69 or 71 instead causes most of the plate voltage to appear across these grid resistors, thereby preventing false impulses from being produced by the parallel tuned circuit.

The plate voltage of tubes 69 and 71 is supplied from the (B+) source through resistors 74 and 75, respectively. The plate output of each tube is fed through a blocking condenser to the control grid of an output amplifier tube. The plate output of tube 69 is applied through blocking condenser 76 to the control grid of tube 77; whereas, the plate output of tube 71 is applied through blocking condenser 78 to the control grid of output amplifier tube 79. The control grid of each of the output amplifier tubes 77 and 79 is connected through an associated grid leak resistor 80 and 81, respectively, to a source of bias voltage. The cathodes of tubes 77 and 79 are both connected to ground.

Tubes 77 and 79 are both biased to cutoff by the fixed bias voltage (B—) applied through grid leak resistors 80 and 81. For either of these tubes to conduct, therefore, the input voltage applied to them from the preceding amplifier stage must raise their total grid-cathode voltage above the cutoff level. Driving the grid of tube 69 positive and the grid of tube 71 negative at the beginning of each track code pulse causes tube 69 to conduct more plate current and at the same time decreases the plate current of tube 71. This condition causes the plate voltage of tube 69 to decrease and the plate voltage of tube 71 simultaneously to increase. The resultant decrease of grid voltage of tube 77 can have no effect on the conduction of this tube because it is already biased to cutoff. The increase of voltage on the grid of tube 79, however, raises the grid-cathode voltage above the cutoff level so that this tube conducts and plate current then flows through the lower winding of code receiving relay CR actuating the contact to a corresponding position. The opposite condition prevails at the end of each track code pulse for then the grid-cathode voltage of tube 69 is decreased while the grid-cathode voltage of tube 71 is increased. Tube 69 then conducts less plate current at the same time that the plate current of tube 71 is increased. As a result, the plate voltage of tube 69 and thus the grid-cathode voltage of tube 77 is raised. The plate voltage of tube 71, on the other hand, decreases and lowers the grid-cathode voltage of tube 79. Therefore, although tube 79 remains cut off, tube 77 conducts and actuates relay CR to the opposite position. In this way, each application of a direct-current code pulse to the rails causes relay CR to be actuated first to one position and then to the other. The contacts of this relay are thus actuated at a rate corresponding to the rate of application of code pulses to the track rails.

Each time that code receiving relay CR, included in each embodiment of the invention, is actuated to close its front contacts 90 and 91 (see Fig. 3), front repeater relay CRFP is energized through a circuit including these contacts 90 and 91. If relay CR is actuated to its alternate positions at a rate corresponding to that at which direct-current pulses are applied to the track rails, front repeater relay CRFP will remain steadily picked up, despite its intermittent energization, because of its slow releasing characteristics. Front contacts 92 and 93 of relay CRFP will then be closed. Therefore, each closure of back contacts 90 and 91 of relay CR will energize back repeater relay CRBP. Since this relay is

also provided with slow releasing characteristics, relay CRBP will also remain picked up despite its intermittent energization. This arrangement of front and back repeater relays of the code receiving relay CR ensures, by the picking up of relay CRBP, that relay CR is actually energized to opposite positions in response to the code pulses appearing on the track relays and is not steadily held in one position.

Contact 94 of relay CR, together with transformer 95, condenser 96, transformer 97, and rectifier 98 provide a decoding circuit that enables relay 180R to be picked up whenever relay CR is energized at the 180 rate. The form of decoding circuit shown in Fig. 3 is typical of that generally employed in coded track circuit signalling systems. Briefly, each time that contact 94 of relay CR is energized to one position or the other, one-half of the primary winding of transformer 95 is energized through a circuit including this contact 94 and also front contact 99 of back repeater relay CRBP. The secondary winding of transformer 95 is shunted by a series resonant circuit including condenser 96 and the primary winding of transformer 97. This series resonant circuit is tuned to 180 cycles per minute with the result that the secondary winding of transformer 97 is energized only when the primary winding of transformer 95 is energized at the 180 rate. The alternating voltage appearing across the secondary winding of transformer 97 is then rectified by full wave rectifier 98 so that relay 180R is energized with direct current. If relay CR is not intermittently actuated to opposite positions at the 180 rate in response to a 180 code applied to the track rails, relay 180R will not be energized.

When relay CR is energized in response to a 180 code, both front contacts 100 of relay CRBP and 101 of relay 180R are closed. Lamp 102 of the cab signal is then energized to display a green aspect. If relay CR is energized at the 75 rate, however, relay CRBP is still energized but relay 180R is dropped away. In that event, lamp 103 of the cab signal is then energized through front contact 100 of relay CRBP and back contact 101 of relay 180R. A yellow aspect is then displayed by the cab signal. If the contacts of relay CR remain steadily in one position or the other, both relays CRBP and 180R are deenergized. A circuit is then completed through back contact 100 of relay CRBP and back contact 104 of relay 180R to energize lamp 105 of the cab signal. A red aspect is then displayed by the cab signal.

By means of the circuit organization shown in Fig. 3 a cab signal may be selectively energized to display a proper signal aspect dependent upon the rate at which the CR relay is energized. Although the 180 and 75 rates have been chosen as indicative of clear and caution signal conditions, other code rates may, of course, be used as desired. By using additional code rates, a larger number of different signals aspects may be displayed by the cab signal.

When the cab signalling equipment is used in territory where commercial alternating current distribution lines are adjacent the right of way, stray currents of the commercial power frequency frequently appear in the track rails. These stray currents may induce corresponding voltages in the train-carried inductors 60 and 61. To ensure that these induced voltages will not adversely affect the output of the decoding means, a series inductance-capacitance circuit is connected between the plate of each of tubes 69 and 71 to the positive voltage source. The plate of tube 69 is connected through condenser 82 and inductance 83 to the (B+) source; whereas, the plate of tube 71 is connected through condenser 84 and inductance 85 to this same source of positive potential. The values of the inductance and capacitance connected from each tube plate to the (B+) source are such that resonance of each series circuit occurs at the frequency of the interfering source, to thereby provide a trap circuit for the usual commercial frequencies. A low impedance shunt path then exists for these frequencies and they are thus prevented from being fed through coupling capacitors 76 and 78 to the grids of tubes 77 and 79. An additional function of these series resonant trap circuits will presently be described.

Several other advantages result from the fact that the embodiment of the invention shown in Fig. 3 employs two channels of amplification. One of these advantages is that intermittent breaks in either the grid or plate circuits of either tube 69 or 71 will not cause the relay to be actuated to opposite positions; it will instead remain energized in one position. Should the common cathode connection of tubes 69 and 71 intermittently break, pulses of the same polarity will be applied to the grids of both tubes 77 and 79; and, since the relay windings are in opposition, the relay will not be erroneously operated. Also, since the output amplifier tubes 77 and 79 are biased to cutoff, intermittent breaks in the connections to these tubes also will not cause the relay to be actuated alternately to opposite positions.

The above description considers the operation of the system when direct current coded pulses are employed in the track rails, but it should be clearly understood that the system operates just as well when the code pulses are rectified alternating current either half-wave or full-wave rectification. Referring to Fig. 2, the track code transmitting circuits may each be modified to be supplied with rectified alternating current. This has been shown for the exit end of track section 5T in Fig. 2A where a half-wave rectifier 5R is shown as connected in series with the secondary of a transformer supplied from a suitable source of alternating current. Such source of alternating current may be the usual commercial 60 cycle alternating power line, or may be any desired alternating current source which might be used for such a purpose. It is to be understood that the exit end of each track section may be considered as thus modified, and also that each entrance end may likewise be modified if desired. The change of the transmitting circuits to include the half-wave rectified current has only been shown in connection with the leaving end of the track section 5T, since it is the pulses transmitted from that end to which the train-carried apparatus is responsive.

The operation of each coding contact, such as contact 40 of relay 5CT, operates at time spaced intervals to produce code pulses at the selected rates. This operation of contact 40 has been indicated in line A of Fig. 7. The code pulses applied to the track rails consist of a number of half-waves of alternating current as indicated graphically in line B of Fig. 7.

Let us assume that a train with vehicle-carried equipment as shown in Fig. 3 enters the track section 5T. Then the code pulses of rectified alternating current act on the receivers 60 and 61 to produce induced voltages which act on the code receiving and decoding apparatus in a way to give the same operation as described for the direct current code pulses.

More specifically, each half-cycle of the half-wave rectified alternating current in each code pulse produces a complete alternating current component in the receivers 60 and 61 corresponding to the frequency of the alternating current source, since the inductive relation of the receivers to the track rails is the equivalent of a transformer. However, the base line or average value of the alternating current component of the induced voltage varies in a manner similar to the transient produced at the beginning of a direct current code pulse. This is illustrated graphically in line C of Fig. 7. The end of the code pulse produces a negative transient voltage which is wholly free of any alternating current component, as graphically shown in line C of Fig. 7. Thus, the over-all transient component of the voltage induced in the receivers by a half-wave rectified alternating current code

pulse is very similar to the transient voltage induced by a direct current code pulse in the track rails (compare lines C of Fig. 7 with line G of Fig. 6).

The transient component of the induced voltage of the receiver circuit is damped by the resistors 63 and 64, the same as previously described for the transient present due to the direct current code pulses. Thus, this transient component provides a distinctive characteristic at the beginning and at the end of each code pulse to give the same operation of the code following relay CR as previously described. In this connection, the amplifier tubes 69 and 71 amplify the induced voltages of the receiver circuit to provide the desired amplitude of input for the control tubes 77 and 79. The trap circuit means, including inductances 83 and 85 together with condensers 82 and 84, is effective to remove most of the fundamental frequency of the alternating current component. In fact, the frequency of the predominant alternating current component remaining in the voltage applied to the grids of tubes 77 and 79 is in the order of the second harmonic of the harmonic of the fundamental alternating current supply, but this second harmonic is of a very small amplitude. This has been illustrated graphically in line D of Fig. 7.

The major voltage variation in the input to the tubes 77 and 79 is the positive and negative transients at the beginning and end of each code pulse, and these characteristic voltages cause the operation of the code following relay CR exactly the same as previously described. The recurrent alternating current component existing between the positive and negative transients is of such small amplitude as to be ineffective to cause the tubes 77 and 79 to produce an output of sufficient magnitude to actuate relay CR.

Furthermore, should this alternating-current component of the input tubes 77 and 79 be of any appreciable value for any reason, it cannot cause operation of the code following relay CR because the relay CR is preferably so constructed that its armature has sufficient inertia or the relay has sufficient magnetic retardation as to be unable to follow the relatively high frequency of the second harmonic of any fundamental frequency that might be employed as a source for the trackway code pulses.

It may be also pointed out that the code transmitting circuits of the trackway apparatus as shown in Fig. 2 may be modified as shown in Fig. 2B to provide full-wave rectified alternating current for the trackway code pulses. This Fig. 2B shows a full-wave rectifier 5RR connected to the secondary of a suitable transformer having its primary supplied with alternating current from a suitable source. It is to be understood that the exit end of each track section may be thus modified, and in addition similar full-wave rectified alternating current may be supplied to the inverse code transmitting apparatus at the entrance end to each track section if desired.

The operation of each code transmitting contact, such as contact 40 of relay 5CT, operates to apply code pulses as indicated in line A of Fig. 8. The opening and closing of this contact apply time spaced code pulses at the rate then selected by traffic conditions. Each code pulse thus applied to the track rails consists of a number of adjacent half-waves of unidirectional current, as indicated graphically in line B of Fig. 8.

Assuming that the vehicle-carried apparatus of Fig. 3 is located on a train entering the track section 5T, then the code pulses act on the receivers 60 and 61 to induce therein voltages which give the same operation of the code following relay CR as described above in connection with direct current trackway code pulses or half-wave rectified alternating current code pulses.

The successive half cycles of alternating current in each code pulse produce a complete alternating current component in the voltages induced in the receiver windings. In other words, the induced voltage has an alternating current component having a frequency in the order of the second harmonic of the fundamental frequency of the alternating current source supplying the trackway code pulses. Since this frequency is considerably higher than the frequency to which the receiving circuit is tuned, the receiving circuit discriminates to some extent against this frequency. Obviously, this relatively high frequency is higher than that induced as the result of the use of half-wave rectified code pulses, and for this reason a greater discrimination is effected by the tuned circuit so that the ripples illustrated in line C of Fig. 8 are shown considerably smaller than those shown in line C of Fig. 7.

It should also be noted that the base line or average value of the alternating component of the voltages induced in the receiver windings varies in a manner similar to the transients produced at the beginning and ending of a direct current code pulse in the track rails. This has been illustrated graphically in line C of Fig. 8. Also, the end of the code pulse produces a negative transient voltage which is wholly free of any alternating component, as graphically shown in line C of Fig. 7. Thus, a comparison of the voltages induced in the receivers for full-wave rectified code pulses with the transients induced as the result of direct current code pulses shows that the transient components are substantially the same in both cases.

The voltages induced in the receivers are supplied to the input of control tubes 69 and 71. Since the alternating current component of such input voltage is substantially the second harmonic of the fundamental frequency, the trap circuits in this case do not materially affect the voltage but they are present to by-pass any of the fundamental frequency which might be erroneously present. In brief, with full-wave rectified track current code pulses, the improved discrimination of the tuned receiver circuit against the second harmonic component reduces the magnitude of that component to such an extent that it appears primarily as a ripple of the major transient voltage. The positive and negative voltage swings of the transient act on the control tubes to cause the operation of the code following relay CR exactly the same as previously described.

Modifications

The two alternative forms of the code detecting apparatus shown in Figs. 4 and 5 both include the parallel tuned circuit comprising inductors 60 and 61 and condenser 62. Also, this tuned circuit in these alternative forms is shunted by resistance to dampen the oscillations that have been described as being produced by code pulses in the track rails. As explained, this damping resistance includes but a single resistor in the embodiment shown in Fig. 4 but the magnitude of this single resistor is preferably chosen to be substantially equal to the sum of the magnitude of the resistors 63 and 64 of Figs. 3 and 4 so that approximately the same degree of damping is obtained.

The embodiment of the code detecting apparatus shown in Fig. 4 includes an amplifier tube 110 and two thyratron tubes 114 and 115. Because no voltage dividing arrangement is here provided by means of equal resistors shunting the parallel tuned circuit, substantially the full voltage appearing across the receivers is applied to the control grid of tube 110. Thus, when this apparatus is used in regions where direct current is employed in the track circuits, the grid voltage of tube 110 is of the general form shown in waveform G of Fig. 6. Similarly, waveform D of Fig. 7 and waveform C of Fig. 8 illustrate the general form of the input voltage to tube 110 when the code detecting apparatus is used in half-wave and full-wave rectified track current territories respectively. Regardless of whether direct current or rectified alternating current is used in the track circuits, however, an essential fact is that distinctive voltage swings of oppo-

site polarity occur both at the beginning and at the end of each track code pulse.

Resistor **111** connected between the cathode of tube **110** and ground provides a class A cathode bias for this tube. Resistor **111** is shunted by condenser **112** which is of sufficient magnitude to avoid degeneration of the input signal. The proper screen grid and plate potential of this tube are supplied from the (B+) source through screen-dropping resistor **113** and primary winding of transformer T1 respectively. Screen currents of the signal frequency are by-passed to the cathode by condenser **117** to minimize degenerative effects.

As the grid voltage applied to tube **110** alternately causes the plate current of this tube to increase and decrease about its quiescent value, corresponding voltage pulsations appear across the secondary windings of transformer T1. For any polarity of voltage induced across the secondary winding of this transformer, corresponding voltages of opposite polarity are applied to the control grids of thyratron tubes **114** and **115**. Thus, if at the beginning of a track code pulse, the grid of thyratron **114** is driven positive, the grid of thyratron **115** will be driven correspondingly negative. Then, at the end of that track code pulse, the conditions will be reversed with the grid of thyratron **114** being driven negative, and the grid of thyratron **115** positive.

The control grids of thyratrons **114** and **115** are both preferably biased to cutoff by their being connected through a grid resistor and transformer winding to the negative terminal of a source of bias potential such as battery **116**. Grid resistors **118** and **119** act as decoupling resistors and also limit the grid current of each thyratron tube when it is in a conducting state.

The plate of thyratron **114** is connected through a load resistor **124** and the upper winding of relay CR to the (B+) source. The plate of thyratron **115** is similarly connected through a load resistor **125** and the lower winding of relay CR to the (B+) source. A condenser **126** is connected from the plate of thyratron **111** to the plate of thyratron **112**.

Assume that at the particular moment to be considered thyratron **115** is conducting and thyratron **114** is not conducting. The plate current of thyratron **115** through the lower winding of relay CR holds the armature of this relay steadily in one position. Assume now that the potential on the grid of tube **114** is increased at the same time that the potential on the grid of tube **115** is decreased. The decrease of potential on the grid of tube **115** can have no effect upon the conducting status of this tube because grid control of a conducting gas tube cannot be practicably accomplished. If, however, the grid of thyratron **114** is driven sufficiently positive with respect to its cathode so that the firing potential of this tube is exceeded, thyratron **114** will conduct. The relatively large plate current through its load resistor and the winding of relay CR then causes its plate potential to decrease. Condenser **126** then discharges, and momentarily lowers the plate potential of thyratron **115** to a relatively low value. Although the negative pulse applied to the grid of tube **115** could not of itself effect the nonconduction of thyratron **115**, the sudden decrease of the plate potential of this tube accompanied by the decrease of its grid potential does permit this tube to be cutoff. The final result is then that thyratron **115** is cut off when thyratron **114** is rendered conductive. With the energization of the respective windings of relay CR reversed, this relay is then actuated to its opposite position. As soon as thyratron **115** is cut off, its plate potential rises and condenser **126** again charges thereby suddenly raising the plate potential of thyratron **114**. This increase of plate potential of the conducting thyratron does not affect, to any marked extent, the conduction of this tube.

The next pulse applied to the grid of thyratron **110** is of such polarity that it drives the grid of thyratron **114** negative and the grid of thyratron **115** positive. By analogy with the previous description, this occurrence causes thyratron **115** to conduct again and the negative pulse appearing on the plate of tube **114** along with the decrease of its grid potential then cuts off thyratron **114**. Relay CR is then actuated once more to its opposite position. Thus, this relay CR is operated to one position and then the other at a rate corresponding to the rate of application of code pulses to the track rails.

The embodiment of Fig. 5 includes two electron tubes **130** and **131** having their grids connected to opposite terminals of the parallel tuned circuit and their plates connected to opposite terminals of a primary winding of transformer T2. Since the cathodes of these tubes are both connected to the junction of resistors **63** and **64** shunting the parallel tuned circuit, substantially one-half of the voltage appearing across the receivers **60** and **61** is applied to the grids of these tubes but in opposite polarity. As the grid of one of these tubes is driven more positive with respect to its cathode at the beginning of a track code pulse, the grid of the other tube is driven correspondingly more negative. At the end of each track code pulse, the grid of the first of these tubes is driven negatively and the other tube is then driven correspondingly more positive.

Class A self-bias is preferably used with respect to tubes **130** and **131** in order that maximum gain may be derived from these tubes. This self-bias is provided by cathode resistor **134** which is shunted by condenser **135** to avoid degeneration of the input signal. If desired, however, other bias levels may be employed, and if a source of fixed bias potential is used the bias of these tubes may be adjusted to cutoff.

The input voltages applied to tubes **130** and **131** causes one of these tubes to conduct more heavily and the other to conduct less at the beginning of each code pulse in the track rails. As a result, a distinctive voltage variation of a particular polarity appears across the secondary winding of transformer T2. At the end of each pulse in the track rails, the situation is reversed, and a distinctive voltage variation of opposite polarity then appears across this secondary winding of transformer T2. Thus, a distinctive voltage of one polarity appears across this secondary winding at the beginning of each code pulse, and a similar appearing voltage of the opposite polarity appears across this secondary winding at the end of each code pulse.

The secondary winding of transformer T2 has a midtap connected to the negative terminal of a suitable source of bias potential such as battery **137**. The remaining terminals of this transformer secondary winding are connected to the grids of tubes **132** and **133** through resistors **138** and **139**, respectively. The plate of tube **132** is connected through resistor **140** to the control grid of tube **133**. The plate of tube **133** is similarly connected through resistor **141** to the control grid of tube **132**. The plate of each of these tubes is also connected through a corresponding load resistor and a winding of relay CR to the (B+) source. The cathodes of both tubes **132** and **133** are connected to ground.

The circuit organization with respect to tubes **132** and **133** constitutes an Eccles-Jordan, trigger circuit. Although shown as including triode tubes **132** and **133**, other tube types such as beam power tubes may be used for this circuit if desired. As is common with such trigger circuits, normally only one or the other of the two tubes included therein can be conducting and the other tube is at that time necessarily cut off. If, for example, tube **132** is conducting, the decrease of its plate potential because of plate current flow through load resistor **143** causes, because of the connection through resistor **140** to the grid of tube **133**, a decrease of potential on the control grid of tube **133** sufficient to bias this tube beyond cutoff. With tube **133** nonconductive, its high plate potential insures that the grid of tube **132** is at a suitably high potential. Actually, of course, the control grid of tube **132** is maintained at the cathode potential by reason

of grid current flow through resistors **141** and **142** and the lower winding of relay CR to the (B+) source.

Assume at the beginning of a track code pulse the polarity of the voltage swing appearing across the parallel tuned circuit is such as to make the upper terminal of the secondary winding of transformer **T2** negative with respect to the bottom terminal of this winding. A negative pulse is then placed upon the control grid of tube **132** and a positive pulse at the same time is then applied to the control grid of tube **133**. If the conduction status of this trigger circuit at this time is such that tube **132** is conducting and tube **133** is not conducting, the negative pulse applied to the grid of tube **132** will cause this tube to become cut off. The sudden reversal that then takes place causes tube **133** to conduct because the decrease of plate current of tube **132** causes an increase in the grid voltage of tube **133**. Previously, the conduction of tube **132** caused the energization of the upper winding of relay CR. Now, however, with tube **132** cut off and tube **133** conducting, this upper winding is deenergized and the lower winding of relay CR is instead energized. Each beginning and end of a code pulse in a track rail produces a corresponding pulse across the secondary winding of transformer T2 with successive pulses of opposite polarity. Consequently, the conducting status of tube **132** and **133** continually shifts from one to the other at a rate corresponding to the rate at which code pulses are applied to the track. Therefore, relay CR is also actuated to alternate positions at corresponding rates.

In this embodiment of the invention as in the embodiment shown in Fig. 4, the energization of relay CR is steady between successive reversals of energization. Therefore, although relay CR has been shown as a polar magnetic stick relay, this relay may, if desirable, instead be a three position polar relay.

Another possibility in connection with Figs. 4 and 5 resides in the fact that the relay CR could be replaced with two neutral relays with their contacts so connected as to jointly govern the decoding apparatus illustrated in Fig. 3. These alternative types of relays have been mentioned merely to emphasize the fact that in these forms of Figs. 4 and 5 the plate current of one or the other of the output control tubes is always flowing, and the magnetic stick characteristics of the polar relay CR are not required.

For the sake of simplicity in the drawing no trap circuit for interfering frequencies has been shown in the output circuit of the amplifiers of Figs. 4 and 5. However, it should be understood that a condenser and inductance, resonant to an interfering frequency, may be connected across the primary windings of the respective transformers T1 and T2 if desired for reasons discussed in connection with Fig. 3. It should be noted that all forms of this invention provide a composite organization in which trackway code pulses may be of direct current supplied from a battery or may be rectified alternating current of either the half or full-wave type. In any event, the use of these different types or unidirectional current provides that the vehicle-carried equipment responds distinctively at the beginning and end of each code pulse so that uniform operation of the code following relay is provided. This facilitates in the proper decoding of the rates employed.

The fact that the code pulse detecting means distinctively responds at the beginning and end of each trackway code pulse is particularly advantageous in a cab signalling system where safety is involved. This is because the failure of a particular tube or the breaking of a wire which might cause an intermittent connection cannot reproduce the effect provided by the trackway code currents. For this reason, the present organization is believed to be particularly advantageous over any similar system provided in the prior art.

The organization is further characterized by the feature that stray or undesired foreign voltages of alternating current are rendered ineffective to cause an erroneous indication in the cab signalling equipment.

Having thus described several forms of the present invention, it is desired to be understood that the various forms are selected to facilitate in the disclosure of the invention rather than to limit the number of forms which it may assume; and it is to be further understood that various modifications, adaptations, and alterations may be applied to the specific form shown to meet the requirements of practice, without in any manner departing from the spirit or scope of the present invention.

What I claim is:

1. In a cab signalling system for coded track circuits having code pulses of unidirectional current applied to the track rails at different rates dependent upon traffic conditions, vehicle-carried equipment comprising, receiver coils positioned in inductive relation to the track rails, means including capacitance and resistance connected with said receiver coils for damping said coils substantially to the critical value for giving a unidirectional output voltage of one polarity when each code pulse is applied and of the opposite polarity when each code pulse is removed, relay means having two different operating windings, means including a vacuum tube amplifier responsive to the output voltages of said receiver coils for supplying current to said windings of said relay means alternately as each code pulse is respectively applied and removed, and decoding means governed by said relay means for operating contacts differently in accordance with the rate of the code pulses existing in the track rails.

2. In a cab signalling system for use with a track circuit supplied with code pulses of unidirectional current applied at different selected rates in accordance with traffic conditions, the combinations including vehicle-carried apparatus comprising, a two channel amplifier capable of giving two distinctive outputs one for each channel, receiver coils positioned adjacent each of the rails and both connected in series to said two channels of said amplifier, circuit means including capacitance and resistance connected to said coils to tune said coils and to dampen the oscillations set up therein by the application and removal of said unidirectional pulses in the track to thereby cause one channel of said amplifier to give its distinctive output upon the application of each pulse in the track and cause the other channel of said amplifier to give its distinctive output upon the removal of each pulse from the track, relay means operable to two different conditions, circuit means connecting said relay means to said two channels of said amplifier for operation to its opposite conditions in response to said two distinctive outputs respectively, and decoding means controlled by said relay means to give different indications in accordance with the rates at which said relay means is operated by said pulses in the track.

3. In a cab signalling system for use with a track circuit supplied with code pulses of unidirectional current applied at different selected rates in accordance with traffic conditions, the combination including vehicle-carried apparatus comprising, receiver coils located on the vehicle adjacent the track rails, capacitance connected across said coils for tuning them to resonate at a relatively low frequency below the usual commercial frequencies, a damping resistor connected across said coils for damping to substantially the critical value the transient oscillations set up therein by the beginning and end of each code pulse in the track rails, said transient oscillations being thereby of opposite polarity for the beginning and end of each code pulse respectively, amplifier means connected to said coils for amplifying said transient oscillations, a code following two-position relay connected to said amplifier and operated alternately between its said two positions in accordance with the successively opposite polarity of outputs of said amplifier, and decoding means selectively controlled by said code following relay to give different indications in ac-

cordance with its rate of operation in response to the then existing rate of code pulses applied to the track rails.

4. In a cab signalling system for use with a track circuit supplied with code pulses of unidirectional current applied at different selected rates in accordance with traffic conditions, the combination including vehicle-carried apparatus comprising, receiver coils located on the vehicle adjacent the track rails, capacitance connected across said coils for tuning them to resonate at a relatively low frequency below the usual commercial frequencies, a damping resistor connected across said coils for damping to substantially the critical value the transient oscillations set up therein by the beginning and end of each code pulse in the track rails, said transient oscillations being thereby of opposite polarity respectively for the beginning and end of each code pulse, amplifier means connected to said coils for amplifying said transint oscillations, a code following two-position relay connected to said amplifier and operated alternately between its said two positions in accordance with the successively opposite polarity of outputs of said amplifier, a trap circut means of the resonated type tuned to the usual commercial frequencies, said trap circuit means being associated with said amplifier for removing the effect of any stray voltages of said commercial frequencies from the output of said amplifier to said code following relay, and decoding means selectively controlled by said code following relay to give different indications in accordance with its rate of operation in response to the then existing rate of code pulses applied to the track rails.

5. In a cab signalling system for railroads using track circuits supplied with pulses of unidirectional current coded at different rates selected in accordance with traffic conditions, the combination includng vehicle-carried apparatus comprising, pickup circuit means including receiver coils adjacent the track and inductively coupled thereto and also including a capacitance for tuning said pickup circuit means to a relatively low frequency, a damping resistor means connected to said pickup circuit means to cause it to give one distinctive output at the beginning of each current pulse in the track and to give a differently distinctive output at the end of each current pulse in the track, amplifier means connected to said pickup circuit means and including a plurality of vacuum tubes for giving correspondingly distinctive outputs as provided by said pickup circuit means, relay means operable to two different conditions, circuit means connected between said amplifier and said relay means for supplying one distinctive output to said relay for operating it to one of its conditions, said circuit means supplying the other distinctive output to said relay for operating it to the other of its conditions, and decoding means controlled by said relay means to give different indications in accordance with the rates at which said relay means is operated to its opposite conditions in response to said unidirectional current pulses in the track.

6. A cab signalling system for railroads comprising, a plurality of track circuits and means for applying code pulses of unidirectional current to said track circuits, vehicle-carried apparatus including receiver coils mounted in inductive relationship to the rails of said track circuit, capacitance connected with said coils to provide a resonant circuit tuned to a relatively low frequency below the usual commercial power frequencies, two equal damping resistors shunting said receiver coils, amplifying means including two channels of amplification and comprising, two input amplifier electron tubes biased above cutoff having their control grids connected to opposite terminals of said receiver coils and both cathodes connected to the junction of said resistors, a plate-cathode circuit for each of said input amplifier tubes including a load resistor, coupling circuit means for applying the output voltage across each of said load resistors between grid and cathode of corresponding relay control tubes both biased to cutoff, relay means operable to two different conditions and having two windings, a plate-cathode circuit for each of said relay control tubes including a winding of said relay means and a source of direct-current potential, and decoding means selectively operated by said relay means according to the coding rate of the track current.

7. A cab signalling system for railroads comprising, a plurality of track circuits and means for applying code pulses of unidirectional current to said track circuits, vehicle-carried apparatus including receiver coils mounted in inductive relationship to the rails of said track, capacitance connected with said coils to provide a resonant circuit for a relatively low frequency, resistance connected across said coils to dampen the electrical oscillations in said coils so that a distinctive voltage output of one polarity is provided for each application of a code pulse to said rails and another distinctive voltage output of opposite polarity is provided by each removal of a code pulse from said rails, amplifying means including two channels of amplification connected to said coils, relay means of the polarized type operable to two different conditions in accordance with its polarity of energization and including two windings each controlled by a respective channel of said amplifier, whereby said distinctive output voltage of one polarity causes said relay means to be operated to one condition and said distinctive voltage output of the opposite polarity causes said relay means to be operated to the opposite condition, and decoding means governed by said relay means and selectively operated according to the coding rate of the track current.

8. A cab signalling system comprising, a plurality of coded track circuits having pulses of half-wave rectified alternating current applied to the track rails, train-carried apparatus including receiver coils mounted in inductive relationship to said rails, capacitance connected with said coil to tune said coils to a relatively low frequency, resistance connected with said coils and capacitance to dampen the oscillations in said coils and capacitance to produce a distinctive output voltage of one polarity at the beginning of each code pulse and another distinctive output voltage of opposite polarity at the end of the code pulse, code-following relay means operable to two different conditions, means including electron tubes connected to said receiver coils for operating said relay alternately to its different conditions in response to said distinctive voltage variations, trap circuit means connected with said electron tubes and tuned to the frequency of the source of said coded track current to attenuate the alternating variations present in said distinctive output voltages, and decoding means governed by said relay means and selectively operated according to the coding rate of the pulses applied to the track rails.

9. In a cab signalling system for railroads, a plurality of coded track circuits and means for applying pulses of unidirectional current to the rails of each track section at selected rates dependent upon traffic conditions, vehicle-carried apparatus comprising, receiver coils mounted in inductive relationship with said track rails, capacitance and associated damping resistance connected with said coils to cause said coils to provide a distinctive output voltage of one polarity as each code pulse is applied to said rails and another distinctive output voltage of the opposite polarity as each code pulse is removed from said rails, a dual-triode type trigger circuit operable to either of two stable conditions and including two electron tubes connected to said receiver coils, relay means operable to two different conditions and governed by said trigger circuit so as to be operated to one of its conditions when said trigger circuit is in one stable condition and to the other of its conditions when said trigger circuit is operated to its other stable condition, and decoding means governed by said relay means and

distinctively operated according to the coding rate of the unidirectional pulses applied to the rails of said track circuits.

10. A cab signalling system for railroads comprising, a plurality of coded track circuits having direct-current pulses applied to the track rails at different rates dependent upon traffic conditions, vehicle-carried apparatus including receiver coils mounted in inductive relationship to said rails, capacitance shunting said receiver coils to form a tuned circuit for a relatively low frequency, resistance connected with said coils to dampen the oscillations of said tuned circuit, whereby a distinctive output voltage of one polarity is provided by each application of a code pulse to said rails and another distinctive voltage output is provided corresponding to each removal of a code pulse from said rails, code-following relay means operable between respective picked-up and dropped-away positions, means including electron tubes connected to said receiver coils for operating said relay alternately between said positions in response to said distinctive output voltages, and decoding means governed by said relay means and selectively operated according to the coding rate of the pulses applied to the track rails.

11. In a cab signalling system for railroads, a plurality of track circuits and means for applying pulses of unidirectional current to said track circuits at selective rates according to traffic conditions, vehicle-carried equipment comprising, receiver coils positioned in inductive relationship to the track rails, capacitance and resistance connected with said coils to respectively tune said coils and dampen the oscillations therein, whereby a distinctive voltage output of one polarity is produced at the beginning of each code pulse and another distinctive voltage output of the opposite polarity is produced at the end of each code pulse, amplifier circuit means including an electron tube biased above cutoff and having said distinctive output voltages applied between its grid and cathode thereby providing corresponding distinctive voltages across a load impedance included in the plate-cathode circuit of said electron tube, circuit means including two gaseous discharge tubes biased beyond cutoff, coupling circuit means for causing said distinctive voltages appearing across said load impedance to be simultaneously applied with opposite polarity between grid and cathode of each of said gaseous discharge tubes, relay means operable between respective picked-up and dropped-away positions and including two windings, a plate-cathode circuit of each of said gaseous discharge tubes including a winding of said relay means, and decoding means selectively operated by said relay means according to the coding rate of the track current.

12. A cab signalling system for railroads comprising, a plurality of track circuits and means for applying code pulses to the rails of said track circuits at selected rates dependent upon traffic conditions, vehicle-carried apparatus including, receiver coils inductively positioned with respect to said rails, capacitance and resistance connected with said coils to respectively tune said coils and to dampen the oscillations appearing in said coils so that a distinctive voltage output of one polarity is provided corresponding to the beginning of each track code pulse and another distinctive voltage output of opposite polarity is provided corresponding to the end of each code pulse, amplifier means including an electron tube biased above cutoff and having said distinctive voltages applied between its grid and cathode to produce corresponding distinctive voltages across a load impedance included in the plate-cathode circuit of said electron tube, circuit means including two gaseous discharge tubes biased beyond cutoff, coupling circuit means for causing said distinctive voltages appearing across said load impedance to be simultaneously applied with opposite polarity between grid and cathode of each of said gaseous discharge tubes, a condenser connected between the plate electrodes of said gaseous discharge tubes, relay means including a two-position relay operable to either of its two positions and including two windings, a plate-cathode circuit for each of said gaseous discharge tubes including a winding of said relay means and a source of direct-current potential, whereby the application of said distinctive voltage of positive polarity between grid and cathode of one of said gaseous discharge tubes causes said tube to become conductive and the resultant decrease of plate potential of said tube applied through said condenser to the plate of said other gaseous discharge tube contemporaneously with the application of said distinctive voltage of negative polarity between grid and plate of said other tube causes said other tube to become nonconductive, thereby causing said relay to be actuated alternately to its different positions, and decoding means selectively operated by said relay means according to the coding rate of the track current.

13. A cab signalling systetm for railroads comprising, a plurality of track circuits and means for applying pulses of unidirectional current to the track rails at selected rates according to traffic conditions, vehicle-carried apparatus including receiver coils positioned in inductive relationship with said track rails, capacitance and resistance associated with said receiver coils to respectively tune said coils and to dampen the oscillations appearing therein, whereby transient output voltages are produced by said receiver coils at the beginning and end of each track code pulse, relay means including a two-position relay operable to either of its two different positions, circuit means including electron tubes connected with said receiver coils and responsive to said transient output voltages for governing the operation of said relay means alternately to one position and then the other, and decoding means selectively controlled by said relay means according to the coding rate of said track current.

14. In a cab signalling system for railroads comprising, a plurality of track circuits means located adjacent said track circuits for applying code pulses of unidirectional current to the track rails of said track circuits at selected rates in accordance with the existing traffic conditions, vehicle-carried apparatus including receiver coils inductively associated with the track rails, capacitance connected with said receiver coils to tune them to a relatively low frequency, a resistance connected across said receiving coils to dampen the oscillations appearing therein whereby transient output voltages are produced by said receiver coils at the beginning and end of each track code pulse, circuit means including electron tubes connected to provide a trigger circuit operable to either of two stable conditions, said circuit means being connected to said receivers and responsive to said transient output voltages so as to be operated to its opposite stable conditions alternately, relay means including a two-position relay operable between its two different positions alternately by the operation of said circuit means, and decoding relay means selectively controlled by said relay means in accordance with its rate of operation as governed by the selected rate of the trackway code pulses.

15. A cab signalling system for railroads comprising, a plurality of track circuits and means for applying pulses of unidirectional current to the rails of said track sections at different rates dependent upon traffic conditions, vehicle-carried equipment comprising receiver coils positioned in inductive relationship to said track rails, circuit means connected with said receiver coils for dampening the electrical oscillations in said coils caused by the application and removal of each track code pulse to give an output voltage of one polarity at the beginning of each code pulse and another output voltage of opposite polarity at the end of each code pulse, code following relay means including a two-position relay operable between its two different operated positions, amplifier means including two electron tubes each having a control grid and cathode and plate, said control grid of each of such tubes connected

to a terminal of said receiver coils through a grid resistor, whereby an intermittent shunting of said grid and plate electrodes of either of said electron tubes produces a large voltage drop across the associated grid resistor thereby preventing a large voltage drop across said receiver coils as might otherwise result in transient oscillations appearing across said receiver coils, circuit means connecting said relay means to said amplifier means whereby said relay means is operated to its different positions in response to said output voltages, and decoding means governed by said relay means and selectively operated according to the coding rate of said track current.

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