

March 14, 1967

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3,309,516

RAILWAY SIGNALING SYSTEMS

Filed April 16, 1964

6 Sheets-Sheet 1

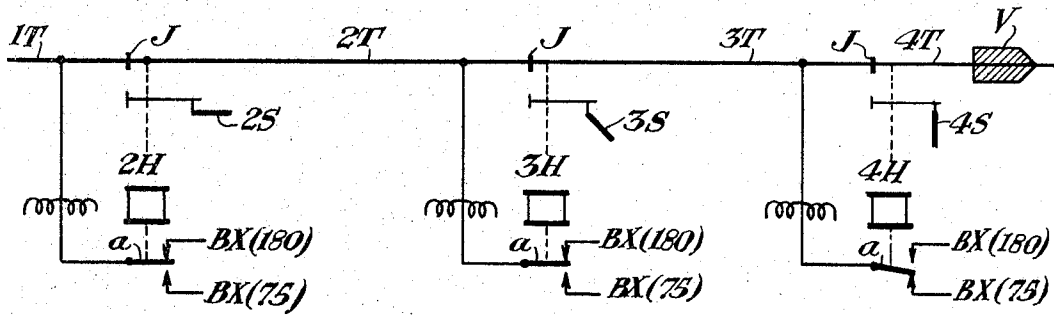


Fig. 1A.

PRIOR ART.

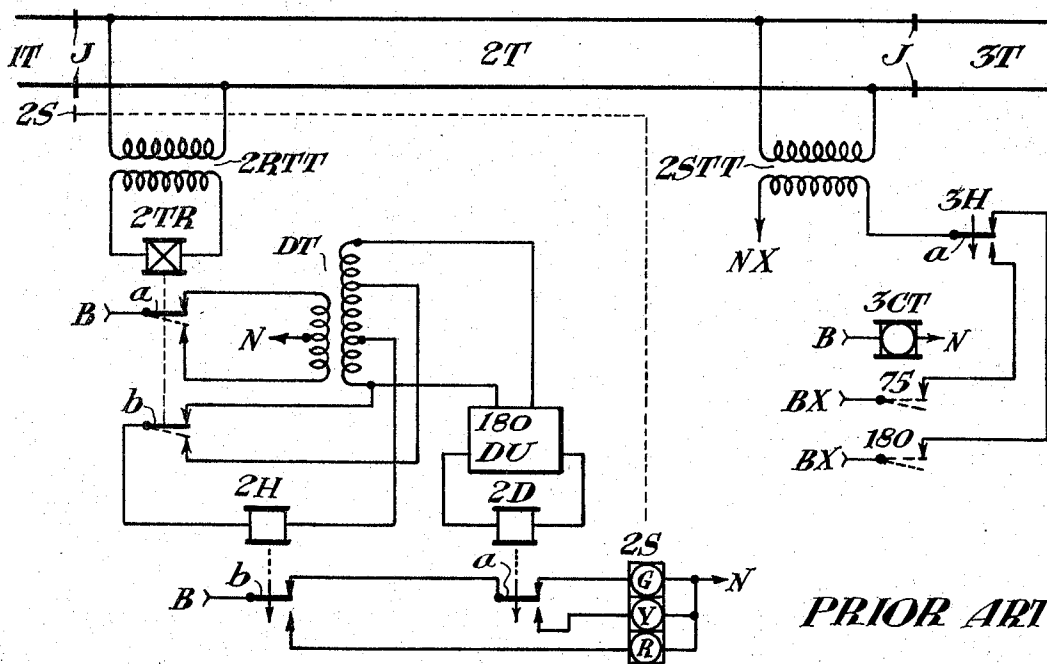


Fig. 1B.

PRIOR ART.

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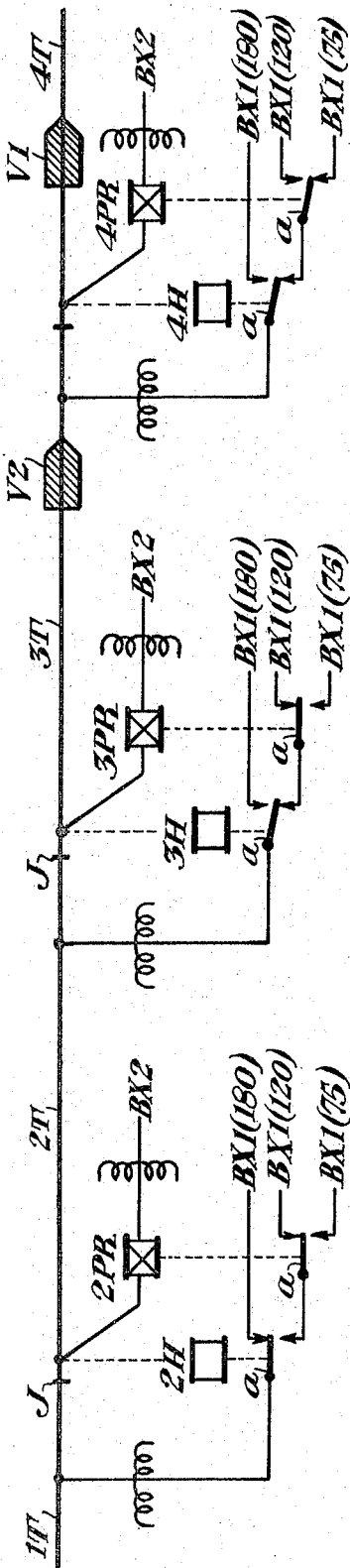


Fig. 2A.

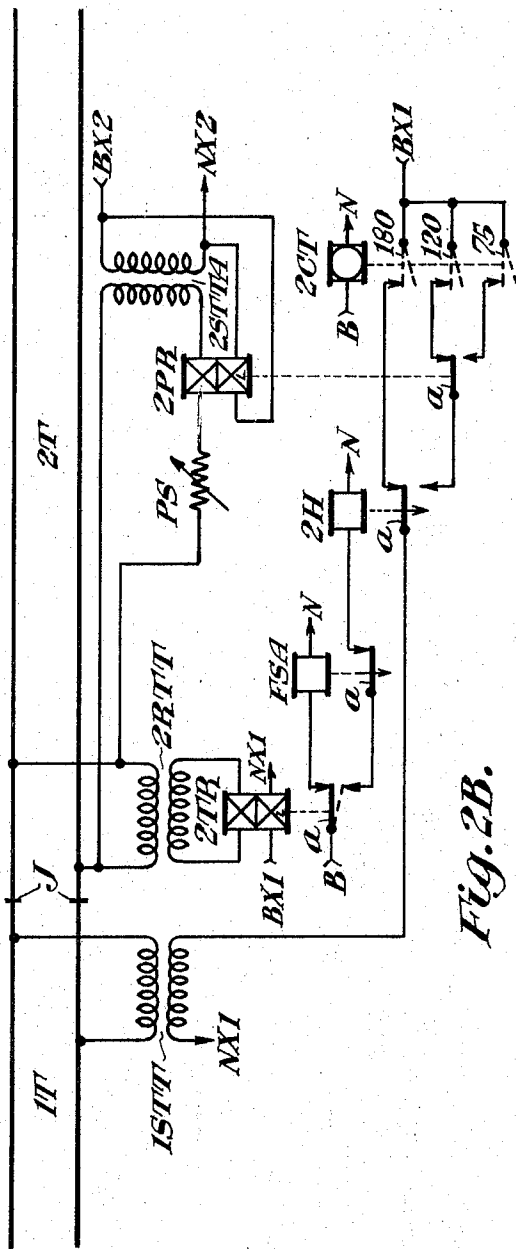


Fig. 2B.

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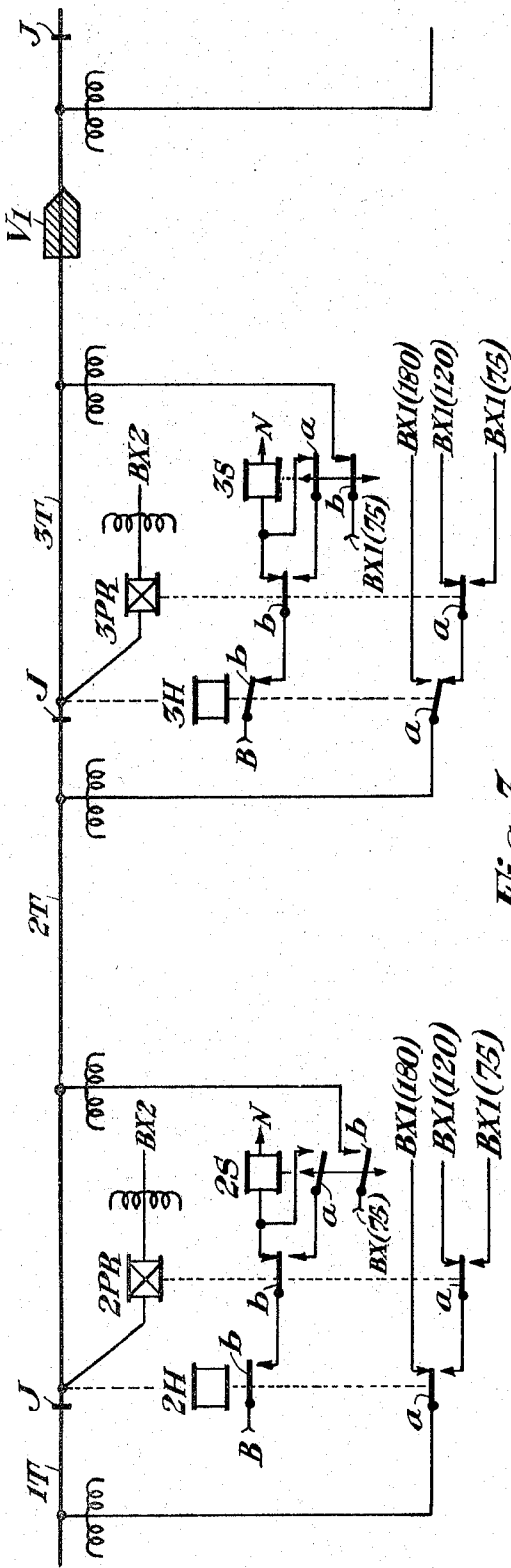


Fig. 3.

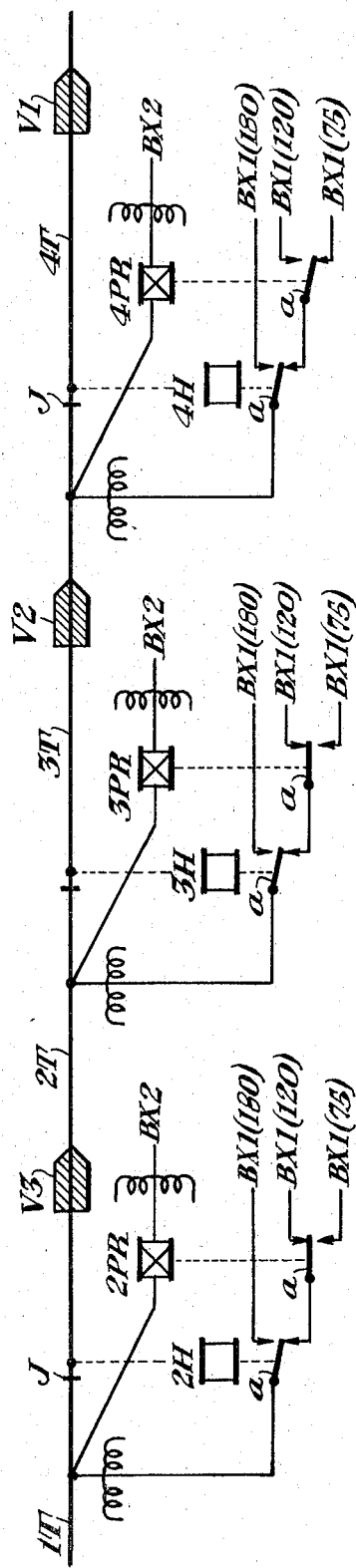


Fig. 4.

March 14, 1967

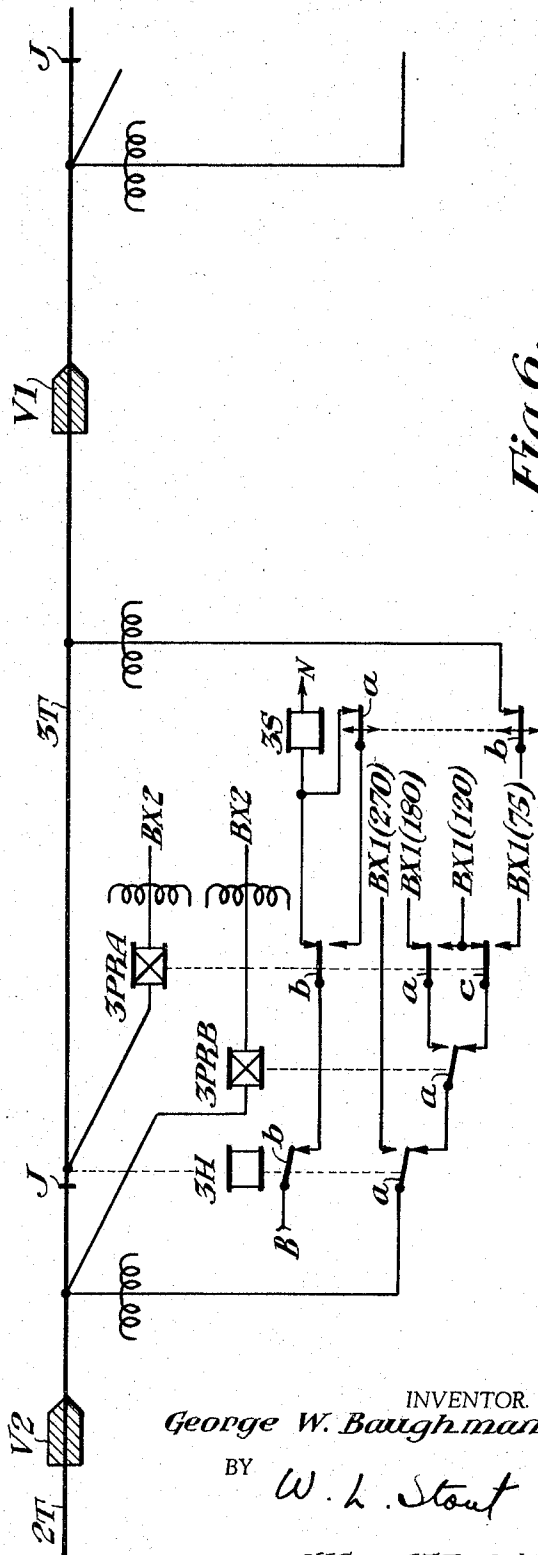
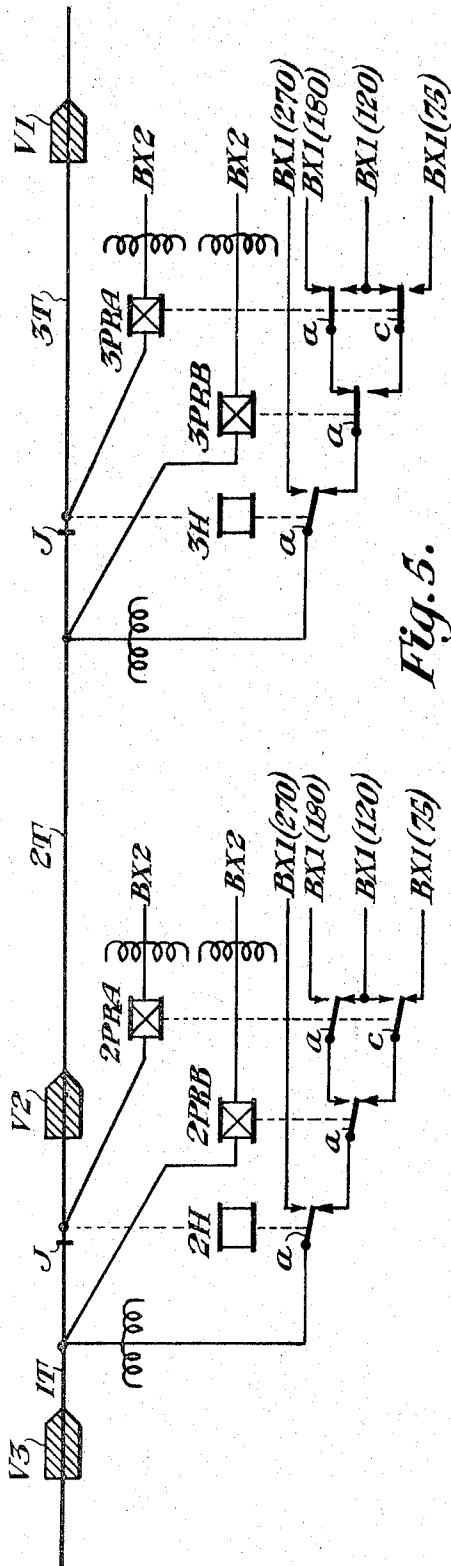
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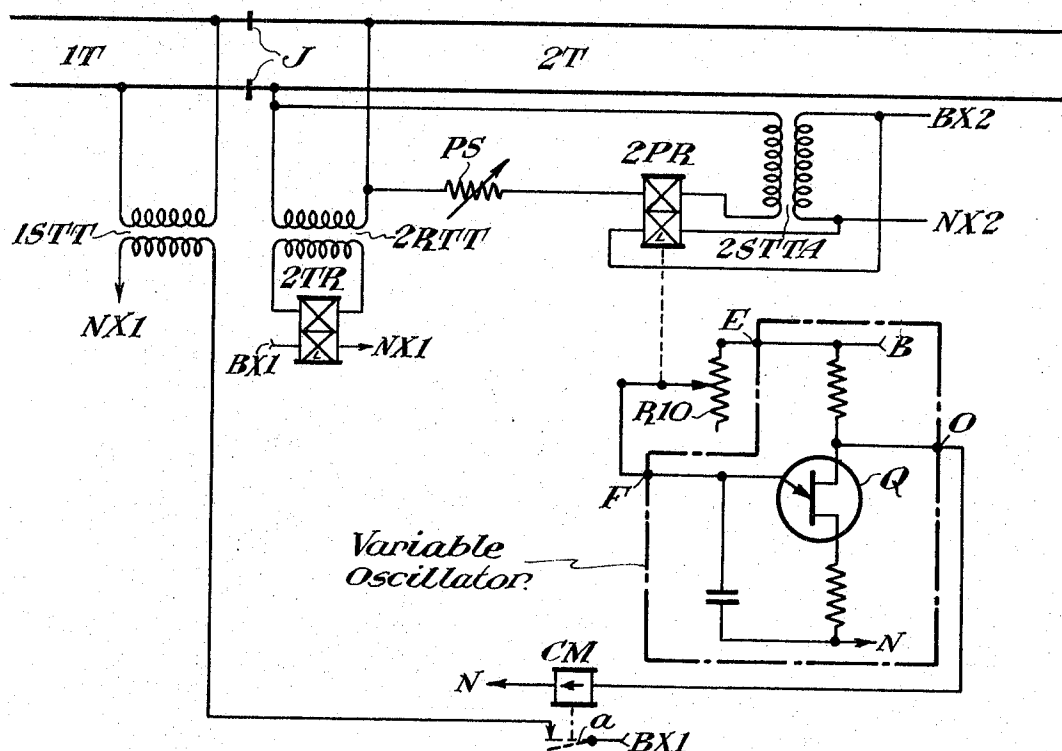


Fig. 7.

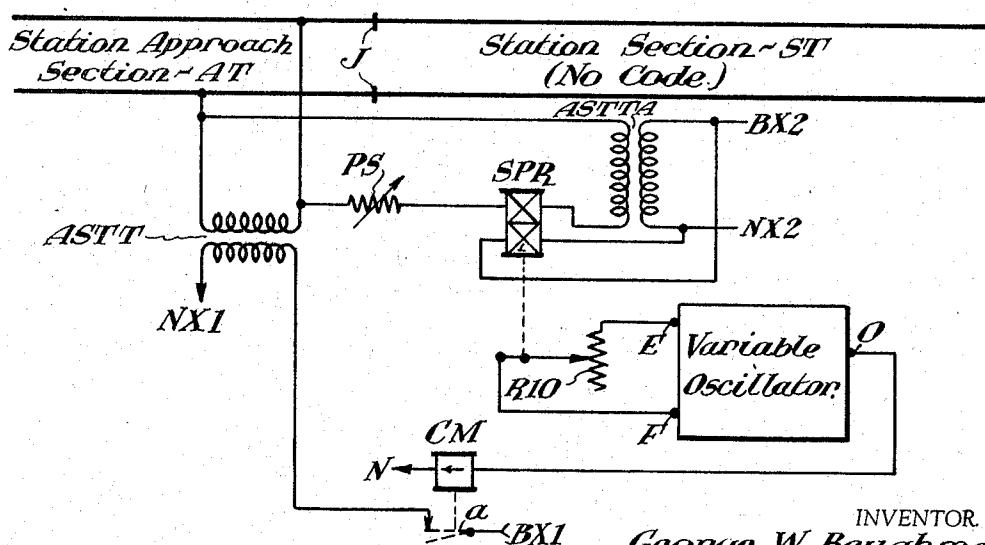


Fig. 8.

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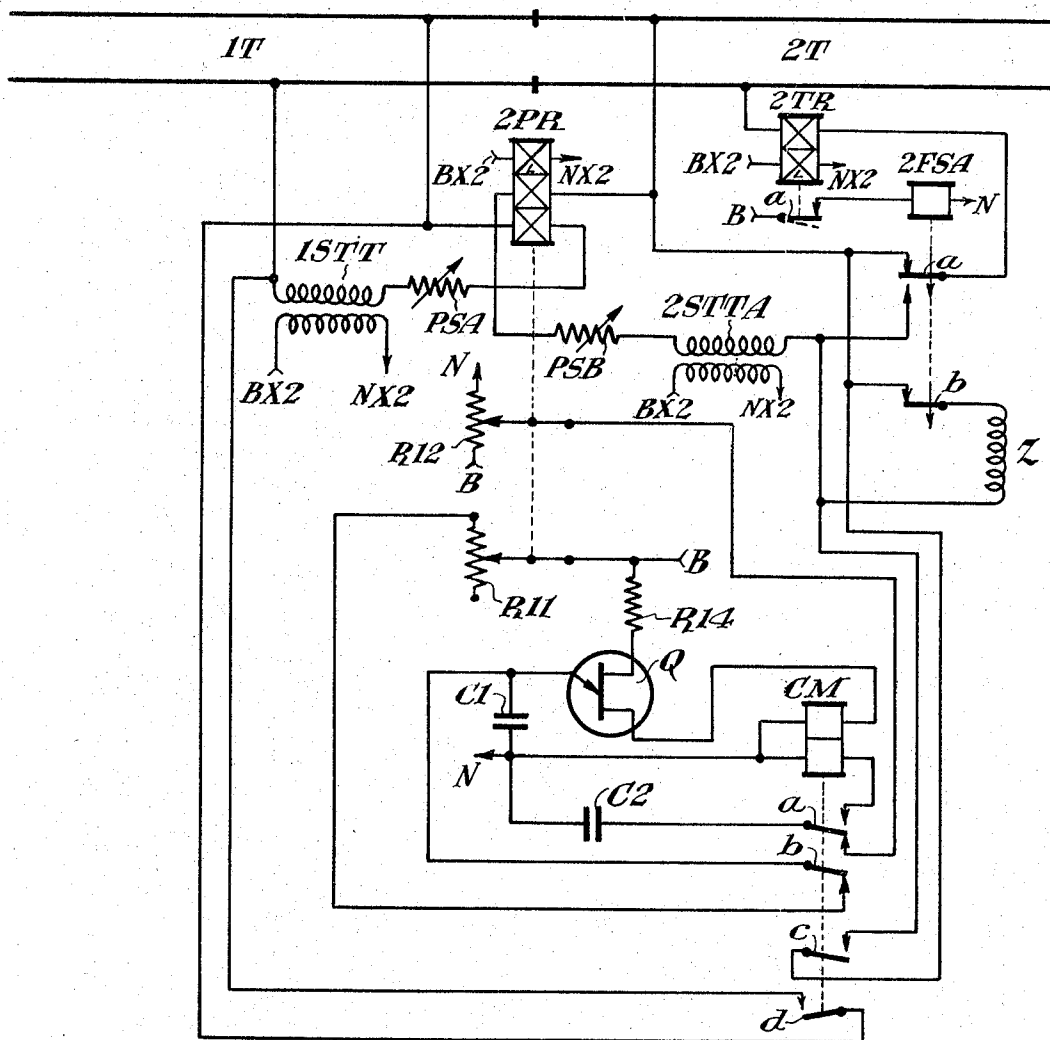


Fig. 9.

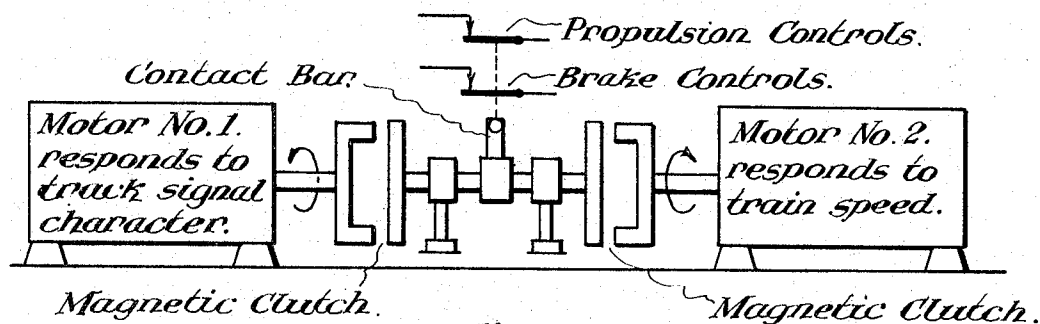


Fig. 10.

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RAILWAY SIGNALING SYSTEMS

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18 Claims. (Cl. 246—34)

My invention relates to railway signaling systems. More specifically, my invention pertains to a railway signaling system for controlling trains which are equipped with cab signals and/or speed control apparatus with no wayside signals provided. The disclosed arrangement provides means for improving the signal indication displayed or the speed control enforced in accordance with the relative advance of, or the distance to, a preceding train.

A specific problem faced by those designing signaling systems for railways, particularly where the frequency of train movements over the track is high as in rapid transit systems, is the provision of means for reducing the headway, i.e., the spacing, between the trains without unduly increasing the cost of the overall system, both as to its installation and its maintenance. In prior art signaling systems designed along conventional lines, the headway between the trains is established by the length of the insulated track sections into which the stretch of railway track is divided. The relationship between the signal indications and the track sections in such systems is expressed in terms of a number of sections providing a similar number, plus one, of possible signal indications. One commonly used arrangement, for example, is defined by the descriptive phrase, a two section-three indication signaling system. Since each train moves at the speed indicated by the aspect displayed by the last wayside signal which that train has passed, each section in this specific example must provide full braking distance so that a train moving at the maximum allowed speed may stop within the next section length on receiving a caution or approach signal indication. This indication is the only possible proceed aspect other than a clear signal and indicates that the second section in advance of the signal is occupied by a preceding train.

Having received such a caution signal, a train, having reduced to the slower speed, maintains that speed throughout the next section regardless of the actual position of the preceding train in the section in advance. Even where cab signals are used to provide a continuous signal indication on the train itself, no change, that is, no increase in train speed, is authorized as long as a preceding train remains anywhere in the next section in advance. Thus a preceding train must move completely out of the section it then occupies before a change to a more favorable signal indication can occur in the cab signal apparatus of an immediately following train. Of course, with cab signals, this change to an improved indication is received immediately as it occurs and an increase in train speed is not delayed until the next wayside signal is reached. If the well known code change or B-point arrangement is used in connection with the cab signal system, a train moving at the approach speed required by a caution signal can advance nearly to the end of the track section before a final stop is made just beyond the B point, i.e., just short of the occupied section, even where wayside signals are not used. However, in spite of such arrange-

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ments and the advantage of receiving an improved indication on the cab signals as it occurs, the train speed and headway between trains is still severely limited by the length of the track sections required to provide full braking distances.

In order to obtain closer headway between successive trains using such conventional prior art signal systems, it is necessary to provide additional signal indications and thus additional track sections. In other words, the existing sections must be divided into shorter length portions of track. This, of course, requires more insulated joints and more wayside apparatus. Thus the expense of installation and the cost of maintenance, especially the cost of maintaining the insulated joints, is increased. This problem of providing close headway becomes particularly acute in rapid transit systems where it is desirable to operate on the closest possible headway during rush hours in order that the maximum number of people may be moved in as short as possible time within the train length limits imposed by station platforms. Here, of course, the trains are more responsive to control, whether it be manual by an operator or automatic as provided by speed control apparatus. Such increased responsiveness enables these trains to move at higher speeds as they close up upon trains ahead and still maintain safe operating conditions. Thus it is of advantage to be able to determine the relative location of the train ahead within a particular track section between signal points. For example, it is of advantage to be able to determine whether the next train in advance is in the first or immediately adjacent portion of the advance section or whether it has moved into a more distant portion of such advance section. Said in another way, it is of advantage to determine the relative distance between successive trains and allow the signal indication to be controlled in accordance with this relative distance in addition to the control provided by the existing track section locations.

Accordingly, it is an object of my invention to provide an improved type of railway signaling system.

Another object of my invention is an improved signaling system for controlling trains through the use of train carried signaling apparatus.

Another object of my invention is a cab signaling system for a railroad which permits closer headway and higher speeds for following trains.

A further object of my invention is a railway signaling system with supplemental detection apparatus to provide an indication of the relative position of a train within a conventional track section.

Another object of my invention is a cab signaling system, for control of railroad operations, which supplements the section control of the signal indications by varying the control for such indications in accordance with the measurement of the relative distance between successive trains occupying adjacent track sections.

It is also an object of my invention to provide a coded cab signaling system in which the track codes supplied to a section are controlled both by the occupancy of the track section in advance and by the relative distance between successive trains.

Still another object of my invention is a coded cab signaling system for railways which supplements the track circuit control of code rates with a control in accordance with the relative distance measurement to the train posi-

tion provided by supplemental, phase sensitive track circuits.

A further object of my invention is a coded railway signaling system including cab signals in which the code rate supplied to a following train in an adjacent section is varied in accordance with the measured distance the preceding train has advanced in the section it is then occupying.

It is further an object of my invention to provide a coded signaling system in which distance measurements provided by supplemental, phase sensitive track circuits are used to modify the code rate supplied to the signal system in order to allow higher speeds by the following trains.

Other objects, features, and advantages of my invention will become apparent in the following specification when taken in connection with the accompanying drawings.

In practicing my invention, I supplement a conventional coded railway signaling system including conventional track sections, each with its coded track circuit, by adding thereto track circuits of the phase sensitive or, as sometimes called, the phase responsive type to determine relative distances to or between moving trains. The basic track circuits of the conventional system may also control wayside signals but are specifically intended in my arrangement to control continuous cab signal apparatus, or speed control apparatus, carried on the trains moving over the track stretch. This cab signal speed control apparatus is responsive only to alternating track current of a preselected frequency. The signal indication displayed, or the speed control enforced, on the train is determined by the signal character carried by the cab signal track current. In the specific system shown in this application, this signal character is generally a code rate at which the track current is interrupted but other possible types of character will also be described. My system is thus based generally on conventional coded alternating current track circuits, of a frequency to which cab signal or speed control apparatus carried by the trains is responsive. Specifically, the alternating current flowing in the rails, which is interrupted or coded at a selected rate to provide a distinctive signal character, by induction influences, i.e., controls, the train carried apparatus to provide the signal indications and/or speed control. In some arrangements of my invention illustrated, the phase sensitive track circuit serves two purposes providing cab signal control as well as train distance determination.

The phase sensitive track circuits which are added by my invention to the conventional system are also, of themselves, of a well known type. Explained briefly, these circuits are responsive to the phase shift, between the track current and the applied voltage, caused by the impedance of the track rails. As used in my invention these phase sensitive track circuits, normally of a different frequency than the cab signal track circuits, are fed into the rails at a selected point and include the rails to the nearest rail shunt which is, generally, the wheels and axles of a train occupying that portion of the track. In one form, by adjustment of the parameters or elements of the phase sensitive circuit, a phase responsive device, e.g., a track relay, can be made to respond to the phase shift resulting when a selected rail impedance exists due to a particular length of track. In other words, the track relay of the phase sensitive circuit is made to respond, that is, pick up or release, when at least a selected length of rail is included between the source of supply of the circuit and the nearest track shunt. In another modification, the elements of the circuit and its adjustment are arranged so that the relay device develops different amounts of torque in accordance with the actual length of the rails included in the circuit to the shunt. That is, in this modification the torque developed in the track relay, resulting in a varying position of its moving elements,

provides an indication of the relative distance of track rails included in the circuit.

As actually shown in the disclosed system, the distinctive energy for the supplemental phase sensitive circuits is fed into the rails from specific wayside locations, i.e., the location of insulated joints between existing track sections. It is at this location that other track circuit apparatus is also located in order to supply the conventional track circuit and cab signal energy. At this location, the track circuit for the section in advance of the location terminates and provides train detection. At such a location, the conventional track circuit for the track section in approach is supplied with energy and the code rate selected at which that track circuit energy is interrupted.

In the basic form of my invention shown, the phase sensitive track circuit is used to detect the distance from the joint location to the rear of a train which is moving away through the stretch of railway track, that is, moving away from the location through the advance track section. Specifically, in this basic use the phase sensitive track circuit provides an indication of the passage of the complete train by a selected point, in the advance track section, a predetermined distance away from the joint location. This indication is then used to change the code rate of the cab signal energy applied to the approach track section, improving this code rate to provide a less restrictive signal indication to an approaching train.

I also use the phase sensitive track circuit to detect the arrival of the train at a selected point in such an approach track section. Under these conditions, the indication of the arrival of this approaching train is used to cause a more restrictive indication, i.e., a less favorable code rate, to be supplied if the advance section is at that time occupied by another train. If both such circuit arrangements are jointly used, the relative distance between successive trains may be established, limited only by the insulated joints at the distant ends of the track sections involved. Under such an arrangement, both distance indications are used jointly to vary the code rate selected for the cab signal energy supplied to the approaching train, a more or less restrictive code rate being selected as the total distance between the trains decreases or increases. Modifying this last arrangement by changing the type of coding apparatus, it is possible to provide a continuously varying code rate at which the cab signal energy may be interrupted rather than selecting between specific code rates fixed at predetermined intervals. With such modification, it becomes possible to dispense with the conventional track circuits so that a train controls its own rate of approach to a specific location which may be the site of a station platform at which the train is to stop. The measured distance to the head of the approaching train is then used to determine the rate of variation of the code rate so that a smooth decrease in the speed of the approaching train may result and an accurate stop at the station platform controlled.

I shall now describe in greater detail the arrangement of the various forms of my invention and shall then point out the novelty thereof in the appended claims. During this detailed description, reference will be made from time to time to the accompanying drawings in which:

FIG. 1A shows in schematic form a conventional prior art signaling system for the purpose of comparison and as a base to which the improvements of my invention are added.

FIG. 1B illustrates the details of a conventional track circuit in diagrammatic form, this circuit illustrating that provided for any one of the track sections of FIG. 1A.

FIG. 2A is a schematic illustration of a coded signaling system using the first basic form of my invention added to the conventional prior art system.

In FIG. 2B, a diagrammatic track circuit arrangement is illustrated for any one of the track sections of the system of FIG. 2A.

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FIG. 3 is a schematic showing of a modification of the system arrangement of FIG. 2A.

In FIG. 4, another signaling system is illustrated using a second form of the arrangement of my invention.

FIG. 5 is a schematic illustration of a third form of my invention combining the basic arrangements of FIGS. 2A and 4.

The arrangement shown in FIG. 6 adds the modification of FIG. 3 to the system arrangement illustrated in FIG. 5.

FIG. 7 is a diagrammatic circuit showing of a wayside location for the form of my invention which provides for continuous variation of the code rate for the cab signal energy.

The circuit diagram of FIG. 8 is an arrangement of FIG. 7 modified for controlling the stopping of a train at a station platform.

The diagrammatic circuit arrangements at a wayside location shown in FIG. 9 illustrates still another form of the arrangement of my invention in which the phase sensitive track circuit is also used to provide the cab signal energy for trains using the stretch of railroad track.

FIG. 10 is a schematic illustration of one possible form of train carried speed control apparatus cooperating with the track circuit arrangements illustrated in FIGS. 7, 8, and 9.

In each of the drawings similar reference characters refer to similar parts of the apparatus. In general, conventional symbols have been used throughout the drawings to designate the various items of the apparatus. Where special symbols have been used, the significance thereof will be explained at the proper place in the specification where reference is first made to that type of apparatus. At each wayside location in each of the drawings, and for the train carried apparatus of FIG. 10, a local source of direct current energy is provided for supplying the relays and similar type apparatus. Any one of several well known sources for such direct current energy may be used here. However, for simplicity, the specific source is not shown but connections to its positive and negative terminals are designated by the reference characters B and N, respectively. In a similar manner, the sources of alternating current available at each wayside location for supplying the track circuits are likewise not specifically shown but their terminals are designated by the general reference characters BX and NX. Where alternating current sources of different frequencies are required, numerical suffixes have been added to these general reference characters BX and NX to distinguish between the specific frequencies. Throughout the various circuit arrangements, slow acting relays are distinguished only by arrows drawn in a vertical direction through the movable parts of the relay contacts. In such cases, the direction of the arrowhead indicates the direction in which the relay is slow acting, that is, slow release or slow pick up. To provide a complete understanding, the term slow release is herein defined as a relay which retains its front contacts closed for a selected period of time after the relay winding is deenergized. Conversely, a slow pick up relay is one in which the front contacts are closed and the back contacts opened only after a selected period of time has elapsed following the initial energization of the relay winding. The local winding of multiple winding or element alternating current track relays is designated by the symbol L within the conventional winding symbol.

Referring now to FIG. 1A, wherein is illustrated in schematic form a conventional prior art coded railway signaling system commonly designated as a two section-three indication signaling system using wayside signals. However, the coded track circuits used in this system are of the alternating current type in order to provide at the same time energy for cab signal apparatus carried by trains moving through this section. It is to be understood that the novelty of my invention is in the arrange-

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ment added to this prior art system and it is shown herein only to establish a base upon which the improvements may be added. It will therefore be explained only briefly in order to establish the conventional symbols used.

A single line symbol is used to indicate the stretch of railroad track which is divided by insulated joints J into various sections. Each such track section is designated by the general reference character T to which is added a prefix numeral to distinguish between the sections, the numbering being in the direction from left to right. This is also the normal direction in which traffic moves through this stretch of track. It is to be noted that the entrance of a train into each track section is governed by a three-position signal, each such signal being designated by the general reference character S prefixed by a numeral corresponding to the section into which the movement is controlled. In other words, these three-position signals provide signal indications commonly called proceed, approach, and stop which are shown conventionally in the diagram by, respectively, signals 2S, 3S and 4S. In order to establish the language used hereinafter, the signal indications of proceed and caution are also at times described as permissive indications. It is to be understood that the proceed indication is a more favorable indication than is the approach or caution aspect. Although the wayside signals are shown by conventional semaphore symbols, the basic system to which my invention is added is not limited to the use of such type signals.

Each section of this stretch of track is provided with a coded alternating current track circuit supplied with energy at the exit end of the track section, the supply of energy being shown in a conventional manner. It is to be noted that the track transformer conventionally used in such circuits is here indicated by a single winding symbol which is conventional in the art. The coded alternating current supply for these track circuits is selected over contacts of the home signal relay H associated with the section in advance of the signal location. For the coded alternating current supply, the parenthetical suffix added to the reference character BX indicates the code rate of the supply in cycles per minute or pulses per minute, as is conventionally used. In these schematic circuits, only the BX terminal of the source is shown.

The track circuit control of each home signal relay is indicated by the conventional dotted line connected to the track symbol at the entrance end of the section to which the relay H is associated. Each such home relay reference character H is prefixed by a numeral corresponding to that of the associated track circuit. This conventional indication of the control by the track circuit over the home signal relay will be used by the schematic illustrations in this application. The complete circuit for the control of such relays will shortly be discussed in connection with FIG. 1B. It may be briefly said that each relay H is energized, i.e., in its picked up condition, when no train is occupying the corresponding section. Conversely when the associated track section is occupied by a train, the home relay H releases and remains in that position. As specifically illustrated, with a train V occupying section 4T, relay 4H is in its released condition and signal 4S is thus displaying the stop indication. Also, over back contact *a* of relay 4H, alternating current coded at a 75 code rate, as designated by the reference character BX(75), is supplied to the track circuit for section 3T. Briefly, relay 3H is thus energized and picked up but signal 3S displays only the approach indication reflecting the reception of 75 code rate through track section 3T. However, the alternating current supply to section 2T is coded at the 180 code rate as selected over front contact *a* of relay 3H. Thus, relay 2H is picked up and signal 2S displays the proceed indication.

Referring now to FIG. 1B, illustrated therein is a detailed circuit arrangement for the track circuit for section 2T shown schematically in FIG. 1A. This particular circuit diagram establishes a basis for much of the appa-

tus shown conventionally in other figures of the drawings. In FIG. 1B, the track section is shown by a diagrammatic two rail symbol, the rails being insulated from those of the adjacent sections 1T and 3T by the usual insulated joints designated at J. At the supply or energy end of the track circuit, that is, at the right, the secondary of track transformer 2STT is connected across the rails of this section. The primary of this transformer is supplied with alternating current from the usual source designated by terminals BX and NX. However, the supply circuit for this primary winding includes a selection of the desired code rate of interruption of the alternating current. For example, a code transmitter 3CT is illustrated at the right side of the drawing by a special relay symbol. The winding of the transmitter is permanently connected between the terminals B and N of the local direct current source. Code transmitter 3CT is indicated as having at least two sets of code following contacts. The symbol used for the movable portion of these contacts is shown by dash lines in each of its two alternate positions to designate that the contact is continuously operating, i.e., coding as driven by the winding of the transmitter. Each set of contacts is designated by a numeral indicating the code rate at which the contact opens and closes during this coding operation. In the specific showing here, the upper contact is designated as operating at the 75 code rate while the lower contact of the two is designated as the 180 code rate contact. Although the form of code transmitter indicated shows contacts having different code rates driven by the same transmitter, it is to be understood that separate code transmitters each having an assigned code rate may be used if desired. The code rate of the alternating current supplied to the primary of the track transformer is selected over a front or back contact of home relay 3H. As indicated, it is assumed that track section 3T is not occupied by any train so that relay 3H is energized in a manner previously explained and the 180 code rate is selected over front contact *a* of this relay. Thus, the track circuit at its energy end is continuously supplied with alternating current, here interrupted at the 180 code rate as selected in accordance with the occupancy condition in advance of this section.

At the relay end of the track circuit, that is, the left or entrance end of section 2T, the track current is received through the windings of another track transformer 2RTT by track relay 2TR. Relay 2TR is shown as an alternating current track relay of the code following type. However, if the output of the secondary winding of transformer 2RTT is rectified, a direct current code following relay may be used. Since track relay 2TR is normally energized, the movable portion of its contacts are shown solid in the upper position. But since the energy received is interrupted at a selected code rate, this fact is designated by the dash symbol for the movable portion of the contacts shown in the lower position. The operation of contact *a* of relay 2TR obviously energizes in opposite directions the two parts of the primary winding of the conventional decoding transformer DT. A portion of the secondary winding of transformer DT is connected to energize home signal relay 2H, the circuit arrangement including transfer contacts *b* of relay 2TR for purposes of mechanical rectification of the output of the transformer secondary. This is necessary since relay 2H is a direct current relay with slow release characteristics. This type of code detection circuit arrangement is conventional and well known in the art and needs no detailed explanation.

The secondary of transformer DT also supplies a low frequency alternating current to the decoding unit designated 180DU. This is a tuned circuit device which further includes a rectifier so that its output may be used to energize the direct current relay 2D which is officially the distant signal relay. The numerical prefix for the designation of the decoding unit, that is, 180, indicates that the tuned circuit is made responsive to an input alter-

nating current having a frequency of 180 cycles per minute, similar to the code rate previously described. Thus, sufficient energy is supplied to relay 2D to cause the relay to pick up only when the alternating current supply to the decoding unit input has the 180 cycles per minute frequency. Since these decoding units are well known in the art, it is not necessary to show in detail this circuit arrangement nor describe any further details of the operation thereof.

Further, in accordance with the positions of relays 2H and 2D, a circuit arrangement is provided for operating signal 2S to the corresponding indication. This signal is shown as a color light unit in the lower center with three lamp units which are individually and separately energized to provide the pertinent signal indication. Since section 2T is not occupied by any train and since alternating track current of 180 code rate is being supplied at the feed end, the code detection circuits so respond to the situation that relays 2H and 2D are picked up to close, respectively, front contacts *b* and *a*. Therefore, the green lamp of signal 2S is lighted to provide a proceed indication.

To illustrate the basic improvement added by my invention to the conventional system, reference is made to FIG. 2B. The circuit diagram illustrated is similar to that shown in FIG. 1B, that is, in detail with conventional symbols. However, the showing is of the combined apparatus located at a single insulated joint location rather than a complete end to end track circuit. A somewhat simplified arrangement for a better understanding thus results from consolidating the receiver portion of the track circuit apparatus for section 2T, the advance section, with the energy supply apparatus for the approach section 1T. Defining these two terms as used hereinafter in the description of the various circuit forms, and in the claims, the track section in advance of a joint location is that section beyond the location in the direction of normal train movement, here (FIG. 2B) the section 2T to the right of joint location J. The section in approach to the location or the approach section is the track section traversed by a train prior to arriving at the location, here section 1T. Thus, at a particular joint location, we find, for the normal direction of traffic, the exit end of the approach track section and the entrance end of the track section in advance of that location.

Considering first the apparatus associated with track section 2T, i.e., the apparatus at the entrance end of the section, code following track relay 2TR is connected to the rails of section 2T through track transformer 2RTT. Relay 2TR is here illustrated as a conventional two element, i.e., two winding, alternating current relay well known in the art. The connections for the track (upper) winding are the same as that illustrated for the conventional track circuit in FIG. 1B. However, the local winding, designated by the character L within the lower winding symbol for relay 2TR, is connected continuously across the terminals of the alternating current source which supplies the conventional track circuit, here the terminals BX1 and NX1. These reference characters indicate, of course, that these are the terminals of a first frequency alternating current source used in the system. The same source supplies the conventional track circuit energy at the exit end of the section. The use of the two element track relay with the local winding connected across the terminals of the same source as that supplying the current at the exit end is necessary to isolate this relay from energization and operation by the second frequency alternating current source to be discussed shortly.

Relay 2TR is normally following the coded track energy received over the track circuit as indicated by the two positions indicated for the movable portion of its contact *a*. Here a somewhat simpler form of decoding circuit arrangement is illustrated, the well known front and back contact repeater arrangement. It is obvious that each time front contact *a* of relay 2TR closes, the winding

of its front contact repeater relay FSA is energized. This relay is provided with slow release characteristics so that once picked up, it holds its front contacts closed for a selected period of time sufficient to bridge the normal open circuit period of front contact *a* of relay 2TR when this relay is following code. The back contact repeater of track relay 2TR becomes the home signal relay 2H, also provided with slow release characteristics. The energizing circuit for this relay includes back contact *a* of relay 2TR and front contact *a* of relay FSA so that relay 2H is energized shortly after code following operation of track relay 2TR begins. Relay 2H is also provided with sufficient slow release time to bridge the normal open circuit period in the code following operation of back contact *a* of relay 2TR. This arrangement using relays FSA and 2H provides for code detection at this location. In other words, the reception of track current of any code speed through the rails of section 2T by track relay 2TR will be detected by the energization and pick up of relays FSA and 2H. This simpler arrangement is possible in the circuit shown since no wayside signals are to be used, the train operation being controlled entirely by cab signals of conventional type. It is also obvious that, in effect, relay 2H is as much a detector of the occupancy of section 2T by a train as is relay 2TR. Said in another way, as long as section 2T is unoccupied, relay 2H is continuously picked up to detect the reception of coded rail current. When a train occupies section 2T so that the code following operation of relay 2TR ceases, relay 2H also detects this occupancy by releasing shortly thereafter and remaining released as long as the section is occupied.

The system of my invention adds a supplemental track circuit supply at this relay or entrance end of track section 2T. The supplemental supply establishes a phase sensitive or phase responsive track circuit. The specific source of supply for the second track circuit is the secondary winding of another track transformer 2STTA. The primary winding of this track transformer is connected to a second alternating current source having a frequency different from that of the first source, the terminals of this second source being herein designated BX2 and NX2. It is to be understood that, throughout the remainder of this specification, the two sources of alternating current will be distinguished by the suffix numeral added to the reference characters BX and NX designating the opposite terminals of the particular source. It is to be also remembered that cab signal apparatus carried by trains traversing the stretch of track is responsive only to alternating track current of one frequency, normally the first frequency supplied by the source having terminals BX1 and NX1.

The lower terminal of the secondary winding of transformer 2STTA is connected through the track winding of a phase responsive relay 2PR and a phase shifting device shown as an adjustable resistor PS to one of the rails of the track section. The return connection from the other rail of the track section is direct to the upper terminal of the secondary winding. Phase responsive track relay 2PR is herein illustrated as a two winding or two element alternating current relay which serves as a series track relay for the supplemental phase sensitive track circuit. The local winding of the relay is connected directly across terminals BX2 and NX2 of the second alternating current source.

The operation of the phase sensitive track circuit is based upon the principles disclosed in Letters Patent of the United States No. 2,884,516 issued to C. E. Staples on Apr. 28, 1959, for a Phase Sensitive Alternating Current Track Circuit. For a full understanding of the operating principles and the specific operation of such circuits, reference is made to this prior patent. Briefly, the principle of operation is based on the fact that the impedance of the track rail shifts the phase angle between the track current and the voltage supplied by the alternating current source, here indicated by terminals BX2 and NX2. This

impedance of the rail portion of the track circuit changes as the shunt effected by the wheels and axles of a train moves throughout the section, the impedance becoming greater as the distance to the shunt from the point of track supply increases. In other words, the impedance of the rails, and thus the shift of the phase angle, changes as a train moves from the specific location J shown in FIG. 2B to the right through section 2T. Adjustable device PS fixes the distance from this particular location at which the phase shift of the track current develops sufficient torque between the track and local windings of relay 2PR to cause this relay to pick up. Thus an indication is provided when a train receding from this particular location clears, that is, completely passes, a point in advance section 2T selected by the appropriate setting of device PS. As previously indicated, in general remarks, if the phase responsive circuit is applied at the exit end of a track circuit, the indication will be of a train reaching a selected point in the approach section and will be specifically indicated by the release of relay PR. Under other conditions, the operation of these phase responsive track relays PR may be controlled so as to reflect the relative distance that a train has moved away from or has approached toward the location at which the track circuit energy supply is provided.

Supply of energy for the regular track circuit of section 1T is similar to that shown in FIG. 1B. This energy is supplied through track transformer 1STT from terminals BX1 and NX1 of the first frequency alternating current source, that is, the cab signal frequency. This track circuit, of course, provides detection of train occupancy of section 1T as well as supplying energy for the conventional cab signals. The supply of energy is switched over various relay contacts in order to provide the pertinent code rate. Assuming that track section 2T is not occupied by a train, the energizing circuit for the primary winding of track transformer 1STT extends from terminal BX1 over the 180 coding contact of code transmitter 2CT, front contact *a* of relay 2H, and through the primary winding of the transformer to terminal NX1. This obviously supplies the rails of section 1T with alternating current interrupted at the code rate of 180 times a minute. When track section 2T is occupied by a train so that relay 2H is released, the code rate selection then is made by contact *a* of phase responsive track relay 2PR. When this relay is in its released condition, selection of the 75 code rate contact of transmitter 2CT is made over back contact *a* of relay 2PR and back contact *a* of relay 2H. However, if relay 2PR is picked up, the circuit over its front contact *a* selects the 120 code rate contact of transmitter 2CT. Thus, when section 2T is occupied, the selection of the code rate for the current in section 1T is in accord with the relative distance that the train has moved through section 2T since relay 2PR in this form is picked up to indicate the passage of the train beyond a selected point, a predetermined distance from this specific location.

In FIG. 2A, an expanded system is illustrated, in schematic form, using track circuit arrangements as illustrated and discussed in FIG. 2B. It is to be noted that, in this schematic showing, the same type conventional symbols are used as were discussed and explained in FIG. 1A. Each section of the stretch of track in FIG. 2A is shown as having a phase sensitive track circuit supply at the relay end of the regular cab signaling track circuits. That is, the phase sensitive track circuit supply is connected to the rails at the entrance end of each track section for the normal direction of traffic. The associated phase responsive relay is indicated as being connected in series with the second frequency alternating current supply for this phase sensitive circuit. Again, train detection at each section is controlled by the regular track circuit and is specifically illustrated as being by the home signal relay H. A dotted line conventionally designates the

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decoding circuitry equivalent to that shown in FIG. 2B, that is, the front and back contact repeaters of track relay TR. In this schematic showing, therefore, train detection in a track section is indicated by the corresponding relay H which picks up or releases as the section is unoccupied or occupied by a train. The H and PR relays associated with a particular section select between the coded BX1 terminals for providing the conventional coded track current for controlling cab signals in the approach track section. For example, relays 3H and 3PR select between terminals BX1 of the 180, 120 and 75 code rates, as indicated by the parenthetical suffix added to the reference BX1, for supplying cab signaling energy to track section 2T.

As indicated previously, the phase sensitive track circuits are used to improve the signal indication provided to a following train in order to allow it to run at the higher speed and at a somewhat closer headway than is possible under a conventional signaling system such as shown and discussed in FIG. 1A. For example, a train V1 is shown occupying section 4T. It is assumed that, as this train proceeds through section 4T, it is only a relative short distance away from the insulated joints J which separate sections 3T and 4T. Said in another way, train V1 is assumed to be in the first portion of section 4T, for example, approximately the first half of the section in advance of the signal or joint location. Obviously, relay 4H is released to denote the occupancy of the section by a train and, under the assumed conditions, relay 4PR is also released. This latter condition occurs since the phase shift caused by the impedance of the rails to the train shunt is insufficient to develop enough torque in the phase responsive relay to cause it to pick up. Accordingly, the code selection at this location is over back contacts *a* of relays 4H and 4PR to terminal BX1 (75). Train V2, shown as occupying section 3T, thus receives a cab signal code rate of 75 which results in a low (approach) speed signal being displayed in the train cab signal indicator.

It is assumed that train V2 in section 3T has proceeded beyond the preselected point, that is, is beyond the half way point of the section so that relay 3PR at the next insulated joint location to the rear of train V2 has picked up. Relay 3H, of course, is released since a train is occupying the section with which it is associated. Code selection then is of terminal BX1(120), the selection being made by back contact *a* of relay 3H and front contact *a* of relay 3PR. A train moving in section 2T will thus receive cab signal energy interrupted at the 120 code rate which provides an intermediate (approach-medium) speed signal to the train operator. Under the conditions shown with no train occupying section 2T, at the apparatus location separating this section from section 1T relays 2H and 2PR are both picked up. The code selection for the current supplied to section 1T is thus made over front contact *a* of relay 2H, which is the 180 code rate. Any train that might be occupying track section 1T will receive cab signal energy coded at this 180 code rate which provides a high speed or proceed indication on the cab signal indicator.

There is one disadvantage to this system as shown in FIG. 2A, particularly if numerous trains move at relatively short intervals over the stretch of track illustrated. Describing this disadvantage specifically in connection with the showing of FIG. 2A, a train moving through track section 2T with the relative position of train V2 unchanged will be operating at an intermediate speed as directed by the cab signal indication. This is a result of the reception of cab signal energy coded at the 120 code rate, as previously explained. Now with train V2 remaining as shown, the following train, upon moving from section 2T into section 3T, will suddenly receive no cab signal energy, thus dropping its cab signal indication to the stop aspect. This results since train V2

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is shunting all cab signal energy applied at the exit end of track section 3T. This sudden change in the cab signal indication from an intermediate speed indication to the stop indication, while not dangerous, may be disconcerting to the engineman of the following train even though familiar with the peculiarities of the signal system. As indicated, no danger is involved in this sudden change since at least one-half track section is available as stopping distance for the following train from its intermediate speed. It is to be understood that the signal system and the track section distances are designed so that this is sufficient stopping distance for a train.

One method for eliminating this disadvantage discussed in the preceding paragraph is illustrated in the schematic arrangement shown in FIG. 3. As in FIG. 2, two track circuit arrangements are provided for each track section, the conventional track circuit for cab signal energy being fed into the rails at the exit end and the phase sensitive track circuit being fed into the rails in series with its associated track relay at the entrance end of each track section. This particular form of my invention adds a stick relay S at each insulated joint location. Describing the circuits for stick relay 3S at the location at the entrance end of track section 3T, it is to be seen that the energizing circuit for relay 3S extends from terminal B over back contact *b* of relay 3H, front contact *b* of relay 3PR, and through the winding of relay 3S to terminal N. The stick circuit for relay 3S includes back contact *b* of relay 3H, back contact *b* of relay 3PR, and front contact *a* and the winding of relay 3S. Relay 3S, as well as the other stick relays, is normally deenergized when no trains are passing through the stretch of track involved. It is obvious that its circuits are interrupted under these conditions at back contact *b* of relay 3H. When a train enters track section 3T, relay 3H releases to close its back contact *b*, but at substantially the same time, relay 3PR also releases to open its front contact *b*, thus maintaining the energizing circuit for relay 3S interrupted. It is to be noted that relay 3S is a slow acting relay, being provided with slow pick up and slow release characteristics. Thus any short interval completion of the energizing circuit at this particular time, i.e., as a train enters track section 3T, is not effective to pick up the relay. As the train passes through section 3T and occupies a relative position indicated by train V1 at the far end of section 3T, relay 3PR picks up, as previously explained, and the pick up circuit for relay 3S is then complete. This latter relay picks up to close its front contacts. If a second or following train now enters section 3T, once again causing the release of relay 3PR, the stick circuit for relay 3S is completed so that the relay retains its front contacts closed since the relay winding remains energized. This assures that any relay S, once picked up by a train, will remain picked up in the event that a second train enters the same track section.

Relay 3S controls an auxiliary or supplemental supply of regular cab signal energy for section 3T. This supply circuit extends from terminal BX1(75), that is, the first frequency alternating current coded at the 75 code rate, over front contact *b* of relay 3S through a track transformer to the rails of the section at a point approximately midway between the ends of section 3T. In actual practice, this point of connection will be closer to the entrance end of section 3T than is the selected point at which relay 3PR picks up. This assures that at least one-half of the section length exists beyond the point of supplemental supply of cab signal energy. The supply of this energy is available when a second train enters section 3T if the first train illustrated by train V1 shown in section 3T has already passed the selected point at which relay 3PR becomes energized with sufficient torque to pick-up. Thus, when this following train enters section 3T, having proceeded through section 2T with an intermediate speed cab signal indication, it receives new cab signal energy coded at the 75 code rate. This results in a low speed cab signal

indication and the engineman reduces the speed of his train accordingly, being prepared to stop short of the mid point of the section. In actuality, of course, he will be informed of this mid point or auxiliary supply location by the reduction of his cab signal indication to the stop aspect at the time that he passes the point of supply. This is a modified form of the well known code change or B-point arrangement so that the train speed may be gradually reduced as the cab signal indication assumes less favorable aspects.

Another arrangement which also avoids the sudden change to the stop indication, that is, the no code condition, for the cab signal indication from its intermediate speed indication is shown in FIG. 4. The system here illustrated differs from that of FIG. 2 in that the phase sensitive circuit at each insulated joint location is connected, not to the section for which the location is the entrance end, but to the approach section for which the location is the exit end. For example, at the insulated joint location between sections 2T and 3T at which home signal relay 3H is located, the phase sensitive track circuit including phase responsive relay 3PR is connected to section 2T, that is, to the exit end of this section. The circuit then is adjusted so that relay 3PR releases as a train approaches through section 2T and reaches a selected point which is approximately midway through the section.

It will be apparent from an inspection of the schematic circuits that there is no change in the coding circuit for the first frequency alternating current supplied for cab signal purposes. For example, as train V3 illustrates in section 2T moves through this section, relay 3PR remains energized, that is, picked up under proper torque conditions until train V3 reaches approximately the mid point between the insulated joint locations. At this time, the impedance of the rails to the shunt is such that relay 3PR releases. Under the conditions shown, train V3 is originally receiving cab signal energy coded at the 120 code rate, the selection being over back contact *a* of relay 3H, in its released position as shown, and front contact *a* of relay 3PR. When relay 3PR releases, the code rate changes to the 75 code rate, the shift in selection being made by the movement of contact *a* of relay 3PR from its front contact position to close its back contact.

Describing the specific situation illustrated in FIG. 4, the occupancy of track section 4T by train V1 results in relay 4H being in its released position. It is assumed that train V2 has moved more than half way through section 3T so that relay 4PR has released in a manner just described. Cab signal energy supplied to section 3T is selected at the 75 code rate over back contacts *a* of relays 4H and 4PR. The low or restricted speed cab signal indication resulting on train V2 informs the engineman thereof that the next track section in advance is occupied by a train and that he can expect to receive a stop signal when he passes the insulated joint location. Incidentally, it may be noted that this joint location, which may also be known as a phantom signal location, will normally be marked by a fixed sign board to notify enginemen of the actual location. Behind train V2, of course, the cab signal energy is shunted from the rails by the train and relay 3H at the entrance end of section 3T is in its released position. As specifically shown, train V3 is assumed to be in the first half of section 2T as it advances in the normal direction. Relay 3PR is still picked up so that the cab signal energy code rate is selected at the 120 rate over back contact *a* of relay 3H and front contact *a* of relay 3PR. A similar situation obviously exists at the location separating sections 1T and 2T providing that no train has advanced into section 1T beyond its preselected point. As train V3 proceeds along its route and passes the mid point of section 2T, relay 3PR releases to shift the cab signal energy code rate to the 75 rate in the manner previously described. Obviously, as train V3 proceeds and enters section 3T with train V2 in the same relative position as

shown, cab signal energy is completely shunted away from train V3 so that its cab signal indication is that resulting from no code reception. Thus the cab signal indication of train V3 changes from an intermediate speed signal through a low speed signal to a stop signal as it proceeds throughout the stretch, allowing the engineman to control his train in a conventional manner and without any sudden and abrupt changes in his cab signal indication.

By combining the two methods shown in FIGS. 2 and 4, a system illustrated in the schematic circuit diagram of FIG. 5 results which takes advantage of the detection of the relative distance to the train in each direction from a particular insulated joint location. For example, referring to FIG. 5 and to location 2, that is, the insulated joints separating sections 1T and 2T, a phase sensitive track circuit supplied by the second frequency alternating current is fed in each direction from this particular location. Specifically, for the advance track section 2T, a phase sensitive circuit including phase responsive relay 2PRA in series energizes the rails behind a train passing through that section. In the opposite direction, a phase sensitive circuit is connected to the rails of section 1T at its exit end and includes phase responsive relay 2PRB in series therewith. Each of these phase sensitive circuits operates in a manner previously described. In other words, relay 2PRA does not pick up until a train moving through section 2T has passed beyond the selected point at approximately the mid location of the section. Conversely, relay 2PRB is normally energized and releases when an approaching train first reaches the preselected point in section 1T which is approximately half way through the section. Normally, of course, with no train occupying any portion of the corresponding section, each relay is in its picked up position.

In order to take full advantage of the possibilities of this particular system arrangement, an additional code rate is required so that four code rate conditions in addition to the no code condition may be provided for cab signal energy. This additional code rate selected is the 270 code rate so that the supplying terminal is designated BX1(270). The code rate selection for the cab signal energy is then over a circuit network including contacts of home signal relay H and relays PRA and PRB at the particular location. Still referring to location 2, it is obvious that, with relay 2H picked up when the track section in advance is unoccupied, the highest code rate is selected to provide a clear or high speed cab signal in the approach section. Specifically, supply terminal BX1(270) is selected over front contact *a* of relay 2H for the cab signal energy being supplied to section 1T through the usual track transformer.

Considering specifically the selection of the various code rates at the insulated joint location between sections 2T and 3T with assumed train positions as indicated by the symbols V1 and V2, that is, each train is beyond, relative to the location, the selected point at which the phase sensitive circuit responds due to the rail impedance to the train shunt. Accordingly, with relay 3H released because of the occupancy of section 3T by train V1 and relays 3PRA and 3PRB picked up, terminal BX1(180) is selected over front contacts *a*, in series, of these two phase responsive relays PR and back contact *a* of relay 3H. Such coded cab signal energy is supplied to section 2T at its exit end. If train V2 now advances beyond the preselected point in section 2T so that relay 3PRB releases, the code rate selection circuit then includes back contacts *a* of relays 3H and 3PRB and front contact *c* of relay 3PRA. Obviously terminal BX1(120) is now selected for supplying cab signal energy to section 2T so that the train cab signal reduces from that which may be considered an intermediate speed to that which would require an advance approach speed.

At location 2, that is, the insulated joints between sections 1T and 2T, trains V3 and V2, occupying the approach and advance sections, respectively, are each closer to the insulated joint location than the preselected point within

their respective sections. Cab signal energy of the 75 code rate is thus supplied to section 1T. The circuit for selecting terminal BX1(75) for this particular cab signal energy includes back contact *a* of relay 2H, which is released because of the occupancy of section 2T by train V2, back contact *a* of relay 2PRB which is released because train V3 is closer in the approach section than the preselected point, and back contact *c* of relay 2PRA, released because train V2 is closer in the advance section than the preselected point. If train V3 has not yet reached, in section 1T, the preselected response point for the phase sensitive circuit supplied at the exit end of that section so that relay 2PRB has sufficient torque applied to pick up, terminal BX1(120) is selected for the cab signal energy over back contact *a* of relay 2H, front contact *a* of relay 2PRB, and back contact *a* of relay 2PRA. It is thus to be noted that terminal BX1(120) may be selected over two separate circuit paths depending upon the relative position of the trains occupying the approach and advance sections associated with the particular insulated joint location. Both such circuit paths have been described in connection with this circuit arrangement of FIG. 5.

In the circuit arrangement of FIG. 5, it is to be noted that if train V1 remains stationary or in the same relative position in section 3T while train V2 advances through section 2T and passes the insulated joint location into section 3T, the cab signal indication of train V2 will change suddenly from the advance approach indication corresponding to the 120 code rate to the stop indication corresponding to the reception of no code as it enters section 3T. This results from the fact that cab signal energy applied at the exit end of section 3T is shunted by the wheels and axles of train V1. This is somewhat similar to the disadvantage discussed in connection with the circuit arrangement of FIG. 2A. As shown simply by a schematic circuit arrangement in FIG. 6, this advantage is eliminated by adding to the system of FIG. 5 the modification provided in FIG. 3. In other words, a stick relay is supplied at each location, here illustrated by relay 3S at location 3 between sections 2T and 3T. Repeating briefly, each stick relay is normally deenergized and remains deenergized upon occupancy of its associated track section until the train has passed beyond the preselected response point in the advance track section. For example, relay 3S is energized when train V1, shown occupying section 3T, has moved beyond the selected point at which the phase sensitive circuit including relay 3PRA responds. If a second train, such as train V2 shown occupying section 2T, moves into section 3T at its entrance end, relay 3S is held energized by its stick circuit. The supplemental cab signal energy supplied at approximately the mid point or slightly short thereof in section 3T is controlled by the connection from terminal BX1(75) over front contact *b* of relay 3S through a track transformer to the rails of the section.

Describing the operation of this arrangement in a specific manner, as train V2 moves through the second half of section 2T, with train V1 positioned as shown, it is obviously receiving cab signal energy coded at the 120 code rate. The supply circuit for this is connected to the exit end of section 2T and includes back contacts *a*, in series, of relays 3H and 3PRB and front contact *c* of relay 3PRA. This latter relay is picked up because sufficient torque is being developed between its windings since train V1 is beyond the preselected response point in section 3T. Under the instantaneous conditions shown, relay 3S is also energized since its energizing circuit is closed. As train V2 passes the insulated joint location and enters section 3T, relay 3S is retained energized by a transfer to its stick circuit when relay 3PRA releases to close its corresponding back contact *b*. Since front contact *b* of relay 3S is closed, cab signal energy at the 75 code rate is applied to section 3T at some point behind train V1. Thus the cab signal apparatus of train V2, which has been responding to energy at the 120 code rate, will now respond to

energy at the 75 code rate so that the cab signal indication changes from an advance approached indication to the approach or restricted indication, that is, the low speed indication. Train V2 can continue to advance at this restricted speed through section 3T until it reaches the code change point corresponding to the point of application of the supplemental cab signal energy. Since the engineman will be expecting the reception of a stop signal at this point, he will have reduced the speed of his train to that which can be instantaneously controlled to stop the train. Thus continued advance of the train is possible without sudden change to a stop signal and the engineman, with safety, may close up behind train V1.

The particular form of the system of my invention illustrated in FIG. 6 provides for the measurement of the relative distance to the position of a train within specified limits in each direction from an insulated joint location separating conventional track circuits. The supply of cab signal energy at the exit end of each section to control approaching trains is varied as to its selection of code rate in accordance with the relative position detected for trains within both the approach and the advance section associated with that particular location. In addition, a supplemental supply of cab signal energy at a selected intermediate point within the advance track section is provided to allow the second train to continue to advance at a restricted speed behind a preceding train. This also eliminates any sudden change to a stop signal indication by the cab signal apparatus from any indication other than the restricted speed indication.

An additional advantage of the system provided by the principle disclosed by my invention is obtained if the code rate may be varied more closely in comparison with the distance between successive trains moving through the stretch. In order to obtain the ultimate operation, a selection between various fixed code rates is not sufficient but requires a continuously variable code rate. The circuit diagram of FIG. 7 illustrates one possible method of obtaining such a continuously variable code rate in accordance with the distance between trains. This modification is applied only to the circuit arrangement of the type shown in FIG. 2B. It is to be noted, however, that the principle is applicable to each type or species of my invention illustrated in the intervening drawing figures. In this particular form, a variable frequency oscillator is provided to drive a code following relay which relay, in turn, controls the code rate of the cab signal energy applied to the rails of the section in approach to that particular location. Since a low frequency, pulse type output is desired, I have chosen to illustrate the variable frequency oscillator as being of the relaxation oscillator type using a unijunction transistor Q. A specific example and description of the oscillator circuit here used may be found in Fig. 13.9, page 194, of the General Electric Transistor Manual, Sixth Edition.

The oscillator circuit arrangement illustrated, except for the biasing resistor R10, is for convenience enclosed in a dot-dash block designated as the variable oscillator. It is to be understood, of course, that other equivalent circuits providing an adjustable pulse output within the desired frequency range may be substituted for that portion of the circuit here enclosed within the conventional dot-dash block or for the entire circuit including the biasing resistor. It is sufficient to understand that, by varying the total resistance connected between terminals E and F of the basic circuitry for the oscillator, variation in the pulse output frequency may be obtained. A smooth variation in the amount of resistance causes a continuous frequency shift in the output from terminal O. By using a variable resistance provided with some form of a slide connector which selects the various resistance values, this slide connector may be placed directly under the control of the phase responsive relay 2PR which acts as a track relay in the phase sensitive track circuit applied to section 2T. In

this form of my invention, the phase sensitive track circuit is so adjusted that relay 2PR follows the varying torque as the phase relation between the track current and applied voltage shifts. In other words, the circuit adjustment is not that in which relay 2PR specifically holds its contacts in a released position until a preselected response point is cleared by a train moving through the section, upon which relay 2PR picks up. Rather, the changing torque causes a continuous operation of the armature or vane of relay 2PR which in turn, through mechanical linkage indicated by a dotted line, causes the slide connector to move in the corresponding direction across biasing resistor R10 of the oscillator. In the specific type of oscillator circuit shown, a reduction in the amount of biasing resistance connected between terminals E and F results in an increase in the frequency of pulse oscillation over the output circuit from terminal O. Since the torque supplied to relay 2PR also increases as the train moves away from this particular joint location, it is to be seen that the slide contact is moved in an upward direction, reducing the resistance in a continuously smooth manner. For the arrangement shown, the specific design of the oscillator circuit is such that its output is of low frequency, for example, from 1 to 10 cycles per second.

The output of the oscillator is in the form of D.C. pulses which drive relay CM, a code following biased relay. This type relay responds to current flowing through its winding only when the current is conventionally in the direction of the arrow shown within the winding symbol. Reverse direction current or no current causes the relay to release, opening front contacts. Such relays are known in the art and require no detailed explanation. Cab signal energy is supplied at the exit end of section 1T through track transformer 1STT, the primary winding of which is supplied from terminals BX1 and NX1 of the first frequency alternating current source. Primary connections also include front contact *a* of relay CM so that the primary current is interrupted at a code rate equivalent to the operation of the relay which, in turn, is following the frequency of the variable oscillator. It is obvious that, as a train moves through section 2T in the normal direction, the oscillator output is increasingly of higher frequency as the rear of the train moves a greater and greater distance away from the insulated joints. This results from the increasing torque developed by relay 2PR which, in turn, decreases the biasing resistance connected in the oscillator circuit. It is apparent that the cab signal apparatus on trains moving through stretches of track supplied with this type of cab signaling system will have to be modified from that conventionally used in the art in order that they will respond to such continuous code rate changes. An alternate manner of operation is to apply the output frequency of the variable oscillator direct to the track rails for controlling the cab signals. Under these conditions, the oscillator output must be in a somewhat higher frequency range to which the cab signal apparatus will directly respond. Under these conditions, cab signal current frequency variations rather than the code rate modulation thereof determine the indications displayed by the cab signal apparatus on a train. A possible design will be briefly discussed hereinafter in the specification.

A somewhat different application of the system arrangement of my invention is illustrated by the diagrammatic circuits shown in FIG. 8. Here the phase sensitive track circuit arrangement is used to provide automatic stopping of a train at a station platform. Such operation, of course, in order to provide a smooth deceleration rate and a final stop requires a continuous code variation such as discussed in connection with FIG. 7. Referring to FIG. 8, a short stretch of track section is shown divided at insulated joints J into an approach track section AT, the approach to the station, and a station section ST. It is in this latter, right hand section that the station platform is located.

Trains, of course, as in previous drawings move in the direction from left to right. Such trains must be equipped with an automatic speed control in order to allow them to be decelerated in an automatic manner to stop at the station platform. It is to be noted that the station section ST is, by special note, defined as having no cab signal or speed control code rate. This condition, of course, exists at least when the train enters the section in its initial stopping operation. It is to be expected in a complete system, that coded current is applied in order to restart the train at the time that the loading of passengers is completed.

The phase sensitive track circuit here detects the distance to an approaching train in section AT. It is assumed that it will be a condition of this system that the section is sufficiently long that the rail impedance as the train enters the section allows phase responsive relay SPR to be fully operated. Said in another way, the torque existing between the local and track windings of relay SPR when a train first enters section AT is sufficient to cause the relay to fully operate. A variable oscillator shown by conventional block is provided with a biasing resistor R10. This is the same unit as shown and discussed in FIG. 7 so that when the resistance of R10 is at its lowest value, which occurs when relay SPR is fully picked up, the oscillator frequency is at its highest. Coding relay CM thus is operating at a high code rate when a train first enters the track section. Thus the speed control or cab signal energy supplied to track section AT has its highest code rate and the train proceeds at the highest authorized speed.

Of course, as the train approaches the station through section AT, the torque developed in relay SPR decreases so that its movable armatures are lowered. This progressively increases the portion of resistor R10 included in the biasing circuit of the variable oscillator so that the oscillator frequency also decreases to lower rates in a smooth curve. This obviously is followed or repeated by a decrease in the rate of coding relay CM so that the code rate of the cab signal energy applied to section AT is thus reduced. Speed control apparatus carried by the train responds by reducing the speed of the train in keeping with the reduction in the code rate of the cab signal energy. By the time that the train reaches the exit end of the section, a very slow speed code rate is being received. As the train passes into section ST, a final brake application occurs as a result of the absence of any cab signal energy in this particular section. The entire arrangement is so designed that the final speed of the train at the exit end of section AT is such that a full brake application immediately upon entering section AT will cause the train to stop in proper position at the station platform. As an alternate arrangement, as previously discussed, the variable frequency output of the oscillator may be directly applied to the rails of section AT. Under this arrangement, the speed control apparatus carried by the train is of a modified form designed to respond directly to the frequency of the rail current rather than to the code rate. This will be more fully discussed later in the description.

In FIG. 5, an arrangement is shown whereby the distance is measured in each direction from the joint location by phase sensitive track circuits. These relative distances are then combined through the use of relay contact matrix to select a code rate for the cab signal energy applied for approaching trains, this rate being varied between the preselected fixed rates in accordance with the relative total distance. Let us now apply the continuously varying code rate principle to the general arrangement shown in FIG. 5. This will enable the system to more clearly obtain the so-called moving block operation for the control of the signaling. Diagrammatic circuits illustrating one possible form of this particular arrangement of my invention are shown in FIG. 9, which illustrates the apparatus at one joint location of such a system.

This apparatus includes means to sum up the distances measured in each direction into a single relative distance measurement between successive trains. This total distance, of course, is limited by the insulated joints at the distant ends of the sections adjacent at the joint location shown. In other words, the total measurement is limited to the total length of the two sections 1T and 2T partially shown. The summation means is illustrated as a phase responsive relay 2PR which is used as a three element, alternating current relay. The top winding is the local winding connected directly across terminals BX2 and NX2 of the alternating current source by which the phase sensitive circuits are energized. Each of the other two windings is a track or control winding connected in a separate phase sensitive track circuit, to be described shortly. As one possible example of such a relay, reference is made to the alternating current relay disclosed in United States Patent No. 1,470,566. When used in the presently disclosed manner, the two parts of winding 22 of this relay, i.e., as shown wound on legs 20 and 21 of core B, FIG. 3 of the patent, are connected as separate track windings, one for section 1T and the other for section 2T. The relay will then operate so that the total torque developed is the summation of the torques developed between each track winding and the single local winding. Other relays or apparatus having equivalent construction may also be used.

The arrangement also includes a track relay 2TR used to detect occupancy of the advance track section 2T. This relay is the usual two element alternating current track relay whose local winding is connected directly across terminals BX2, NX2 of the alternating current source. It is to be noted that only a single source of alternating current is used in this arrangement for both the phase sensitive track circuits and the corresponding cab signal/speed control and train detection track circuit. Since primary interest rests in the use of the phase sensitive circuits, terminals BX2, NX2 are used to represent this source. In order to maintain a separation between the phase sensitive circuits and the train detection circuit for a single track section, the polarity of the source connections to the rails must be considered, as will be discussed when the circuit connections are traced.

Relay 2TR is normally energized by a form of stick circuit extending from the lower rail of track section 2T through the control winding of relay 2TR and front contact *a* of repeater relay 2FSA to the other rail of the track section. The polarity of the connections to the track and local windings must be the same so that the direction of current flow in each winding is such as to aid and cause the relay to pick up. Since the current supplied to the far or exit end of section 2T is coded, relay 2TR, when the section is unoccupied, will follow this code, as indicated by the lower dash representation of its contact armature. Therefore it is necessary to provide a code detection relay such as front contact repeater relay 2FSA. The simple energizing circuit for relay 2FSA includes the relay winding and front contact *a* of relay 2TR, which is periodically closed during the code following operation of the track relay. Since relay 2FSA has slow release characteristics, it maintains its front contacts closed during code operation. As in FIG. 2B, a back contact repeater or home signal relay 2H may also be provided and its contacts used in the circuits. However, it is not needed here for an understanding of the operation.

The lower winding of relay 2PR is connected across the rails of section 1T in a phase sensitive circuit extending from the lower rail symbol through the secondary winding of track transformer 1STT, phase shifting device PSA, and the lower winding of relay 2PR to the other rail of the track section. The primary winding of transformer 1STT is connected directly across terminals BX2 and NX2. The center winding of relay 2PR is associated with the advance track section 2T. When this section is unoccupied, a circuit extends through this center winding

of relay 2PR which may be traced from the right hand terminal of the winding over front contact *b* of relay 2FSA through impedance reactor Z, the secondary winding of track transformer 2STTA, and phase shifting device PSB to the other terminal of the relay winding. This circuit serves the purpose of simulating a connection across the track section unoccupied, the impedance Z being the equivalent of the impedance of the rails of the full track section. When section 2T is occupied, the circuit for the center winding of relay 2PR is traced from the lower rail symbol of section 2T through the control winding of relay 2TR, back contact *a* of relay 2FSA, secondary winding of transformer 2STTA, phase shifting device PSB, and the center winding of relay 2PR to the other rail of the track section. It is to be noted that the primary winding of transformer 2STTA is connected across the terminals of the alternating current source. Although windings of both relays 2PR and 2TR are connected in series with the rails of the section in this last traced circuit, relay 2TR is not responsive since the connections to the secondary of transformer 2STTA are so selected that the polarity of the current supplied and flowing in the control winding of relay 2TR is opposite to that in its local winding.

The torque developed by relay 2PR as a result of the currents flowing in its local and the two control windings is used to move slide wire connectors of resistor R11 and potentiometer R12. These slide wire connectors are in their lowest positions when no torque is developed and are moved to the highest position when full torque is developed by the relay. This manner of operation is similar to that shown in the circuit arrangements of FIGS. 7 and 8. It is apparent that the highest torque between the lower winding of relay 2PR and its local winding is developed when an approaching train first enters section 1T and this torque decreases as the train approaches nearer to the particular joint location shown. The highest possible torque between the center control winding and the local winding develops when a train occupying section 2T is at the distant or exit end of the section. This condition also is simulated when section 2T is unoccupied by the circuit for this center control winding over front contact *b* of relay 2FSA which includes impedance Z. When a train first occupies section 2T at this location, the torque developed between these two windings of relay 2PR is at its lowest point. However, the position of the slide wire connectors controlled by relay 2PR will be a result of the summation of the torques developed between each control winding and the single local winding.

The control arrangement to provide the variable code rate in the circuit arrangement of FIG. 9 is different from that discussed and shown in FIGS. 7 and 8. Here I have chosen to use a time delay relay circuit arrangement embodying a single unijunction transistor Q. This delay circuit is used to control the operation of a coding relay CM. The circuit arrangement used is similar to that shown in Fig. 13.15 on page 198 of the General Electric Transistor Manual, Sixth Edition. Although reference may be made to this printed publication for an understanding of the arrangement, I shall here describe the operation briefly in order to effect a fuller understanding of the complete circuit arrangement shown. The charge on capacitor C1 effects or controls the conductivity of transistor Q. That is, when the positive potential on the upper plate of capacitor C1 reaches the "peak point" value transistor Q becomes conducting. The charging circuit for capacitor C1 extends from terminal B through resistor R11, back contact *b* of relay CM, and capacitor C1 to terminal N. The charging time of capacitor C1 is determined by the portion of resistor R11 included in this circuit by the setting of the slide connector. It is apparent that when transistor Q becomes conducting, capacitor C1 discharges through the circuit including the emitter-lower base path of transistor Q and the upper winding of relay CM, causing the relay to pick up.

The closing of front contact *a* of relay CM completes a holding circuit for the relay which is effective for a period of time determined by the charge on capacitor C2, which is connected in series with the lower winding of relay CM under this condition. The total charge existing on capacitor C2 is determined by the voltage setting of the slide connector on potentiometer R12 whose main resistor winding is connected across terminals B and N. The charging circuit extends from the slide wire connector of this potentiometer through back contact *a* of relay CM and capacitor C2 to terminal N.

When capacitor C1 has discharged to a value below the "peak point" voltage, transistor Q returns to its non-conducting condition. However, relay CM is held picked up until the charge on capacitor C2 is dissipated, at which time the relay releases. This restores the charging circuit for capacitor C1 and after the established time interval, transistor Q again conducts and relay CM picks up. This coding action continues indefinitely, the rate being determined by the slide wire connector settings of potentiometer R12 and resistor R11 which, in turn, are responsive to the total torque developed in relay 2PR. The circuit parameters in this time delay relay circuit arrangement are designed so that equal pick up and release times are obtained in the operation of relay CM. In other words, the code rate developed by relay CM is provided with equal on and off times and this equality extends through all possible code rates developed in accordance with the settings of potentiometer R12 and resistor R11.

During the following description of the operation of this circuit arrangement in FIG. 9, it is to be noted that the cab signal or speed control energy applied to section 1T at this location is obtained from the same source as the energy for the phase sensitive track circuits, that is, the second frequency alternating current source. Thus, approaching trains, by means of the same alternating current flowing in the rails, determine, by the measured distance, the code rate of the speed control energy which they are receiving. The coding circuits are in the form of shunt connections across the secondaries of the track transformers for the phase sensitive circuits. For section 2T, this shunt is provided periodically at the code rate over front contact *c* of relay CM while for section 1T, the shunt across the secondary of transformer 1STT is provided by front contact *d* of relay CM. When front contacts *c* and *d* of relay CM close, each shunts the energy of the phase sensitive circuit away from the corresponding track section. For section 1T, this also results in a code off time for the cab signal energy being supplied to an approaching train. It is also obvious that each shunt connection provided by these relay contacts is in effect a shunt across the rails at the joint location of the corresponding track section. This affects the operation of relay 2PR since the phase shift during this period is that resulting from a train shunt at the same location. This provides a check of the release of relay 2PR under such conditions and the proper operation of the other elements of each phase sensitive track circuit. Thus, this particular type of track current coding action is a fail safe check on the operation of the two phase sensitive track circuits and thus increases the safety of the entire arrangement.

Each time the shunts are removed by the release of relay CM, relay 2PR is restored to the position resulting from a summation of the torque developed which is a measure of the relative distance between trains in sections 1T and 2T. This causes a new relay pickup action by the time delay relay arrangement so that the coding cycle is continuous. Obviously, as the trains occupy positions closer to this particular joint location, the code rate is reduced. However, as a specific example, as the train approaches through section 1T this code rate reduction occurs as a continuous operation and not from code rate to code rate in fixed steps. Thus, the code rate signal supplied to an approaching train, and the resulting

speed indication, continuously reduces as a particular occupancy condition of section 2T remains fixed. This arrangement, of course, may be used as an alternate arrangement for the station stopping control shown in FIG. 8 whereby the station platform is located in section 2T. Under these conditions, the presence of a preceding train at the station platform would be noted by the occupancy detection relay 2TR. However, as this preceding train left the platform and moved on through section 2T, its actual distance and therefore the speed of the approaching train is determined by the phase sensitive arrangement shown. This allows the approaching train to move at the highest possible allowable speed in approaching the platform and yet make a smooth station stop in the proper location as was discussed previously in connection with the circuit of FIG. 8.

It will be obvious to those skilled in the railway signaling art that conventional train carried cab signal or speed control apparatus presently used is not suited to a signaling system similar to the type shown in FIGS. 7, 8, and 9. In other words, train carried apparatus designed for decoding distinctive fixed code rates is not suitable if the wayside system derives a code which varies smoothly between upper and lower limits in accordance with the wayside conditions to provide continuous information to the train in a smooth variation rather than by fixed code steps. Thus, if this type system is used, the train carried decoding equipment must be compatible to the smooth change in frequency of the track code. This modification is especially necessary if the signal character is carried in accordance with the frequency of the rail current rather than a code rate. In either event, one method which is suitable for the operation of the train carried apparatus is to have a first shaft rotating in proportion to the speed indication determined by the signal character, e.g., code rate, received from the current flowing in the track rails. With this apparatus, a second shaft then rotates in proportion to the actual train speed. The speed of rotation in the first shaft is a measure of the safety of traffic conditions in advance of the train while the speed of rotation of the second shaft is an indication of train speed. Means are then provided to compare the speeds of rotation of the two shafts. When shaft No. 1 is rotating at a faster rate than shaft 2, the speed of the train may be increased safely until the speeds of rotation of the two shafts are equal. However, if shaft No. 2 is rotating at a higher speed than shaft 1, the speed of the train must be reduced. The degree of difference in the rotation speed of the two shafts may be used to determine whether only power will be shut off from the train or whether a brake application must also be made. A wide difference in the speed of rotation of the two shafts, when shaft 2 is rotating faster, will cause an emergency rate of brake application.

A schematic diagram showing one possible arrangement of apparatus to fulfill these requirements is illustrated in FIG. 10. Here we have two motors which rotate in opposite directions as schematically indicated by the rotation arrows associated with the external shafts of the motors. Each motor directly controls and causes to rotate one portion of an associated magnetic clutch. The unit discs of the two magnetic clutches are connected by a rotatable shaft. Thus, the angle of rotation of this shaft is a measure of the difference in the torques exerted on the discs by the magnetic clutches, that is, the portion controlled directly by the two motors. This difference of torque, of course, is a measure of the difference in rotation speed of the two motors. The shaft connecting the two discs controls the contact bar which moves the contact armatures through mechanical connections indicated by a conventional dotted line to close or open contacts in accordance with the angle of rotation of this shaft from its normal position. The contacts may be arranged to operate at different angles of rotations so that, as indicated, one contact is used to

control the propulsion power for the train while the second contact is associated with the brake control apparatus. Other contacts may be provided for other purposes, particularly for effecting an emergency brake application if the angle of the shaft exceeds a preselected amount.

Motor No. 2 may be controlled in accordance with the train speed by some form of axle generator, several such types of apparatus being well known in the art. Thus, the speed of rotation and therefore the torque exerted on the clutch disc will be proportional to the train speed. Motor No. 1, meanwhile, will be controlled in accordance with the signal character carried by the track current. Conventional track receivers may be used to pick up this code signal from the rails by the usual inductive method. If necessary, the received signals are amplified to provide sufficient energy to operate the motor. Motor No. 1 is then driven in accordance with the received signal, that is, the received code rate in the system shown. For example, this motor may be a synchronous step type motor, also well known to the art. The two motors will be so geared that they produce equal torque on the associated magnetic clutch discs when the train speed is equal to the allowed speed in accordance with the received signal. This equality will be in effect over the entire range of allowable train speed and code rates. If the alternate system of using the direct frequency of the track current as an indication of the signal character carried, motor No. 1 may be of the type whose rotation speed will be in accord with the frequency of the energy supplied thereto. Since specific details of this arrangement for governing the speed of the train are not considered to be any part of my invention, the schematic block diagram form of illustration has been used and the brief explanation is considered sufficient for an understanding of a method by which the speed control of the train may be implemented.

The arrangement of my invention thus results in a railway signaling system embodying a form or type of moving block principle for controlling the train carried signals. This results in the control of train movements over a stretch of track, by a cab signal indication or speed control apparatus, in accordance with the relative distance between that train and a preceding train within the stretch. This distance measurement is accomplished by the use of the phase sensitive track circuit arrangement. In accordance with the degree of accuracy and control desired, and the desired efficiency of the operation of the circuit, selection may be made from the various forms in keeping with the results desired.

Although several arrangements of apparatus embodying the forms of my invention have been described in the preceding specification and disclosed in the accompanying drawings, it is intended that various other modifications and changes within the scope of the appended claims may be made in these forms without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. A signaling system for a stretch of railway track traversed by trains equipped with speed control apparatus responsive only to a preselected signaling current flowing in the rails and carrying at any one time a selected distinctive signal character establishing an allowed speed for a train, comprising in combination,

(a) circuit means having connections to the rails for supplying said signaling current having selections of signal character extending over predetermined sections of track,

(b) distance means also with connections to said rails and controlled by the presence of trains for measuring independent of said sections of track the relative distance between a train within a predetermined section of track and a location at which that train must be prepared to stop,

(c) selection means controlled by said distance means

and having connections to said circuit means for varying the selection of the distinctive signal character carried by said signaling current in accordance with said measured relative distance.

2. A signaling system for a stretch of railway track traversed by trains equipped with speed control apparatus responsive only to a preselected signaling current flowing in the rails carrying at any one time a selected distinctive signal character establishing an allowed speed for a train, comprising in combination,

(a) circuit means having connections to the rails for supplying said signaling current with selections of signal character extending over predetermined sections of track in accordance with the movement of preceding trains,

(b) distance means also with connections to said rails and controlled by the presence of trains for measuring the relative distance between successive trains independent of said sections of track,

(c) selection means controlled by said distance means and with connections to said circuit means for varying the selection of the distinctive signal character carried by said signaling current in accordance with the measured relative distance between successive trains.

3. A signaling system for a stretch of railway track over which move in a single direction trains equipped with cab signal apparatus responsive only to a preselected signaling current in the rails carrying at any time one of a plurality of signal characters, comprising in combination,

(a) track circuit means having connections to the rails for supplying said signaling current with a selection of signal character extending over predetermined track sections in accordance with the movement of preceding trains,

(1) said track circuit means being further responsive to the movement of trains for detecting a train occupying any of said sections,

(b) distance means also with connections to said rails and controlled by the presence of trains for measuring the relative distance between successive trains independent of said track sections,

(c) selection means controlled by said distance means and said track circuit means and with connections for varying the selection of the signal character carried by said signaling current in accordance with the measured relative distance between successive trains.

4. A signaling system for a stretch of railway track divided into sections over which trains move in a single direction, comprising in combination,

(a) track circuit means for each section having connections to the rails for supplying to said rails preselected signaling current carrying a distinctive signal character,

(b) speed control apparatus on each train responsive only to said preselected current for controlling the speed of that train in accordance with the distinctive signal character,

(c) distance means associated with said track circuit means having connections to said rails and controlled by the presence of trains for measuring independent of said sections the relative distance between successive trains moving through said stretch,

(d) selection means controlled by said distance means and having connections to said track circuit means for varying the distinctive signal character carried by said signaling current in accordance with the measured relative distance between trains.

5. A signaling system for a stretch of railway track traversed by trains equipped with speed control signal apparatus responsive only to a preselected signaling current flowing in the rails and carrying at any one time a

selected distinctive signal character which establishes the allowed speed of a train, comprising in combination,

- (a) circuit means having connections to the rails for supplying said preselected signaling current at predetermined locations along said stretch,
 - (1) said signaling current supplied at each location having an independently selected distinctive signal character,
 - (b) train detection means having connections to the rails and responsive to said signaling current for detecting the presence of trains,
 - (1) said detection means having other connections for controlling the independent selections of distinctive signal character in accordance with the detected locations of trains,
 - (c) distance means with connections to said rails and responsive to the presence of trains for measuring the relative distance between successive trains independent of said predetermined locations,
 - (d) selection means having connections to said circuit means and controlled by said distance means for modifying the selection of signal character by said detection means in accordance with the relative distance measured between successive trains.
6. In a railway signaling system for a stretch of railroad track which is divided into track sections by insulated joints at selected locations and which is traversed in a single direction by trains equipped with continuous cab signal apparatus, said apparatus being responsive to signaling current of a predetermined frequency flowing in said rails for varying the cab signal indication in accordance with the selected one of a plurality of signal characters carried by said signaling current, at each joint location the combination comprising,
- (a) transmitting means with connections for supplying said signaling current to the rails of the approach track section,
 - (b) measuring means having connections to the rails for measuring the relative distance, as limited by the insulated joints at the other end of said approach section and the section in advance of that location, between a train occupying said advance section and another train approaching through said approach section,
 - (c) said measuring means controlling the associated transmitting means for selecting the signal character carried by the signaling current supplied to said approach section in accordance with said measured relative distance.
7. In a railway signaling system for a stretch of railroad track which is divided into track sections by insulated joints at selected locations and which is traversed in a single direction by trains equipped with continuous cab signal apparatus, said apparatus being responsive to signaling current of a predetermined frequency flowing in said rails for varying the cab signal indication in accordance with the selected one of a plurality of signal characters carried by said signaling current, at each joint location the combination comprising,
- (a) transmitting means with connections for supplying said signaling current to the rails of the approach track section,
 - (b) receiving means having connections to the rails of the section in advance of that location and responsive to said signaling current for detecting the presence of a train occupying said advance section,
 - (1) said receiving means having other connections to the associated transmitting means for controlling the selection of the signal character carried by said signaling current when a train is detected in said advance section,
 - (c) measuring means having connections to the rails for measuring the relative distance, as limited by the insulated joints at the other end of said approach and advance sections, between a train occupying said

- advance section and another train approaching through said approach section,
 - (d) said measuring means controlling the associated transmitting means when said receiving means detects a train in said advance section for changing the selection of the signal character carried by the signaling current supplied to said approach section in accordance with said measured relative distance.
8. In a railway signaling system for a stretch of railroad track which is divided into track sections by insulated joints at selected locations and which is traversed in a single direction by trains equipped with continuous cab signal apparatus, said apparatus being responsive to signaling current of a predetermined frequency flowing in said rails for varying the cab signal indication in accordance with the selected one of a plurality of signal characters carried by said signaling current, the combination comprising,
- (a) transmitting means at the exit end of each track section with connections for supplying said signaling current to the rails of the associated track section,
 - (b) distance means associated with each transmitting means and having connections for measuring the relative distance between a train approaching through said corresponding track section and a train occupying the track section in advance thereof,
 - (c) said distance means controlling the associated transmitting means for selecting the signal character carried by the signaling current supplied to said corresponding section in accordance with the measured relative distance.
9. In a railway signaling system for a stretch of railroad track which is divided into track sections by insulated joints at selected locations and which is traversed in a single direction by trains equipped with continuous cab signal apparatus, said apparatus being responsive to signaling current of a predetermined frequency flowing in said rails for varying the cab signal indication in accordance with the selected one of a plurality of signal characters carried by said signaling current, for a particular track section the combination comprising,
- (a) a transmitting means at the exit end of said particular track section with connections for supplying said signaling current to the rails of the associated track section,
 - (b) a receiving means with connections to the rails at the entrance end of said particular section and responsive to said signaling current supplied at the exit end for detecting the presence of a train occupying that section,
 - (1) said receiving means controlling the transmitting means for the section in approach to said particular section for changing the signal character carried by the signaling current supplied to said approach section when a train occupies said particular section,
 - (c) a distance means at said exit end having connections to the rails for measuring the relative distance between a train approaching through said particular track section and a train occupying the section in advance thereof,
 - (d) said distance means controlling the associated transmitting means when said advance section is occupied for selecting the signal character carried by the signaling current supplied to said particular section in accordance with the measured relative distance.
10. In a signaling system for a stretch of railroad track which is divided into track sections by insulated joints at selected locations and which is traversed in a single direction by trains each equipped with continuous cab signal apparatus, said apparatus being responsive only to signaling current of a predetermined frequency flowing in the rails to display one of a plurality of permissive indications in accord with the selected one of a plurality of

signal characters carried by said signaling current, at each joint location the combination comprising,

- (a) transmitting means with connections for supplying said signaling current to the rails of the approach track section,
- (b) supply means with connections to the rails of said advance section for supplying current of a second frequency to those rails,
- (c) distance means controlled by the associated supply means and responsive to said second frequency current only when a receding train passes a preselected point in said advance section,
- (d) said distance means controlling the associated transmitting means for selecting a signal character for said signaling current corresponding to a more favorable indication when said receding train has passed said preselected point.

11. In a signaling system for a stretch of railroad track which is divided into track sections by insulated joints at selected locations and which is traversed in a single direction by trains each equipped with continuous cab signal apparatus, said apparatus being responsive only to signaling current of a predetermined frequency flowing in the rails to display one of a plurality of permissive indications in accord with the selected one of a plurality of signal characters carried by said signaling current, at each joint location the combination comprising,

- (a) transmitting means with connections for supplying said signaling current to the rails of the approach track section,
- (b) receiving means having connections to the rails of the section in advance of that location and responsive to said signaling current for detecting the presence of a train occupying that advance section,
- (c) supply means with connections to the rails of said advance section for supplying current of a second frequency to those rails,
- (d) distance means controlled by the associated supply means and operable in response to the flow of said second frequency current only when at least a preselected distance through said advance section is free of train occupancy,
- (e) said distance means controlling the associated transmitting means only if the associated receiving means detects the presence of a train for selecting a signal character for said signaling current corresponding to a more favorable indication when said distance means is in its operated condition.

12. In a signaling system for a stretch of railroad track which is divided into track sections by insulated joints at selected locations and which is traversed in a single direction by trains each equipped with continuous cab signal apparatus, said apparatus being responsive only to signaling current of a predetermined frequency flowing in the rails to display one of a plurality of permissive indications in accord with the selected one of a plurality of signal characters carried by said signaling current, at each joint location the combination comprising,

- (a) transmitting means with connections for supplying said signaling current to the rails of the approach track section,
- (b) receiving means having connections to the rails of the section in advance of that location and responsive to said signaling current for detecting the presence of a train occupying that advance section,
- (c) supply means with connections to the rails of said approach section for supplying current of a second frequency to that section,
- (d) distance means controlled by the associated supply means and responsive to said second frequency current only until an approaching train reaches a preselected point within said approach section,
- (e) said distance means controlling the associated transmitting means only if said advance section is occupied for selecting a signal character for said sig-

naling current corresponding to a less favorable indication when said approaching train reaches said preselected point.

13. A railway signal system for a stretch of track over which trains move in a single direction, said stretch divided into sections by insulated joints at selected locations, each train equipped with coded cab signal apparatus, for each track section the combination comprising,

- (a) a coded track circuit connected for supplying to the rails of the associated section at the exit end an alternating current having a first frequency and coded at a selected one of a plurality of code rates,

(1) said cab signal apparatus being responsive only to rail current of said first frequency for displaying a signal indication in accordance with the received code rate,

(2) said track circuit also providing an indication at the entrance end of said associated section of the occupancy of that section by a train,

- (b) a phase sensitive track circuit with connections to the rails for supplying an alternating current of a second frequency at the entrance end of the associated section and responsive to the rail length from said entrance end to a train moving through that section for indicating when that train has passed a preselected point in said associated section,

(c) said phase sensitive track circuit controlling the coded track circuit for the section in approach to said associated section for changing the code rate of the first frequency current supplied to said approach section to a more favorable rate when the train occupying said associated section has passed said preselected point.

14. A railway system for a stretch of track over which trains move in a single direction, said stretch divided into sections by insulated joints at selected locations, each train equipped with coded cab signal apparatus, for each track section the combination comprising,

- (a) a coded track circuit connected for supplying to the rails of the associated section at the exit end an alternating current having a first frequency and coded at a selected one of a plurality of code rates,

(1) said cab signal apparatus being responsive only to rail current of said first frequency for displaying a signal indication in accordance with the received code rate,

(2) said track circuit also providing an indication at the entrance end of said associated section of the occupancy of that section by a train,

- (b) a phase sensitive track circuit with connections to the rails for supplying an alternating current of a second frequency at the exit end of the associated section and responsive to the rail length from said exit end to a train approaching through that associated section for indicating when that train arrives at a preselected point in said associated section,

(c) said phase sensitive track circuit controlling the coded track circuit for said associated section, when the track circuit for the section in advance indicates that a train occupies said advance section, for changing the code rate of the first frequency current supplied to said associated section to a less favorable rate when the train occupying said associated section arrives at said preselected point.

15. In a signaling system for a stretch of railroad track which is divided into track sections by insulated joints at selected locations and which is traversed in a single direction by trains each equipped with continuous cab signal apparatus, said apparatus being responsive only to signaling current of a predetermined frequency flowing in the rails to display one of a plurality of permissive indications in accord with the selected one of a plurality of signal characters carried by said signaling current, at each joint location the combination comprising,

- (a) transmitting means with connections for supplying

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said signaling current to the rails of the approach track section,

- (b) receiving means having connections to the rails of the section in advance of that location and responsive to said signaling current for detecting the presence of a train occupying that advance section,
- (c) supply means with connections to the rails of said approach section for supplying current of a second frequency to that section,
- (d) distance means controlled by the associated supply means and responsive to said second frequency current only until an approaching train reaches a preselected point within said approach section,
- (e) selection means controlled by the associated distance means and the associated receiving means for selecting the signal character carried by said signaling current supplied by the associated transmitting means,

- (1) said associated distance means changing the signal character to one corresponding to a less permissive cab signal indication when an approaching train reaches said preselected point only if said associated receiving means has detected a train occupying said advance section.

16. A signal system for a stretch of railway track over which trains move in a single direction, said stretch divided into sections by insulated joints at selected locations, each train being equipped with coded cab signal apparatus, comprising in combination for each track section,

- (a) a coded track circuit connected for supplying to the rails of the corresponding section at its exit end an alternating current of a first frequency and coded at a selected one of a plurality of code rates,

- (1) said cab signal apparatus being responsive only to rail current of said first frequency for displaying a signal indication in accordance with the code rate,

- (2) said track circuit further providing at the entrance end of said corresponding track section an indication of the occupancy of that section by a train,

- (b) a first phase sensitive track circuit with connections for supplying an alternating current of a second frequency to the rails of said corresponding section at its exit end,

- (1) said first circuit being responsive to the phase of said second frequency rail current for indicating when an approaching train occupying said corresponding section reaches a point a preselected distance from said exit end,

- (c) a second phase sensitive track circuit with connections for supplying said second frequency alternating current to the rails of said corresponding section at its entrance end,

- (1) said second circuit being responsive to the phase of said second frequency rail current for indicating when a train traversing that section has passed a point a preselected distance from said entrance end,

- (d) code selection circuit means jointly controlled by said first phase sensitive track circuit of said corresponding section and the coded track circuit and second phase sensitive track circuit of the section in advance of said corresponding section,

- (1) said selection circuit means having connections to the corresponding coded track circuit for selecting the code rate of said first frequency alternating current supplied to said corresponding section in accordance with the occupancy indication for said advance section and the combined indication of the relative distance between trains occupying said corresponding and advance sections.

17. In a signal system for a stretch of railway track

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over which trains move in a single direction, said stretch divided into sections by insulated joints at selected locations, each train being equipped with coded cab signal apparatus, at each joint location the combination comprising,

- (a) code transmitting means connected for supplying to the rails of the section in approach to that location an alternating current of a first frequency and coded at a selected one of a plurality of code rates,

- (1) said cab signal apparatus being responsive only to rail current of said first frequency for displaying a signal indication in accordance with the code rate,

- (b) code detection means having connections to the rails of the section in advance of that location and responsive only to coded rail current of said first frequency for indicating the occupied and nonoccupied conditions of said advance section,

- (c) a first phase sensitive means having connections for supplying an alternating current of a second frequency to the rails of said approach section and responsive to the phase of said second frequency rail current in that section for indicating when an approaching train reaches a point in said approach section a preselected distance from that location,

- (d) a second phase sensitive means having connections for supplying said second frequency alternating current to the rails of said advance section and responsive to the phase of said second frequency rail current in that section for indicating when a receding train has passed a point in said advance section another preselected distance from that location.

- (e) code selection means jointly controlled by said code detection means and said first and second phase sensitive means and having connections for selecting the code rate of said first frequency alternating current supplied by said code transmitting means in accordance with the occupancy condition of said advance section and the relative location indicated for trains in said approach and advance sections.

18. A signaling system for a stretch of railway track which is divided into track sections by insulated joints at selected locations, said stretch being traversed at times in a single direction by trains equipped with continuous cab signal apparatus, said apparatus being responsive only to signaling current of a predetermined frequency flowing in the rails to display one of a plurality of permissive indications as controlled by the selected one of a plurality of code signals carried by said signaling current, comprising in combination at each joint location,

- (a) a receiving means having connections to the rails of the section in advance of that location and responsive to said signaling current for normally occupying a first position,

- (1) said receiving means operable to a second position to detect the occupancy of that advance section by a train,

- (b) transmitting means with connections to the rails of the section in approach to that location for supplying said signaling current to the rails of that approach section,

- (1) said transmitting means controlled by the associated receiving means for changing the code signal carried by said signaling current as said associated receiving means occupies its first and second positions,

- (c) supply means with connections to the rails of said advance section for supplying current of a second frequency to those rails,

- (d) distance means interconnected with said supply means and operable in response to said second frequency current only when a receding train has passed beyond a predetermined point in said advance section,

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(e) switching means controlled by said distance means and having connections for supplementing the control of said transmitting means by said receiving means in its second position for changing the code signal carried by said signaling current when said distance means is in its operated condition to provide a more favorable indication to a train in said approach section.

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